



Designation: G86 – 17

Standard Test Method for Determining Ignition Sensitivity of Materials to Mechanical Impact in Ambient Liquid Oxygen and Pressurized Liquid and Gaseous Oxygen Environments¹

This standard is issued under the fixed designation G86; 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 method² describes test equipment and techniques to determine the impact sensitivity of materials in oxygen under two different conditions: (1) in ambient pressure liquid oxygen (LOX) or (2) under pressure-controlled conditions in LOX or gaseous oxygen (GOX). It is applicable to materials for use in LOX or GOX systems at pressures from ambient to 68.9 MPa (0 to 10 000 psig). The test method described herein addresses testing with pure oxygen environments; however, other oxygen-enriched fluids may be substituted throughout this document.

1.2 This test method provides a means for ranking nonmetallic materials as defined in Guide G63 for use in liquid and gaseous oxygen systems and may not be directly applicable to the determination of the sensitivity of the materials in an end-use configuration. This test method may be used to provide batch-to batch acceptance data. This test method may provide a means for evaluating metallic materials in oxygen-enriched atmospheres also; however, Guide G94 should be consulted for preferred testing methods.

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

1.4 *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.* See also Section 9.

1.5 *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:*³

- D1193 Specification for Reagent Water
- D4080 Specification for Trichloroethylene, Technical and Vapor-Degreasing Grade
- G63 Guide for Evaluating Nonmetallic Materials for Oxygen Service
- G88 Guide for Designing Systems for Oxygen Service
- G93 Guide for Cleanliness Levels and Cleaning Methods for Materials and Equipment Used in Oxygen-Enriched Environments
- G94 Guide for Evaluating Metals for Oxygen Service

2.2 *Military Document:*⁴

- MIL-D-16791 Detergent, General Purpose (Liquid, Non-ionic), Type One

2.3 *American Chemical Society:*⁵

- Trichloroethylene, Reagent Grade

2.4 *Compressed Gas Association:*⁶

- G-4 Oxygen
- G-4.1 Cleaning Equipment for Oxygen Service
- G-4.3 Oxygen, Gaseous, Type I B
- G-4.3 Oxygen, Liquid, Type II B
- G-10.1 Nitrogen, Gaseous, Type I B
- G-10.1 Nitrogen, Liquid, Type II B

³ 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.

⁴ Available from Standardization Documents Order Desk, DODSSP, Bldg. 4, Section D, 700 Robbins Ave., Philadelphia, PA 19111-5098, <http://dodssp.daps.dla.mil>.

⁵ Available from American Chemical Society (ACS), 1155 Sixteenth Street, NW Washington, DC 20036, <http://www.acs.org>.

⁶ Available from Compressed Gas Association (CGA), 4221 Walney Rd., 5th Floor, Chantilly, VA 20151-2923, <http://www.cganet.com>.

¹ This test method is under the jurisdiction of ASTM Committee G04 on Compatibility and Sensitivity of Materials in Oxygen Enriched Atmospheres and is the direct responsibility of G04.01 on Test Methods.

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² *NASA Handbook 8060.1B, Pressurized Liquid and Gaseous Oxygen Mechanical Impact Test*, Sept. 1981, pp. 4-72.

2.5 NASA Standard:⁷

NSS 1740.15 Safety Standard for Oxygen and Oxygen Systems

2.6 ASTM Adjuncts:

ABMA-Type Impact Tester and Anvil⁸

3. Terminology

3.1 Definitions of Terms Specific to This Standard:

3.1.1 energy threshold, *n*—the highest impact energy level at a given pressure for which the passing criteria have been met.

3.1.2 GOX, *n*—gaseous oxygen.

3.1.3 LOX, *n*—liquid oxygen.

3.1.4 mechanical impact, *n*—a blow delivered by a plummet that has been dropped from a pre-established height onto a striker pin in contact with a sample.

3.1.5 reaction, *n*—a chemical change or transformation in the sample initiated by a mechanical impact.

3.1.5.1 Discussion—A reaction from ambient pressure, LOX mechanical impact may be determined by an audible report, an electronically or visually detected flash, obvious charring of the sample, sample cup assembly, or striker pin.

3.1.5.2 Discussion—Reactions in pressurized LOX or GOX are typically indicated by an abrupt increase in test sample temperature, chamber pressure, and light levels and may be supplemented by obvious changes in odor, color, or material appearance as a result of thermal decompositions observed during examination after the test.

3.1.6 pressure threshold, *n*—the highest pressure at a given impact energy level for which the passing criteria have been met.

4. Summary of Test Method

4.1 The mechanical impact test system is designed to expose material samples to mechanical impact in the presence of liquid or gaseous oxygen at pressures from ambient to 68.9 MPa (0 to 10 000 psig). The basic test system configuration consists of: an electromagnet, a plummet, plummet guide tracks, plummet hold/release mechanism, base plate, anvil plate, a sample cup assembly holder, sample cup assembly, and striker pin (see Fig. 1). For tests conducted under pressure-controlled conditions, the anvil plate and sample cup assembly holder are replaced with a test chamber equipped with a striker pin or striker pin counterloader (see Fig. 2), test chamber purge, pressurization and vent systems (see Fig. 3), and a plummet catcher (see Fig. 4). The general procedure is to prepare the test sample and record significant pretest data.

4.2 Ambient LOX Impact Test—The test conditions (pressure and temperature) are the ambient pressure of the test facility and the boiling point of LOX at that pressure. Each sample is placed into a sample cup assembly (see Fig. 5, Fig.

