(NASA-CR-160138) DEVELOPMENT OF LIGHTWEIGHT, FIRE-RETARDANT, LOW-SMOKE, HIGH-STRENGTH, THERMALLY STABLE AIRCRAFT FLOOR PANELING Final Report (Boeing Commercial Airplane Co., Seattle) 60 p HC A04/MF A01 N79-21133 Unclas G3/24 14754

Development of Lightweight, Fire-Retardant, Low-Smoke, Thermally Stable Aircraft Floor Paneling

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Prepared for
National Aeronautics and Space Administration
under contract NAS9-15062

NASA
National Aeronautics and
Space Administration

JUNE 1978

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1.0 SUMMARY

A lightweight, fire-retardant, low-smoke, high-strength, thermally stable aircraft floor panel has been developed, constructed, FAA certified, and installed in a commercial airplane for service evaluation. In addition, two 1.22-m (4-ft) by 1.83-m (6-ft) panels fabricated with a 1.70-m (67-in.) radius of curvature and one 1.22-m (4-ft) by 1.22-m (4-ft) flat panel of the same construction were delivered for testing in NASA Contract No. NAS9-15168.

The service evaluation test is being performed on a panel installed in the left forward entry doorway of a United Airlines model 747 aircraft, A/P No. N4703U. This test will be completed by July 1983. The panel was fabricated by Boeing and is constructed with two-ply face sheets of a Deco, Inc. modified phenolic resin impregnated S-glass tow (XMP-100) bonded with Narmco 9252-112 modified phenolic adhesive to Orbitex 9-lb/ft^3 Nomex^R honeycomb core filled with Solar polyimide foam to a density of 48 kg/m^3 (3 lb/ft^3). The nominal weight of the panel stock is 3.64 kg/m^2 (0.75 lb/ft^2).

The program had three objectives. The primary objective was to construct a floor panel suitable for high-traffic areas that would be more fire resistant and generate less smoke and toxicants than the flooring currently used in commercial aircraft. This objective was accomplished. A second objective was to construct the panel without comprising the strength, fatigue endurance, impact resistance, or other physical properties of the flooring. The mechanical tests performed show that the developed panel is comparable to the flooring currently in use. The service evaluation should establish that this objective was accomplished. The third objective was to develop a panel that could be economically priced and mass produced. Because some of the materials used to construct the panels were themselves produced using laboratory-scale equipment, it is not presently possible to mass-produce the developed panel at prices near that of present aircraft flooring.

2.0 INTRODUCTION

The development of a lightweight, fire-retardant, low-smoke, high-strength, thermally stable aircraft floor paneling began with NASA Contract No. NAS9-14753. The objective of NAS9-14753 was to develop a panel that was suitable for use as underseat flooring. Several promising candidate systems were developed, and it was recommended that further development be done that would include more extensive testing, and the development, construction, and flight testing of a high-traffic (aisle and galley) panel.

This program was a follow-on to NAS9-14753, and consisted of three tasks–screening, verification, and end item fabrication.

During the screening task, 14 floor panel systems were examined. The screening tests were used to select the most satisfactory face sheet adhesive, and core systems. At the completion of the screening phase, three high-traffic panel systems were selected for verification testing.

The verification tests were used to select the one most satisfactory floor panel system for fabrication into a service evaluation panel, and panels for large-scale and laboratory testing by Boeing in NASA Contract No. NAS9-15168. The verification phase fully characterized the three candidate systems through a series of mechanical, environmental, fatigue, and flammability tests.

The end item fabrication task consisted of constructing the service evaluation panel, obtaining FAA certification, arranging its installation in a commercial aircraft, and conducting the first annual inspection. In addition, two curved panels and one flat panel were constructed in support of NASA Contract NAS9-15168.

3.0 TEST PROGRAM

The test program consisted of a screening phase and a verification phase.

Screening phase tests were performed on 14 candidate materials. The screening task was further segmented into three steps—adhesive selection, face sheet selection, and core selection. The screening phase tests consisted of the following flammability, mechanical strength, and durability tests:

<u>Flammability</u>

FAR 25-32 Vertical Burn

Boeing Burn-Through

Smoke Density

Toxic Gas Emission

Limiting Oxygen Index (LOI)

Chemical Properties (TGA)

<u>Mechanical Strength/Durability</u>

Impact

Fatigue (Food Roller Cart)

Weight

Flexure

Verification phase tests were performed on three candidate systems. The tests consisted of all the screening phase tests plus the following flammability, mechanical strength, durability, and humidity exposure tests:

<u>Flammability</u>

Flammability Properties (Lennox Oil Burner)

<u>Mechanical Strength/Durability</u>

Insert Pullout (Shear)

In-plane Panel Shear

Core Shear

Core Compression

Peel

Warpage

Humidity Exposure

Weight Gain

Peel

Flexure

3.1 PANEL CONSTRUCTIONS

The construction of screening phase candidate panels is shown in table 1. Candidate panels were fabricated by adhesive bonding of precured skins or by cocuring the adhesive and the uncured face sheet material. The Boeing-constructed panels were fabricated with precured skins. All the panels used two plies of unidirectional glass as the face skin material.

The adhesive materials included film and roller-coated polyimides, phenolics, epoxies, and undefined proprietary resins.

The core materials were all Nomex^{R} honeycomb with and without foam fillers, except for the Boeing-constructed Panel No. 7 which used Solar rigid polyimide foam.

The panels constructed by Boeing were fabricated using an autoclave. The other panels were press cured. Pictures of the verification phase panels and the fabricated end items are shown in figures 2 and 14.

3.2 TEST PROCEDURES AND MATERIAL REQUIREMENTS

The details of the test methods are described in the appendix, sections A.1 through A.14. Photographs and diagrams of the test equipment are shown in figures 1 through 13.

3.2.1 PANEL WARPAGE, WEIGHT, AND THICKNESS MEASUREMENTS

Warpage—The warpage measurements were made on the panels as received. Measurements were made across both the length and width of the panels as described in the appendix, section A.1. The maximum acceptable gap was 0.19 cm/m (0.025 in./ft).

