NSTS 22648

# Flammability Configuration Analysis for Spacecraft Applications

October 1988

National Aeronautics and
Space Administration

**Lyndon B. Johnson Space Center**
Houston, Texas

# Preface

This document was prepared to assist payload customers of the Space Transportation System (STS) with flammability assessments required by NHB 1700.7, "Safety Policy and Requirements for Payloads Using the Space Transportation System," to facilitate the assessment and review process, and to make integration easier for the payload customer. It explains procedures and techniques which are considered by NASA to meet the intent of the safety requirements, but it does not preclude alternative approaches.

Leonard S. Nicholson

Leonard S. Nicholson, Manager

NSTS Integration and Operations Office

# Table of Contents

# Tables



# Figures

# 1 Introduction

## 1.1 Purpose

This document presents guidelines for the assessment of flammability hazards associated with Space Transportation System (STS) payload hardware according to the requirements of NHB 1700.7, "Safety Policy and Requirements for Payloads Using the Space Transportation System", paragraph 209.2. These guidelines are intended to simplify compliance with the flammability requirements of NHB 8060.1, "Flammability, Odor, and Offgassing Requirements and Test Procedures for Materials in Environments That Support Combustion", and present assessment procedures, configuration test results, and selected flammability analyses for a representative set of configurations. Selected solutions to flammability problems are included for utilization by STS payload organizations.

## 1.2 Scope

The guidelines described herein are intended for assessment of flammability problems associated with air and oxygen-enriched environments in manned spacecraft. Assessment requirements for specific environments are shown in Table 1-I. Material usages for all configurations (contained or exposed to the spacecraft environment) are considered. Proper application of these guidelines will produce acceptable flammability configurations (in defined environments) for payload hardware located in any compartment of the Orbiter vehicle or payload carrier, and may reduce the anticipated effort devoted to assessment and testing. However, use of these guidelines does not preclude the responsibility of the payload organization for hardware safety.

TABLE 1-I.- ASSESSMENT REQUIREMENTS FOR CONFIGURATION ENVIRONMENT

| LOCATION | APPLICABLE REQUIREMENTS | ATMOSPHERE |
|---|---|---|
| Orbiter Crew Compartment | NHB 1700.7 paragraph 209.2a | 10.2 psia/ 30% oxygen |
| Other manned compartments (e.g. Spacelab) | NHB 1700.7 paragraph 209.2b | as designated by NASA |
| Orbiter Payload Bay | NHB 1700.7 paragraph 209.2c | 14.7 psia 20.9% oxygen |

## 1.3 Definitions

Barrier, Fire - An obstruction (such as a partition) that prohibits or tends to inhibit the propagation of burning. May be internal or external in configuration.

Break, Fire - A gap, opening, or nonflammable material between flammable materials which would prevent propagation of burning.

Containers, Sealed - Containers that are enclosed adequately enough to preclude the replenishment of a combustible atmosphere under conditions of a fire.

Containers, Vented - Containers that are unsealed and permit atmosphere exchange.

Containment, Fire - The situation in which a fire and/or burning particles do not progress, in any manner, beyond the confines of a configuration.

Flammable - A material which fails to meet acceptance criteria when tested according to the requirements of NHB 8060.1 (i.e., one that will burn more than 6 inches when ignited).

Heat Sink - A structure or panel of high thermal conductivity in intimate contact with a burning material which extracts sufficient heat by conduction to lower the temperature below the ignition point and extinguish burning. An effective heat sink could limit initial ignition.

Ignition Source - A source of heat sufficiently intense and localized to induce combustion. For flammability considerations, any electrical wire or elevated temperature component is considered an ignition source. Monopropellants, strong oxidizers, bases, etc. must also be considered.

Nonflammable - A material that meets the acceptance criteria when tested according to the requirements of NHB 8060.1 (i.e., one that self-extinguishes within 6 inches when ignited).

Positive Ignitors - Ignitors that produce a controlled flame.

Propagation Paths - The paths taken by a flame front external to (or within) an enclosure that represent fire paths between flammable materials. They are not necessarily straight or coplanar.

Void Space - Unoccupied volume in a container.

## 1.4 Acronyms and Abbreviations

| | |
|---|---|
| ABS | acrylonitrile butadiene styrene |
| EMS | entry monitor system |
| ECTFE | ethylene chlorotrifluoroethylene |
| ETFE | ethylene tetrafluoroethylene |
| FEP | fluorinated ethylene propylene |
| IMU | inertial measurement unit |
| mil | milli-inch (0.001 inch) |
| NSTS | National Space Transportation System |
| PBI | polybenzimidazole |
| PVC | polyvinylchloride |
| R/C | rotational controller |
| scfm | standard cubic feet per minute |
| TFE | tetrafluoroethylene |
| TVSA | thrust vector servo amplifier |

## 1.5 Background

The guidelines described herein were derived from the NASA fire experience base, which includes the results of the extensive configuration flammability testing conducted since the Apollo 204 fire. As an initial step in fire assessment, NASA assumes that ignition sources are always present. This assumption emphasizes potential propagation paths for fires and dictates use of nonflammable materials as determined by test 1 (upward propagation test) in NHB 8060.1. MSFC HDBK-527/ JSC 09604, "Material Selection List for Space Hardware Systems", lists both nonflammable and flammable materials and should be used in the selection process. Since use of nonflammable materials is not always possible, further assessment of the nature and propagation paths of a potential fire is necessary. A flammability assessment determines whether a propagation path exists and if it creates a fire hazard to the STS or its payloads.

Flammability assessments have been conducted extensively in the past to determine potential fire propagation by analysis and testing. These assessments assumed worst-case environmental conditions (temperature, atmospheric composition, and pressure) and, in test cases, included deliberate placement and sequential ignition of positive ignitors.

The flammability assessment processes for evaluating potentially flammable configurations are presented herein, including summary guidelines and test example cases of their applications. These test example cases present acceptable and unacceptable configurations which can be used to assess (by similarity) the fire risk of other configurations. Many examples were tested at high oxygen concentrations. Configurations which are acceptable under these conditions can be considered acceptable for lower oxygen concentrations. Copies of test reports can be obtained from the National Space Transportation System (NSTS) Integration and Operations information office.

# 2 Flammability Assessment Guidelines Summary

The guidelines which follow provide assessment proceaures which allow users to evaluate flammability hazards associated with their equipment. Users can employ these guidelines (and the examples in Sections 3 through 6) as a similarity basis for certifying their hardware. An explanation of this assessment process and its results are to be included in the hazard report.

When a flammability assessment results in an unacceptable configuration, reduction of flammability hazards is necessary to correct the flammability problems. The primary methods used by NASA to reduce flammability hazards are (1) the limitation of flammable materials by replacement with nonflammable materials and (2) the restriction of propagation paths, either by covering flammable materials with a nonflammable material or by separation of flammable materials.

To conduct a flammability configuration assessment, the following procedure should be used.

1. Identify the flammable materials which are used in the given environment in amounts greater than 0.1 pounds (or 10 square inches) in the crew habitable compartment or greater than 1.0 pounds (or 12 linear inches) in other compartments. This is usually accomplished by compiling a materials list identifying all nonmetallic materials and their worst-case use conditions (including exposure environment and thickness), and then determining their flammability characteristics by consulting MSFC HDBK-527/JSC 09604 or the Materials and Processes Technical Information System (MAPTIS) data base. For information regarding the MAPTIS data base, contact the Materials and Processes Laboratory (mail code EH) at NASA George C. Marshall Space Flight Center (MSFC) at (205) 544-2487 (or FTS 824-2487).

2. Determine whether the externally exposed materials (including container housings) represent fire propagation paths exceeding 6 inches in the crew habitable compartments or 12 inches in other compartments. For any given material application, propagation from one flammable material application to the next is not acceptable and should be precluded. Fire propagation paths can be limited by fire breaks and heat sink effects, such as 2 mils (or less) of a flammable material bonded to or sprayed on a metal substrate at least 20 mils thick. If fire propagation is possible, positive action must be taken to control or eliminate the hazard. Sample solutions are included in following sections of this document.

3. If the configuration is a container, evaluate its capability to contain an internal fire. Fire propagation in a sealed container depends upon the container structural configuration. If the sealed container does not contain oxygen or contains an inert gas, then it can be assumed that fire will not be initiated. Further, it is assumed that for sealed metal containers which contain air, fire will be contained if the container wall is at least 60 mils thick.

   Since oxygen is available to vented containers, it cannot be assumed that the container will contain a fire. However, tests have shown that it is possible for vented containers to contain fires if the container vents are covered with a fine metal (non-aluminum) screen or if the vent area is less than 1 percent of the total surface area. For other vented container configurations, conditions which would lead to uncontrolled fires (such as air flow, vent type, and vent location) must be addressed.

   For payloads that are not powered while mated with or installed in the Orbiter vehicle, internal ignition sources are generally excluded from containers. Therefore, fire initiation is unlikely, and this fact can be the basis for acceptability. However, long-term ground-based power testing must not present a significant fire hazard

Orbiter stowage lockers can be treated as containers that contain fire. Flammable materials stowed in these lockers are usually for short-term use and do not constitute a fire risk if used in a controlled manner and returned to the locker immediately after use. However, powered payloads/experiments that are stowed in lockers for an entire mission (or are located in place of a locker) present a potential fire hazard and must be evaluated as such.

Figure 2-1 is a logic diagram outlining the above assessment procedure. In the case of an unacceptable configuration, the user has two options: (1) use fire break concepts to reduce the flammability hazard by isolating the flammable materials, or (2) conduct a test to show that the configuration is acceptable. If the assessment results in the need for additional testing, the user may contact NASA material specialists for more information.

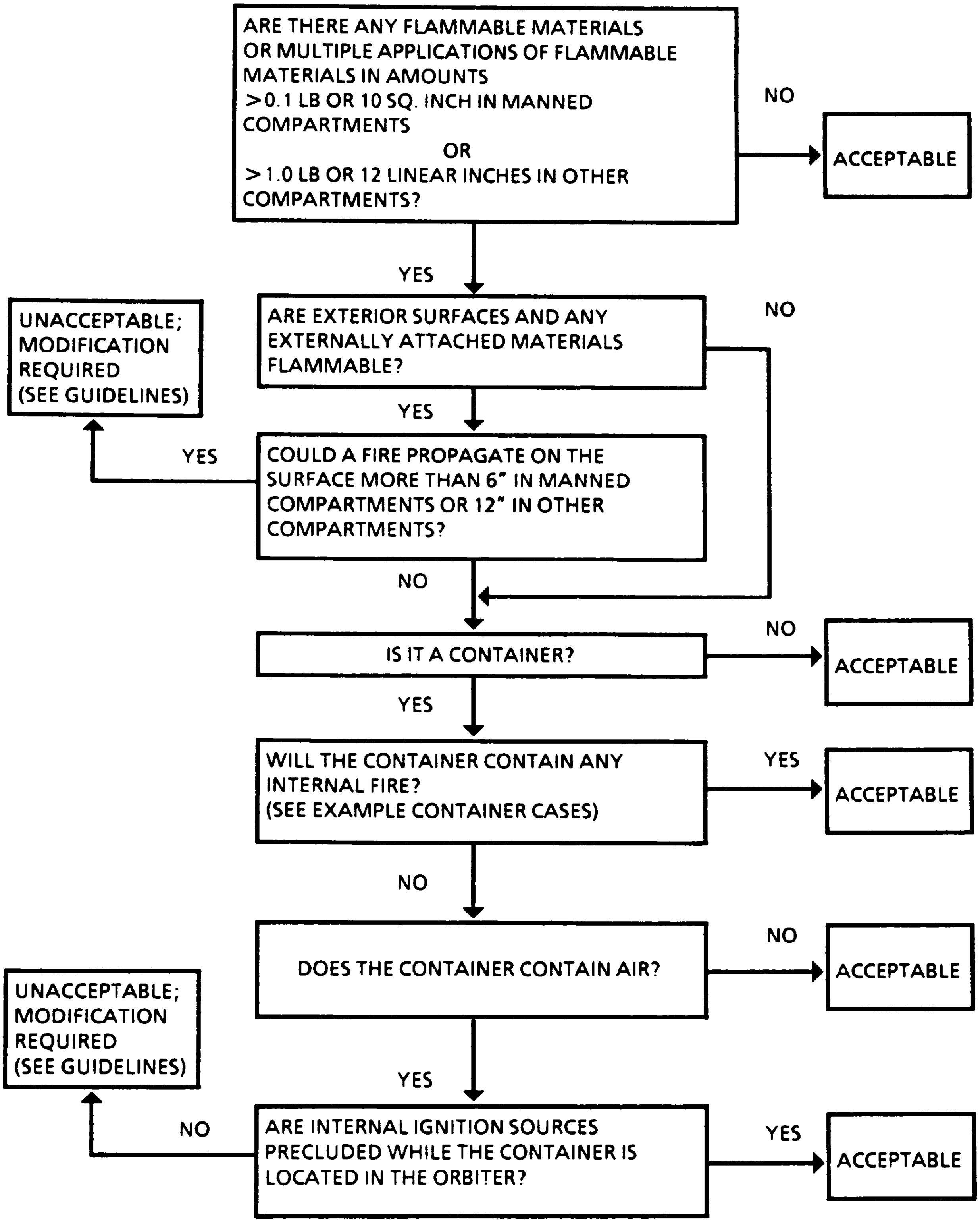


Figure 2-1.- Flammability assessment logic diagram.

# 3 Guideline Application Examples for Exposed Off-the-Shelf Equipment

Many small, "off-the-shelf" components are used in a spacecraft, such as cameras, power tools, medical devices, and personal hygiene items. Most items of this type are accepted "as is" if they are stowed in nonflammable, vented containers (such as stowage lockers) and are taken out only as required and returned after use.

Examples of the methods used to reduce the flammability hazards of flammable components are provided; these methods include replacement of a hazardous material with a nonflammable material or covering the hazardous material with a nonflammable material. Also provided are examples of tests that verified these methods.

## 3.1 Flammability Reduction Methods

### 3.1.1 Commercial Items

Commercial items (including connectors) with flammable housing materials (such as acrylonitrile butadiene styrene (ABS), polyvinylchloride (PVC), polyethylene, and/or polyamides) may be wrapped completely with a 3-mil aluminum tape per Federal Specification L-T-80. Aluminum tape will protect most plastics, foam, and cardboard from external flame initiation. If aluminum tape cannot be used for electrical reasons, a nonflammable fiberglass tape with a silicone adhesive will give the same protection. However, when an item is wrapped with fiberglass tape, each rotation should overlap the previous one by 50 percent for acceptable flammability protection.

For items requiring electrical power, filling them with a suitable material such as a nonflammable glass-filled epoxy potting compound will provide acceptable flammability protection from internal ignition sources. If this method is incompatible with the hardware when internal ignition sources exist and flammable materials are used, the guidelines below for container configurations will apply.

