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Designation: G 124 – 95

Standard Test Method for Determining the Combustion Behavior of Metallic Materials in Oxygen-Enriched Atmospheres[1]

This standard is issued under the fixed designation G 124; 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 test apparatus and technique to determine the minimum test gas pressure that supports self-sustained combustion (the threshold pressure) and the average regression rate (apparent burn rate) of a standardized sample of a metallic material that has been ignited using a strong promoter.

1.2 The data obtained from this test method are dependent on the precise test sample configuration and provide a basis for comparing the combustion behavior of materials. No criteria are implied for relating these data to the suitability of a material's use in any actual system. The application of data obtained from this test method is discussed in Guides G 88 and G 94.

1.3 Requirements for an apparatus suitable for this test method are given, as well as an example of such an apparatus. The example, however, is not required to be used.

1.4 This test method is for gaseous oxygen or any mixture of oxygen with diluents that will support combustion, at any pressure within the capabilities of the apparatus.

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

1.6 *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.* Specific hazards statements are given in Section 9.

2. Referenced Documents

2.1 *ASTM Standards:*

G 88 Guide for Designing Systems for Oxygen Service[2]

G 93 Practice for Cleaning Methods for Material and Equipment Used in Oxygen-Enriched Environments[2]

G 94 Guide for Evaluating Metals for Oxygen Service[2]

2.2 *Federal Specification:*

BB-0-925 Oxygen, Technical, Gas and Liquid[3]

2.3 *Military Standard:*

MIL-0-27210E Amendment 1—Oxygen, Aviator's Breathing, Liquid and Gas[3]

TABLE 1 Example Data Set for Type 316 Stainless Steel[A]

Material	Pressure, MPa	Number of Samples	
		Partial Burn	Complete Burn
UNS 31600	1.75	10	0
	3.45	8	2
	6.90	0	10

[A] These data were produced at NASA White Sands Test Facility, New Mexico, 88004

3. Terminology

3.1 *Definitions of Terms Specific to This Standard:*

3.1.1 *average regression rate (apparent burn rate)*—the average rate at which the burning/solid-metal interface advances along the test sample length.

3.1.2 *igniter*—a material to ignite the promoter that can burn under an electrical influence, such as a small-diameter wire.

3.1.3 *promoter*—a material that can add supplemental heat and increase the temperature to start combustion of the material being tested.

3.1.4 *self-sustained combustion*—combustion that consumes a sample to the point at which the sample holder affects further combustion (assuming sufficient oxygen).

3.1.5 *threshold pressure*—the minimum gas pressure (at a specified oxygen concentration and ambient temperature) that supports self-sustained combustion of the entire standard sample.

4. Summary of Test Method

4.1 A small rod of the material is suspended in a chamber filled with pressurized test gas. The chamber contains sufficient oxygen so that not more than 10 % of the oxygen will be consumed when the material combusts completely. A promoter (typically aluminum or magnesium) applied to the bottom of the rod starts combustion of the material. The test pressure is reduced and another rod is tested if combustion of the entire rod occurs. This continues until self-sustained combustion of

[1] This test method is under the jurisdiction of ASTM Committee G-4 on Compatibility and Sensitivity of Material in Oxygen Enriched Atmospheres and is the direct responsibility of Subcommittee G04.01 on Test Methods.

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[2] *Annual Book of ASTM Standards*, Vol 14.02.

[3] Available from Standardization Documents Order Desk, Bldg 4 Section D, 700 Robbins Ave., Philadelphia, PA 19111-5094, Attn: NPODS.

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the rod does not occur for at least five tests at one pressure. The lowest pressure at which self-sustained combustion occurred is the threshold pressure for the material, and the difference between it and the highest pressure level that produced only incomplete combustion is the margin of potential error. Astute initial estimates of the threshold can reduce the amount of testing necessary to demonstrate the threshold to within the required uncertainty.

5. Significance and Use

5.1 This test method will allow comparisons of the combustion characteristics of various metallic materials. The combustion characteristics that can be evaluated include (*1*) threshold pressure and (*2*) average regression rate (apparent burn rate) of the sample.