Weight—The weight measurements were made on trimmed, squared portions of the panels as described in the appendix, section A.1. The desired weight range for a high-traffic panel was 3.4 kg/m^2 (0.70 lb/ft^2) to 4.6 kg/m^2 (0.95 lb/ft^2).

Thickness—The thickness measurements were made around the periphery of the panels as described in appendix section A.1. The required thickness range was 1.0 cm (0.39 in.) to 1.04 cm (0.41 in.).

3.2.2 IMPACT STRENGTH TESTS

The impact strength tests were made on trimmed portions of the panels as described in the appendix, section A.2. The minimum acceptable impact resistance was 0.41 kg-m (35 in.-lb).

3.2.3 FAR 25-32 FLAME TESTS

The vertical flammability tests were conducted on specimens as described in the appendix, section A.3, and were part of the FAA flight certification requirements. The maximum allowable extinguishment time was 15 seconds. The maximum allowable burn length for the 12-second ignition tests was 20.3 cm (8.0 in.), and 15.2 cm (6 in.) for the 60-second ignition test.

3.2.4 BURN-THROUGH TESTS

The burn-through tests were conducted to measure the fire barrier capability of the panels to a 1093°C (2000°F) flame. The test procedure is described in the appendix, section A.4. The desired maximum backface temperature after 10 minutes exposure was 260°C (500°F).

3.2.5 SMOKE AND TOXIC GAS GENERATION TESTS

The smoke and toxic gas emission tests were conducted to measure the specific optical density (D_s) and the quantities of cyanide (HCN), chloride (HCl), fluoride (HF), sulfur oxides, nitrogen oxides, and carbon monoxide at 4 minutes exposure to 2.5 watts/cm^2 flaming mode in an NBS Smoke Density Chamber. They were performed as described in the appendix, section A.5. The maximum allowable D_s value was 75. No acceptable levels of toxicants were established because the thermal stability requirement of 204°C (400°F) eliminates the need for toxicity criteria.

3.2.6 LIMITING OXYGEN INDEX (LOI) TESTS

The LOI tests were conducted on the face sheet, face sheet plus adhesive, and core materials because it was impractical to slice the sandwich panels to the required dimensions. The test procedure is described in appendix section A.6. The minimum desired oxygen index value was 40.

3.2.7 CHEMICAL PROPERTIES (TGA) TESTS

The TGA tests were conducted to measure the percent of weight loss when the panel was heated to pyrolysis in a Mettler thermal balance. The test was performed as described in the appendix, section A.7. The desired result was for the panel to be thermally stable to a temperature of 204°C (400°F).

3.2.8 FATIGUE (FOOD CART ROLLER) TESTS

The fatigue tests were conducted to measure the ability of the panels to sustain the loading imposed by the wheels of food and beverage carts used by the airlines. The test was performed as described in the appendix, section A.8. The high-traffic panel was required to withstand 120,000 cycles at a loading of 58 kg (128 lb) per wheel plus an additional 35,000 cycles at a loading of 71.6 kg (158 lb) per wheel.

3.2.9 ROLLING DRUM PEEL TESTS

The peel tests were conducted to measure the strength of bond between the face skin and the core. The test was performed as described in the appendix, section A.9. The minimum desired peel strength was 1.15 kg-cm (30 lb-in.) per 7.62-cm (3-in.) width for specimens not exposed to humidity aging.

3.2.10 FLEXURE, CORE SHEAR, AND COMPRESSION TESTS

The longbeam flexure and deflection, core shear, and compression tests were performed as described in the appendix, section A.10. For high-traffic panels, the desired flexure strength was 104 kg (230 lb) with a maximum deflection of 2.16 cm (0.85 in.) at a 45.3-kg (100-lb) load. The desired core (short beam) shear strength for a high-traffic panel was 266 kg (585 lb). The desired core compression for a high-traffic panel was 727 kg (1600 lb) per 2.54 cm (1.0 in.) square.

3.2.11 INSERT PULLOUT (SHEAR) TESTS

The insert shear tests were conducted to measure the interlaminar shear strength of the panel face skin and its bondability. The tests were performed as described in the appendix, section A.11. The minimum acceptable load was 382 kg (840 lb).

3.2.12 PANEL IN-PLANE SHEAR TESTS

The in-plane shear test was performed to measure the in-plane strength of the panels. The tests were performed as described in the appendix, section A.12. The minimum acceptable shear load was 1823 kg (4010 lb).

3.2.13 ENVIRONMENTAL EXPOSURE TESTS

The condensing humidity tests were conducted to measure the weight gain of the panels and the longbeam flexure and peel strength retention. The test was performed as described in the appendix, section A.13. The maximum desirable percentage gain in weight was 6.0%. The desired longbeam flexure and peel strength retention was 80%.

3.2.14 FLAMMABILITY PROPERTIES TESTS

The Lennox oil burner test was conducted to measure the ability of the panels to support a 91-kg (200-lb) weight after a 10-minute exposure to a 1093°C (2000°F) flame from an oil burner. The test was performed as described in appendix section A.14.

4.0 TEST RESULTS

4.1 DATA PRESENTATION FORMAT

Summaries of the test data are presented in tables 2 and 3. The individual values of test data are presented in tables 4 through 17. The panel numbering system is used for convenience and identifies the panels described in table 1.

The discussion of the test results is oriented toward stating what significance they had in selecting the best face sheet, adhesive, and core materials, and in selecting the panel systems for verification testing and end item fabrication.

4.2 PRESENTATION AND DISCUSSION OF RESULTS

4.2.1 PANEL WEIGHT, WARPAGE, AND THICKNESS DATA

The panel weights varied from 2.9 kg/m^2 (0.60 lb/ft^2) to 4.7 kg/m^2 (0.97 lb/ft^2). Weights varied primarily due to different core and honeycomb core filler materials. Weight was not chosen as a factor for excluding an otherwise satisfactory material from the verification testing phase.

