Designation: G98 – 17

Standard Test Method for Galling Resistance of Materials[1]

This standard is issued under the fixed designation G98; 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 test method covers a laboratory test which ranks the galling resistance of material couples. Most galling studies have been conducted on bare metals and alloys; however, non-metallics, coatings, and surface modified alloys may also be evaluated by this test method.

1.2 This test method is not designed for evaluating the galling resistance of material couples sliding under lubricated conditions because galling usually will not occur under lubricated sliding conditions using this test method.

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, health and environmental practices and determine the applicability of regulatory limitations prior to use.*

1.4 *This international standard was developed in accordance with internationally recognized principles on standardization established in the Decision on Principles for the Development of International Standards, Guides and Recommendations issued by the World Trade Organization Technical Barriers to Trade (TBT) Committee.*

2. Referenced Documents

2.1 *ASTM Standards:*[2]

E177 Practice for Use of the Terms Precision and Bias in ASTM Test Methods

E691 Practice for Conducting an Interlaboratory Study to Determine the Precision of a Test Method

G83 Test Method for Wear Testing with a Crossed-Cylinder Apparatus (Withdrawn 2005)[3]

3. Terminology

3.1 *Definitions:*

3.1.1 *galling*—a form of surface damage arising between sliding solids, distinguished by macroscopic, usually localized, roughening and creation of protrusions above the original surface; it often includes plastic flow or material transfer, or both.

3.1.1.1 *Discussion*—The onset of galling usually requires that the contact pressure exceeds some threshold value. Galling can be a precursor to seizing or loss of function. The identification of galling is somewhat subjective, and complete agreement does not exist, even among experts.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *threshold galling stress*—the stress midway between the highest non-galled stress and the lowest galled stress as determined by this test method.

4. Summary of Test Method

4.1 This test method uses available laboratory equipment capable of maintaining a constant, compressive load between two flat specimens, such as hydraulic or screw feed compression testing machines. One specimen is slowly rotated one revolution 360° relative to the other specimen. The surfaces are examined for galling after sliding. The criterion for whether galling occurs is the appearance of the specimens based on unassisted visual examination. If the specimens have not galled, a new set of specimens is tested at increased load. This process is continued until galling occurs.

4.2 Appropriate load intervals are chosen to determine the threshold galling stress within an acceptable range.

4.3 The higher the threshold galling stressing, the more galling resistant is the test couple.

5. Significance and Use

5.1 This test method is designed to rank material couples in their resistance to the failure mode caused by galling and not merely to classify the surface appearance of sliding surfaces.

5.2 This test method should be considered when damaged (galled) surfaces render components non-serviceable. Experience has shown that galling is most prevalent in sliding systems that are slow moving and operate intermittently. The galling and seizure of threaded components is a classic example which this test method most closely simulates.

[1] This test method is under the jurisdiction of ASTM Committee G02 on Wear and Erosion and is the direct responsibility of Subcommittee G02.40 on Non-Abrasive Wear.

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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] The last approved version of this historical standard is referenced on www.astm.org.

5.3 Other galling-prone examples include: sealing surfaces of value trim which may leak excessively due to galling; and pump wear rings that may function ineffectively due to galling.

5.4 If the equipment continues to operate satisfactorily and loses dimension gradually, then mechanical wear should be evaluated by a different test such as the crossed cylinder Test Method (see Test Method G83). Chain belt pins and bushings are examples of this type of problem.

5.5 This test method should not be used for quantitative or final design purposes since many environmental factors influence the galling performance of materials in service. Lubrication, alignment, stiffness and geometry are only some of the factors that can affect how materials perform. This test method has proven valuable in screening materials for prototypical testing that more closely simulates actual service conditions.

6. Apparatus

6.1 Commonly available laboratory equipment has been used to conduct galling tests. Both Brinell hardness testers and servo-hydraulic testing machines have proven to be satisfactory as loading devices. Any apparatus that can apply and maintain a constant compressive load should be acceptable.

7. Test Specimens

7.1 This test method uses a cylindrical flat-on-flat geometry. One specimen is called the button (or pin) and is generally (but not necessarily) rotated about its axis on the flat specimen called the block.

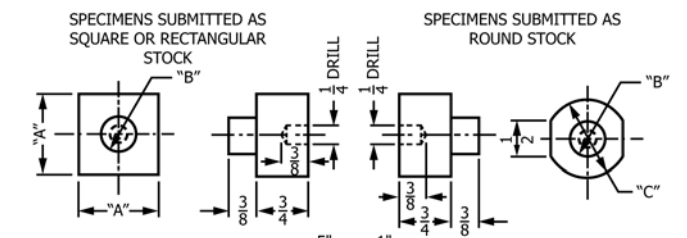
7.2 Some typical button geometries are shown in Fig. 1.