6. Interferences

6.1 Any internal materials that may bake out or vaporize during the combustion process at test temperature/pressure may interfere with the chemistry of the fire propagation.

6.2 The specific atmosphere in the test chamber can have a severe effect. Therefore, alien air, argon, nitrogen, carbon dioxide, moisture, and others can be important interfering gases.

6.3 The test is conducted under stagnant conditions. A flowing system or one that facilitates buoyant convective currents may be a significantly more severe climate.

6.4 The specific temperature of the test sample prior to ignition can have an important effect.

NOTE 1—The promoters discussed in this test method have produced favorable results over a wide range of metal test specimens with the degree of precision sought to date. As the threshold is approached or when interaction between promoter and metal occur promoter can thwart the ignition process. Hence the prospect that future work may refine the promoter and enable the measurement of lower thresholds than are measurable today cannot be ruled out.

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7. Apparatus

7.1 A schematic of a typical system is shown in Fig. 1. Other designs may also be used, if they fulfill the requirements below.

7.2 *Test Chamber*—A cross-section of a typical stainless steel test chamber is shown in Fig. 2. No more than 10 % of the available oxygen should be consumed during a test. Appendix X1 provides criteria for establishing the lowest test pressures that meet this criterion for various vessel volumes. If the chamber cannot be made sufficiently large, an accumulator can be attached that contains more test gas if the chamber cannot be made sufficiently large; however, this is not as severe a test environment as in the larger vessel. The test chamber shall not contribute any chemical interference to testing.

NOTE 2—The addition of an accumulator can act as a snubber to suppress pressure rises that occur due to temperature rises and pressure drops that result from oxygen consumption, but it will have a much smaller effect in preventing local buildup of diluents in the oxygen. Each of these influences will exhibit a progressively greater effect and consequence in smaller vessels.

NOTE 3—The significance of ensuring an adequate oxygen inventory is to avoid the observation of apparently negative test results at conditions that are above the threshold but for which extinguishment may, nonetheless, occur due to depletion of oxygen, consequential reduction of pressure, or concentration of diluents. However, in any test in which complete combustion of the specimen occurs, the result is valid, regardless of whether the test conditions met the minimum recommended requirement for oxygen inventory.