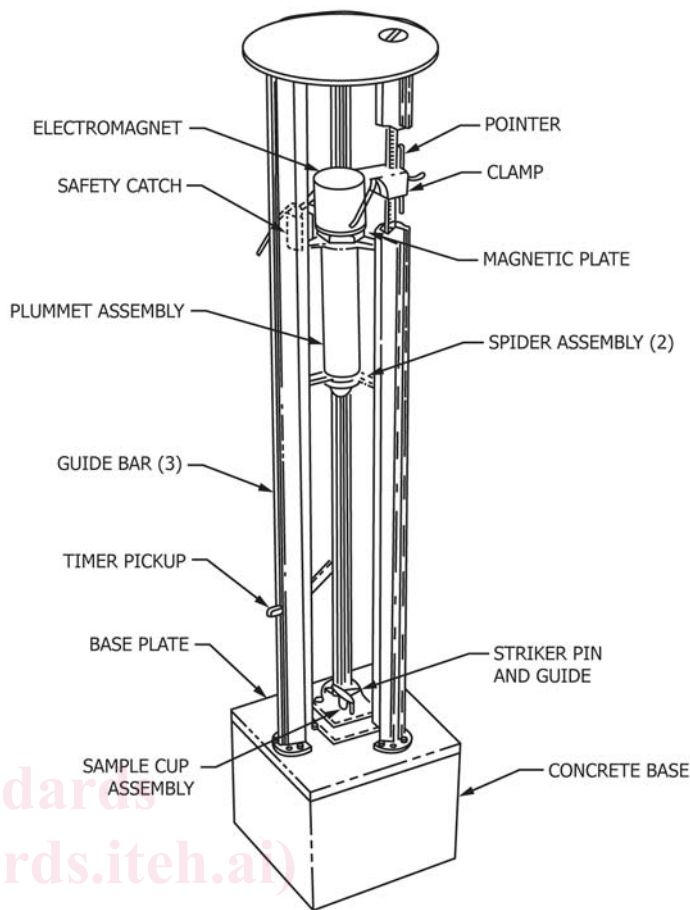


FIG. 1 Oxygen Impact Test Frame

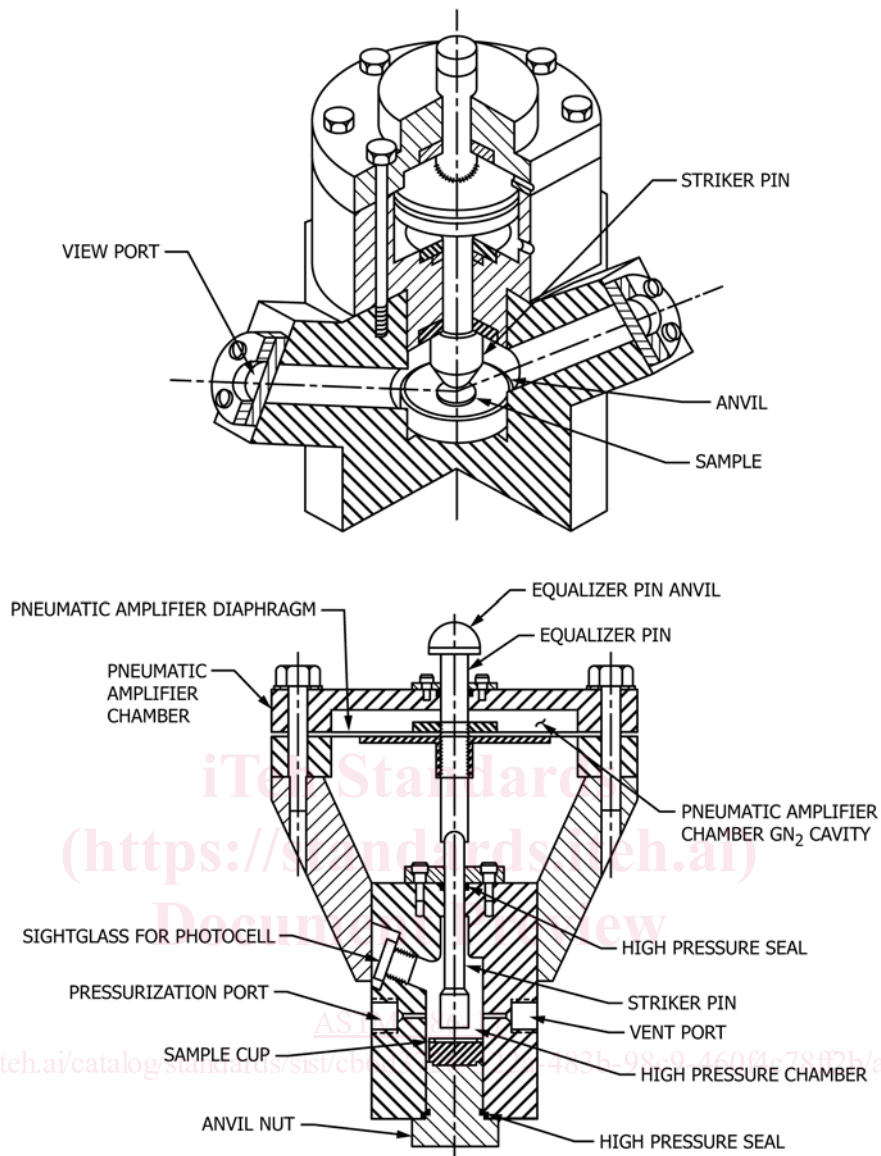
11, and Fig. 14), precooled in a sample freezing box (Fig. 6), covered with LOX, and placed in the sample cup assembly holder seater in the anvil assembly of the impact tester. The plummet is dropped from a selected height onto the striker pin, which transmits the energy to the test sample. Observation for any reaction is made and noted. Drop tests are continued using a fresh sample, sample cup assembly, and striker pin for each drop until the threshold level is determined or the test series is completed.

NOTE 1—When testing samples that are sometimes capable of initiating false reactions with the aluminum cups, use stainless steel disks as false bottoms in the cups. To minimize interaction, insert disks should be used between abrasive samples and one-piece cups, or sample cup assemblies/holders with a steel base (Fig. 11 and Fig. 14) should be used in place of aluminum one-piece cups.

4.3 For materials tested in pressurized LOX or GOX, each sample is placed in the test chamber. The test chamber is filled with liquid or gaseous oxygen, pressurized to the required test pressure, and the striker pin or striker pin counterloader is pressed down against the top of the test sample. The plummet is dropped from a selected height onto the striker pin or striker pin counterloader. Instrumentation devices that monitor the test chamber interior for pressure, temperature, and light emission provide evidence of test sample reaction. The sample is removed from the chamber, and the sample is inspected for other evidence of reaction such as odor or charring. Drop tests

⁷ Available from National Aeronautics and Space Administration (NASA), NASA Headquarters, Suite 1M32, Washington, DC 20546.

⁸ Detailed drawings from the ABMA-Type Impact Tester and Anvil Region Assembly are available at a nominal fee from ASTM International, 100 Barr Harbor Dr., Philadelphia, PA 19428. Request Adjunct ADJD2512.



1	Pneumatic Amplifier Chamber	9	High-Pressure Chamber
2	Equalizer Pin Anvil	10	Sample Cup Assembly
3	Equalizer Pin	11	Anvil Nut
4	Pneumatic Amplifier Diaphragm	12	High-Pressure Seal
5	Pneumatic Amplifier Chamber GN ₂ Cavity	13	Pressurization Port
6 and 8	Striker Pin	14	Vent Port
7	High-Pressure Seal	15	Sightglass for Photocell

FIG. 2 Two Types of High-Pressure Test Chambers

are continued using a fresh sample, sample holder, and striker pin or striker pin counterloader for each drop, until the threshold level is determined or the test series is completed. Additional modifications to the above procedure are required when testing is performed at temperatures above ambient.

