Designation: E2712 – 22

Standard Test Methods for Bulge-Forming Superplastic Metallic Sheet[1]

This standard is issued under the fixed designation E2712; 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 These test methods describe procedures for determining the biaxial formability of a test specimen of superplastic metallic sheet in a circular die.

1.2 The intent of these test methods are primarily to be used as tests of superplasticity as measured by the ability to form to a prescribed depth in a die cavity without rupturing. These test methods can also be used to generate material for the measurement of cavitation in the formed part. These can be used as go/no go criteria for qualification to a specification.

1.3 These test methods have been used successfully with aluminum alloys. The use of these test methods on other metals should be verified.

1.4 The values stated in SI units are to be regarded as standard. No other units of measurement are included in this standard.

1.5 *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.*

1.6 *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]

E6 Terminology Relating to Methods of Mechanical Testing

E2448 Test Method for Determining the Superplastic Properties of Metallic Sheet Materials

3. Terminology

3.1 The terms specified temperature and indicated temperature are used as defined in Terminology E6.

4. Summary of Test Method

4.1 Two methods of bulge forming are included in these test methods.

4.1.1 In the Dome Rupture Test method, the test specimen is formed into a die of a fixed depth as prescribed in a specification. If it touches the base of the die without rupturing, then it is considered to have met the specification.

4.1.2 In the Cavitation Test method, the depth of the die is reduced so that the material fills the die. A portion excised from the center of the formed part may be examined for internal cavitation within the test specimen.

5. Significance and Use

5.1 When a superplastic material is regularly being used in industrial production, it is often convenient to use the bulge test to qualify a batch or heat lot to an acceptance criterion. Comparing these test methods with Test Method E2448, the bulge test does not require a machined test specimen, it is more convenient to perform, and it most closely simulates the multiaxial stresses and strains present in forming parts. These test methods do not measure the intrinsic superplastic properties of a material. Test Method E2448 should be used in that instance.

6. Apparatus

6.1 The bulge test consists of forming a test specimen in the form of a sheet of material into a right circular cylindrical die using pressurized gas. The apparatus is shown in Fig. 1. The diameter of the die cavity shall be 100 mm ± 0.5 mm, and the specified depth of the vessel shall be suitably designed for the pressure and temperature envisaged for the test. The surface finish of the die cavity shall be *R*a=0.4 μm maximum.

6.2 The depth of the die (X in Fig. 1), may be varied by means of inserts or other methods to the depth set by the specification. For convenience, a series of inserts of different heights may be installed in the die to provide different depths according to the bulge test requirements.

NOTE 1—A depth of 55 mm has been successfully used on superplastic-forming (SPF) 5083 aluminum alloy.

[1] This test method is under the jurisdiction of ASTM Committee E28 on Mechanical Testing and is the direct responsibility of Subcommittee E28.02 on Ductility and Formability.

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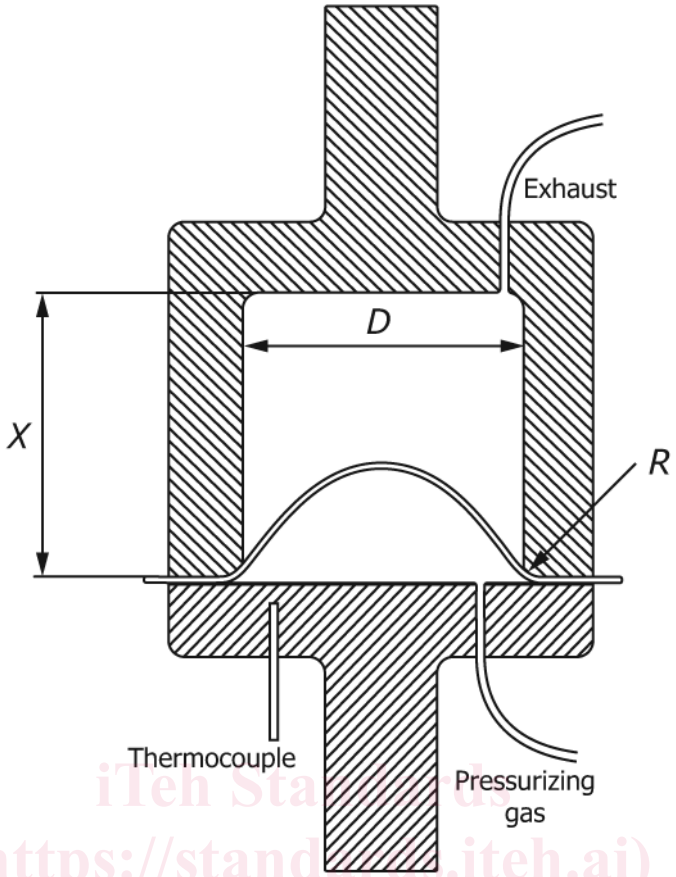
[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.



Dimensions	
	mm
X – Depth of the die, typical, approximate	55
R – Radius of the die entry	5.0±0.1
D – Diameter of the die cavity	100.0±0.5
Die cavity surface roughness average, *Ra*, max	0.4 µm

FIG. 1 Bulge-Forming Apparatus

6.2.1 The insert shall allow the free passage of gas around its periphery to the exhaust hole in the die.

6.3 The die entry radius shall be 5.0 mm ± 0.1 mm.

6.4 A lower plate with a control thermocouple may be moved to press against the die.

NOTE 2—A plate with a gas seal bead 0.7 mm high by 8 mm wide and a 136 mm inside diameter has been used successfully.

6.5 A gas pressurization system with a gauge or other suitable means of measuring pressure and detecting test specimen failure shall be provided at the lower plate to form the material into the cavity. An exhaust port in the die may be connected either to the atmosphere or to a second gas pressurization system that provides a back pressure to the test specimen.