### 3.1.2 Wires and Cables

PVC or chloroprene-insulated power cables are generally not used. Cables to be connected with Orbiter electrical circuitry are usually made of Teflon or polyimide-insulated wire, and meet one of the following specifications:

MIL-C-17/60

MIL-C-17/93

MIL-C-27500 (Teflon jacket only)

MIL-W-16878 slash numbers 4A, 5A, 6, 11, and 13

MIL-W-22759 slash numbers 1, 5-8, 12, 28, 29, 30, and 31

MIL-W-81381

Cables that do not meet any of the above specifications are protected from external ignition sources by one of the following methods:

a. Wrapping with a nonflammable fiberglass-backed/silicone adhesive tape

b. Covering with a sleeve of double-layer 7.5 oz/yd$^2$ Nomex fabric or a single layer of beta cloth, polybenzimidazole (PBI), or other nonflammable fabrics

c. Covering with a braided Teflon sleeve

d. Covering by heat shrinking a polyvinylidene fluoride or Teflon sleeve

Wire and cable accessories such as cable markers, spacers, and cable ties should not contribute to fire propagation paths. Polyvinylidene fluoride or fluoroelastomeric cable markers are generally used. Other types of cable marker material may be acceptable if used in small discrete amounts or covered with a clear Teflon TFE or FEP sleeve. Most types of spacers are usually acceptable because of their heat sink effects. Acceptable lacing cords can be made from Teflon TFE, Teflon TFE/glass, or Nomex, and acceptable cable ties can be made from ETFE or ECTFE fluoropolymers. When flammable cable tie wraps are used, spacing of 2 inches or more between ties generally results in a non-fire-propagation condition.

### 3.1.3 Tubes and Hoses

External tubes or hoses (such as a vacuum cleaner hose) made from flammable materials are either replaced with a nonflammable material or covered with a fire barrier. Clear Teflon TFE or FEP tubes and hoses are readily available to replace flammable materials. If flammable tubes or hoses must be used, the exterior can be protected by a covering of double-layer 7.5 oz/yd$^2$ Nomex or a single layer of PBI, beta cloth, or other nonflammable fabric.

### 3.1.4 Hook and Pile Fasteners

Most types of hook and pile fasteners are flammable. However, Nomex hook and pile fasteners and Astro Velcro burn at relatively lower rates than nylon hook and pile fasteners. To prevent long flame propagation paths, the following usage limits are generally applied:

a. Maximum size: 4 square inches, individually or in pieces

b. Maximum length: 4 inches

c. Minimum separation distance: 2 inches in any direction from another piece

## 3.2 Test Example of Aluminum Tape Overwrap

A battery powered screwdriver was tested to demonstrate the effectiveness of 3-mil aluminum tape as a fire barrier (see test reference 1). The plastic-cased screwdriver burned completely when tested unprotected, but was unaffected when tested wrapped with the tape. Figures 3-1 and 3-2 show the pretest and post-test conditions of the screwdriver without tape protection. Figure 3-3 shows the same type of screwdriver wrapped with aluminum tape.

NASA also tested a disposable dishrack with a cardboard outer case overwrapped with 3-mil aluminum tape (see test reference 2). Only the area near the ignitor was scorched; the rest of the container was unaffected. Figures 3-4 and 3-5 show the pretest and post-test conditions of the dishrack.

## 3.3 Test Example of Nomex Sleeve Covering

A flammable silicone rubber vacuum cleaner hose was covered with a sleeve of double-layer Nomex and tested for flammability at 25.9 percent oxygen (see test reference 3). This sleeve provided the hose with enough protection so that only a small area of the Nomex sleeve was scorched. Figures 3-6 and 3-7 show the pretest and post-test conditions of the hose.


Figure 3-1.- Battery-powered screwdriver (pretest)


Figure 3-2.- Battery-powered screwdriver (post-test).

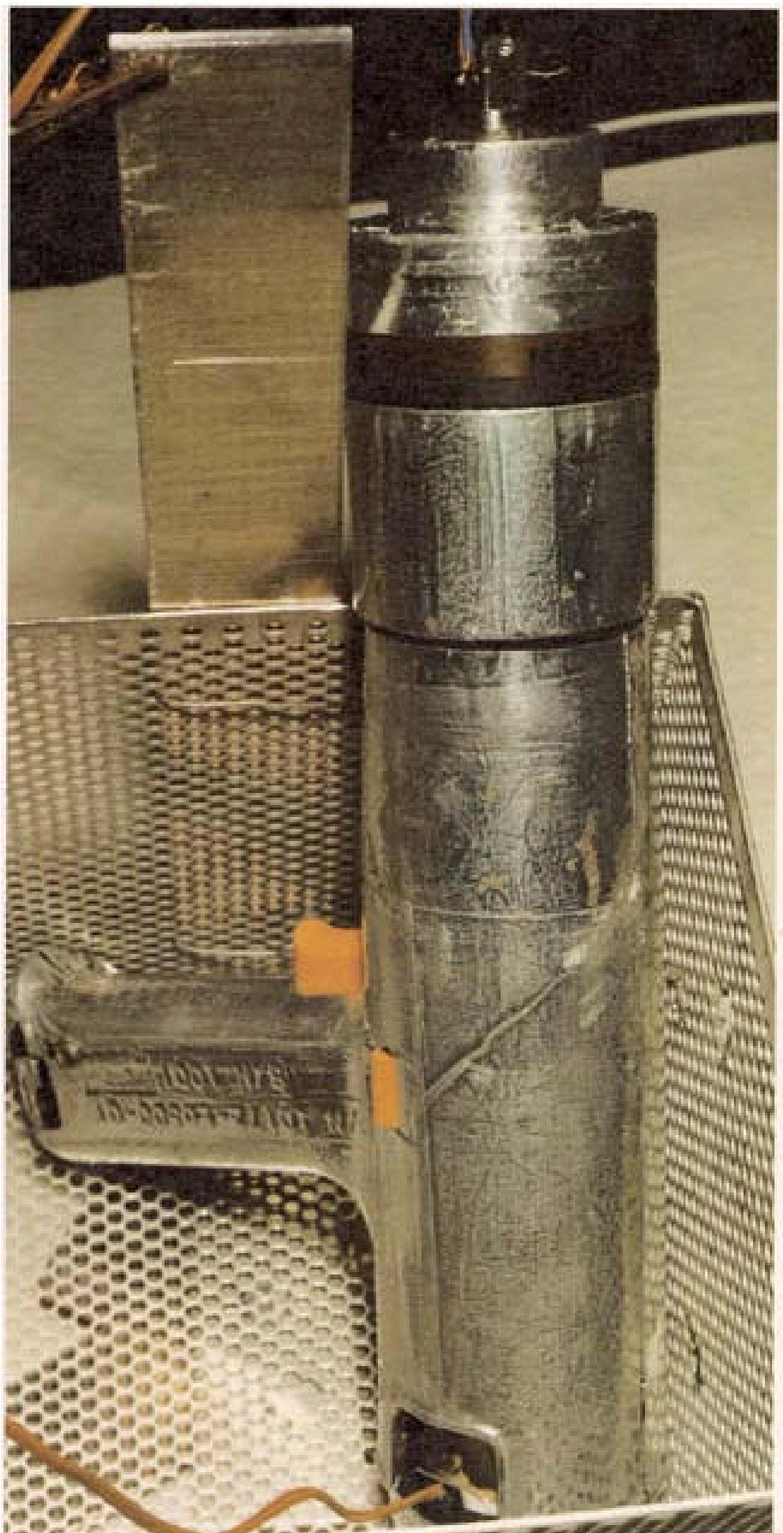

Figure 3-3.- Battery-powered screwdriver (taped)

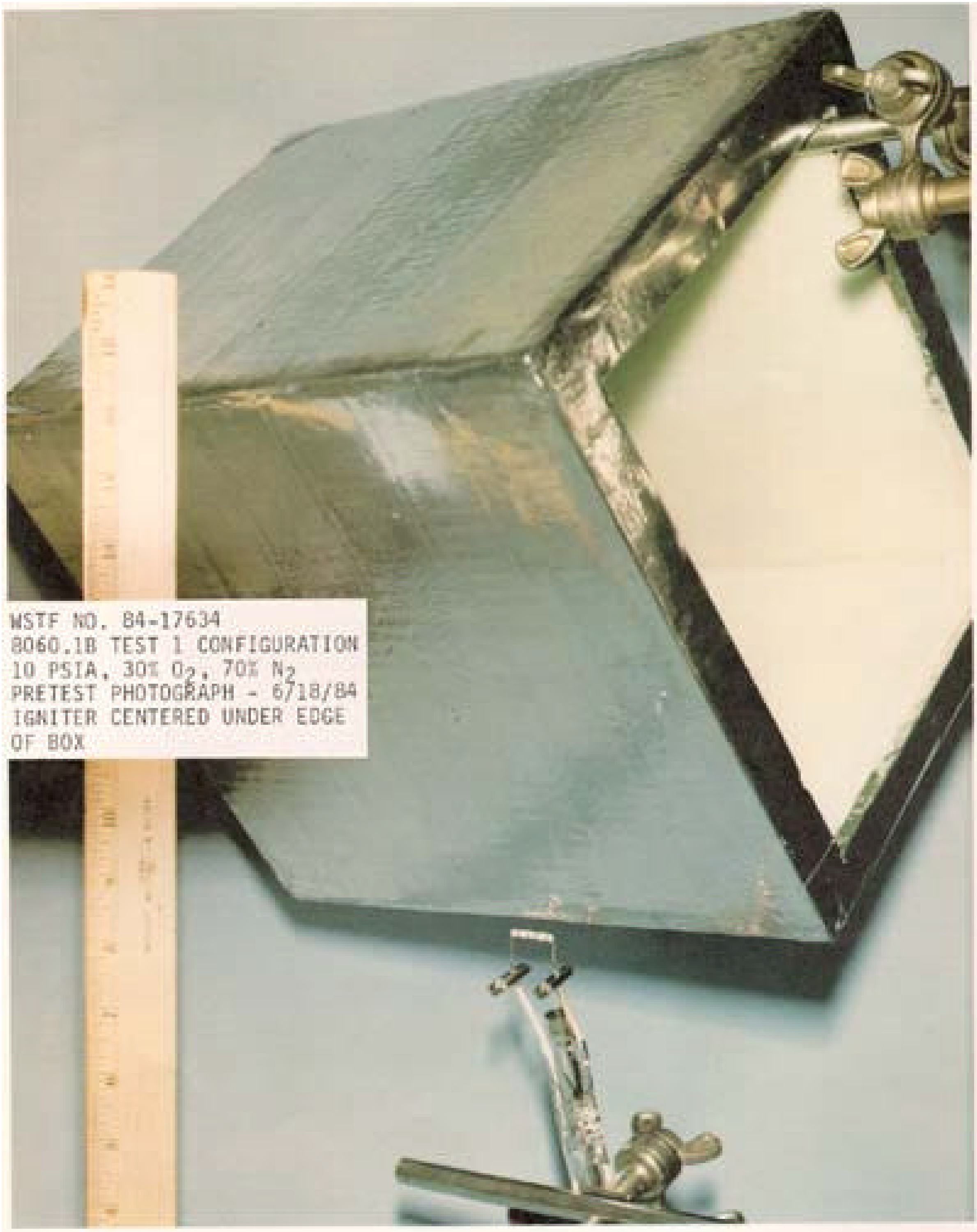


Figure 3-4. - Disposable dishrack (pretest).

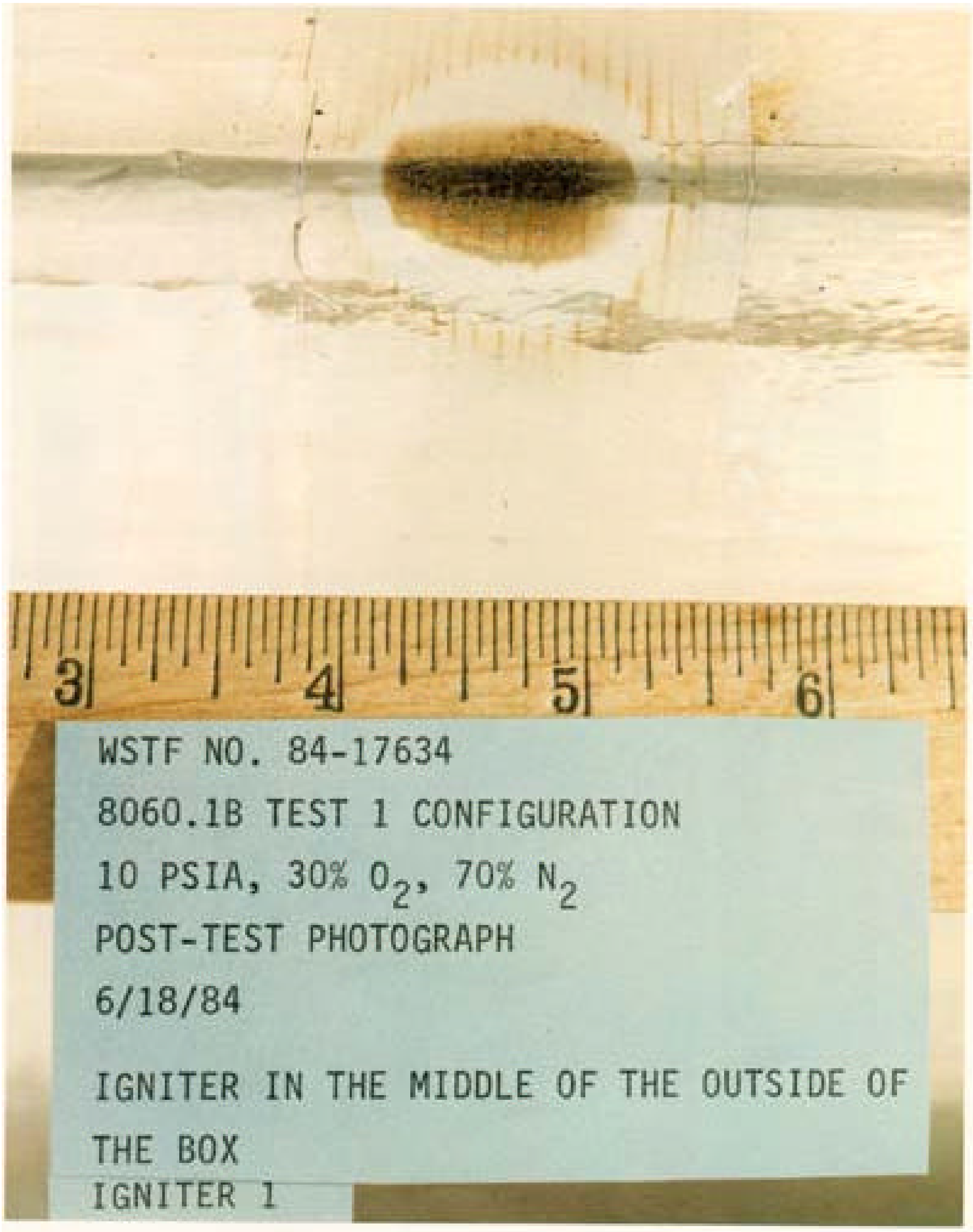


Figure 3-5.- Disposable dishrack (post-test)