4.4 This test method may be used to determine the impact sensitivity of a material, batch-to-batch acceptance, or to satisfy other prescribed pass-fail criteria.

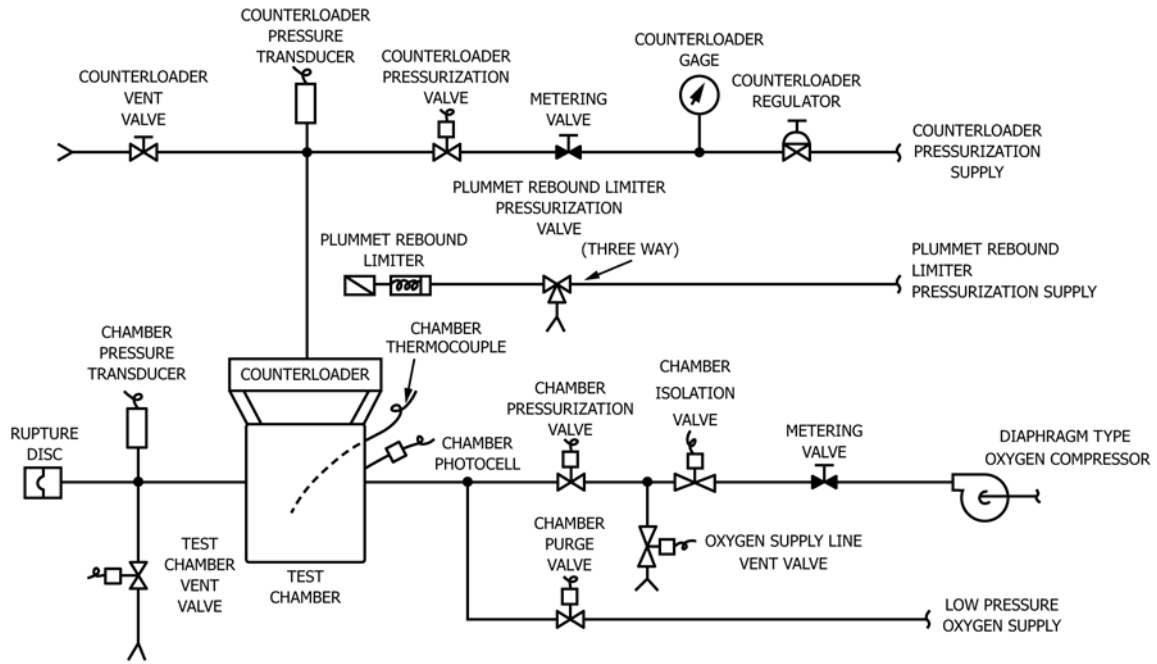


FIG. 3 Typical Pressurization Piping system for a LOX/GOX Pressurized Test System

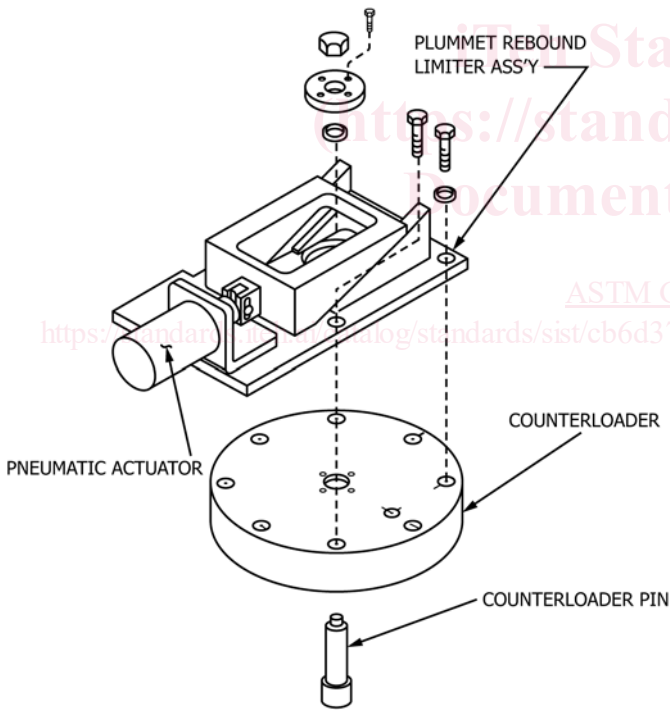
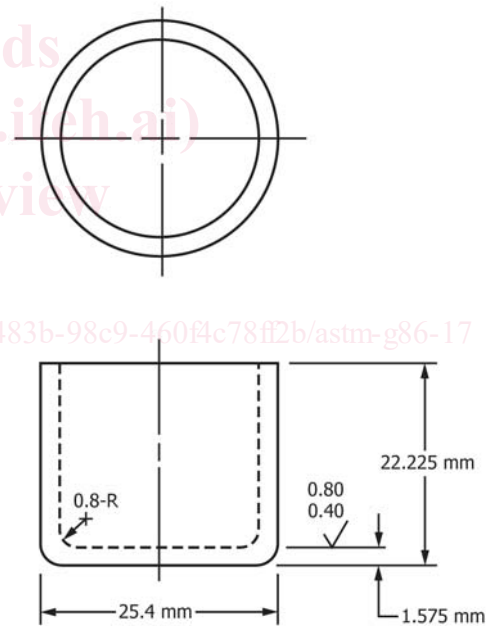


FIG. 4 Typical Plummet Rebound Limiter Assembly



- NOTE 1—Break sharp edges
- NOTE 2—All surfaces to be 0.40 μm (16 $\mu\text{in.}$) or smoother.
- NOTE 3—The thickness and parallelity of the cup bottom shall be controlled to 2.0 mm by coining.
- NOTE 4—Material: Aluminum 5052 temper H32.

FIG. 5 LOX Impact Tester One-Piece Sample Cup Assembly

5. Significance and Use

5.1 This test method evaluates the relative sensitivity of materials to mechanical impact in ambient pressure liquid oxygen, pressurized liquid oxygen, and pressurized gaseous oxygen.

5.2 Any change or variation in test sample configuration, thickness, preparation, or cleanliness may cause a significant change in impact sensitivity/reaction threshold.