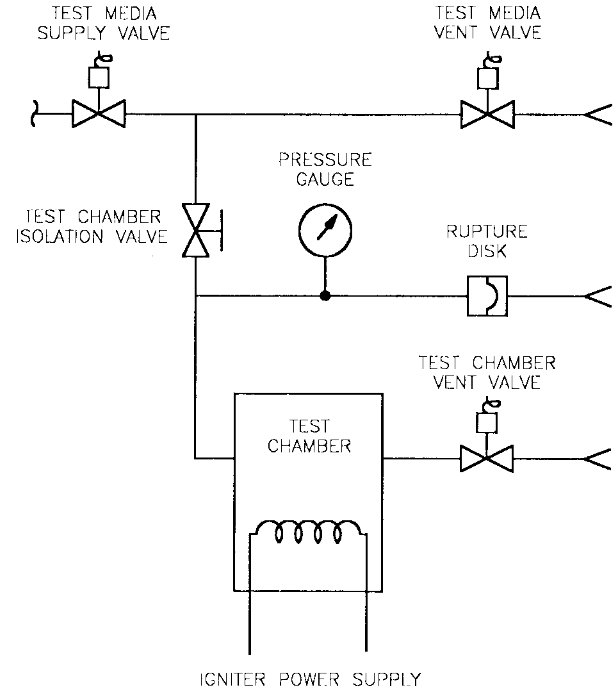

FIG. 1 Schematic of Typical System

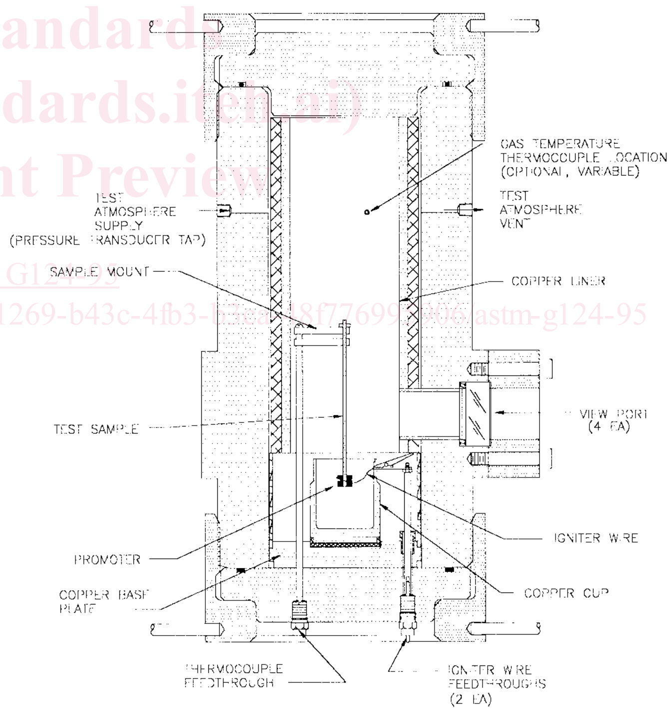

FIG. 2 Typical Stainless Steel Test Chamber Cross-Section

7.3 *Sample holder*, capable of securing the sample at the top and supporting it in a vertical position. There shall be sufficient space beneath the sample for the igniter and any drops of liquid material that may fall during the test.

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7.4 *Thermocouple*, used to measure gas temperature in the chamber.

7.5 *Pressure Transducer*, used to measure gas pressure in the chamber, accurate to within ± 1 % of reading.

7.6 *Liner and Base Plate*—A burn-resistant (for example, copper) liner and base plate in the test chamber serve as an internal shield to protect the components from combustion products, molten slag, and so forth.

7.7 *Sight Glass*, capable of withstanding the maximum test pressure anticipated. If video or film recording of the burning event contained in the test chamber is desired, the sight glass shall transmit compatible light.

7.8 *Igniter Power Supply*, electrically isolated and capable of providing adequate current to initiate the igniter wire within a few seconds of the application of power.

7.9 *Test Cell*, (a room to house the test chamber), constructed of noncombustible material (such as concrete or metal) with sufficient strength to provide protection from explosion or fire hazards. A continuous ventilation system shall circulate fresh air in the test cell. The cell shall provide a facility that can be maintained at a high level of good housekeeping. The test cell shall be cleaned periodically to avoid contamination of the sample and equipment.

7.10 *Piping System*, which purges, pressurizes, and vents the test chamber. The piping system shall be designed to permit remote test chamber purge, pressurization, and venting without unsafe exposure of personnel. The chamber shall be purged and pressurized through one line and vented through a separate line to minimize the chances of contaminant migrating into the pressurization line, which might influence subsequent tests. A typical piping system for this test is shown in Fig. 1.

7.11 *Control Area*, which will isolate test personnel from the test cell during tests. This control area shall be provided with the necessary control and instrumentation features to perform test chamber purge, pressurization and venting operations, and monitoring of the test chamber instrumentation during the test.

7.12 *Data Acquisition System (Optional)*, capable of recording, storing, and accessing the pressure and temperature data at a rate of ten samples/s (minimum). It shall also include a video recording device that displays the "real-time" burn phenomenon. The video recording can be used for regression rate determination.

8. Reagents and Materials

8.1 *Gaseous Oxygen*—Oxygen purity equal to or greater than that of practical systems is preferred, especially when testing alloys containing aluminum, magnesium, zirconium, etc. (that is, metals believed to burn at least in part in the vapor phase). An analysis of the test oxidant is required. The use of oxygen greater than 99.5 % pure may affect the test results significantly **(1)**,[4] and its use shall be noted on the data sheet.

NOTE 4—Some applications involve the use of oxygen mixed with other gases, and data in the literature **(1, 2)** indicate that the rankings of materials can be different depending on the amount and kind of diluents present. Although the basic apparatus and principle of this test are valid when used with oxygen mixed with other gases, alterations to the test method may be necessary. At present, these alterations have not been studied sufficiently for inclusion in this test method.