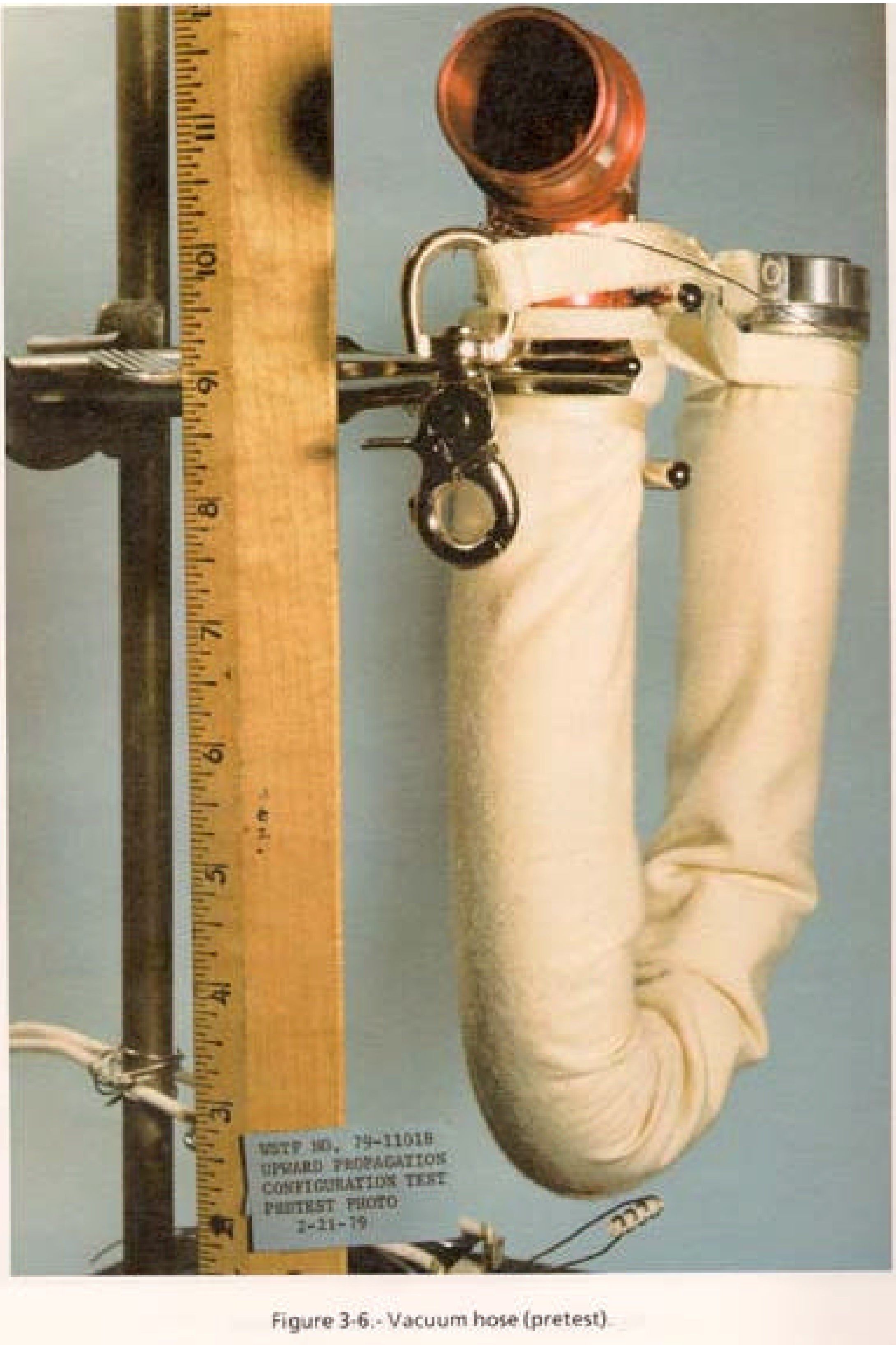


Figure 3-6.- Vacuum hose (pretest).

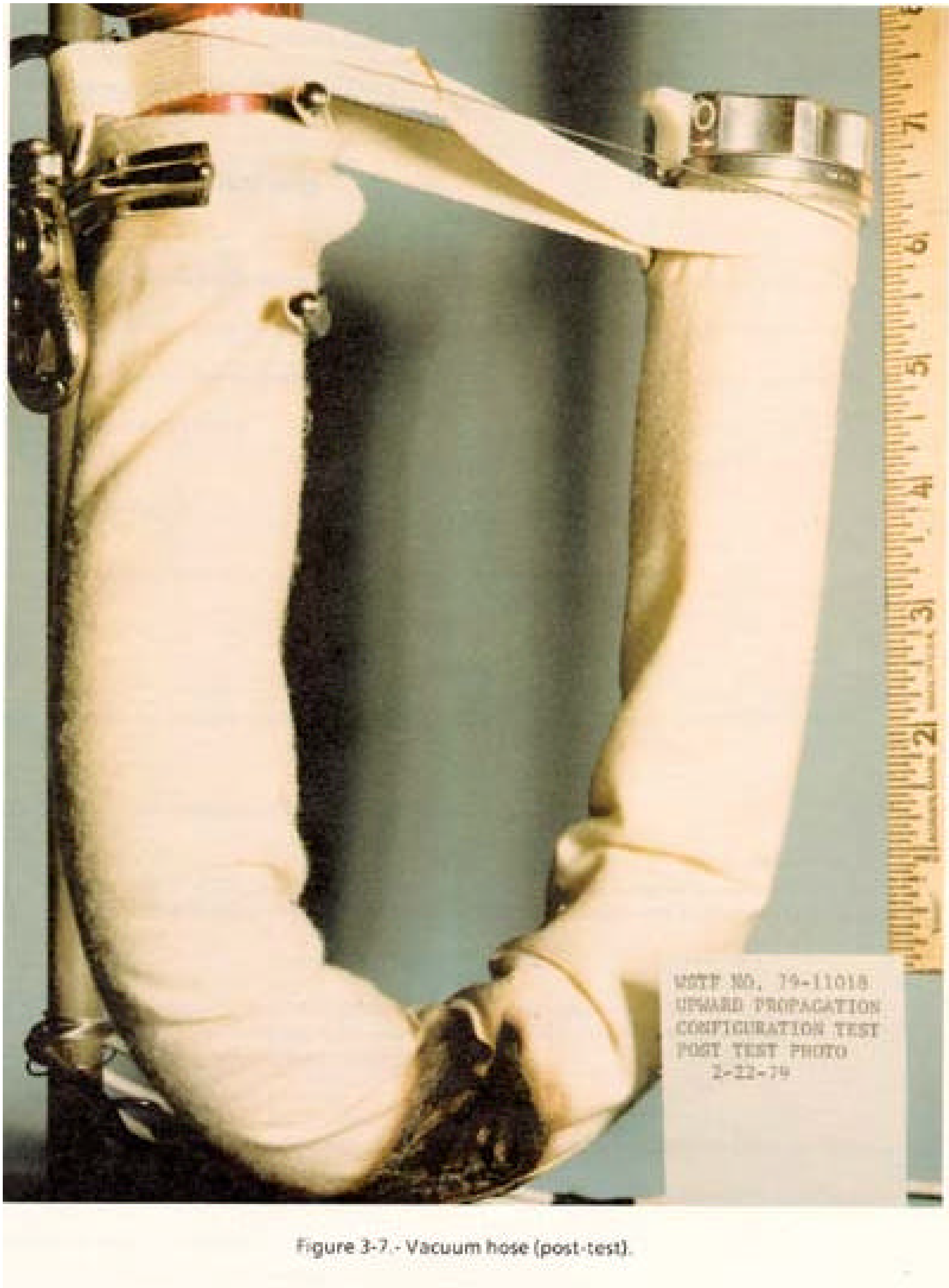


Figure 3-7.- Vacuum hose (post-test).

# 4 Guideline Application Examples for Exposed Stowage Bags and Lockers

## 4.1 Configuration Examples

Metal stowage lockers that do not contain ignition sources are acceptable without reservation. Material selection criteria for nonmetallic stowage lockers must be based on fire containment capability and should be supported by test data. Acceptable stowage bags may be constructed from the following fabrics:

a. Beta cloth

b. Double-layer Nomex of weight greater than 7.5 ounces/square yard

c. PBI

d. Other flame-retardant fabrics

The following are examples of acceptable stowage bags:

a. Beta cloth bag. A bag made of beta cloth is acceptable for stowage of potentially flammable materials. The disadvantages of beta cloth are its low durability and a tendency to shed glass fibers.

b. Nomex bag. Bags made of double-layer Nomex fabric weighing 7.5 ounces/square yard (or single-layer Nomex weighing 6.5 ounces/square yard and treated with ammonia dihydrogen phosphate fire retardant) are also acceptable.

These containers, made of nonflammable nonmetallic materials, can have flammable items stowed inside them provided they do not contain ignition sources and are not susceptible to spontaneous ignition or chemical reaction.

## 4.2 Test Examples

The Apollo food stowage box, constructed of polyimide/glass laminate 0.063 inches thick, was designed for stowage of flammable food packages. It was externally ignited in 100 percent oxygen at 16.5 psia (see test reference 4). The only damage to the box was that polyimide was charred away from the fiberglass in areas exposed to the flame. Figures 4-1 and 4-2 show the pretest and post-test conditions of the box.

NASA has also tested double-layer Nomex bags. The wet wipe dispenser is made of double-layer Nomex and is normally filled with wet wipes. When tested at 25.9 percent oxygen at 14.3 psia, flame scorched the area surrounding the ignitor. Figures 4-3 and 4-4 show the pretest and post-test conditions of this bag (see test reference 5).

Figure 4-1.- Apollo food storage box (pretest).

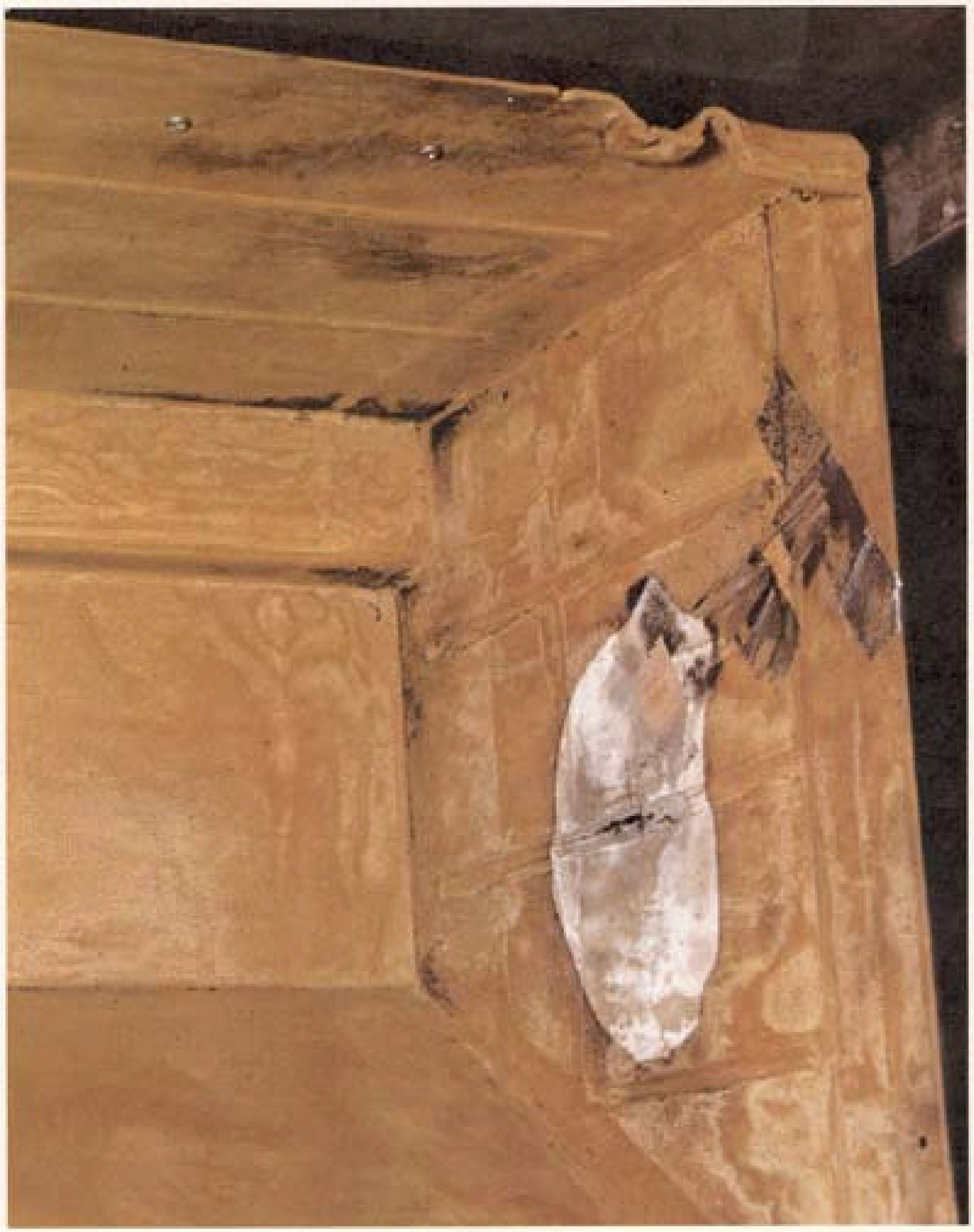

Figure 4-2.- Apollo food storage box (post-test).

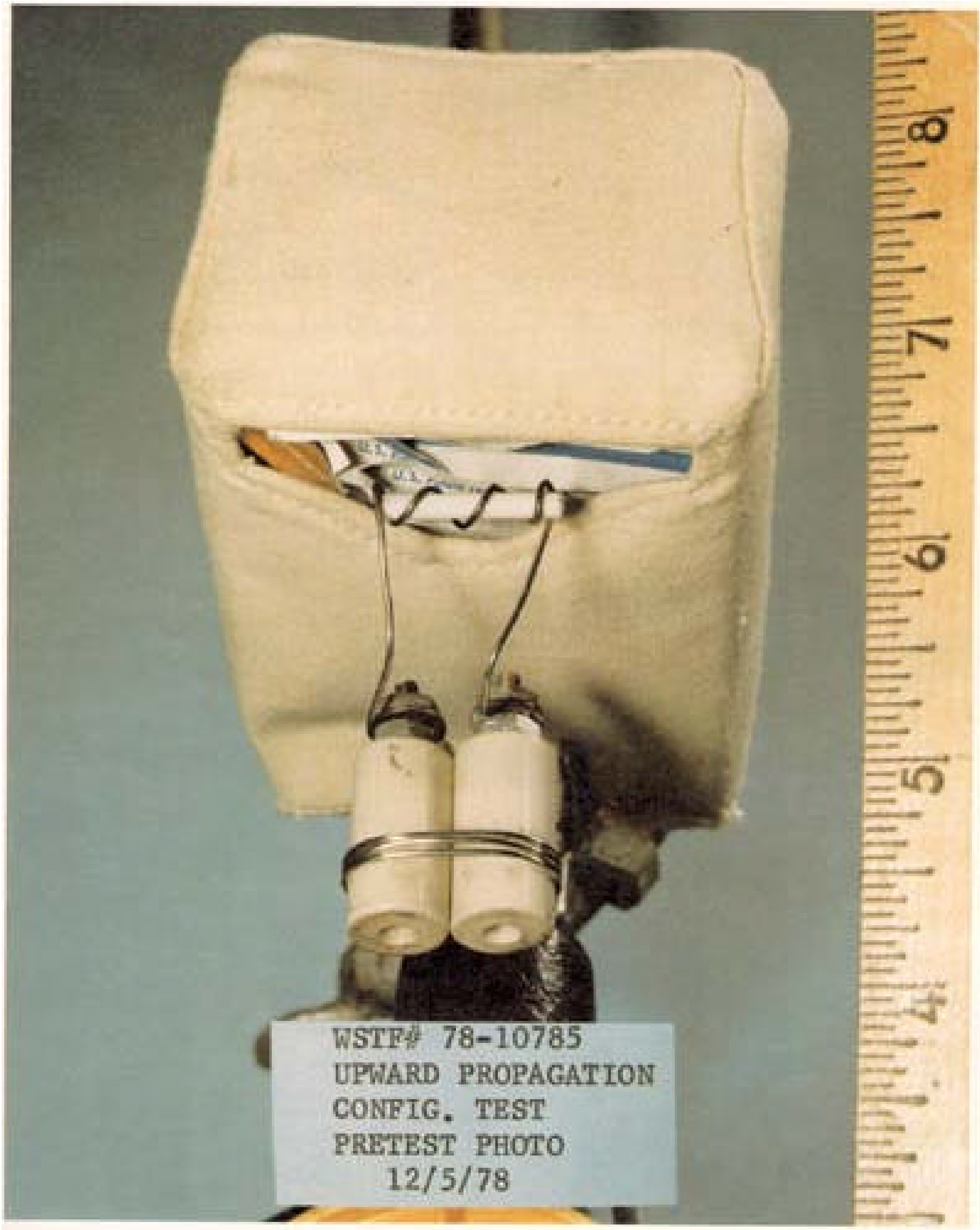


Figure 4-3.- Wet wipe dispenser (pretest).