5.3 Suggested criteria for discontinuing the tests are: (1) occurrence of two reactions in a maximum of 60 samples or less tested at the maximum energy level of 98 J (72 ft•lbf) or one reaction in a maximum of 20 samples tested at any other energy level for a material that fails; (2) no reactions for 20

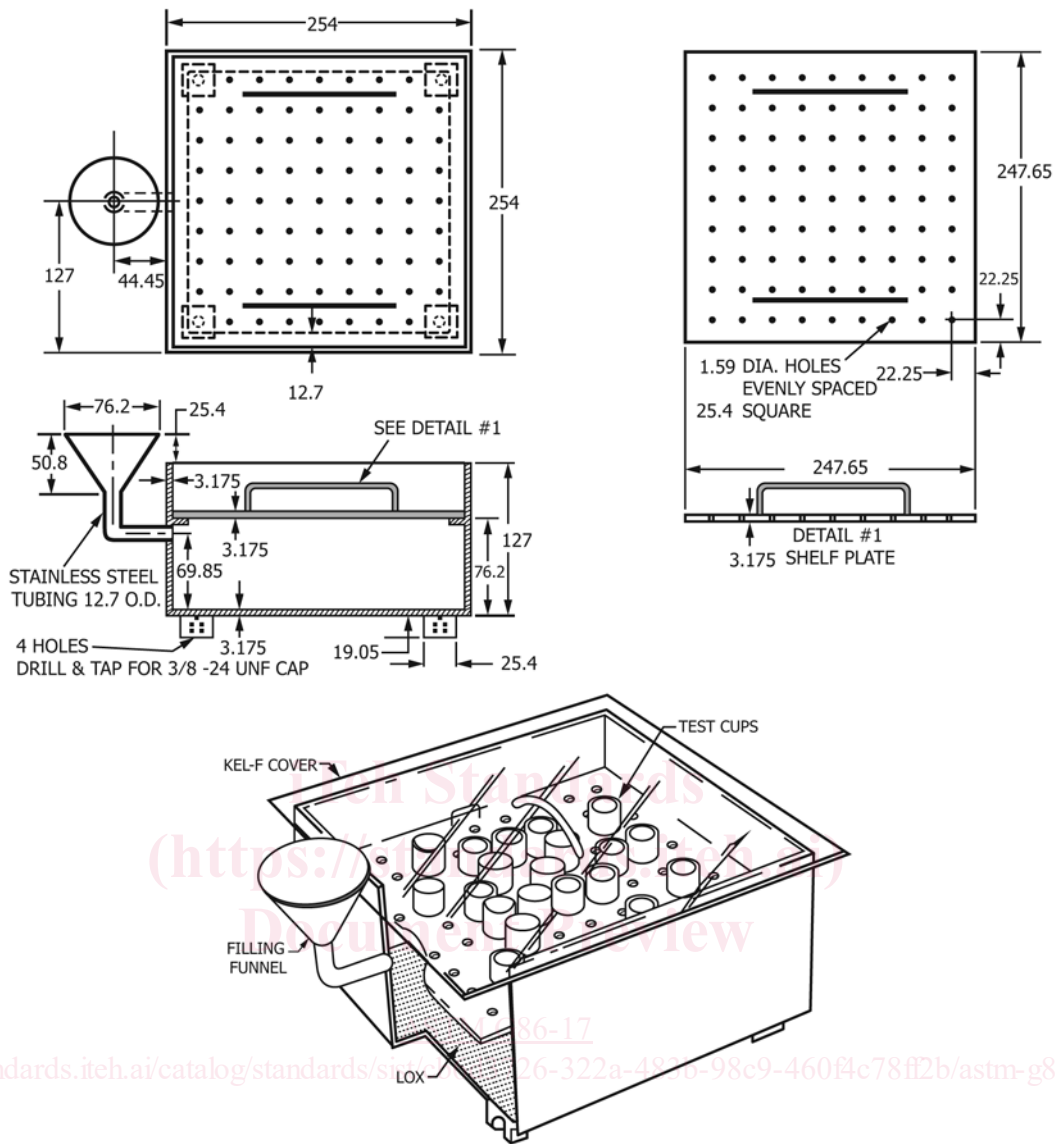


FIG. 6 Typical Sample Freezing Box

samples tested at the 98-J (72-ft•lbf) energy level; or (3) a maximum of one reaction in 60 samples tested at the maximum energy level.

6. Criteria for Acceptance for Ambient LOX and Pressurized LOX and GOX Mechanical Impact Test

6.1 To meet the requirements for acceptability, the material shall show no reaction when being subjected to 20 successive impact tests tested at 98 J (72 ft•lbf) using the equipment described in Section 10.

6.2 The test may be discontinued and the materials considered to have failed if there is one reaction in 20 drops at any energy level less than 98 J (72 ft•lbf).

6.3 A material is acceptable after 60 successive impact tests with not more than one reaction at 98 J (72 ft•lbf). The test may be terminated and the material considered to have failed if there are two reactions in 60 tests or less at 98 J (72 ft•lbf).

6.4 The material shall show none of the following reactions during any of the tests.

- 6.4.1 Audible explosion.
- 6.4.2 Flash (electronically or visually detected).
- 6.4.3 Evidence of burning (obvious charring, see Note 2).
- 6.4.4 Major discoloration (as a result of ignition only rather than other phenomena).
- 6.4.5 A temperature or pressure spike in elevated temperature tests.

NOTE 2—A burnt odor alone is not considered sufficient proof that a reaction has occurred. If a reaction occurs (including those during bounce of plummet), it shall be reported as evidence of sensitivity. Inclusion of bounce reactions applies to ambient LOX mechanical impact tests only.

6.5 All materials that fail and remain candidates for use shall be subjected to LOX or GOX mechanical impact energy threshold determinations in the thickness of use.

6.6 The material to be tested must be traceable back to the original manufacturer and to a specific batch or lot numbers, or both.

6.7 The thickness of the sample shall be the worst-case thickness. While the worst-case thickness has been found to vary from material to material, the general trend has been that thinner samples of materials are more reactive.

6.8 For the ambient LOX impact test, test conditions (pressure and temperature) are the ambient pressure of the test facility and the boiling point of LOX at that pressure. For the pressurized test, test conditions (pressure and temperature) shall be determined for each test according to the requirements specified by the requester.

6.9 Preparation of the samples for testing involve the following tasks.

- 6.9.1 Receiving the visually inspecting the material,
- 6.9.2 Preparing the sample to the specified dimensions,
- 6.9.3 Cleaning the samples, and
- 6.9.4 Inspecting the samples.

7. Sample Preparation

7.1 Test material requirements and documentation:

7.1.1 *Traceability*—The material to be tested may be traceable back to the original manufacturer and to specific batch or lot numbers, or to both. When received, the test material should be accompanied by proper identification (for example, product data sheets, batch or lot numbers) identifying the sample, material manufacturer, and appropriate material safety data sheets. It is the responsibility of the procuring authority to identify material traceability.

7.1.2 *Usage Conditions*—The worst-case usage thickness, conditions and any cleanliness requirements shall be identified by the procuring authority.

7.1.3 *Minimum Recommended Material Quantities*—Sufficient material shall be available to permit preparation and testing of 140 separate samples as defined in **Table 1**.