8.2 *Promoter*—The promoter shall consist of a sufficient quantity of material to ignite the test specimens. Some examples of promoter material are aluminum and magnesium **(3)**. No promoter may be necessary at all at times; the igniter wire itself may provide sufficient energy to ignite the sample. Nonmetallic promoters may be used; however, the combustion products of such promoters might contaminate the test media.

NOTE 5—In selecting the promoter material, the possibility of a chemical reaction between the test material and the promoter should be considered. Also, for certain metals, the chemical energy released from the combustion of promoter might be insufficient to ignite the metal. Other ignition sources, for example, electrical or laser, may be used in such cases.

8.3 *Igniter Wire*—The igniter wire shall be made of a material capable of igniting the promoter. Some examples of the igniter wire material are nickel/chromium or aluminum/palladium.[5]

9. Hazards

9.1 *High-Pressure Oxygen System*—**Warning:** There are hazards involving the use of a high-pressure oxygen system. The following guidelines will reduce the dangers:

9.1.1 Personnel should be isolated from the test system when it is pressurized. Preferably, personnel should be shielded by both physical protection (for example, the test cell) and distance.

9.1.2 The test system itself should be isolated to prevent danger to people not involved in the test.

9.1.3 The test system should incorporate equipment able to handle the maximum operating pressure safely, including an appropriate safety-factor.

9.1.4 The system should be kept clean to prevent unintentional ignition.

9.1.5 The test system should be double-isolated from the test gas supply system.

9.1.6 Remote readout devices should be provided so personnel do not have to approach the test system to obtain operating data.

9.2 *Oxygen*—**Warning:** Oxygen enrichment accelerates combustion vigorously. Care should be taken at all times when working with oxygen. CGA Pamphlets G-4.0 **(4)** and G-4.1 **(5)** and Practice G 93 provide further details.

9.3 *Metal Oxides*—**Warning:** Toxic metal and oxide dusts may be produced when using this test method. These dusts are often toxic to breathe or touch; safety procedures appropriate to the hazard must therefore be followed.

9.4 *Vessel Failures*—**Warning:** The vessel described in this experiment has contained the combustion of ferrous, aluminum, and copper alloys successfully. Molten metal slags produced in these tests can be very destructive, and as pressure or oxygen purity increases, the intensity of the combustion

[4] The boldface numbers in parentheses refer to the list of references at the end of this test method.

[5] The trade name for aluminum-palladium wire is Pyrofuze. It is a registered trademark of the Pyrofuze Corp., 121 S. Columbus Ave., Mt. Vernon, NY 10553, and is available from them.

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increases, so the possibility of a burn-through or failure of the vessel or associated piping cannot be ruled out.

10. Preparation of Test Samples and Promoters

10.1 *Preparation of Samples*—The samples shall be prepared as cylindrical rods, 3.2-mm diameter and 150-mm long (±5 %), as shown in Fig. 3. The portion of the sample included in the sample mount and the promoter shall be excluded from this measurement. Samples shall be prepared exclusively for this test.

10.2 *Preparation of Promoters*—The promoter shall consist of a sufficient quantity of a material to ignite the sample positively.

10.3 *Cleaning*—Samples and promoters shall be cleaned and dried as they would be in the end-use application.

10.4 *Assembly*—The promoter shall be installed on the bottom end of the sample when it is ready to be installed in the test system.

11. Preparation of Apparatus

11.1 *General*—Maintain the test chamber, its accessories, and the test cell in a visibly clean condition in order to ensure reproducibility of the results, to provide personnel safety, and to meet the requirements of calibration and standardization as described in Section 12. Clean the sample preparation equipment as required to prevent the cross-contamination of test materials.

12. Calibration and Standardization

12.1 The test facility shall demonstrate successfully the ability to obtain repeatable data when testing a reference material. The user should purchase a sufficiently large quantity of a single batch of material and verify the repeatability of the test system before it is placed into service and periodically thereafter. A frequency of once per year is recommended. It is possible that the data may not be reproduced exactly. The user should determine the repeatability that is acceptable for their applications.