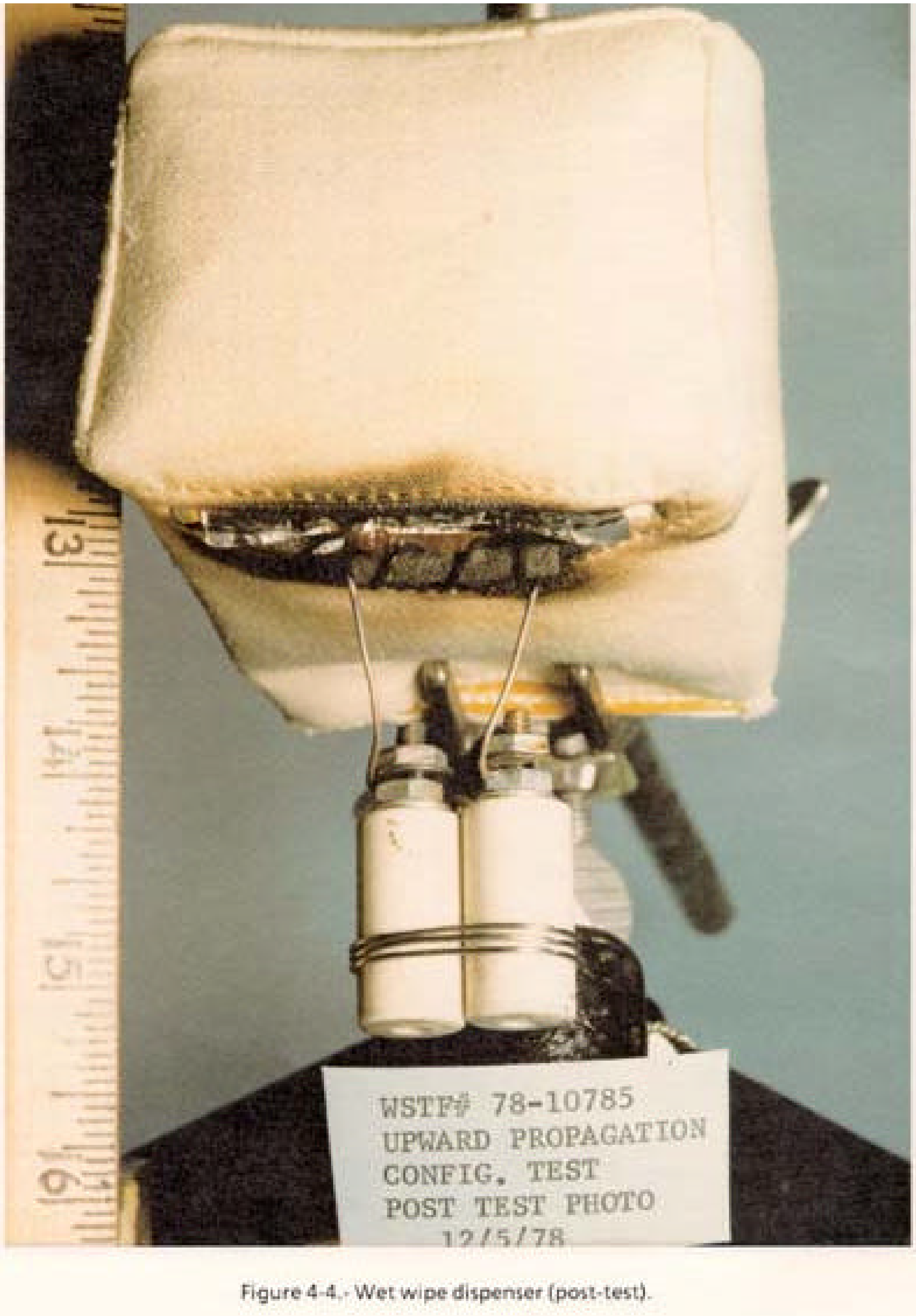


Figure 4-4.- Wet wipe dispenser (post-test).

# 5 Guideline Application Examples for Exposed Payload Bay Materials

## 5.1 Payload Thermal Control Blankets

Thermal control blankets are the most widely used materials in the payload bay that could be flammable. These blankets typically contain 12 to 40 layers of film (0.0005 to 0.002 inches in thickness) separated by some type of scrim cloth. Blanket materials are usually constructed of metal-coated polyethylene terephthalate or polyimide film, organic separator scrim, or beta cloth. Beta cloth and polyimides (at least 1.5 mil thick) are the only nonflammable materials.

Acceptable thermal control blankets are typically constructed as follows:

a. The outer layer is made of nonflammable material such as polyimide film (at least 1.5 mil thick), metal foil, or beta cloth.

b. Internal layers can be a combination of flammable films or scrims.

c. The innermost layer (adjacent to the outer surface of the payload) is also made of nonflammable materials.

d. Edges are hemmed or suitably finished so that the inner flammable layers are protected.

## 5.2 Wires

Acceptable wires for payload bay payloads are Teflon- or polyimide-insulated (according to the specifications listed in Section 3.1.2) or covered with a fire barrier material. However, flammable insulation is acceptable on wires in payload bay payloads which are not powered (including during ground testing) until the payload is in a vacuum where it will not burn. Potentially flammable or untested wire must be evaluated according to "worst-case" payload bay environment and ignition conditions.

## 5.3 Fiber Reinforced Laminates

Several payloads have used fiber-reinforced laminates as structural material. These laminates may be flammable if used in thicknesses of less than 0.125 inches. The flammability characteristics of thin laminates should be verified by test, or the laminates should be protected. Where flammable laminates are used, ignition sources (such as electrical wires, heaters, etc.) should not be located within 6 inches of the laminates. Otherwise, fire breaks should be placed on the exposed surfaces of these laminates at 12-inch intervals. Aluminum tape 3 mils thick and 3 inches wide (per Federal Specification L-T-80) is an acceptable fire break when applied to the laminate surface at 12-inch intervals.

# 6 Container Configurations

Containers can be configured to contain fires. Obviously, if a container has walls made of flammable materials it cannot serve this purpose and should be evaluated according to the guidelines in Section 3. Most of the containers presented in this section are metal-wall electronic black boxes enclosing circuit boards and other electronic components.

The fire containment capability of these containers must be evaluated according to the amount of fuel involved, container wall characteristics, and the presence of a combustion-supporting environment.

## 6.1 Acceptable Configurations for Sealed Containers

A sealed container can be considered to contain a fire if it contains an environment which will not support combustion, or if it meets the following conditions:

a. Exterior walls more than 60 mils thick

b. Void space not exceeding 30 percent of total volume

## 6.2 Sealed Container Test Examples

A thrust vector servo amplifier (TVSA) was tested in 100 percent oxygen to verify that the "worst case" design (using the most flammable materials) inert gas-filled sealed container will not burn (see test reference 6). The TVSA consisted of a metal box containing circuit boards and electrical components conformally coated with polyurethane, a flammable material. It was sealed with a verified leak rate less than $10^{-4}$ standard cc/sec and contained an inert gas atmosphere of nitrogen at approximately 17 psia. The internal TVSA wiring was electrically overloaded until the wire insulation fused and the internal pressure increased to 19 psia. No visible evidence of damage (such as smoke, flame, or case rupture) was noted during or after the test.

Several components with limited void space also passed the flammability configuration test. Figures 6-1 and 6-2 show the pretest condition of a typical unit, the master events sequence controller. All circuitry and components in this unit (which was 30 percent void space) had been coated with room-temperature vulcanizing silicone rubber.

A positive ignitor was placed inside the unit and the contents were ignited at 16 psia in 100 percent oxygen (see test reference 7). After the resultant fire was contained, post-test examination of the unit revealed local surface burning of the silicone rubber as shown in Figure 6-3.

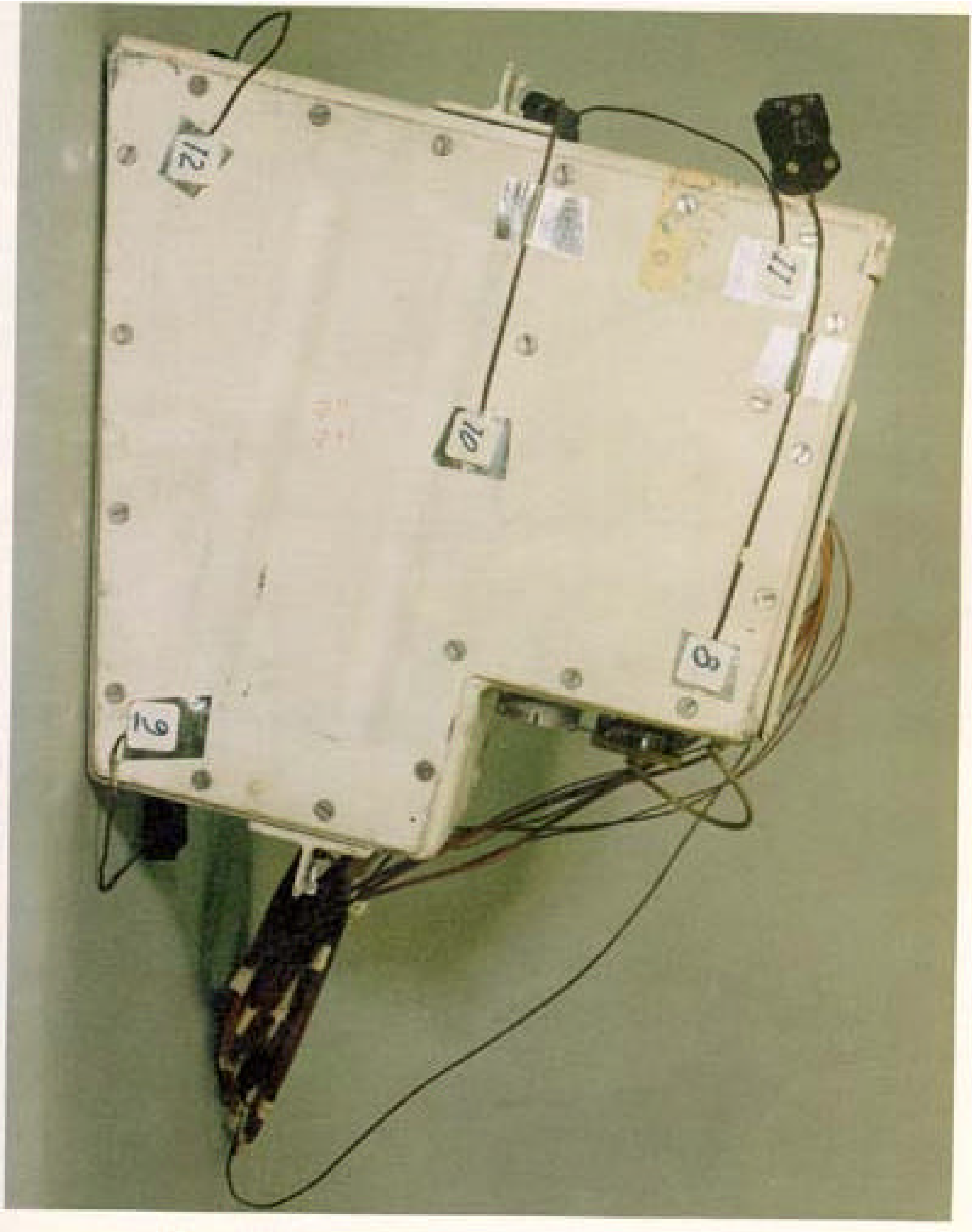


Figure 6-1. - Master events sequence controller, closed (pretest).

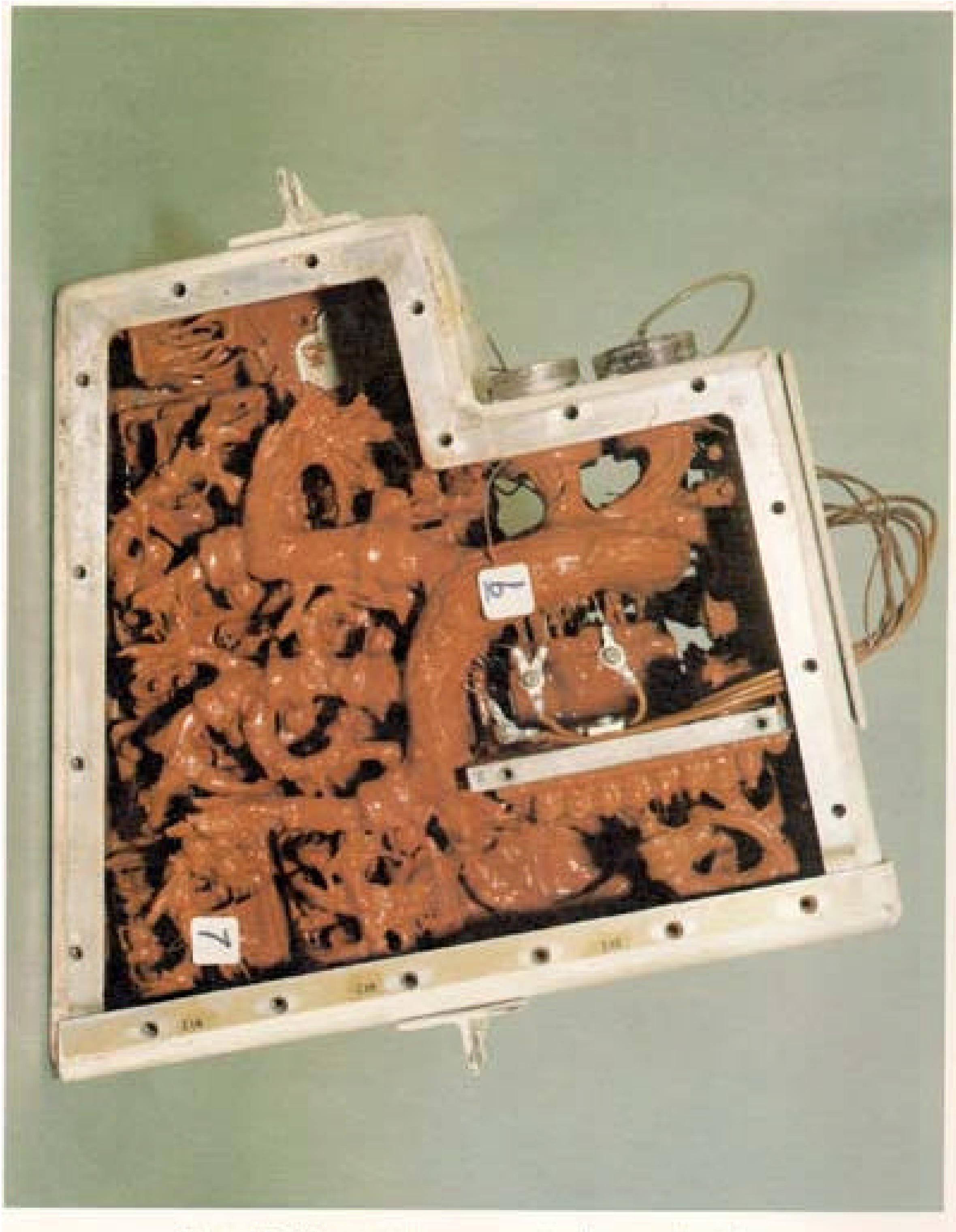

Figure 6-2 - Master events sequence controller, open (pretest)

Figure 6-3. - Master events sequence controller (post-test).

