Standard Test Method for Determination of the Susceptibility of Metallic Materials to Gaseous Hydrogen Embrittlement[1]

ϵ[1] NOTE—Editorial changes throughout this test method.

1. Scope

1.1 This test method covers quantitative determination of the susceptibility of metallic materials to hydrogen embrittlement, when exposed to gaseous hydrogen, in any conditions.

1.2 The values stated in SI units are to be regarded as the standard. The values given in parentheses are for information only.

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. Summary of Test Method

2.1 A thin disk of the metallic material to be tested is introduced as a membrane into a test cell and submitted to helium pressure to burst. The fracture will be caused only by mechanical overload, and no physical-chemical secondary action is involved because of the inert nature of helium. An identical disk of the same material is introduced in the same test cell and submitted to hydrogen pressure to burst. Metallic materials susceptible to hydrogen embrittlement will burst under a pressure below the helium burst pressure. Materials not susceptible will fracture under a pressure identical to the helium pressure. The ratio between the helium burst pressure (P_{He}) and the hydrogen burst pressure (P_{H2}), P_{He}/P_{H2}, will indicate the susceptibility of the material to hydrogen embrittlement.

3. Significance and Use

3.1 This test method will provide a guide for the choice of metallic materials for applications in which hydrogen in any form (liquid, gaseous, monoatomic, etc.) produced by corrosion, electrolysis, chemical process, etc. is present.

3.2 The number corresponding to the P_{He}/P_{H2} ratio will be a relative indication of the severity of degradation of the mechanical properties to be expected.

4. Apparatus

4.1 The basic system consists of the following:

4.1.1 *Test Cell*, as shown in Fig. 1, fabricated with type 316, ¼-hard stainless steel.

4.1.2 The test cell is pressurized with hydrogen or helium through a pneumatic system, illustrated in Fig. 2.

5. Gases

5.1 *Helium*, purity 99.995 minimum, 6000-psig (41 600-kPa) cylinder.

5.2 *Hydrogen*, purity 99.995 minimum, 6000 psig (41 400 kPa).

6. Specimen Preparation

6.1 The specimens for the test cell, illustrated in Fig. 1, shall have a diameter of 58 mm (2.28 in.) and a thickness that varies between 0.25 and 1 mm (0.010 and 0.039 in.), most frequently 0.75 mm (0.030 in.).

6.2 Three sets of two specimens with identical dimensions and temper conditions shall be prepared for each test, and their dimensions shall be measured and recorded.

7. Procedure

7.1 Perform the burst test by helium pressure as follows:

7.1.1 Insert one of the sets of two identical disks from the three sets into the Test Cell (Item 9 of Fig. 2) after checking that the NBR O-rings (27 × 3.2 mm, 70A Durometer hardness) are in perfect condition. Then close the cell and tighten the bolts.

7.1.2 Close Valves 3, 5, and 11; open Valves 4, 6, and 7 and apply a vacuum of 10-2 torr for 3 min to eliminate air and residual test gases from the system. Close Valves 4, 6, and 7.

7.1.3 After placing the slave hand of Gage 8 to the zero position, open Valves 3 and 6 of the helium high-pressure tank and carefully open the needle Valve 7 to raise the helium pressure at the approximate rate of 50 to 80 bars/s, up to burst pressure.

7.1.4 When the disk is burst, rapidly close Valves 3, 6, and 7.

7.1.5 Record the burst pressure as indicated by the slave hand of Gage 8 and carefully open Valve 11 to bring the pressure inside of the gage to atmospheric pressure. Then,