The panel warpage results varied greatly. Panels 1 and 2 were fabricated by bonding the face skins to the honeycomb core individually. This caused warpage beyond the requirement of 0.21 cm/m (0.025 in./ft). The first and third submissions of panel 8 were also warped more than desired. Panel warpage in itself did not exclude any materials from the verification phase testing.

The panels having a thickness outside the required range were number 8 and number 13. Panel 8 (submission 3) was made from a sheet of honeycomb core that was too thin. Panel number 13 was too thick due to the face sheets being out of tolerance. Thickness was not a factor in itself for excluding any materials from the verification test phase.

4.2.2 IMPACT STRENGTH TEST RESULTS

The impact results were generally much higher than the minimum requirement of 0.41 kg-m (35 in.-lb). The one exception was panel number 12. The glass content of the face skins was lower than that of the other panels. The low impact values contributed to the DuPont 6113 polyimide skins being excluded from the verification test phase.

4.2.3 FAR 25-32 FLAME TEST RESULTS

The 12- and 60-second vertical flammability test results were satisfactory for all the panels. Individual differences in extinguishment time and burn length were not a factor in selecting materials for inclusion in the verification test phase.

4.2.4 BURN-THROUGH TEST RESULTS

The burn-through test results varied from 234°C (453°F) to 435°C (815°F). Panel number was the only one to have a backface temperature within the desired range. This was due to the fact that panel number 7 had rigid Solar polyimide foam as the core material, which served as a flame barrier once the exposed face was penetrated. The panels having a foam material in the honeycomb core generally had a lower backface temperature than those pan without foam in the honeycomb.

The relatively low backface temperature achieved by panel number 2 contributed to the selection of Narmco 9252-120 phenolic adhesive for the verification test phase. Pictures of burn-through specimens from the panels selected for the verification phase are shown in figures 15, 17, and 19.

4.2.5 SMOKE AND TOXIC GAS GENERATION TEST RESULTS

The smoke and toxic gas generation test results show that all the candidate materials produ quantities of smoke much lower than the maximum allowable D_S. The smoke generation levels did not, therefore, prevent any materials from being selected into the verification pha testing. Toxic gas levels similarly were very low, and did not prevent any material from bei selected into the verification phase testing.

4.2.6 LIMITING OXYGEN INDEX (LOI) TEST RESULTS

The LOI test results show that the face skin materials met the desired level of 40, with the exception of panel number 13. The Ferro CPI 2214 polyimide skins had an LOI of 32. Th low value contributed to its being excluded from the verification phase testing.

The LOI results for the face sheet plus adhesive test specimens show that panels number 8 a 13 did not meet the desired level. The effect of the adhesives in general was to lower the L values achieved on the skins alone.

The core materials from the panels having a foam in the honeycomb were difficult to test. The results show that those specimens in which the foam adhered securely to the test coup had a satisfactory value, i.e., panels number 8 and 14. The specimens that were prepared fr panels without a foam in the honeycomb core, or where the foam did not adhere to the tes coupons, had values below the desired minimum. The rigid Solar polyimide foam had a valı of 50 when tested by itself. There was no significant difference between the results on the the Orbitex and Hexcel honeycomb cores.

4.2.7 CHEMICAL PROPERTIES (TGA) TEST RESULTS

The thermal stability of the panels were determined by performing TGA tests. The temper at which the sample began to lose weight, lost 5%, and lost 10% of its initial weight shows h the panel would behave under the condition of a rapidly increasing temperature. The result show that some weight loss occurred in all the candidate panels prior to reaching a temperature of 204°C (400°F). The weight loss in all the panels was less than 10% at this temperat and the weight loss in panels number 5, 6, 7, 9. 12, and 14 was less than 5%.

4.2.8 FATIGUE (FOOD CART ROLLER) TEST RESULTS

The food cart roller test results show that only four panels passed the test: numbers 8, 9, 13, and 14. The mode of failure in the unsatisfactory panels was core crushing, with the exception of panel number 12 which failed due to skin delamination from the core. The panels that did not meet the roller cart requirement were eliminated from the verification test phase.

4.2.9 ROLLING DRUM PEEL TEST RESULTS

The peel test results show that none of the panels met the desired minimum peel strength. The primary mode of failure on all specimens was within the adhesive. This indicates that the adhesive materials are the cause of the failure rather than the bonding surfaces of the skins and the cores. The strength of the bond between the face sheets and the core was sufficient to permit normal machining techniques on all the panels except numbers 1, 4, and 6. It appears that the mechanism that promotes good adhesive properties also contributes to smoke generation. The candidate adhesives for this effort were required to have low smoke numbers.

4.2.10 FLEXURE, CORE SHEAR, AND COMPRESSION RESULTS

4.2.10.1 Long Beam Flexure and Deflection

The long beam flexure results show that panels number 2, 3, 4, 5, 7, 8, 9, 13, and 14 met the desired minimum load requirement; all the panels tested met the maximum allowable deflection requirement.

The mode of failure on specimens from panel number 6 was in the skin-to-core bond. The mode of failure of all the other panels was compression of the upper skin.

4.2.10.2 Core (Short Beam) Shear

The core shear results show that panels number 1, 4, 5, 6, and 7 did not meet the desired minimum load. The mode of failure in panels number 1, 4, 5, and 6 was failure of the bond between the face skins and the core. The mode of failure in panel number 7 was within the Solar rigid foam.

4.2.10.3 Core Compression

The core compression results show that panels number 4, 5, and 6, which used 80.1 kg/m^3 (5.0 lb/ft^3) honeycomb core, had compressive strengths less than the desired minimum. The low compressive strength of panel number 7 explains the low roller cart test results.

4.2.11 INSERT PULLOUT (SHEAR) TEST RESULTS

The insert shear results for panels numbers 8 and 14 show values well above the required minimum. The mode of failure was within the inserts. The results for panel number 9 show values well below the required minimum. The mode of failure on all the specimens was within the face skins.