## 6.3 Vented Container Assessment

The fire containment capability of vented containers must be carefully evaluated, since these containers allow introduction or replenishment of oxygen. Definition of acceptable vented container configurations is very difficult, even with qualifications.

A primary consideration in determining acceptability is the availability of oxygen to support combustion of fuels. Vents can establish flow conditions because of convective forces (chimney effects) which continually provide oxygen. In such cases, rapid burning may penetrate the container wall and present a hazard. Minimizing the number and size of vents, providing a nonlinear flow path, and/or covering vents with fine metal (non-aluminum) screens can reduce this hazard. Oxygen supply can also be influenced by forced air flow conditions provided by fans inside a container. The effect of such conditions is dependent upon the flow rate, with intermediate rates being the most likely worst case.

The extent of fuel also affects the flammability of vented containers. Tests have shown that when flammable foam is utilized to reduce the volume of combustible atmosphere, the hazard may be increased rather than reduced. Obviously, if the use of flammable materials is minimized, the fire hazard will also be minimized.

## 6.4 Vented Container Examples

### 6.4.1 Flammable Foam Filler

As a vented container example, a static inverter filled with flammable polyurethane foam was soaked and tested at 16 psia in 100 percent oxygen. It exploded. Test results indicate that the pressure increased so rapidly as the oxygenated polyurethane foam burned that it could not be relieved through the container vents (see test reference 8). Other types of foam will also burn, but they increase the internal pressure more gradually. Figures 6-4 and 6-5 show the pretest and post-test conditions of this unit.

Another static inverter was converted from a vented container to a hermetically sealed unit to meet flammability requirements. Its metal case was strengthened and the entire assembly was sealed with epoxy and silicone rubber. The redesigned unit was tested under the same conditions as before and passed the flammability test.

### 6.4.2 Acceptable Vented Containers

The Apollo entry monitor system (EMS) and the Apollo rotational controller assembly (R/C) were tested in 100 percent oxygen at 6.2 and 16.5 psia (see test references 9 and 10). The EMS is a metal box containing circuit boards, a power supply, etc. When ignited, it burned for over 4 minutes and reached a peak internal temperature of 1250 degrees F. The R/C burned for 3 minutes and reached an internal temperature of 1280 degrees F. This unit is a hand controller-type device (with a silicone rubber boot over the handle opening to form a dust seal) containing polyurethane-coated circuit boards. When tested at 16.5 psia, the polyurethane melted and flowed throughout the

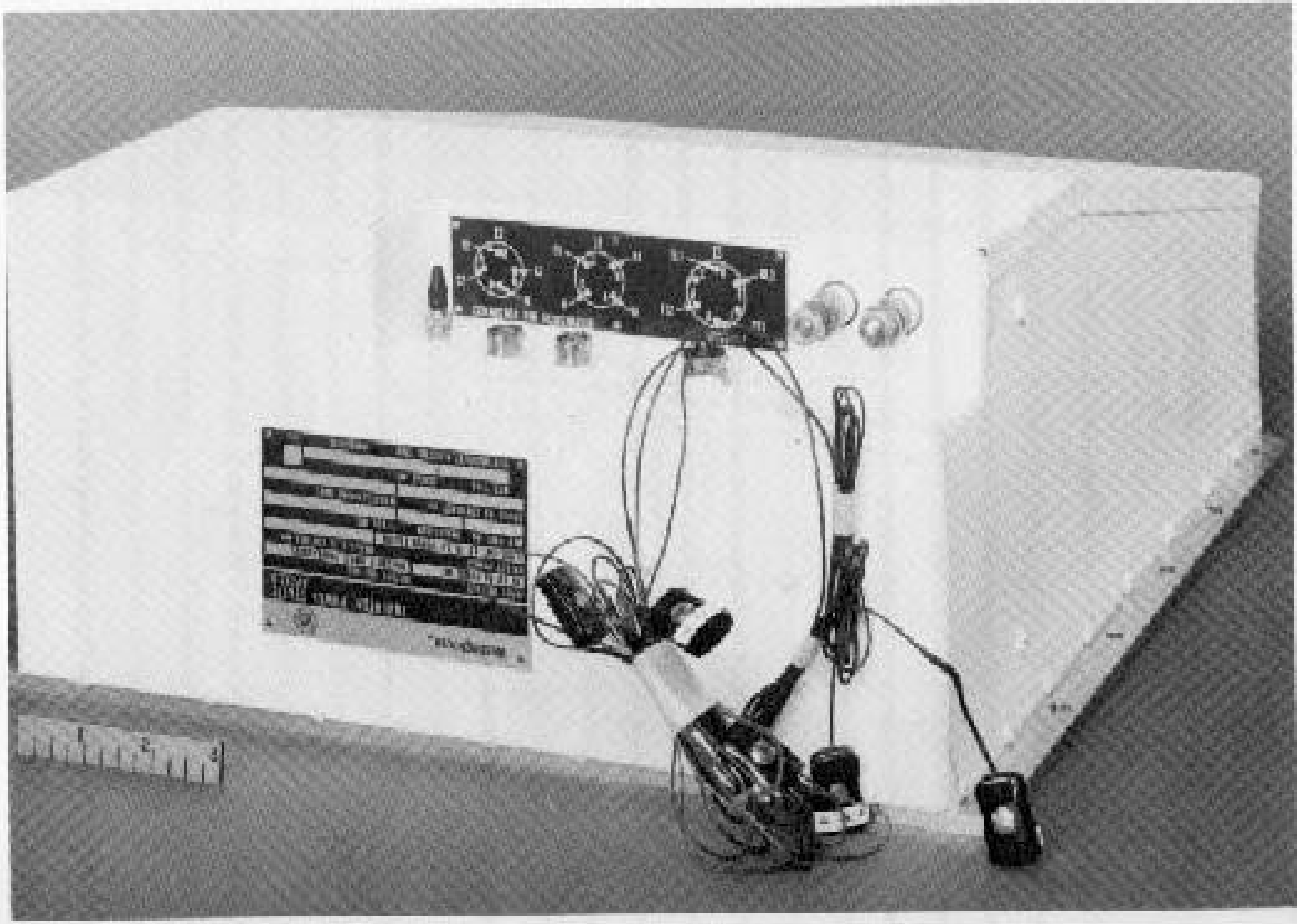

Figure 6.4. Static inverter (pretest)

Figure 6-5 - Static inverter (post-test) internal area of the unit. However, both of these units contained the resulting fire. Figures 6-6 and 6-7 show the pretest and post-test conditions of the EMS, and Figures 6-8 and 6-9 show the pretest and post-test conditions of the R/C.

### 6.4.3 Vented Containers with Forced Air Flow

One of the first components of this type to be tested was the Shuttle inertial measurement unit (IMU) (see test reference 11). The IMU is a formed aluminum box containing polyurethane-coated circuit boards, chloroprene vent hoses, MIL-W-81044 wire, and about 20 percent void space. Two flammability tests were conducted on the IMU at its normal cooling flow rate of 6.3 standard cubic feet per minute (scfm). One was conducted in 25.9 percent oxygen at 14.3 psia and the other in 30 percent oxygen at 10.0 psia. The unit passed both flammability tests. Figures 6-10, 6-11, 6-12 and 6-13 show the pretest and post-test conditions of this unit.

A proximity switch box constructed of sheet metal was also tested (see test reference 12). This box contained electrical components, polyurethane-coated circuit boards, and 50 percent void space. Tests were conducted with a gas flow rate of 1.1 scfm in 25.9 percent oxygen at 14.3 psia, and in 30 percent oxygen at 10.0 psia. This unit also passed configuration tests at both atmospheres. Figures 6-14, 6-15, and 6-16 show the pretest and post-test conditions of this unit.

Tests were also conducted to evaluate the effects of air flow and air flow rates on the flammability of worst-case items contained in typical electronic boxes (see test references 13 and 14). These tests were performed using relatively high flow rates of 6.5 to 20.0 scfm. The boxes were constructed of sheet metal using the following worst-case materials: (1) polyurethane packing foam (see Figure 6-17), (2) MIL-P-13949 type GE uncoated circuit boards, and (3) MIL-W-81044 electrical wire. All

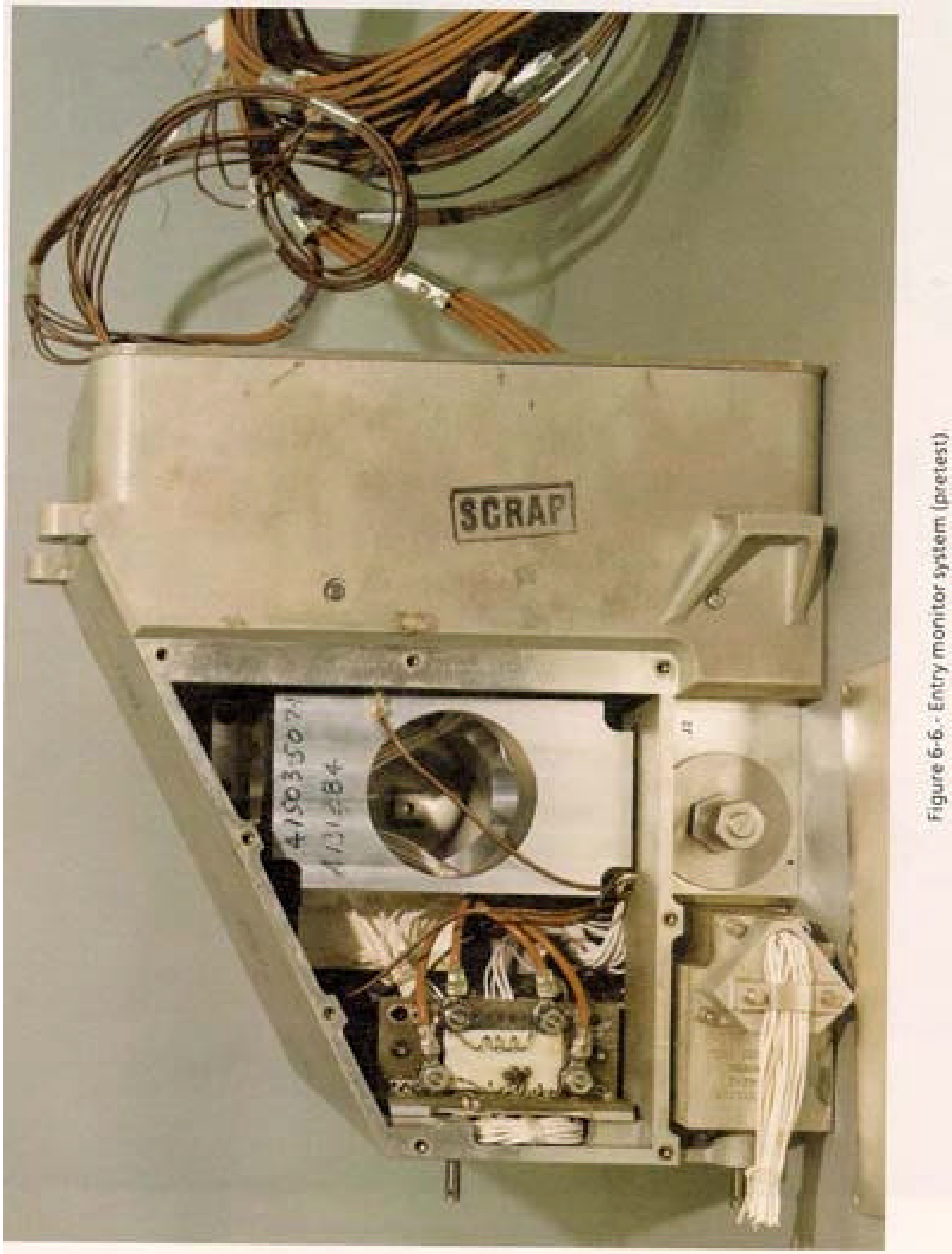


Figure 6-6.- Entry monitor system (pretest)

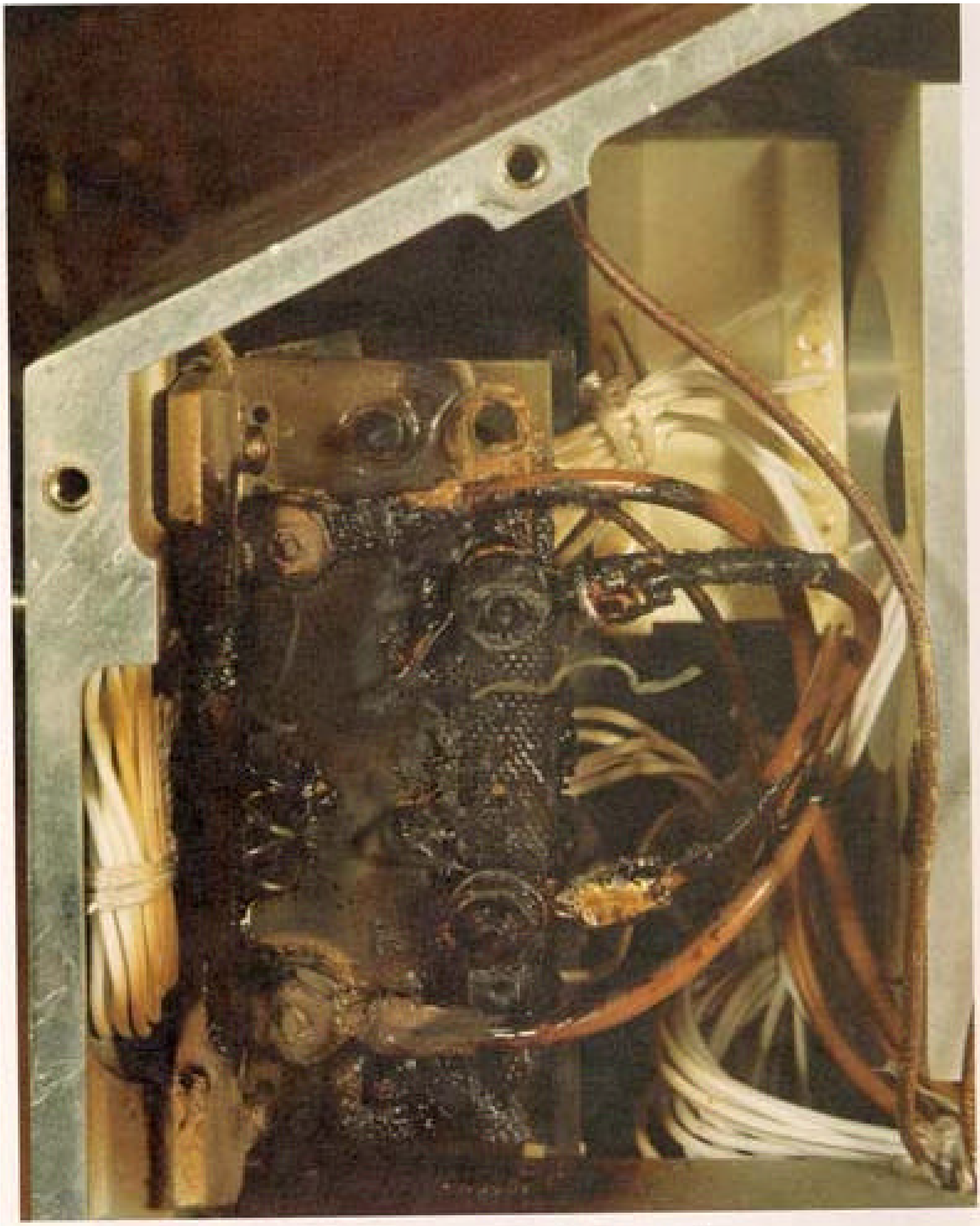

Figure 6-7.- Entry monitor system (post-test).