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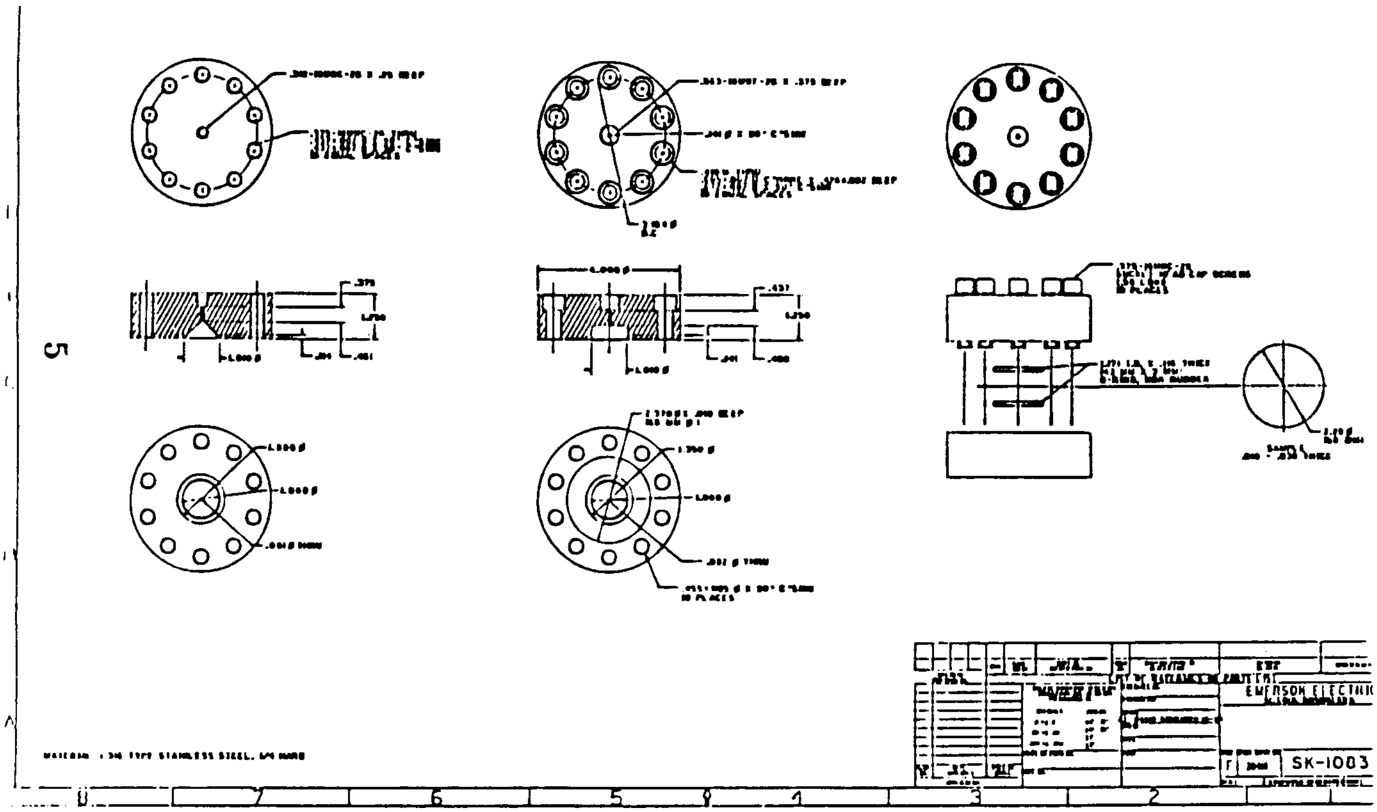
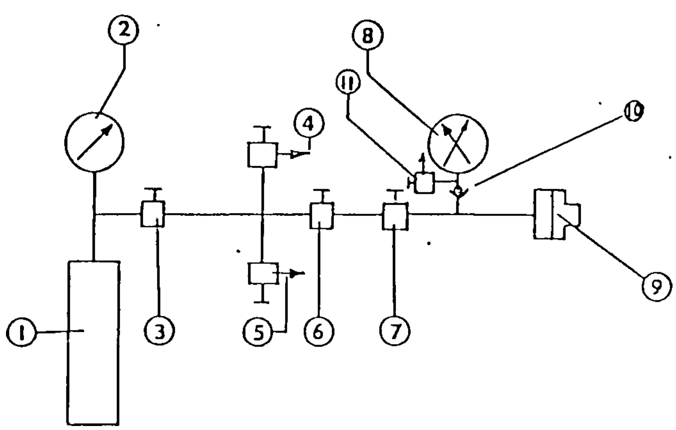