7.2 *Test Material Receiving and Sample Processing*

7.2.1 *Receiving and Inspection*—Upon receipt the testing facility shall inspect the supplied test material and documentation to verify that all requirements of subsection 7.1 have been met. The material shall be inspected and any flaws shall be noted and discussed with the procuring authority. Additional cleaning procedures shall be implemented if required by the procuring authority.

7.2.2 *Preparing Samples to the Proper Dimensions:*

7.2.2.1 Materials normally used in thicknesses greater than 6.35 mm (¼ in.) shall be sized and tested as 17.5-mm diameter disks of 6.35 ± 0.13-mm (0.250 ± 0.005-in.) thickness. Failure of samples to meet the requirements of this test method shall be cause for the rejection of the material. Greases, fluids, and other materials, whose thicknesses are directed by conditions of use, shall be tested as 1.27 ± 0.13-mm (0.050 ± 0.005-in.) layers in insert cups. Materials not readily available in sheet form shall be tested in the available configuration. Specimens shall be free of ragged edges, fins, or other irregularities.

NOTE 3—Unless otherwise requested by procuring authority, the test facility should filter all test liquids using ≤5 micron filters to prevent particulate contamination.

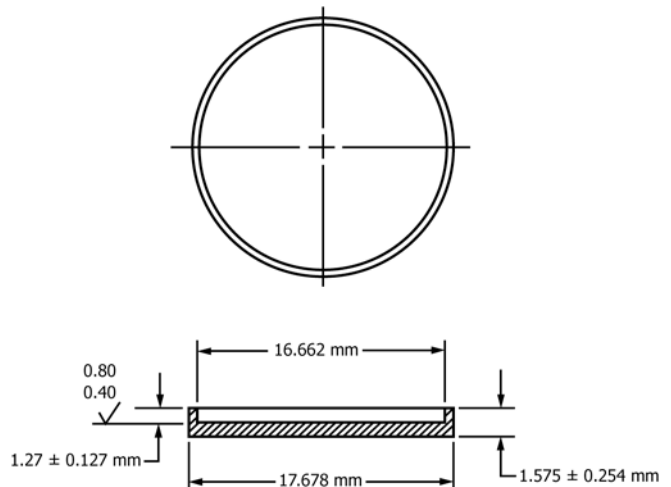
7.2.2.2 *Preparation of Liquid Samples as Supplied*—Prepare a homogenous sample. A microburet may be used to transfer the specimen into the sample cup assemblies. For viscous materials, a microsyringe may be used. Determine the volume of the sample required to obtain a sample thickness of 1.27 ± 0.13 mm (0.050 ± 0.005 in.) and transfer directly into the sample cup assembly or insert cup before freezing. (This determination is required due to variations from liquid to liquid in physical properties such as density, surface tension, and volatility.) A micrometer depth gage with leveling blocks is suggested for measurement. The work table must be level. If testing in liquid oxygen is to be performed in LOX, check the thickness of four liquid samples after they are frozen and record. Limit exposure to atmosphere during preparation of liquid samples and prepare all samples to be tested for the day simultaneously.

7.2.2.3 *Preparation of Liquid Samples, Concentrated*—Concentrate the liquid specimens of cleaning agents before their addition to the one-piece sample cup assembly if acceptance is based on a nonvolatile residue insensitivity requirement. Concentrate the liquid sample to 2 % of its original volume by evaporating the sample in a large round-bottom

TABLE 1 Recommended Minimum Quantities of Material Required for Testing

Material Form ^A	Minimum Quantities
Sheets	2000-cm ² (319-in. ²) total area by 3.5-mm (⅛-in.) maximum thickness
Coatings, inks, and adhesives	120 cm ³ (4 fluid oz.)
Foams	2000-cm ² (310-in. ²) total area by 3.5-mm (⅛-in.) maximum thickness
Insulated wires	267 cm (105 in.) in length

^A Actual test configurations and material quantities for material forms other than those listed (for example, O-rings and seals) must be established and approved by the responsible procurement or user materials organization.



NOTE 1—Material: stainless steel 300 series.

NOTE 2—Break all sharp edges 0.19 mm.

FIG. 7 LOX Impact Tester Insert Cup

flask heated in a constant-temperature water bath, at a temperature no higher than 5 °C below the boiling point of the sample. Pass air over the surface of the sample at a rapid rate. A potential apparatus and procedure for the sample preparation is given in Annex A1, Method A. Add the 2 % concentrated sample to the one-piece sample cup assembly, two-piece sample cup assembly base, or insert cup until a thickness of 1.27 ± 0.13 mm (0.050 ± 0.005 in.) is obtained. If testing is to be performed in LOX, check the thickness of four liquid samples after they are frozen and record. Limit exposure to atmosphere during preparation of liquid samples and prepare all samples to be tested for the day simultaneously.

7.2.2.4 *Preparation of Liquid Sample Residues*—Place 5 mL of the concentrated sample (obtained as is described in 7.2.2.3) in the one-piece sample cup assemblies or insert cups and heat in an oven at 5°C below the boiling point. Blow filtered air over the samples and remove the vapors by vacuum. A detailed description of the apparatus and the procedure is presented in Annex A2, Method B. If testing is to be performed in LOX, check the thickness of four liquid samples after they are frozen and record. Limit exposure to atmosphere during preparation of liquid samples and prepare all samples to be tested for the day simultaneously.

7.2.2.5 *Leak Check Compounds, Dye, Dye Penetrant, and Emulsifier*—Clean, unsealed, undyed sulfuric acid-anodized 6061-T6 aluminum alloy disks (or other substrate specified by the manufacturer or requester as a means to simulate end-use configuration), of similar dimensions to the insert disk (Fig. 8) are used as a substrate. When appropriate, insert disks maybe used as the substrate disc. Clean the disks before use (see 11.2.2.1). After cleaning, dip new anodized disks in the test materials for 15 min and drain for 15 min with the disks oriented vertically. Cure the sample as specified, then store the prepared disks in a clean container until required for testing. If the substrate disc is not a standard Insert Disc, blank insert disc test checks (see 11.4) preformed during testing shall be

performed using virgin substrate discs, cleaned by the same process as those used for the test samples.

7.2.2.5.1 *Reactions involving materials prepared on aluminum disks* have the potential to be extremely severe as a result of ignition of the aluminum disk, which may be initiated by a reaction of the test material. For this reason, insert discs (Fig. 8) are typically used for preparing this type of material.