Figure 6-8.- Rotational controller (pretest).

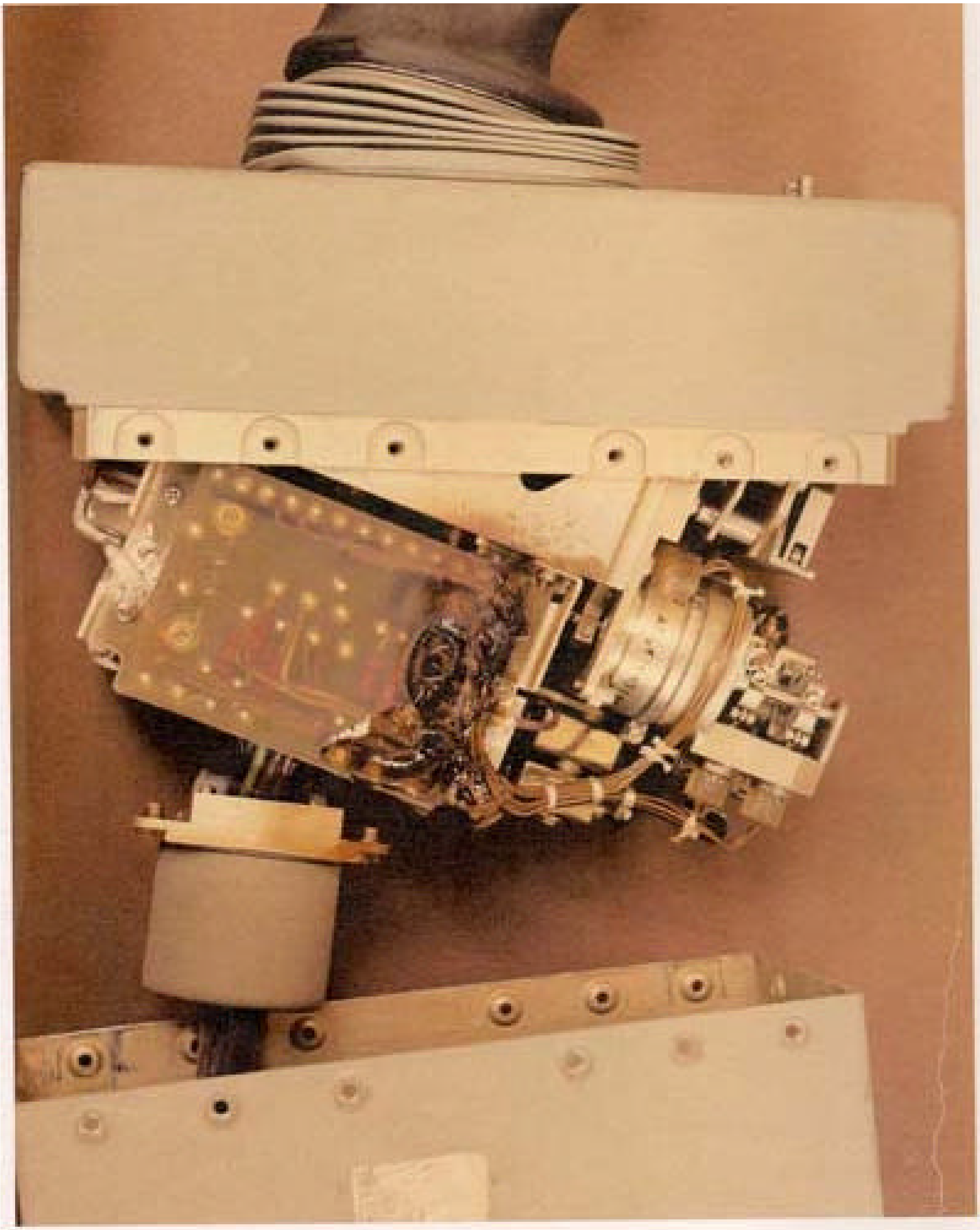

Figure 6-9.- Rotational controller (post-test).


Figure 6-10. - Inertial measurement unit, external view (pretest)

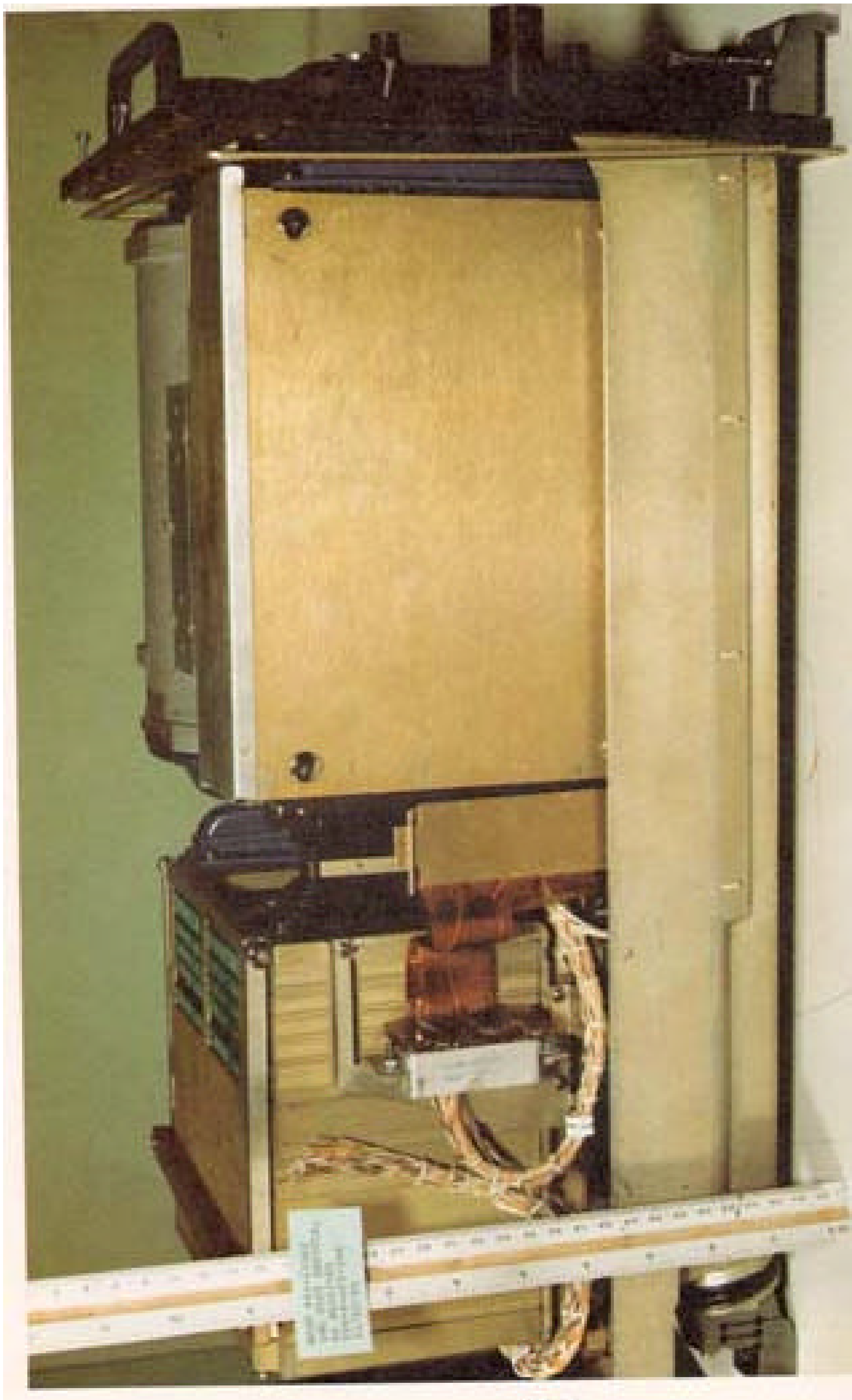

Figure 6-11.- Inertial measurement unit, internal view (pretest).

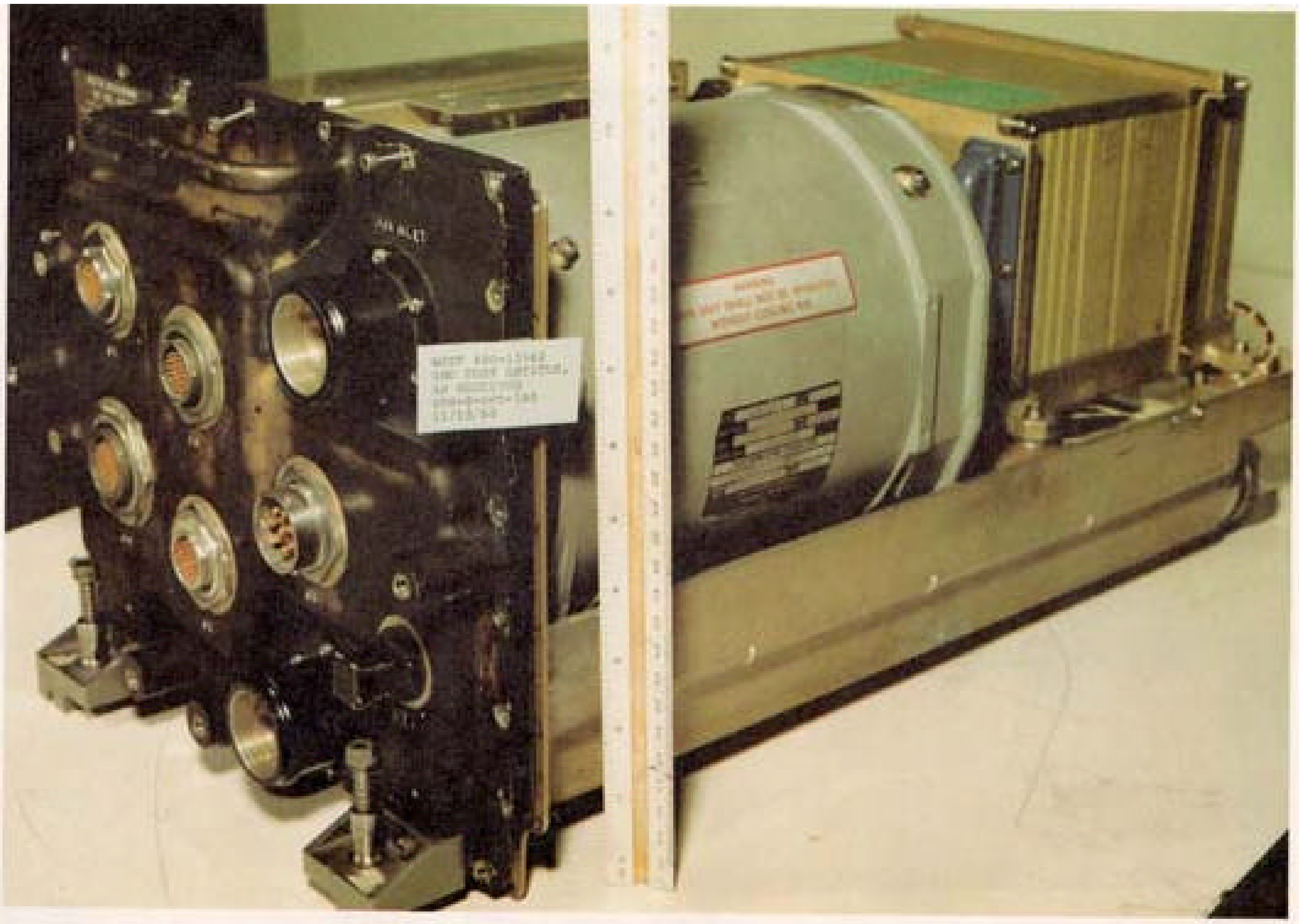

Figure 6-12.- Inertial measurement unit (pretest).

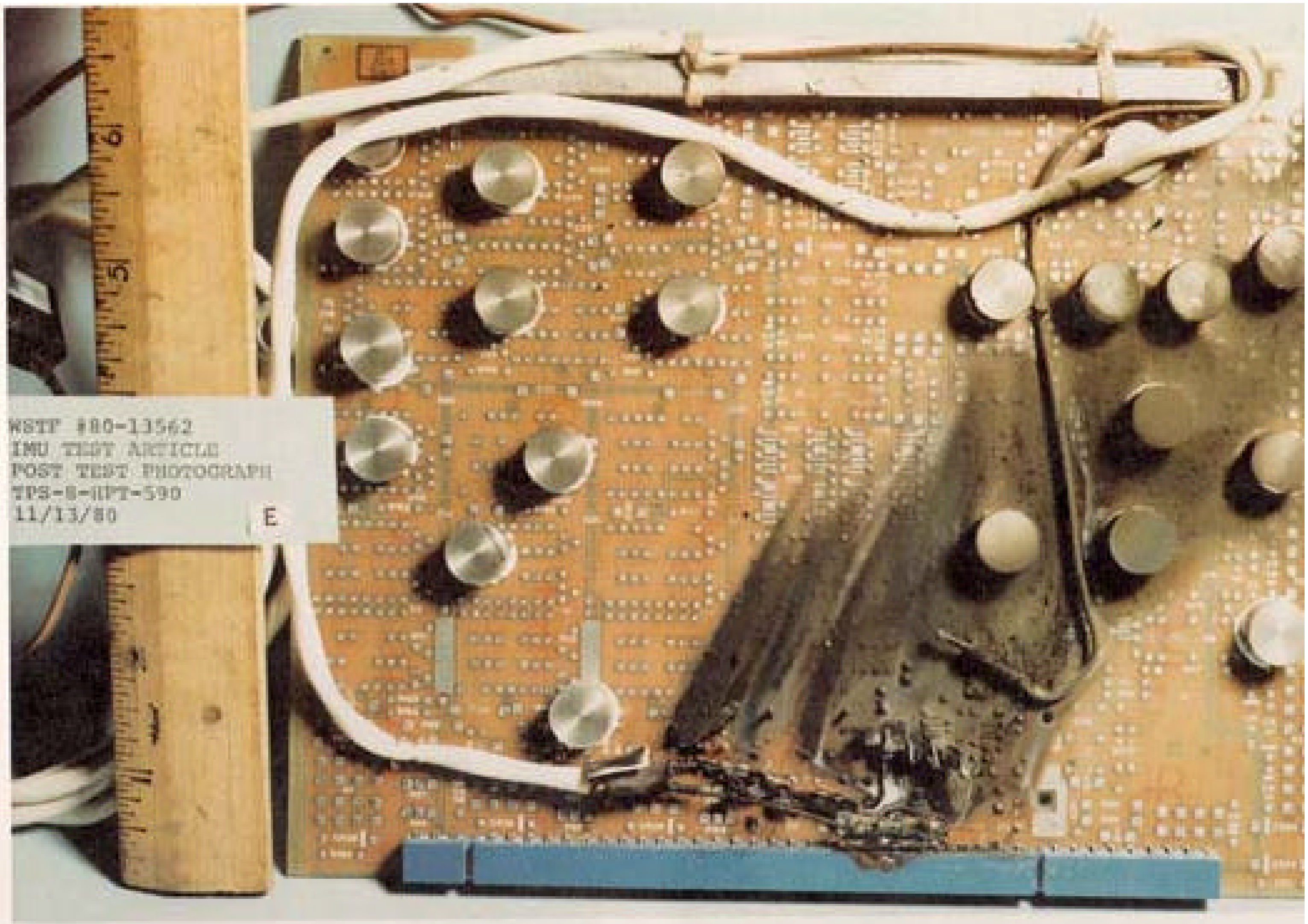


Figure 6-13.- Inertial measurement unit circuit board (post-test).