4.2.12 PANEL IN-PLANE SHEAR TEST RESULTS

The in-plane shear test was the last verification test performed, and panel number 14 had been selected for end item fabrication on the basis of the results of the previous tests. The results show that the in-plane shear strength of panel number 14 is well above the desired minimum requirement.

4.2.13 ENVIRONMENTAL EXPOSURE TEST RESULTS

4.2.13.1 Weight Gain

The weight gain on all the panels tested was above the desired maximum of 6%. The weight gain of those specimens having the edges sealed was less than the gain of those without sealed edges, but did not meet the 6% goal. Panels number 8 and 14 had a greater gain in weight than panel number 9. This indicates that the foam filler contributes to water absorption. The mechanism for water absorption appeared to be through the face skins. Water was observed to be in all the honeycomb cells of the peel specimens that had been exposed.

4.2.13.2 Peel (Rolling Drum)

The peel results for all the panels tested show values that are well below the desired minimum strength retention of 80%. The values for specimens having the edges sealed were higher than those for the unsealed specimens, but did not meet the 80% retention goal. The mode of failure for all specimens was within the adhesive.

4.2.13.3 Flexure (Long Beam)

The long beam flexure results show that panel number 9 met the 80% strength requirement. The specimens were exposed without having the edges sealed. The results for panel number 14 do not vary significantly between the specimens with and without sealed edges. The results for panel number 8 show that the unsealed specimens lost all their strength. The mode of failure was in the face-skin-to-core bond. The specimens having the edges sealed have much higher values, and the mode of failure was compression of the upper skin.

4.2.14 FLAMMABILITY PROPERTIES TEST RESULTS

The Lennox oil burner results show that none of the panels were able to support a 91-kg (200 lb) load after a 10-minute exposure. Panel number 9 (which had no foam filler in the honeycomb core) had a backface temperature of 700°C (1362°F) at 10 minutes. Decomposition of the panel appeared to stop within the first 5 minutes of exposure. Panels number 8 and 14 showed very similar flame resistance at 10 minutes into the test. The backface temperatures were 468°C (875°F) and 425°C (807°F), respectively. At 5 minutes into the test, both panels appeared to have stopped decomposing. The backface temperatures at 5 minutes were 339°C (643°F) and 396°C (744°F), respectively. The oil burner results correlated very well with the burn-through results. Pictures of the test specimens are shown in figures 16, 18, and 20.

5.0 CONCLUSIONS AND RECOMMENDATIONS

5.1 CONCLUSIONS

On the basis of the results achieved on this program, the following conclusions can be made:

1. A lightweight, fire-retardant, low-smoke, high-strength, thermally stable aircraft floor paneling has been developed and constructed that has mechanical strength nearly equivalent to flooring presently in use. The skin to core bond strength and humidity resistance of the developed panel is less than present aircraft flooring.

2. The burn-through resistance of an aircraft floor panel constructed with Nomex^R honeycomb core increases significantly when the core is filled with a flame-resistant foam material, but this imposes a significant weight penalty with no increase in mechanical strength.

3. Smoke generation levels within the 75 maximum D_s requirement are easily achieved by using either phenolic or polyimide resin impregnated fiberglass laminates as the face skin material.

4. A non-smoke adhesive material for bonding the face sheets to the honeycomb core, that has the strength and humidity resistance equivalent to what is used on present aircraft flooring, has not yet been developed.

5.2 RECOMMENDATIONS

Based on the test results and fabrication experience gained on this program, the following recommendations are made:

1. It is recommended that development continue on the process for putting the Solar polyimide foam into large sections of honeycomb core. Present aircraft flooring is fabricated from sheet stock measuring 1.22 m (4 ft) wide by 3.66 m (12 ft) long. The largest pieces of Solar foam-filled core that could be procured on this program were 61 cm (2 ft) by 91 cm (3 ft).

2. It is recommended that development be continued on non-smoke adhesives for bonding the face sheets to the honeycomb core using applicable screening and verification tests from this program, the objective being to achieve a bond strength and resistance to humidity exposure equivalent to present aircraft floor panel stock.

3. The construction of the panel stock, from which the service evaluation panel was fabricated, included a curing cycle of 90 minutes in an autoclave. The preferred method of fabricating floor panel stock is by curing in a press. It is recommended that the processing technology base be expanded by developing an optimum fabrication process for the low-smoke floor panel stock.

4. The flammability testing conducted on this program used relatively small test specimens. It is recommended that floor panels of the configuration delivered for service evaluation be included in large-scale cargo area and passenger cabin testing scheduled to be conducted in the future.

APPENDIX
EQUIPMENT AND DETAILS OF PROCEDURES

A.1 PANEL WARPAGE, WEIGHT, AND THICKNESS MEASUREMENTS

The panel warpage was determined by measuring the maximum gap between a straight edge and the panel. The panel was placed on a flat, rigid surface with the concave side up. The straight edge was placed across the concave side of the panel from one edge to the other. The straight edge was held in a manner that exerted no more than 4.1 kg/m (3 lb/ft) of panel width when in position for measurement.

The panel weight was determined by weighing a minimum 30.5 cm (12 in.) square section of material to ±2.27 gm (0.005 lb). The weight then was divided by the panel area.

The panel thickness was determines by measuring around the entire periphery of a section of material and again as far inward as the thickness tester would allow. The thickness was measured to ±0.013 cm (0.005 in.).

A.2 IMPACT STRENGTH TESTS

Impact strength was determined by using the Gardner impact test fixture shown in figure 1.