7.2.2.6 *Preparation of Greases and Semisolids*—Press a sufficient amount of sample material (a slight excess) into an insert cup or the sample recess of a two-piece sample cup assembly 1.27 ± 0.13 mm (0.050 ± 0.005 in.) deep (see Fig. 7) with a cleaned, stainless steel spatula to form a uniform sample free of bubbles and void areas. Scrape the excess sample level to the rim of the insert/recessed sample cup until a smooth surface is obtained. It is necessary to fill the cup uniformly. Store the prepared cups in a clean container until required for testing.

7.2.2.7 *Preparation of Solids*—Cut and prepare samples of solid material to a diameter of 17.5 to 19.1 mm (0.69 to 0.75 in.). Sheet material not available in 1.52 ± 0.13 -mm (0.060 ± 0.005 -in.) thickness is tested in the thickness intended for use when that thickness is not more than 6.35 mm (0.250 in.). Materials normally used in a thickness greater than 6.35 mm (0.250 in.) are cut to provide disks of 6.35 ± 0.13 mm (0.250 ± 0.005 -in.) thickness.

7.2.2.8 *Sample Preparation of Material Configurations Insufficient for Standard Sample Fabrication*—Cut or otherwise section the test material into small pieces 1.27 to 6.35 mm (0.05-0.25 in.) along each dimension and combine multiple pieces to form a collection of uniform thickness constituting an individual test sample with a total mass of 400 to 600 mg (0.0141 to 0.0212 oz).

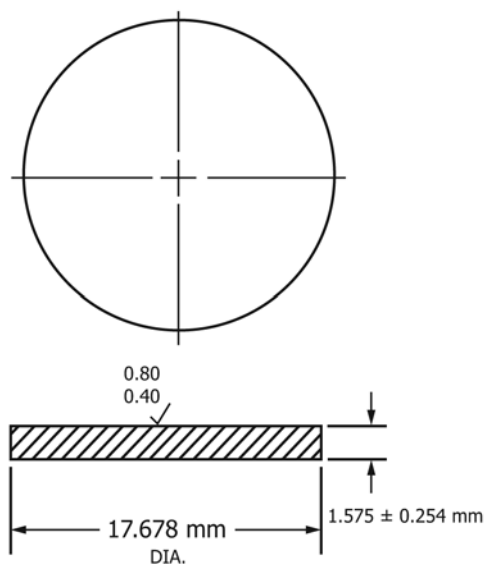
NOTE 4—This method is only intended for use when a material’s usage configuration renders all other preparation methods impractical.

7.2.2.9 *Preparation of Solder (Solid or Flux-Core Type)*—Prepare solder samples as follows: melt the solder (solid or flux-core type) at a temperature no higher than 25°C above the melting point of the solder in a mold to form an ingot. Roll the ingot to form a flat sheet 0.51 ± 0.13 (0.020 ± 0.005 in.) thick. Punch disks of 17.5-mm ($1\frac{1}{16}$ -in.) diameter from the sheet. Clean the disks by detergent washing, water rinsing, drying, and vapor degreasing in an appropriate solvent. Store the prepared samples in a clean container until required for testing.

7.2.2.10 *Preparation of Coatings, Paints, Adhesives, and Potting Compounds*—Materials of this type are prepared as follows.

(1) Coating materials (such as paints, dry film lubricants, and conformal coatings) shall be applied to 17.5-mm ($1\frac{1}{16}$ -in.) diameter by 1.6-mm (0.063-in.) thick 300 series stainless steel disks in the same manner and to the same thickness intended for use. After the samples have dried, they shall be placed in the regular sample cup assemblies for ambient pressure testing and used as prepared in the pressurized impact tester.

(2) Elastomeric coatings and adhesives shall be applied as a coating to 300 stainless steel disks using Method 1 or Method 2 described below and cured according to applicable instructions.



NOTE 1—Material: Type 347 stainless steel.

NOTE 2—Break all sharp edges 0.19 mm.

FIG. 8 Insert Disk

(a) *Method 1 (Single-Dip Coat)*—Dip coat insert disks to specified thickness and place on clean aluminum foil or on polytetrafluoroethylene (PTFE) to air dry. The coated inserts shall be removed from the foil and turned over after 30 min to allow both sides to dry. The specimens shall be cured as specified before testing. The coating thickness shall be checked on at least four samples and recorded.

(b) *Method 2 (Brush Coat)*—Material shall be applied onto insert disks using a single brush stroke with a soft nonshedding brush, in single brush coats of finished coating as specified. Each specimen shall be visually examined for contamination (especially bristles from the brush) following application of each coat. The coated specimens shall be air dried for a minimum of 24 h following application of the final coat before testing.

7.2.2.11 *O-Rings*—Each size from each batch of O-rings or O-ring materials or both shall be sampled and tested as follows unless it can be demonstrated that test results on different sizes and batches are comparable. To clean O-rings before testing, rinse with tap water, rinse in nonionic detergent solution, rinse in DI water, drain for a minimum of 10 min, and dry using a gaseous nitrogen purge.

(1) *Extruded O-Rings* 140 sample disks 17.5-mm ($1\frac{1}{16}$ -in.) diameter by the thickness of the O-rings shall be cut from a strip after the chopping operation. The disks shall be similarly processed and deflashed with the same equipment used for the O-rings. The disks shall be cleaned as specified for the material and its use.

(2) *Molded O-Rings* 140 sample disks 17.5-mm ($1\frac{1}{16}$ -in.) diameter by the thickness of the O-rings, and which have been similarly processed and deflashed, shall be furnished.

(3) *O-Rings From Standard Stock or Where Above Procedures Are Impractical* O-rings 1.27-cm ($\frac{1}{2}$ -in.) outside diameter or less shall be sampled and tested as a complete O-ring. O-rings larger than 1.27-cm ($\frac{1}{2}$ -in.) outside diameter shall be tested as one segment (approximately 1.91 cm ($\frac{3}{4}$ -in.) long). To clean O-rings before testing, rinse with tap water, wash in nonionic detergent solution, rinse in DI water, drain for a minimum of 10 min, and dry using a gaseous nitrogen purge. If a sample is not impacted during testing, it shall be placed in a new sample cup assembly and precooled before retesting. As an alternative, sufficient samples may be prepared to account for the normal impact misses.

7.2.2.12 *Heat Shrink Tubing*—Heat shrunk tubing shall be preshrunk before testing in accordance with the manufacturer's instructions.

7.2.2.13 *Insulated Wires*—Tests samples shall be cut to 17.5 to 19.1 mm (0.69 to 0.75-in.) lengths. Ends shall remain unstripped. Test samples shall be straightened as much as possible and tested in this configuration.

7.2.3 *Cleaning*—The samples should be cleaned by the same method that will be used in the material application.

7.2.3.1 Test in the as-received condition when the test material is received in a certified clean condition or customer specified final use condition.