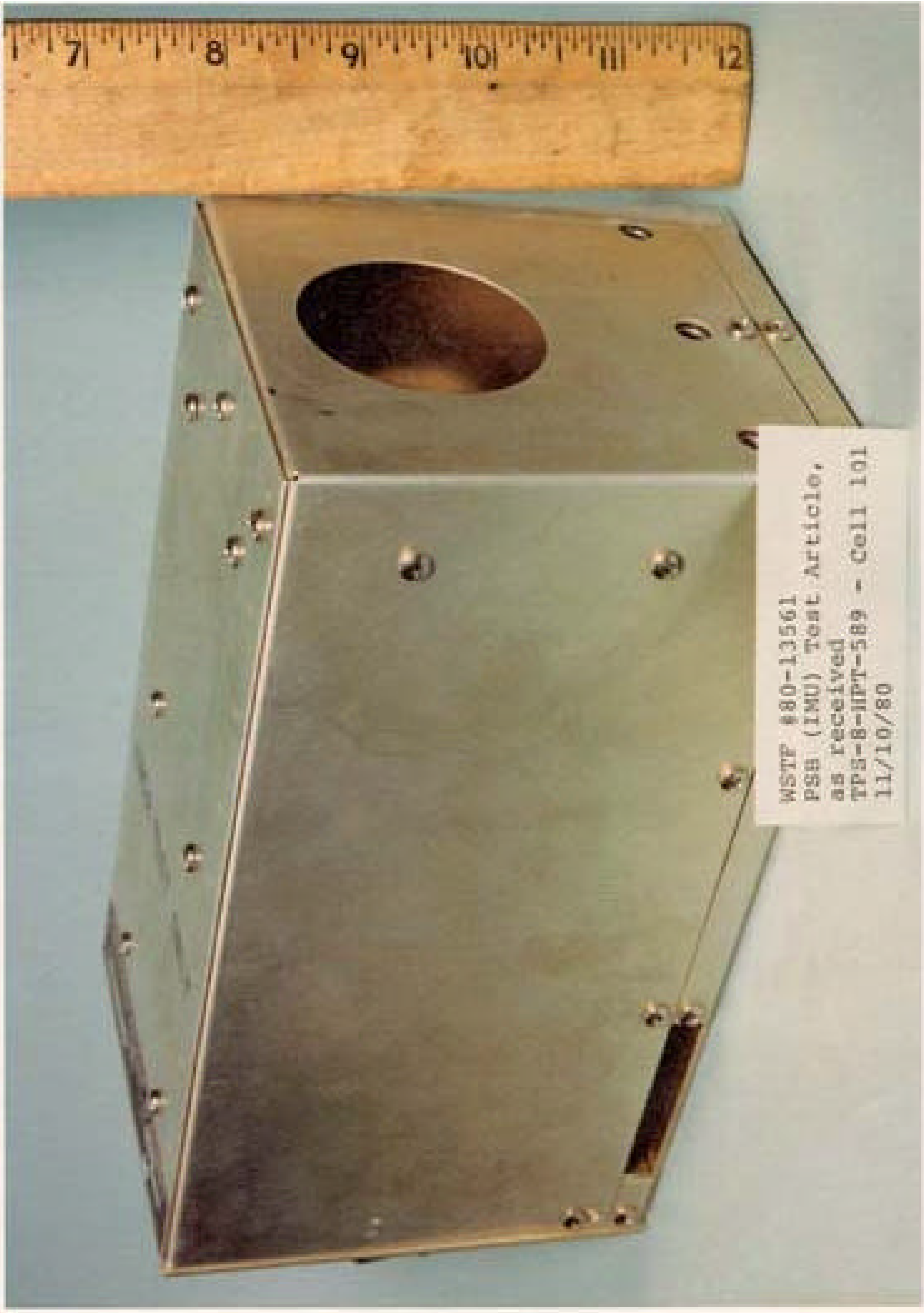


Figure 6-14.- Proximity switch box, external view (pretest)

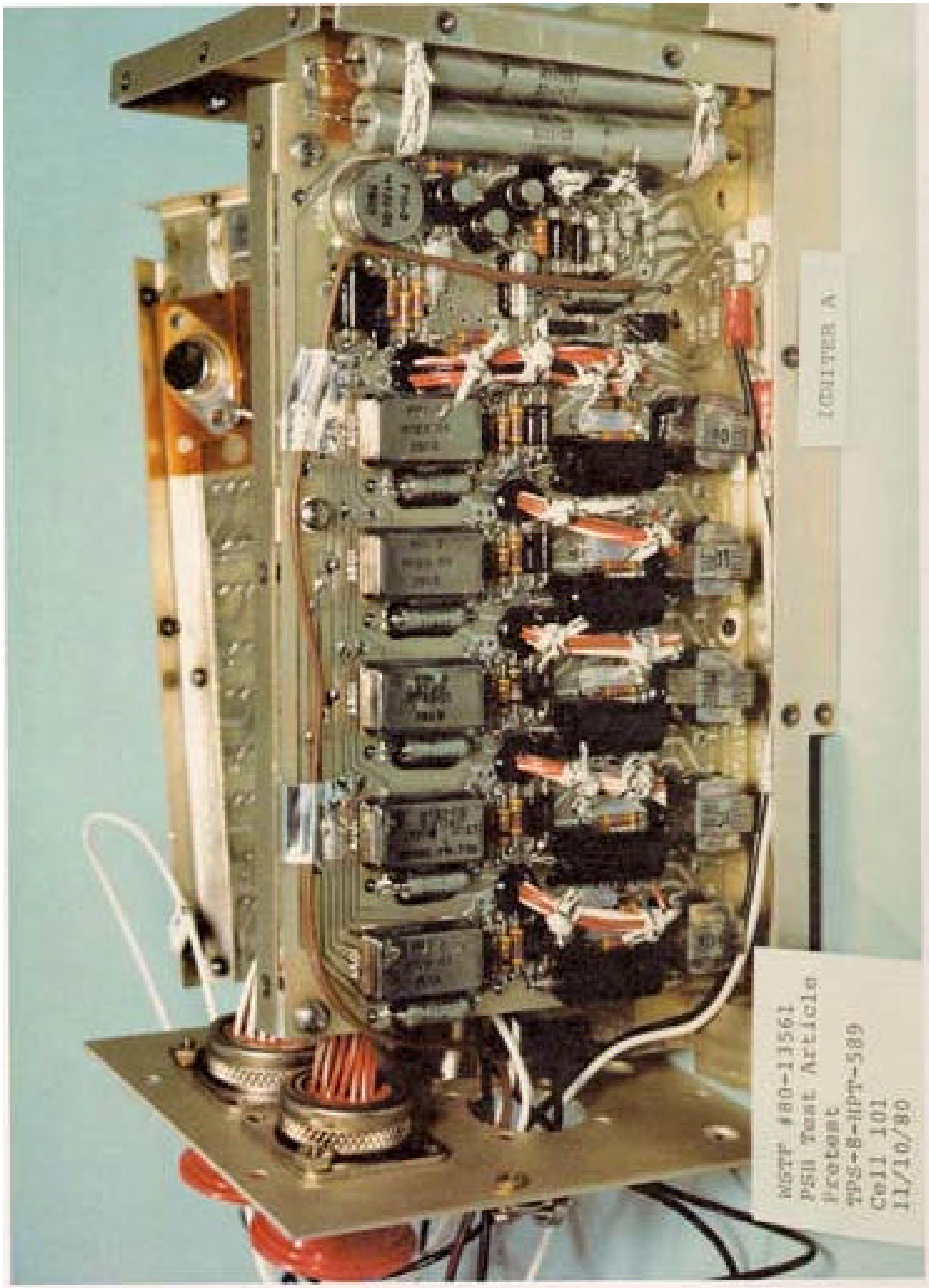


Figure 6-15.- Proximity switch box, internal view (pretest).

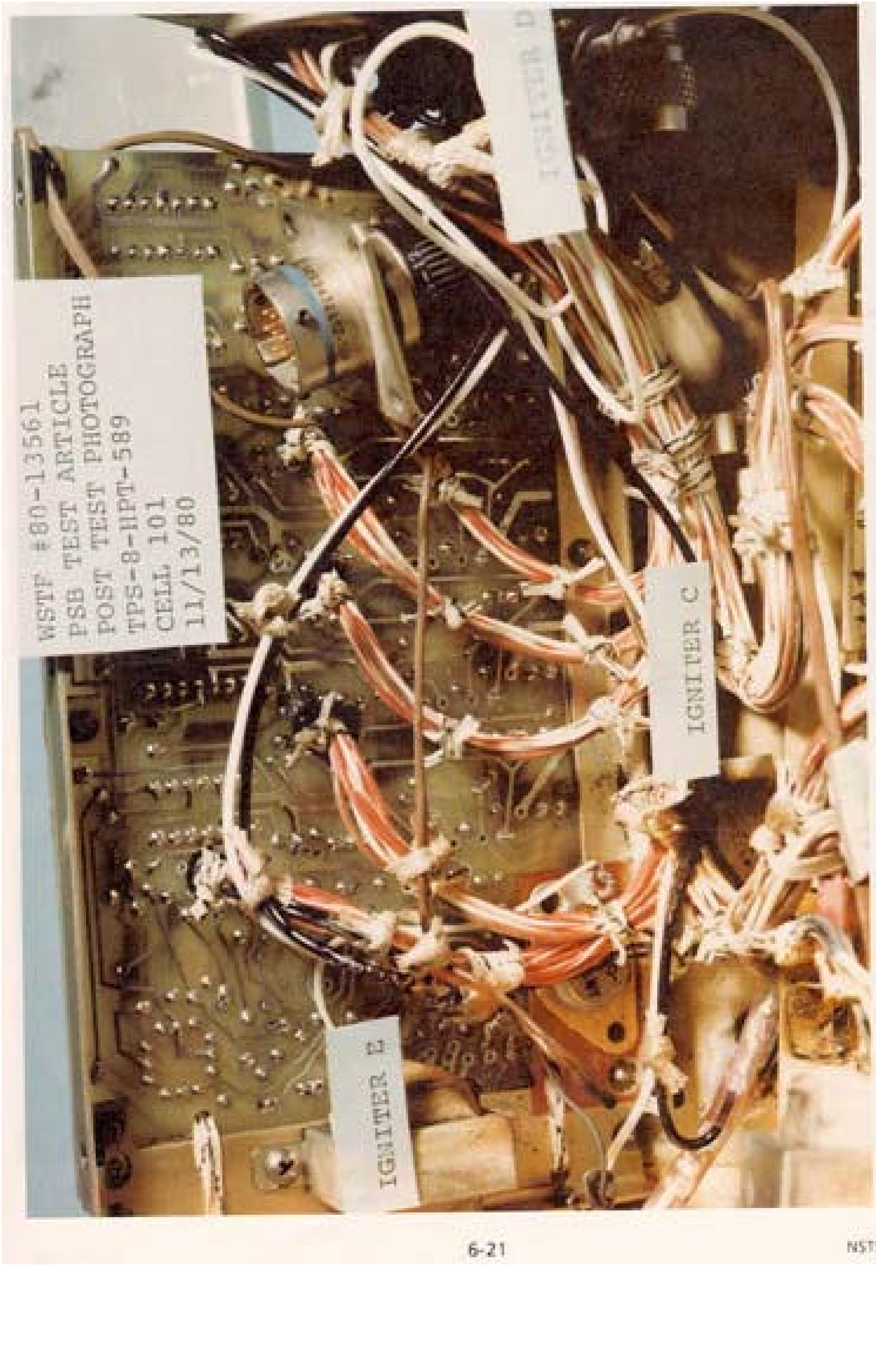


Figure 6-16 - Proximity switch box, internal view (post-test)