6.6 The apparatus shall be provided with a means of heating it to the specified temperature for the material being tested.

NOTE 3—Usually, it is enclosed in a furnace equipped with doors opening in the front

6.7 The apparatus shall be provided with a means of moving the die or lower plate to insert and remove test specimens and also to provide a force on the plate to counteract the force exerted by the pressurized gas.

NOTE 4—Usually, it is installed in a hydraulic press or clamping mechanism.

7. Procedure

7.1 *Dome Rupture Test:*

7.1.1 *Test Specimen*—Clean a test specimen of superplastic material sized at least 160 mm by 160 mm so that it is free of surface contaminants. The die and plate shall be clean and free of any lubricant. No lubricant shall be used in the test unless specifically required by the lot acceptance criteria. If desired, the rolling direction may be marked in one corner of the specimen.

NOTE 5—The presence of lubricant greatly affects the depth to which the material forms before rupturing. Although very important for production, lubricant adds an unnecessary variable to the test method,

which is why it is not generally used. It follows that the apparent superplasticity of a material in the bulge test is less than what can be accomplished in a production environment; however, the bulge test is only used as a pass/fail criteria, not as a quantitative test to replicate actual forming conditions.

7.1.2 Before testing, bring the vessel up to the specified temperature. Place the test specimen onto the lower plate, and then mechanically clamp the plate to the die with sufficient force to prevent gas leakage or the test specimen drawing across the seal during the test.

7.1.3 Start the test as soon as the indicated temperature reaches the minimum temperature in the range specified in 7.1.3.1, and record the time taken.

7.1.3.1 From the time from initiation of applying gas pressure until the termination of test or fracture the difference between the indicated temperature and the specified temperature shall not exceed the following limits:
Specified temperatures less than or equal to 700 °C: ±3°C
Specified temperatures greater than 700 °C: ±6°C:

7.1.3.2 If the SPF properties of the material are highly dependent on the thermal history before forming, a different heating profile may be specified, recorded, and controlled for the test to allow optimum forming conditions to be realized.

NOTE 6—This is especially true when recrystallization or other metallurgical phenomena occur.

7.1.4 Apply the specified forming pressure to the underside of the test specimen.

7.1.4.1 After the forming pressure is fully applied, the difference between the indicated pressure and the specified pressure shall not exceed the following limits:
Specified pressure less than or equal to 1 MPa : ±50 kPa
Specified pressure greater than 1 MPa: ±5 % of specified pressure.

7.1.4.2 A variable pressure/time profile may be specified if required.

7.1.4.3 Maintain the pressure on the die side of the test specimen (back pressure) at atmospheric pressure via the exhaust vent. A constant or variable back pressure may be used if specified.

7.1.4.4 Record the forming and back pressures.

NOTE 7—The pressure is dependent on the alloy being tested, test specimen thickness, and other factors. A pressure of $0.15 \times t$ MPa has been used successfully on 5083 aluminum alloy at 773K, where t is the test specimen thickness in millimetres.

NOTE 8—Back pressure minimizes cavitation in the test specimen during forming and is especially important for some aluminum alloys.

7.1.5 Continue the test until the test specimen ruptures, as indicated by a sudden drop in pressure in the gas system. Release the forming pressure, back pressure, and clamp force immediately. The time taken to failure may be recorded. If after a suitable length of time, as determined by experience, the test specimen has not ruptured, then it may be deemed to have fully formed in the die.

7.1.6 Remove the test specimen from the apparatus and allow it to cool on a flat surface.

7.2 *Cavitation Test:*

7.2.1 For this test, choose a sufficiently shallow die so that the test specimen will form into the entire shape of the die without rupturing.

NOTE 9—The depth of the die determines the amount of superplastic strain the material undergoes measured at the center of the formed cup.

7.2.1.1 Report the die depth.

7.2.2 Follow the same test procedure as for the dome rupture test, but halt the test after a specified time, when the test specimen has fully formed into the whole die cavity. The time may be established from computer analysis or prior testing of similar test specimen

NOTE 10—The time is easily determined by those practiced in the art of SPF.

8. Analysis

8.1 *Dome Rupture Test*—Examine the dome for evidence that it touched the base of the die, indicated by the formation of a flat circular area on the crown of the dome. This area will normally not be the area of rupture. If it touched the base, it met the criteria; if it ruptured without forming a flat area at the crown, it shall be considered to have failed the criteria.

8.2 *Cavitation Test*—Excise a specimen 10 mm by 10 mm from the center of the formed cup. Examine it for cavitation. The method used to determine cavitation is not part of this test method and shall be specified on the bulge test acceptance criteria.

8.3 The superplastic strain of the test specimen is defined as:

$$e_{SPF} = \frac{(t_0 - t_1)}{t_1} \times 100\ (\%) \qquad (1)$$

where:

t_0 = initial thickness of the test specimen measured at its center and
t_1 = final thickness of the test specimen measured in the same place on the formed cup.

9. Report

9.1 The following shall be reported:
9.1.1 Specimen identification,
9.1.2 Material certification,
9.1.3 Test specimen initial thickness and sheared size,
9.1.4 Specified temperature of the test,
9.1.5 Strain rate, variable pressure/time parameters, or the constant pressure used, and
9.1.6 Depth of the die (X in Fig. 1).

9.2 For the dome rupture test, the following should be reported:
9.2.1 Statement that the specimen passed or failed the specification height.

9.3 For the cavitation test, the following should be reported:
9.3.1 Method used to determine cavitation,
9.3.2 Amount of cavitation expressed as a volume percentage, and
9.3.3 Superplastic strain.

10. Precision and Bias

10.1 No information is presented about either the precision or bias of these test methods for bulge-forming superplastic materials since these tests are nonquantitative.