The impact blows were produced by dropping a 0.91- or 1.82-kg (2- or 4-lb) projectile onto a steel impact point that was tapered conically to a 3.175-mm (0.125-in.) flat face at the panel contact end. The impacts were spaced not less than 3.8 cm (1.5 in.) from the edge of the specimen or another impact. The test specimens were impacted at 4.6 kg-cm (4-in.-lb) force intervals until failure occurred. Failure was taken to be a puncture of the face sheet. Puncture was determined by lightly probing the area of the impact with a freshly sharpened writing pencil. The material was considered to be penetrated if the point protruded entirely through the area of impact. The minimum size of an impact specimen was 2.54 by 30.48 cm (10 x 12 in.).

A.3 FAR 25-32 FLAME TESTS

The 12- and 60-sec vertical ignition tests were conducted in accordance with FAR 25-32, paragraph 8. A typical test setup is shown in figures 3 and 4.

The Bunsen Burner was operated on Matheson B-gas supplied from storage tanks. The flame was adjusted to give a temperature of 871° ±10°C (1600° ±50°F) with a flame height of 38.1 mm (1.5 in.) total and a blue cone height of 19.05 mm (0.75 in.) high. Flame temperature was measured using a Leeds and Northrup model 8659 bridge-type potentiometer and chromel-alumel thermocouple.

The specimens were 7.62 cm (3 in.) wide by 30 cm (12 in.) long. They were conditioned at 26° ±1.5°C (78° ±3°F) and 50% relative humidity for a minimum of 24 hours prior to testing.

An electric timer accurate to within 0.1 sec was used to measure the length of time the burner flame was applied to the specimen and the length of time the specimen burned after removal of the burner. Burn length was determined by measuring the damaged area with a rule accurate to 0.25 cm (0.1 in.).

A.4 BURN-THROUGH TESTS

The laboratory scale burn-through tests were performed using the Boeing test apparatus shown in figures 5 through 8.

The test apparatus uses a Meeker blast burner fed with commercial propane gas as the heating source. The operating conditions were adjusted to provide an incident heating rate of 8.52 to 10.2 w/cm^2 (8.5 to 9 Btu/ft^2-sec) at the center of the exposed face of the test specimen. The burner temperature was measured by the platinum-platinum (13%) rhodium thermocouple shown in figure 6. Thermocouple output was recorded by the Varian recorder shown in figure 5. The burner temperature was recorded throughout the test.

The backface temperature was measured by a spring-loaded chromel-alumel thermocouple, shown in figure 7. The thermocouple output was also recorded by the Varian recorder. The backface temperature was recorded throughout the test.

The test specimens were 11.1-cm (4.375-in.) squares. They were conditioned at 26°C (78°F) and 50% humidity for a minimum of 24 hours prior to testing.

The test apparatus was brought to the proper operating conditions and the flame baffle (shown in figure 8) in the position of the test specimen. The recorder chart was started. The specimen insertion door was opened and the test specimen inserted. The specimen pushed the flame baffle away from the burner and out of a slot in the opposite wall. When the specimen insertion door was closed, a lever mechanism (shown in figure 7) moved the backface thermocouple into contact with the specimen and, simultaneously, a microswitch marked the recorder chart. The outputs from the flame temperature thermocouple and the backface temperature thermocouple were continuously drawn on the recorder chart throughout the test.

A.5 SMOKE AND TOXIC GAS GENERATION

The smoke and toxic gas generation tests were performed using the Aminco Smoke Density Chamber shown in figure 9. This apparatus is of the design used by the National Bureau of Standards and is described in NBS Technical Note 708, "Interlaboratory Evaluation of Smoke Density Chamber," December 1971.

The test chamber contains a radiant heat furnace, specimen holder, gas burner, photometer system, and gas sampling system.

The radiant heat furnace is electrically powered. It is mounted within an insulated ceramic tube and positioned to irradiate a vertically mounted specimen. The irradiance level was adjusted to average 2.5 v/cm^2 over the central area of the specimen having a diameter of 3.81 cm (1.5 in.).

The specimen holder exposes a 6.51-cm (2.562-in.) square area of the specimen to the radiant heat of the furnace. The specimen sits 3.81 cm (1.5 in.) from the furnace opening.

A gas burner, consisting of six jets, produces flamelets along the bottom edge of the exposed face of the specimen. The flamelets impinged on the specimen surface throughout the test.

The photometric system consists of a high-intensity light source and photocell. The light path is oriented in the vertical plane. Light transmittance values are measured on an Aminco Photomultiplier Photometer and plotted on a Moseley 7100B Strip Chart Recorder. Light transmittance is recorded throughout the test.

The percentage change in the light transmission is converted to an optical density value (D_S) by the following equation:

$$D_S = \frac{V}{AL} \log 10 \quad \frac{100}{t}$$

where :

D_S = optical density

V = chamber volume, 0.51 m^3

L = light path length, 0.91 m

A = exposed surface area of specimen, 42.4 cm^2

T = percent transmission

The gas sampling system consists of a group of four vacuum lines mounted in the center of the test chamber. Braeger colorimetric tubes were inserted into the vacuum lines, and predetermined quantities of air were drawn through the tubes at 4 minutes into the smoke test runs. Each Draeger tube measures a specific type of gaseous product. The gases monitored were cyanide (HCN), chloride (HCl), fluoride (HF), sulfur oxides, and nitrogen oxides.

A Beckman model 865 Infrared Analyzer was used to monitor carbon monoxide. The output was plotted on the same chart used to record light transmittance.

The test specimens were 7.62-cm (3-in.) squares. The specimens were conditioned for 25 hours in an oven at 60°C (140°F) and then placed in a cabinet at 50% relative humidity and 26°C (78°F) for a minimum of 24 hours prior to testing. The back, edges, and unexposed front surface of the specimens were covered by a single sheet of aluminum foil, and a square of asbestos millboard was used to back the specimens.

A.6 LIMITING OXYGEN INDEX (LOI)

The limiting oxygen tests were performed using the oxygen-nitrogen test apparatus shown in figure 11. The tests were performed in accordance with ASTM D2863T.

The test specimens were 150 mm (6 in.) long by 6.5 ±0.5 mm (0.26 ±0.01 in.) wide and 3.0 ±0.5 mm (0.125 ±0.01 in.) thick. They were conditioned at 50% relative humidity and 26°C (78°F) for a minimum of 24 hours prior to testing.