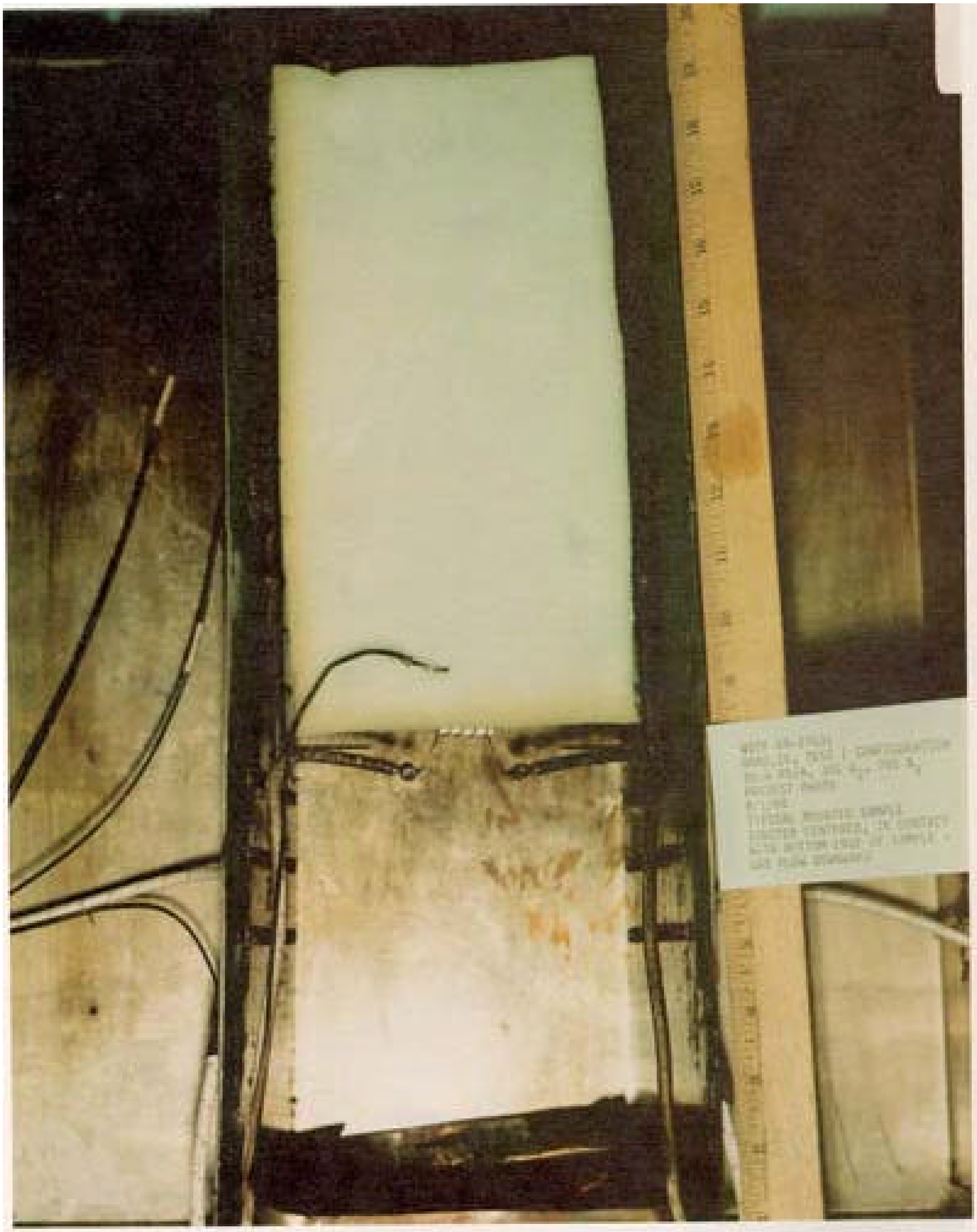

Figure 6-17.- Typical electronic box with urethane foam (pretest).

materials were tested separately to verify their flammability. Figure 6-18 shows a typical electronic box used in this type of testing. These tests used two ignition methods: (1) electrical overload of a polyvinylchloride-insulated wire inside the foam and (2) ignition using the standard cleanweld ignitor wrapped with a nichrome wire. In the standard box, the circuit board material would not ignite at 20 scfm, but would burn at 15 scfm. The polyurethane foam ignited and burned at 20 scfm, but the fire was contained in the box. At 15 scfm, burning foam ignited the aluminum screen (see Figure 6-19) and fire escaped outside the box. Additional tests on the same unit with the same types of materials (but with air velocities below 10 scfm) demonstrated containment of the fire in the box. These results indicate that units with air velocities of 10 through 20 scfm are the most hazardous. At velocities below 10 scfm, the unit acts as a vented container. At velocities above 20 scfm, air tends to cool the area surrounding the flame and extinguish the fire.

### 6.4.4 Chimney Effect Example

Spacelab air cooling ducts were also tested. These ducts (with plenum chambers) were lined with a flammable polyurethane foam. In a test on a simulated air duct with 24.5 percent oxygen flowing through it, the foam ignited and exploded the plenum chamber. This example is a case of large void space creating a "chimney effect."

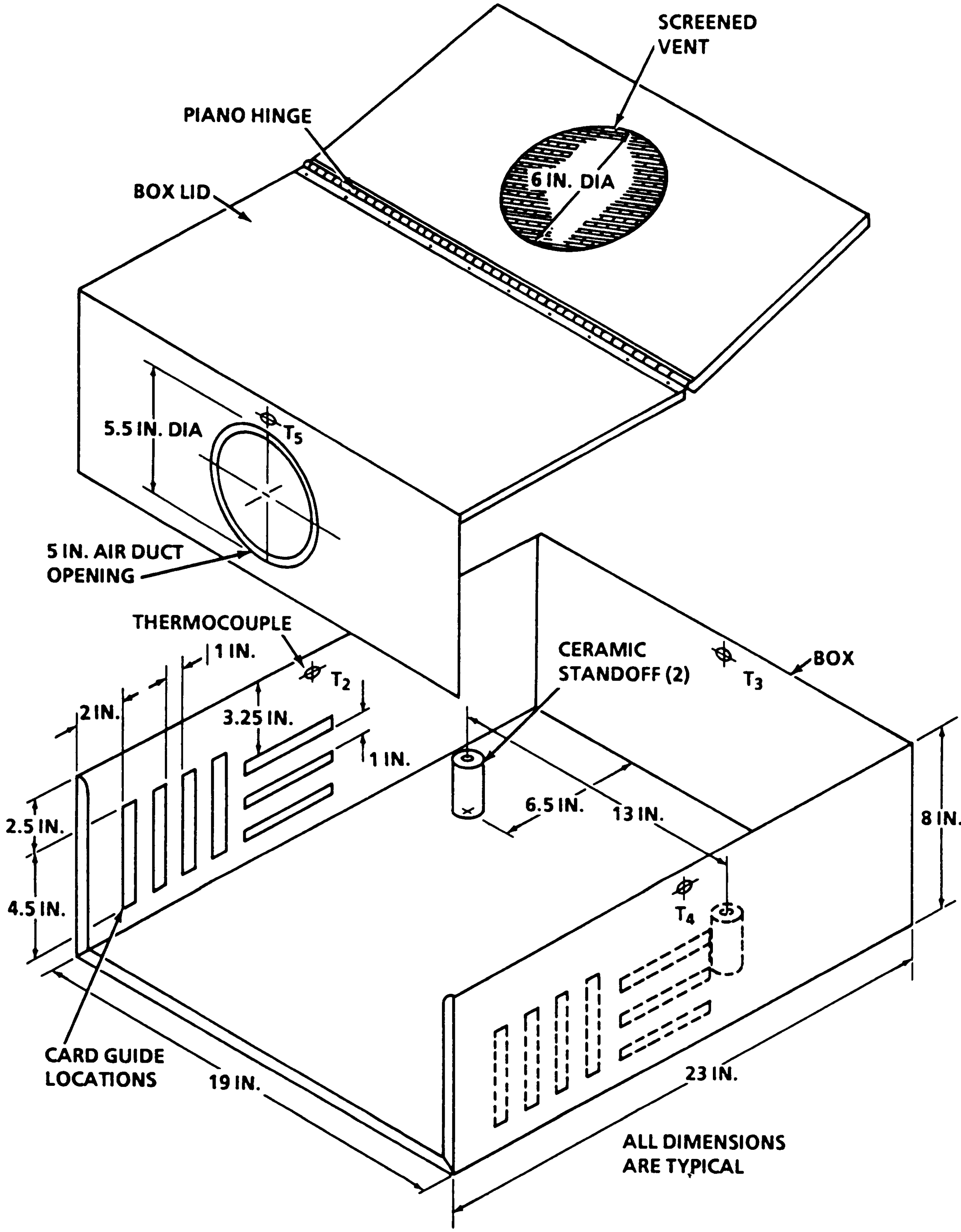


Figure 6-18.- Aluminum box used for containing test samples.

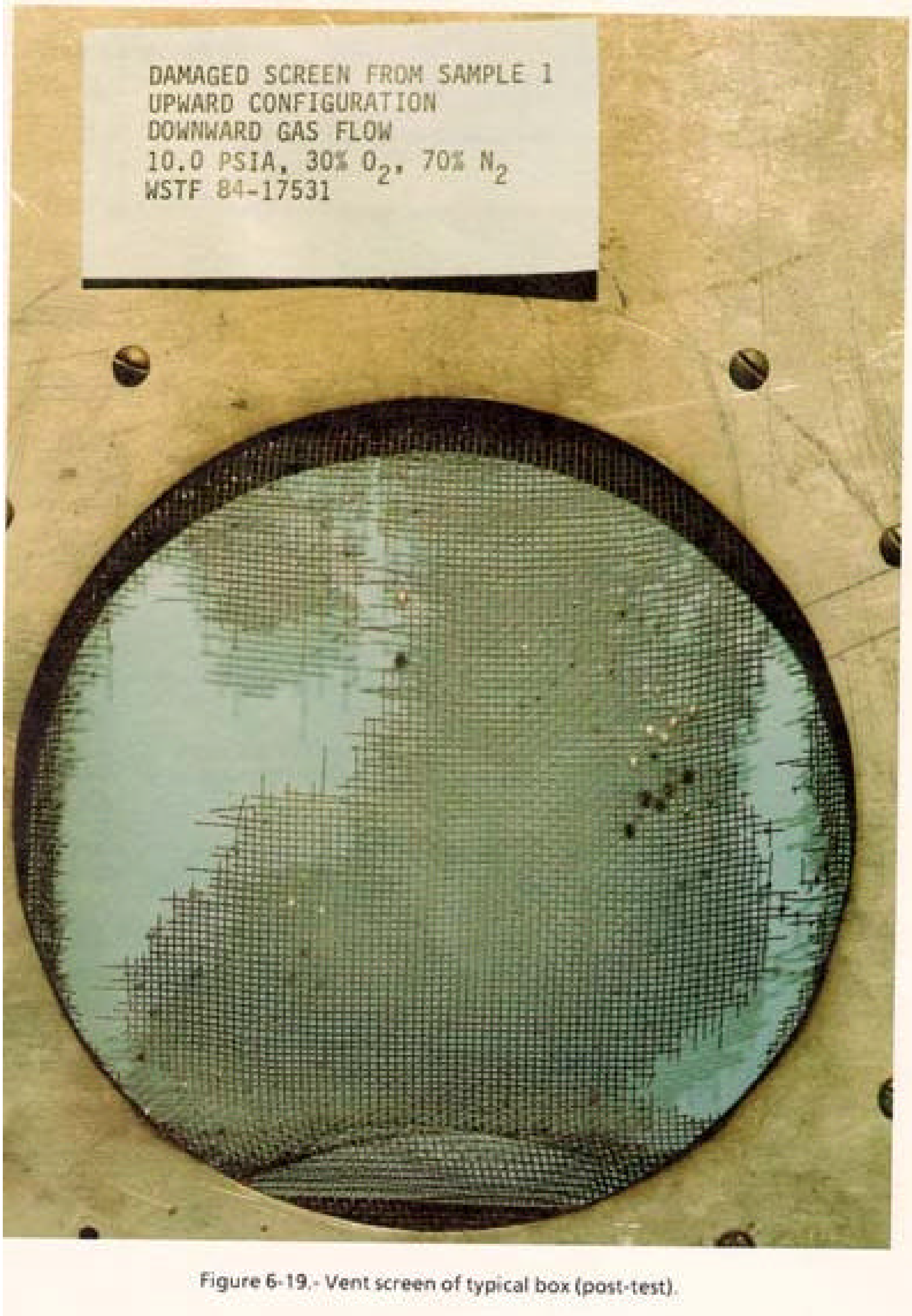


Figure 6-19.- Vent screen of typical box (post-test).

# 7 Test References


1. WSTF 85-18799, "EZ502 Cordless Electric Screwdriver", NASA White Sands Test Facility.

2. WSTF 84-17634, "Disposable Dishrack", NASA White Sands Test Facility.

3. WSTF 79-11018, "WAVA Hose with Nomex Cover", NASA White Sands Test Facility.

4. ATR 142016, "Flammability Tests of Lower Equipment Bay (LEB) Food Container", North American Rockwell Corporation, Space Division; March 22, 1968.

5. WSTF 78-10785, "Wet Wipe Dispenser with Disposable Towelettes", NASA White Sands Test Facility.

6. ATR 142010A, "Flammability Test, Hermetically Sealed Container, Thrust Vector Servo Amplifier (TVSA)", North American Rockwell Corporation, Space Division; April 12, 1968.

7. ATR 142009, "Flammability Tests of Vented Container, Master Events Sequence Controller (MESC)", North American Rockwell Corporation, Space Division; November 27, 1967.

8. ATR 142007, "Flammability Tests of Vented Container, Static Inverter", North American Rockwell Corporation, Space Division; July 12, 1967.

9. ATR 142014, "Flammability Tests of Vented Container, Entry Monitor System (EMS)", North American Rockwell Corporation, Space Division; November 16, 1967.

10. ATR 142011, "Flammability Tests of Vented Container, Rotational Controller (R/C)", North American Rockwell Corporation, Space Division; January 3, 1968.

11. WSTF 80-13562, "Inertial Measurement Unit (IMU) Flammability Unit", NASA White Sands Test Facility.

12. WSTF 80-13561, "Proximity Switch Box MC452-0124", NASA White Sands Test Facility.

13. TR-325-001, "Atmosphere and Ignition Effects on "Typical" Electronic Box and Contents", NASA White Sands Test Facility, December 14, 1984.

14. TR-325-002, "Atmosphere and Ignition Effects on "Typical" Electronic Box and Contents", NASA White Sands Test Facility, November 30, 1984.

# 8 Specification References

| | |
|---|---|
| L-T-80B | Tape, pressure-sensitive adhesive (aluminum backed) |
| MIL-C-17/60C | Cables, radio frequency, flexible, coaxial, 50 ohms, M17/060-RG142 |
| MIL-C-17/93G | Cables, radio frequency, flexible, coaxial, 50 ohms, M17/093-RG178 and M17/93-00001 |
| MIL-C-27500F | Cable, electrical shielded and unshielded, aerospace |
| MIL-P-13949G | General specification for plastic Sheet, laminated, metal clad (for printed wiring boards) |
| MIL-W-16878E | General specification for wire electrical, insulated |
| /4A | Polytetrafluoroethylene (PTFE) 200C, 600 volts |
| /5B | Polytetrafluoroethylene (PTFE) 200C, 1000 volts |
| /6B | Polytetrafluoroethylene (PTFE) 200C, 250 volts |
| /11A | Fluorinated ethylene propylene (FEP) 200C, 600 volts |
| /13A | Fluorinated ethylene propylene (FEP) 200C, 250 volts |
| MIL-W-22759D | Wire, electric, fluoropolymer-insulated, copper or copper alloy |
| /1E | TFE and TFE-coated glass, silver-coated copper conductor, 600 volt |
| /5B | Abrasion resistant, extruded TFE, silver-coated copper conductor, 600 volt |
| /6B | Abrasion resistant, extruded TFE, nickel-coated copper conductor, 600 volt |
| /7B | Abrasion resistant, extruded TFE, medium weight, silver-coated copper conductor, 600 volt |
| /8B | Abrasion resistant, extruded TFE, medium weight, nickel-coated copper conductor, 600 volt |
| /12F | Extruded TFE, nickel-coated copper conductor, 600 volt |
| /28 | Extruded TFE, polyimide coated, silver-coated copper alloy conductor, 600 volt |
| /29 | Extruded TFE, polyimide coated, nickel-coated copper alloy conductor, 600 volt |
| /30 | Extruded TFE, polyimide coated, silver-coated high strength copper alloy conductor, 600 volt |
| /31 | Extruded TFE, polyimide coated, nickel-coated high strength copper alloy conductor, 600 volt |

| | |
|---|---|
| MIL-W-81044B | Wire, electric, crosslinked polyalkene, crosslinked alkane-imide polymer, or polyarylene insulated, copper or copper alloy |
| MIL-W-81831A | Wire, electric, Polyimide-insulated copper or copper alloy |