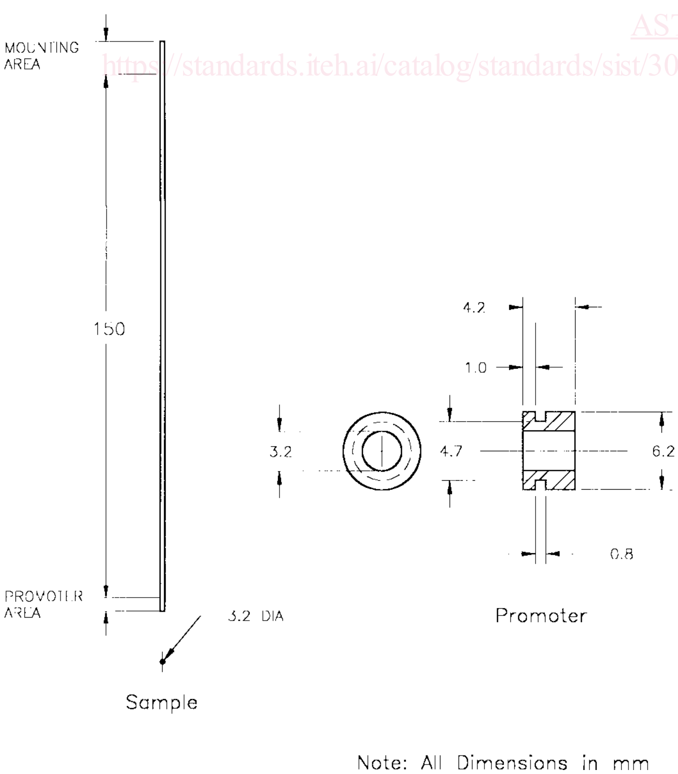

FIG. 3 Typical Test Sample Dimensions

13. Conditioning

13.1 Pressurize and vent the chamber a sufficient number of times to ensure that no more than 0.01 % of the original atmosphere in the vessel remains. This may be accomplished by pressurizing the vessel at one inlet location and venting from a more remote outlet location (preferably diametric to the inlet) several times. If the vessel is pressurized on each cycle to the absolute pressure, P_h, and then vented to atmospheric pressure, P_a, the minimum number of cycles, n, required is equal to or greater than that given by the following relationship:

$$n = \frac{-4}{\log_{10}(P_a/P_h)} \quad (1)$$

Alternately, the vessel may be purged and the vent gas analyzed to confirm oxygen purity.

14. Procedure

NOTE 6—Care should be taken to avoid contaminating the test sample after it has been cleaned.

14.1 Press-fit the promoter, if used, to the bottom of the test sample.

14.2 Measure the length of the sample. The portion included in the sample mount and the promoter is excluded.

14.3 Wrap the igniter wire around the promoter.

14.4 Install the test sample in the chamber.

14.5 Attach the igniter wire to the igniter wire terminals.

14.6 Seal the chamber. Pressurize and vent a sufficient number of times to ensure that no more than 0.01 % of the original atmosphere in the vessel remains, or evacuate to 1.33 Pa (~0.01 torr).

14.7 Pressurize with test gas to the test pressure. A schedule of suggested test pressures is given in Table 2. When the margin of error must be minimized, tests may be conducted at intermediate levels. Astute use of the existing data given in Guide G 94, Table X1.1, may enable the initial selection of test pressures near the ultimate threshold and reduce the amount of unnecessary testing.

14.8 Activate the data acquisition system to record all necessary data, including the video recorder, if being used.

14.9 Apply electrical power to the igniter wire.

14.10 When the promoter has stopped burning, turn off power to the igniter wire, or leave the power on for a preset time.

14.11 Turn off the data acquisition system when sample-burning has ceased completely, or when the maximum pressure has been reached.

14.12 Vent the gases in the test chamber and verify that the chamber is depressurized. Ensure that no personnel are exposed to the vent gases.

14.13 Unseal the chamber and remove the test sample from

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