The objective of the test was to determine the minimum oxygen concentration that would allow the specimen to burn. This was accomplished by adjusting the flow rates of nitrogen and oxygen to a point where the specimen would continue to burn after removal of the ignition flame. An initial concentration of oxygen was selected on the basis of past experience with similar materials. The volumetric flow of the oxygen and nitrogen gases was set according to calibrated glass flow meters. The gases were allowed to flow past the specimen for 30 seconds to purge the system. Then the specimen was ignited so that the entire tip was burning. The ignition flame was removed and the length of time the specimen burned was timed and recorded.

The oxygen index was calculated by the following formula:

$$n(\%) = \frac{100 \times 0_2}{0_2 + N_2}$$

where 0_2 and N_2 are the volumetric flows (cm^3/sec).

A.7 CHEMICAL PROPERTIES (TGA) TESTS

The chemical properties tests were performed using the Mettler thermal balance (TGA).

The test specimens were ground samples of the sandwich weighing 30 to 48 mg.

A standard air atmosphere was maintained in the test cell, and the cell was heated at 6°C/min (10.8°F/min). The change in the sample weight was automatically measured and continuously recorded on a strip chart. The test was run until weight loss ceased.

A.8 FATIGUE (FOOD CART ROLLER TEST)

The fatigue tests were performed using the Boeing test apparatus shown in figure 11.

The apparatus consisted of a specimen holder, roller caster plate with wheels and weight pan, and an electrically driven angle drive and shaft with a universal joint.

The specimen holder duplicates the aircraft floor beam supports. The test fixture held two specimens.

The roller caster plate was supported upon the test specimens by three Bassick polyurethane wheels. The wheels were attached to the plate with casters mounted in a 50.8-cm- (20-in.-) diameter circle with 120° spacing. The wheel track was centered over the two test panels. The weight pan was loaded with 3 stacks of lead plates. Each stack was centered along the radius of a caster, and bolted to the weight pan by a threaded dole. The roller caster plate with wheels weighed 10.9 kg (24 lb) and the lead plates weighed 1.36 kg (30 lb) each.

The electrically driven angle drive and shaft with a universal joint was supported directly above the roller caster plate, and rotated the center plate at a constant 20 revolutions per minute.

The test specimens were fully fabricated panels measuring 54.1 cm (23.1 in.) wide by 99.8 cm (33.9 in.) long. Each test panel had 28 Shur-Lok 5107 inserts installed equilaterally around the edges by which it was bolted to the test fixture.

The specimens were tested continuously until failure occurred or the requirements were met. The initial loading was 58 kg (128 lb) per wheel for the first 120,000 revolutions. The final loading was 71.8 kg (158 lb) per wheel for an additional 35,000 cycles. Failure was considered to have occurred when skin delamination or core crushing was visible.

A.9 ROLLING DRUM PEEL TESTS

The peel tests were performed using a Tinius-Olsen universal test machine equipped with a proportional recorder. The tests were performed in accordance with MIL-STD-401, Sandwich Peel.

The specimens were cut with the long axis parallel to the direction of the inner ply of the face skin. They measured 7.6 cm (3 in.) wide by 30 cm (12 in.) long. Tests were performed on specimens before and after humidity aging.

A.10 FLEXURE, CORE SHEAR, AND COMPRESSION TESTS

The flexure tests were performed using a Tinius-Olsen universal test machine equipped with a proportional recorder. Deflections were measured using a Tinius-Olsen D2 deflectometer. The tests were performed in accordance with MIL-STD-401 and ASTM C365.

A.10.1 LONG BEAM FLEXURE AND DEFLECTION TESTS

The panel bending load capability was determined in long beam bending using a 50.8-cm (20-in.) span and quarter-point loading. The cross-head speed was 1.27 cm (0.5 in.) per minute. The ultimate breaking load and the deflection at 45.3 kg (100 lb) load were recorded.

The test specimens measured 7.62 cm (3.0 in.) wide by 60.9 cm (24.0 in.) long. Tests were performed on specimens before and after humidity aging.

A.10.2 SHORT BEAM FLEXURE (CORE SHEAR)

The core shear strength in bending was determined using a 10.1-cm (4-in.) span with mid-point loading. The cross-head speed was 0.25 cm (0.1 in.) per minute. The ultimate breaking load was recorded.

The specimens measured 7.62 cm (3.0 in.) wide by 17.8 cm (7.0 in.) long. The 7.62-cm (3.0-in.) dimension was in the core ribbon or "L" direction.

A.10.3 CORE COMPRESSION

The compressive strength of the core was determined using a cross-head speed of 0.05 cm (0.02 in.) per minute. The ultimate strength was taken at the maximum load within the 0.1-cm (0.04-in.) strain.

The specimens were cut from fabricated panels (stabilized) and measured 5.08 cm (2.00 in.) square.

A.11 INSERT PULLOUT (SHEAR) TESTS

The insert shear tests were performed using a Tinius-Olsen universal test machine equipped with the Boeing insert shear test fixture shown in figure 12.

The shear strength of the specimen was determined using a loading rate of 0.25 cm (0.10 in.) per minute. The ultimate load was recorded.

The test specimens were prepared from fabricated panels and measured 7.62 cm (3.0 in.) wide by 25.4 cm (10.0 in.) long. The 2.54-cm (10.0-in.) dimension was in the core ribbon or "L" direction. The inserts were Shur-Lok 5107, and were bonded with Ciba Araldite AY1(Hy953F adhesive. The specimens were allowed to cure for 7 days at room temperature prior to testing.

A.12 PANEL IN-PLANE SHEAR TESTS

The in-plane panel shear tests were performed using a Warner and Swasy test machine equippe with the Boeing "picture frame" test fixture shown in figure 13.