7.2.3.2 If the cleaning procedure is not specified, clean the sample before testing by rinsing with tap water, then washing in a nonionic detergent solution, then rinsing with filtered

(25- μ m absolute or smaller filter rating) distilled water, and using filtered (25- μ m absolute or smaller filter rating), dry, low hydrocarbon air or inert gas. If necessary, the samples may be cleaned by rinsing with an oxygen-compatible solvent that is compatible with the test material, prior to the fore mentioned cleaning procedure.

7.2.3.3 If the sample material cannot be wetted with any cleaning solution without altering the test sample, the samples shall be blown clean using filtered (25- μ m absolute or smaller filter rating), dry, low hydrocarbon air or inert gas.

7.3 *Nonmetallic, Solid, Metallic, and Solvent-Resistant Samples*—If received in a certified clean condition, test in the as-received condition. Otherwise, clean the sample before testing by rinsing with tap water, then washing in nonionic detergent solution, then finally rinsing in DI water. Drain for a minimum of 10 min and dry using a gaseous nitrogen purge.

8. Reagents and Materials

8.1 *Alkaline Cleaner*, for test chambers, striker pins, sample cup assemblies, and sample holder units, consisting of a solution of 15 g of sodium hydroxide (NaOH), 15 g of trisodium phosphate (Na_3PO_4), and 1 L of distilled or deionized water.

8.2 *Deionized Water*, conforming to Specification **D1193**, Type IV.

8.3 *Detergent*, a noncorrosive cleaner that is compatible with liquid oxygen in the concentration used, conforming to MIL-D-16791.

8.4 *Gaseous Oxygen*, conforming to CGA G-4.3 Type I B. Oxygen of higher purity may be used if desired (see **Note 5**).

8.5 *Liquid Oxygen*, conforming to CGA G-4.3, Type II B.

NOTE 5—Gaseous mixtures of the appropriate oxygen concentration and certified analysis may be purchased commercially.

8.6 *Gaseous Nitrogen*, CGA G-10.1, Type IB.

8.7 *Liquid Nitrogen*, CGA G-10.1, Type IIB.

8.8 *Trichloroethylene*, ACS reagent grade or Specification **D4080**.

9. Safety Precautions

9.1 LOX

9.1.1 When testing is to be performed in liquid oxygen, normal safety precautions applicable to the handling and use of liquid oxygen must be used.

9.1.2 The hazards associated with handling oxygen are very serious. Contact with the skin can cause frostbite. Contact of liquid oxygen with hydrocarbons or other fuels constitutes a fire or explosion hazard because such mixtures can be sensitive to shock, impact, or vibration.

9.1.3 Personnel working with liquid oxygen must be familiar with its characteristics. Approved goggles or face shields, fire-retardant protective clothing, gloves, and boots must be worn during handling or transfer. Such operations should be performed by no less than two persons, as a minimum. Extreme caution should be exercised in preventing contact with oils or other combustible materials. All tools must be degreased

before use. Precautions should be taken to prevent accumulation of moisture in lines, valves, traps, and so forth to avert freezing and plugging which would cause subsequent pressure ruptures. Care should also be taken to prevent undesired entrapment of liquid oxygen in unvented sections of any system.

9.1.4 Direct physical contact with LOX, cold vapor, or cold equipment can cause serious tissue damage. Medical assistance should be obtained as soon as possible for any cold injury. Proper immediate bystander response be as follows:

9.1.4.1 If it is safe to do so, remove the patient from the source of the cold.

9.1.4.2 In the event of limb-size cryogenic exposure, appropriate response may include an attempt to warm the affected area rapidly with moist heat from a shower, eyewash, or warm water bath, not exceeding 39°C (102°F).

9.1.4.3 Massive full-body cryogenic exposures present significant additional concerns, but removal of the victim from the exposure atmosphere and keeping the victim's airway open are important. Loosely wrapping the victim in a blanket until the arrival of the ambulance team is also advised.

9.1.4.4 Some important don'ts: don't remove frozen gloves, shoes, or clothing; salvageable skin may be pulled off inadvertently. Don't massage the affected part; don't expose the part to temperatures higher than 45°C (112°F), such as heat or fire; this superimposes a burn and further tissue damage; don't apply, ice, snow, or ointments.

9.1.5 Safety shower and other protective equipment should be inspected periodically to ensure that they are operational when needed. Personnel handling liquid oxygen must ensure that oxygen vapors do not remain absorbed in their clothing before smoking or approaching any source of ignition. Desorption of oxygen may be accomplished by remaining in a well-ventilated area for 30 min after exiting the test area.

9.2 GOX

9.2.1 This is a hazardous test. Normal safety precautions applicable to the operation and maintenance of high-pressure gas systems must be followed when working with the test system.

9.2.2 Complete isolation of personnel from the test apparatus is required whenever the test chamber contains a test sample and is pressurized above atmospheric pressure with oxygen. Violent reactions between test materials and high-pressure oxygen must be expected at all times. Test chamber component failure caused by violent test sample reaction has produced shrapnel, flying objects, dense smoke, and high-pressure gas jets and flames inside the test cell. Test cell design and layout, test procedures, personnel access controls, and emergency shutdown procedures must be designed with this type of failure expected any time the test system contains oxygen.

9.2.3 Complete isolation is assured by locating the test apparatus in an enclosure and behind an barricade. The operator is stationed in a control room on the other side of the barricade. Visual observation of the test shall be accomplished by means such as a reinforced window, periscope, mirrors, or closed-circuit television.

9.2.4 Equipment used in a 69-MPa (10 000-psig) oxygen system must be properly designed and rated for oxygen service. Proper design of high-pressure oxygen systems includes designing for minimum internal volumes, thereby limiting the magnitude of catastrophic reactions that may occur while testing materials. Components such as valves, pressure regulators, gages, filters, and the like, must be fabricated from materials that have a proven record of suitability for high-pressure oxygen service. Examples of such materials are Monel 400, Inconel 600, nickel, and selected stainless steels (see [Note 6](#)).

NOTE 6—Where not otherwise indicated, stainless steel shall be of the AISI 300 series.

9.2.5 High-pressure oxygen systems require the utmost cleanliness. Therefore, components should be designed to facilitate disassembly, thorough cleaning, and reassembly without compromise of cleanliness level. Screening tests performed on nonmetallic materials have shown that the impact sensitivity of these materials can vary from batch to batch. Since nonmetallic materials are usually the most easily ignited components in a high-pressure oxygen system, nonmetallic items to be used in this test apparatus, such as seats, seals, and gaskets, should be chosen from the best (that is, least sensitive) available batch of material.