7.3 The only critical dimension is diameter "B'' of the contact area. The 6.4-mm (0.25-in.) diameter hole accommodates a ball bearing for alignment purposes during the test. All other dimensions may be varied to the user's convenience.

7.4 The block specimen must have sufficient area to accommodate at least one test; however, most users have found that blocks of length 76 mm (3 in.) to 152 mm (6 in.) are ideal for multiple tests. A reasonable width is 19 mm (0.75 in.). Thickness is not critical. Tests have been successfully run on blocks with thicknesses from 1.5 mm (0.06 in.) to 25.4 mm (1 in.).

7.5 Maintain block flatness at 0.33 mm/m (0.004 in./ft).

7.6 The arithmetic average surface finish of both test surfaces should be between 0.25 and 1.1 µm (10 and 45 µin.). Leave specimens as-ground or polished with abrasive paper to achieve the finish.



Metric Equivalents

in.	mm	in.	mm
¼	6.4	⅝	16
⅜	10	¾	19
½	13	⅞	22
0.500 ± 0.003	12.7 ± 0.08	1⅛	29

FIG. 1 Typical Button Geometries

8. Procedure

8.1 An overall view of the galling test set-up is shown in Fig. 2.

8.2 *Cleaning*—Immediately prior to testing, clean the test surfaces of the specimens using a procedure that will remove any scale, oil film, or foreign matter. The following cleaning technique is suggested for metallic specimens: clean the button and block in trichloroethane, ultrasonically, if possible; a methanol rinse may be used to remove any traces of trichloroethane residue (see Note 1). Materials with open grains (some powder metals) must be dried to remove all traces of the cleaning solvent which may be entrapped in the material. Demagnetize steel specimens having residual magnetism.

NOTE 1—This cleaning procedure is not appropriate for polymers. If a polymer is being tested, a cleaning procedure that does not alter the chemistry or surface should be determined.

8.3 Mount specimens in the loading device and degrease again if possible. Lightly load the specimens. Twist the button by hand to make sure it is seated flat on the block.

8.4 Apply the selected load. If there is no estimate of the galling resistance of the test couple, it is advisable to start with 890 N (200 lb) and increase the stress in subsequent tests as desired. This will minimize damage to the specimens so that they may be remachined and used for further testing.

8.5 Immediately rotate one specimen (usually the button, but not necessarily) one revolution. Use an open-end wrench, adjustable wrench, or some other special tool in order to grip the specimen for rotating by hand. A mechanized system may also be used to rotate one specimen relative to the other. This may allow torque measurement during testing which may provide useful data on incipient scoring.

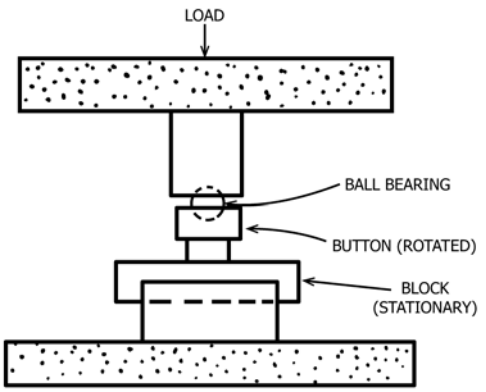


FIG. 2 Schematic Diagram of Galling Test Set-Up

8.6 Actual sliding time should be between 3 to 20 s. Stopping for regripping the turning tool is permitted, but this elapsed time is not counted in the 3 to 20 s test time.

8.7 Release the load.

8.8 Examine both specimens for galling. If the specimens appear smooth and undamaged (burnishing does not constitute damage) to the unaided eye, repeat the procedure at a higher load with untested specimens.

8.9 If the surfaces exhibit scratch marks, this is not galling. A wavy surface is not considered galled. At least one of the contacting surfaces must exhibit torn metal for galling to have occurred. If fracture of any cold welded areas has taken place in the plane of the surfaces and no distinct raised metal (protrusion) is found, galling has not occurred for the purposes of this test method.

8.10 If galling has occurred even on just one specimen, test at a lower load to establish an interval between the highest non-galled stress and the galled stress. This interval should be no greater than 34.5 MPa (5 ksi) for threshold galling stresses greater than 138 MPa (20 ksi) and no greater than 21 MPa (3 ksi) for stresses 138 MPa (20 ksi) or less.