The shear strength of the specimens was determined by applying loads to opposite corners of the test fixture until failure. The loading rate was 2.54 cm (1.0 in.) per minute. The applied test loads and corresponding machine head travel were recorded in a strip chart.

The test specimens were prepared from fabricated panels and measured 30.5 cm (12 in.) squar A fiberglass laminate doubler, 0.25 cm (0.10 in.) thick by 3.8 cm (1.5 in.) wide (continuous around the four edges) was bonded to both faces of the specimen. Ten equally spaced 0.64-cm (0.25-in.) holes were drilled through each edge of the specimen so it could be bolted to the picture frame. One-third of the test specimens was modified before testing by removing the center portion; cutting along the inboard edges of the doublers leaving a square ring 30.5 cm (12 in.) by 30.5 cm (12 in.) and 3.8 cm (1.5 in.) wide.

The in-plane panel shear load was obtained by subtracting the failure load of the modified test specimens from the failure load of the unmodified test specimens from the failure load of the unmodified specimens.

A.13 ENVIRONMENTAL EXPOSURE TESTS

The environmental exposure was performed in a Precision Scientific humidity cabinet operate at 60° ±1.1°C (140° ±2°F) and 95 to 100% relative humidity in accordance with Federal Test Method Standard 141a, Method 6062.

A.13.1 PANEL GAIN IN WEIGHT

The panel gain in weight after humidity aging was determined by recording the weight of each specimen, placing the specimens into the humidity cabinet for 30 days, removing the specimer blotting them dry of clinging water, and reweighing them.

The weight gain specimens were cut from fabricated panels and measured 7.62 cm (3.0 in.) wide by 33.0 cm (13.0 in.) long. Specimens were prepared in both the "W" and "L" directions.

The percent gain in weight was calculated from the following formula for each specimen and the average for each panel:

$$\text{Percent Weight Gain} = \frac{\text{Final Weight} - \text{Initial Weight x 100}}{\text{Initial Weight}}$$

A.13.2 PEEL AND LONG BEAM FLEXURE TESTS

The peel and long beam flexure tests were performed after humidity aging using the same equipment and procedures as were used for the unexposed specimens.

The humidity exposure specimens were cut from the same panels and to the same dimensions as the unexposed specimens. The specimens were put into the humidity chamber for 30 days, and were tested within 4 hours after removal from the chamber. Specimens were exposed both with and without the edges sealed.

A.14 FLAMMABILITY PROPERTIES (LENNOX OIL BURNER) TESTS

The large-scale burn-through tests were performed using the Lennox model 0B-32 oil burner.

The apparatus consisted of a kerosene burner, extension tube, specimen holder, flame temperature and backface temperature thermocouples, and a temperature recorder.

The burner used 7.6-1 (2.0 gal) of kerosene per hour to provide a 1093°C (2000°F) flame that "wetted" an elliptical area of the specimen measuring 25.4 cm (10 in.) by 38.3 cm (15 in.). The burner was equipped with an extension tube that directed the flame to the bottom side of the specimen. The specimen holder held the specimen in the horizontal plane, and positioned the specimen precisely at the 1093°C (2000°F) gradient of the flame. Thermocouples were positioned in the flame and against the backface of the specimen. The temperatures were monitored continuously and recorded every 15 seconds throughout the run.

The test specimens were undamaged roller cart specimens.

Table 1.—Panel Construction

Panel	Fabricator	Face Sheets	Adhesive	Core
1	Boeing	Deco XMP-100 phenolic	American cyanamid BR-34-18 polyimide	Hexcel HRH-10, 1/8-in. cell, NOMEX^R, 9.0 lb/ft^3
2	Boeing	Deco XMP-100 phenolic	Narmco 9251-112 phenolic	Hexcel HRH-10, 1/8-in. cell, NOMEX^R, 9.0 lb/ft^3
3	General veneer	Deco XMP-100 phenolic	Undefined epoxy	Hexcel HRH-10, 1/8-in. cell, NOMEX^R, 9.0 lb/ft^3
4	Deco	Deco XMP-100 phenolic	Undefined phenolic	Hexcel HRH-10, 1/8-in. cell, NOMEX^R, 5.0 lb/ft^3, filled with undefined phenolic foam
5	Deco	Deco XMP-100 phenolic	Undefined phenolic	Hexcel HRH-10, 1/8-in. cell, NOMEX^R, 5.0 lb/ft^3
6	Deco	Deco XMP-100 phenolic	Undefined phenolic	Hexcel HRH-10, 1/8-in. cell, NOMEX^R, 5.0 lb/ft^3, filled with Solar polyimide foam
7	Boeing	Deco XMP-100 phenolic	Narmco 9251-112 phenolic	Solar rigid polyimide foam

Table 1.—(Concluded)

Panel	Fabricator	Face Sheets	Adhesive	Core
8	Nordam	Deco XMP-100 phenolic	Undefined	Orbitex, 9 lb/ft^3 NOMEX^R honeycomb core, filled with Philadelphia Quartz Silica Microspheres
9	Air Logistics	Air Logistics 4005-5500-14 phenolic	Undefined phenolic	Orbitex, 9 lb/ft^3 NOMEX^R honeycomb core
10	Ciba Geigy	Ciba Geigy phenolic	Ciba phenolic	Orbitex, 9 lb/ft^3 NOMEX^R honeycomb core
11	Ciba Geigy	Ciba Geigy phenolic	Ciba phenolic	Orbitex, 9 lb/ft^3 NOMEX^R honeycomb core, filled with Ciba phenolic foam
12	Boeing	DuPont 6113 polyimide unidirectional S glass	Narmco 9251-112 phenolic	Orbitex, 9 lb/ft^3 NOMEX^R honeycomb core
13	Boeing	Ferro CPI 2214 polyimide unidirectional S glass	Narmco 9251-112 phenolic	Orbitex, 9 lb/ft^3 NOMEX^R honeycomb core
14	Boeing	Deco XMP-100 phenolic	Narmco 9252-120 phenolic	Orbitex, 9 lb/ft^3 NOMEX^R honeycomb core, filled with Solar polyimide foam