9.2.6 The test chamber shall be isolated from the oxygen source by a double-block-and-bleed valve arrangement consisting of two block valves in series with a vent valve between them. Each block valve shall be locked closed and the vent valve locked open whenever personnel are working in test cell. By ensuring two-valve isolation and continuous venting, the chance of exposing personnel to high-pressure oxygen as a result of inadvertent valve actuation or leakage during sample changeout is minimized (see [Fig. 9](#)).

9.2.7 When testing is to be performed at elevated temperature, normal safety precautions applicable to the operation and maintenance of electrical systems must be followed.

9.2.8 The sample heater, heater wiring, and control system must be designed for continuous usage. Adequate precautions must be taken to eliminate the potential for electrical shock. The heater circuit shall be equipped with a safety switch and warning lights in the immediate vicinity of the tester to permit personnel working on the test chamber to assess the condition of the heater circuit. A local method of opening the circuit must be provided in the test chamber area which is in series with the control area heater control switch. A typical instrumentation control system is shown in [Fig. 3](#).

9.2.9 When performing tests at elevated temperatures, personnel must wear heat-resistant gloves for handling hot components or allow the heated components to cool completely before handling them.

9.3 Trichloroethylene

9.3.1 **Warning**—Harmful if inhaled. High concentrations may cause unconsciousness or death. Contact may cause skin irritation and dermatitis. Avoid prolonged or repeated breathing of vapor or spray mist. Use only with adequate ventilation. Eye irritation and dizziness are indications of overexposure. Do not

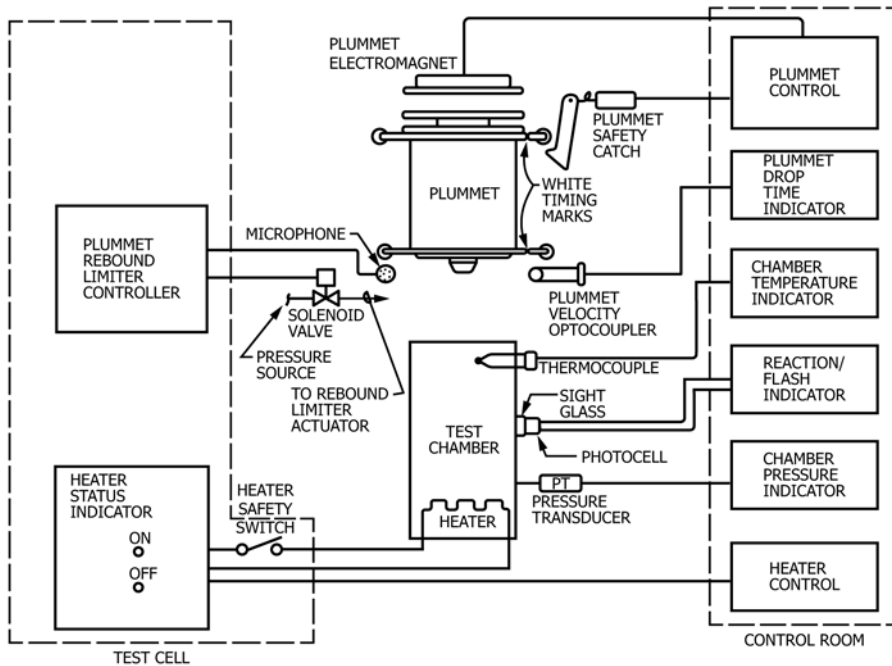


FIG. 9 Typical Instrumentation/Control Diagram for Pressurized LOX/GOX System

take internally. Swallowing may cause injury, illness, or death. Avoid prolonged or repeated contact with skin. Do not get in the eyes. Do not allow to contact hot surfaces, since toxic products can be formed.

9.4 Oxygen

9.4.1 **Warning**—Oxygen vigorously accelerates combustion. Keep oil and grease away. Do not use oil or grease on pressure regulators, gages, or control equipment, except as suggested by Guide G63. Guides G63, G88, and G94 should be used in the selection of materials used in test systems. Use only with equipment conditioned for oxygen service by carefully cleaning to remove oil, grease, and other combustibles. Keep combustibles away from oxygen and eliminate ignition sources. Keep surfaces clean to prevent ignition or explosion, or both, on contact with oxygen. Always use a pressure regulator. Release pressure regulator tension before opening the cylinder valve. All equipment and containers used must be suitable and recommended for oxygen service. Never attempt to transfer oxygen from the cylinder in which it is received to any other cylinder. Do not mix gases in cylinders. Do not drop the cylinders. Make sure cylinders are maintained upright and secured at all times. Keep cylinder valves closed and capped when not in use. Stand away from outlet when opening a cylinder valve. For technical use only; do not use for inhalation purposes. Keep cylinders out of sun and away from heat. Keep cylinders away from corrosive environments. Do not use a cylinder without a label. Do not use dented or damaged cylinders.

9.4.2 See Compressed Gas Association Pamphlets G-4, "Oxygen" and G-4.1, "Cleaning Equipment for Oxygen Ser-

vice" for details of safe practice in the use of oxygen. Practice G93 may be consulted for cleaning practices also.

10. Test Apparatus

10.1 *Ambient Mechanical Impact Test System*—The impact tester for the ambient LOX impact test shall have a rugged structural frame capable of maintaining accurate vertical alignment under repeated shock conditions (see Fig. 1), a mechanism for dropping a plummet which weighs 9.072 ± 0.023 kg (20 ± 0.05 lb) (see Note 7) through a distance of 1.10 ± 0.005 m (43.3 ± 0.2 in.), which will transmit to the test sample an approximate impact energy of 98 J (72 ft•lbf), a striker pin (see Fig. 10) nominally 1.27 cm ($\frac{1}{2}$ in.) in diameter and 5.08 cm (2 in.) long, and a one- or two-piece sample cup assembly (see Fig. 5 and Fig. 11) approximately 2.22-cm ($\frac{7}{8}$ -in.) inside diameter by approximately 2.22-cm ($\frac{7}{8}$ -in.) inside depth made from 0.16-cm ($\frac{1}{16}$ -in.) thick aluminum alloy. The initial alignment and subsequent operation of the impact tester shall be such that the plummet falls uniformly under essentially friction-free conditions. This shall be verified by suitable means on each drop to ensure that ± 3 % of the theoretical drop time is attained. Measurement shall be made as close to the striker pin as possible. See Section 12 for the calibration of the impact tester.

NOTE 7—The weight times the drop height specified is not duplicated for the purposes of this test by combinations other than 9.072 ± 0.023 kg (20 ± 0.05 lb) through a distance of 1.10 ± 0.005 m (43.3 ± 0.2 in.). For example, doubling the mass of the plummet and halving the drop height would not duplicate the specified requirement. Drop height shall be measured from the nose of the plummet to the top of the striker pin with the cup and stainless steel disk in position.