FIG. 1 Test Cell



1. High-pressure tank
2. Pressure gage
3. High-pressure valve
4. To vacuum pump
5. To pressure intensifier
6. High-pressure valve
7. Needle valve
8. Slave hand pressure gage
9. Test cell
10. Check valve
11. Pressure bleed valve

FIG. 2 Schematic of Disk Pressure Test

when this pressure is reached, open the test cell and set aside the fractured disk for eventual further examination of the fractured surfaces. Identify the helium burst pressure as P_{Hc}.

7.1.6 Repeat Steps 7.1.1-7.1.5 for the first of the two identical disks from the remaining two sets. Calculate the average of the three sets for P_{He}.

7.2 Perform the burst test by hydrogen pressure as for the burst of the disk by helium pressure; only connect the high-pressure hydrogen tank to the test system instead of the helium tank.

7.2.1 Insert the second of the two identical disks from the three sets into the Test Cell (Item 9 of Fig. 2) after checking that the NBR O-rings (27 × 3.2 mm, 70A durometer hardness) are in perfect condition. Then, close the cell and tighten the bolts.

7.2.2 Close Valves 3, 5, and 11; open Valves 4, 6, and 7, and apply a vacuum of 10-2 torr for 3 min to eliminate air and residual test gases from the system. Then close Valves 4, 6, and 7.

7.2.3 After placing the slave hand of Gage 8 to the zero position, open Valves 3, of the hydrogen high pressure tank, and 6, and carefully open the needle Valve 7 to raise the hydrogen pressure at the approximate rate of 50 to 80 bars/s, up to burst pressure. The pressure raise rate shall be the same as that used for the helium burst.

7.2.4 When the disk is burst, rapidly close Valves 3, 6, and 7.

7.2.5 Record the burst pressure as indicated by the slave hand of Gage 8 and carefully open Valve 11 to bring the pressure inside of the gage to atmospheric pressure. Then, when this pressure is reached, open the test cell, and set aside the fractured disk for eventual further examination of the fracture surface. Identify the hydrogen burst pressure as P_{H2}.

8. Calculation

8.1 Calculate the hydrogen embrittlement susceptibility for the metallic material that has been submitted to test as follows:

$$S_{H2} = P_{He}/P_{H2} \quad (1)$$

where:

S_{H2} = susceptibility to hydrogen embrittlement,
P_{He} = burst pressure with helium, and
P_{H2} = burst pressure with hydrogen.

9. Interpretation of Results

9.1 If the ratio P_{He}/P_{H2} is equal to 1.000, the material is considered to be not susceptible to hydrogen embrittlement. If the ratio is above 2, the material is considered to be sensitive to hydrogen, and provisions must be taken to avoid exposure to hydrogen, both gaseous and electrolytic. If the ratio yields fractional values, for example, 1.0125, embrittlement may be expected after long exposure to hydrogen in any form.

10. Report

10.1 Report the results considered acceptable, with identification of the alloy, its chemistry, heat treatment, temper, and the measured dimensions of the specimens.

11. Precision

11.1 It is advisable to perform three tests for the same material and temper and to calculate the average.

11.2 *Reproducibility*—The results of the test for each material and condition obtained by the same operator usually differ by the following percentages: normally processed and machined specimens, 2 to 3 %; ultra high-strength materials 5 to 10 %.

11.3 Results differing by more than the indicated percentages should be considered suspect and unacceptable.

12. Keywords

12.1 gaseous disk pressure test; hydrogen embrittlements; ratio analysis; relative susceptability