8.11 If galling is questionable or borderline, repeat at a higher load to confirm the previous test stress.

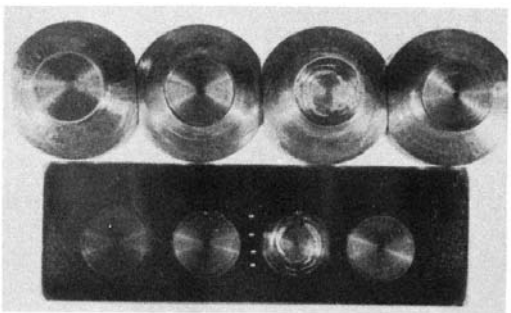
8.12 A typical series of test specimens is shown in Fig. 3.

8.13 Calculate the threshold galling stress as the stress midway between the highest non-galled test and the lowest galled test. Use the original diameter of the button to calculate the contact stress. Assume full contact of the button diameter even though in some lightly loaded tests, this may not always be the case.

9. Report

9.1 The following data should be included in the test report:

9.1.1 Composition and hardness of specimens,



Gall Buttons appear on top.
Gall Block appears underneath.

Contact Stress:				
MPa	131.7	169.6	247.5	193.0
(ksi)	19.1	24.6	35.9	28.0
Comment	OK	OK	Galled	OK

NOTE 1—Another test at 220.6 MPa (32 ksi) would be necessary to establish the threshold gall stress within acceptable limits.

FIG. 3 Typical Gall Test Series

9.1.2 Thermal history of specimens,

9.1.3 Threshold galling stress for test couples, interval used, and rotation time,

9.1.4 Initial surface finish, preparation, and cleaning technique,

9.1.5 Any unusual event during the test, for example, buckling of the button,

9.1.6 Mechanical test system used, such as mechanical or hydraulic, type, size, and

9.1.7 Temperature, humidity, atmosphere.

10. Precision and Bias[4]

10.1 The precision of this test method is based on an interlaboratory study of Test Method G98, conducted in 2016. Four laboratories participated in this study. Each of the four labs reported duplicate test results for a single type of stainless steel. Every "test result" reported represents an individual determination. Except for the use of only four laboratories and a single material type, Practice E691 was followed for the design and analysis of the data; the details given in ASTM Research Report No. G02-1017.

10.1.1 *Repeatability (r)*—The difference between repetitive results obtained by the same operator in a given laboratory applying the same test method with the same apparatus under constant operating conditions on identical test material within short intervals of time would in the long run, in the normal and correct operation of the test method, exceed the following values only in one case in 20.

10.1.1.1 Repeatability can be interpreted as the maximum difference between two results, obtained under repeatability conditions, that is accepted as plausible due to random causes under normal and correct operation of the test method.

10.1.1.2 Repeatability limits are listed in Table 1 below.

10.1.2 *Reproducibility (R)*—The difference between two single and independent results obtained by different operators applying the same test method in different laboratories using different apparatus on identical test material would, in the long run, in the normal and correct operation of the test method, exceed the following values only in one case in 20.

10.1.2.1 Reproducibility can be interpreted as the maximum difference between two results, obtained under reproducibility conditions, that is accepted as plausible due to random causes under normal and correct operation of the test method.

10.1.2.2 Reproducibility limits are listed in Table 1 below.

10.1.3 The above terms (repeatability limit and reproducibility limit) are used as specified in Practice E177.

10.1.4 Any judgment in accordance with 10.1.1 and 10.1.2 would normally have an approximate 95 % probability of being correct; however, the precision statistics obtained in this ILS must not be treated as exact mathematical quantities which are applicable to all circumstances and uses. The limited number of materials tested and laboratories reporting results guarantees that there will be times when differences greater than predicted by the ILS results will arise, sometimes with

[4] Supporting data have been filed at ASTM International Headquarters and may be obtained by requesting Research Report RR:G02-1017. Contact ASTM Customer Service at service@astm.org.

TABLE 1 Threshold Galling Stress (psi)

Material	Average[A] $\bar{x}$	Repeatability Standard Deviation s_r	Reproducibility Standard Deviation s_R	Repeatability Limit r	Reproducibility Limit R
Type 303 Stainless Steel	29.85 MPa (4.330 ksi)	9.136 MPa (1.325 ksi)	11.59 MPa (1.682 ksi)	25.58 MPa (3.710 ksi)	32.46 MPa (4.709 ksi)

[A]The average of the laboratories' calculated averages.

considerably greater or smaller frequency than the 95 % probability limit would imply. The repeatability limit and the reproducibility limit should be considered as general guides, and the associated probability of 95 % as only a rough indicator of what can be expected.

10.2 *Bias*—At the time of the study, there was no accepted reference material suitable for determining the bias for this test method, therefore no statement on bias is being made.

10.3 The precision statement was determined through statistical examination of eight test results, from four laboratories, on Type 303 Stainless Steel.

11. Keywords

11.1 button-on-block test; galling; galling resistance ranking; macroscopic surface damage; seized components; sliding metallic surfaces; threshold galling stress