Panel	Fabricator	FAR 25-32 60 sec vertical	Boeing burn thru Back face Temp @ 10 min °C	NBS smoke D_s @ 4.0 min	Toxicity PPM @ 4.0 min						Limiting oxygen index			TGA °C @ 5% wt loss	Impact kg-m (in.-lb)	Cycles of food Roller cart	Weight kg/m^2 (lb/ft^2)	Flexure ult load kg (lb)	Flexure deflection cm (in.)	Core compression kg/cm^2 (lb/in^2)
					HCN	HCl	HF	CO	SO_2	NO_x	Face sheet	Face + adhesive	Core							
1	Boeing	Pass	372.8 (703)	—	—	—	—	—	—	—	—	—	32	—	0.78 (67)	—	3.45 (0.71)	—	—	—
2	Boeing	Pass	351.7 (665)	5	2	None	None	150	None	8	100	58	32	340	0.70 (60)	126,029 + 1,595	3.40 (0.70)	191.2 (422)	1.55 (0.61)	—
3	General Veneer	Pass	435.0 (815)	13	1	None	None	110	None	2	100	—	32	320	0.74 (63)	92,363	2.91 (0.60)	157.2 (347)	1.80 (0.71)	355.3 (1,986)
4	Deco	Pass	297.8 (568)	10	2	None	None	146	None	12	100	—	32	330	0.58 (50)	13,614	4.18 (0.86)	134.2 (296)	1.73 (0.68)	189.3 (1,058)
5	Deco	Pass	381.7 (719)	1	2	None	None	86	None	5	100	—	32	420	0.47 (40)	10,238	2.91 (0.60)	151.0 (333)	1.55 (0.61)	185.0 (1,034)
6	Deco	Pass	378.9 (714)	1	2	None	None	101	8	7	100	—	32	415	1.3 (111)	4,000	3.35 (0.69)	74.8 (165)	1.96 (0.77)	186.0 (1,040)
7	Boeing	Pass	233.9 (453)	8	Trace	None	None	60	None	3	100	58	50	410	0.49 (42)	1,900	4.42 (0.91)	149.7 (330)	1.78 (0.70)	35.78 (200)
8	Nordam	Pass	325.0 (617)	1	17	None	None	60	None	Trace	81	36	50	353	0.90 (77)	120,000 +130,000	4.71 (0.97)	137.0 (302)	1.78 (0.70)	232.6 (1,300)
9	Air	Pass	411.1 (772)	1	Trace	None	None	50	None	6	76	57	33	410	0.44 (38)	120,000 + 35,000	3.40 (0.70)	149.7 (330)	1.65 (0.65)	366.4 (2,048)
10	Ciba Geigy	Pass	375.6 (708)	1	Trace	None	None	100	20	5	57	44	33	380	0.82 (70)	120,000 + 20,500	3.01 (0.62)	89.8 (198)	1.70 (0.67)	305.2 (1,706)
11	Ciba Geigy	Pass	404.4 (760)	15	Trace	None	None	90	15	8	57	44	33	—	0.80 (68)	—	3.20 (0.66)	—	—	—
12	Boeing	Pass	432.2 (810)	3	Trace	None	None	130	None	7	48	44	33	415	0.23 (20)	3,637	2.91 (0.60)	—	—	—
13	Boeing	Pass	337.8 (640)	35	5	Trace	None	170	None	65	32	32	33	380	1.05 (90)	120,000 + 35,000	4.52 (0.93)	131.5 (290)	1.12 (0.44)	—
14	Boeing	Pass	307.2 (585)	12	Trace	None	None	60	None	4	100	58	45	410	0.76 (65)	120,000 + 35,000	3.64 (0.75)	160.1 (353)	1.42 (0.56)	415.2 (2,321)

Table 2.—Summary of Screening Test Data

Table 3.—Summary of Verification Test Data

Verification tests		Panel number and fabricator		
		No. 8 Nordam	No. 9 Air Logistics	No. 14 Boeing
FAR 25-32 flammability tests		Pass	Pass	Pass
Boeing burn-through back face temperature @ 10 min		314 (597)	417 (782)	298 (569)
NBS smoke D_S @ 4 min		22	3	19
Toxicity ppm @ 4 min	HCN	2.0	Trace	Trace
	HCl	None	None	None
	HF	None	None	None
	CO	120	80	112
	SO_2	None	None	None
	NO_X	25	7	6
Limiting	Face sheet	100	75	100
Oxygen	Face + adhesive	35	58	58
Index	Core	50	33	40
TGA temperature, °C, @ 5% weight loss		367	390	377
Impact Kg - m (in-lb)		0.91 (78)	0.44 (38)	0.76 (65)
Food roller cart, cycles		120,000 +35,000	120,000 +35,000	120,000 +35,000
Weight Kg/m^2 (lb/ft^2)		4.71 (0.97)	3.40 (0.70)	3.64 (0.75)
Flexure ultimate load Kg (lb)		—	147.4 (325)	—
Core shear ultimate load Kg (lb)		362.9 (800)	296.6 (654)	373.8 (824)
Flammability properties (Lennox oil burner) back face temp. minutes: °C	1.0	60.0	136.1	69.4
	2.0	95.6	431.7	139.4
	3.0	141.1	623.9	273.9
	4.0	246.7	681.7	351.1
	5.0	339.4	700.0	395.6
	6.0	396.1	707.8	413.9
	7.0	434.4	723.9	421.1
	8.0	456.1	731.7	422.8
	9.0	463.9	736.7	423.9
	10.0	468.3	738.9	425.0
Insert pullout (shear) Kg (lb)		557.5 (1229)	330.2 (728)	640.5 (1412)
In-plane panel shear Kg (lb)		—	—	3496.3 (7708)
Core compression Kg/cm^2 (lb/in^2)		232.5 (1300)	366.4 (2048)	415.2 (2321)
Rolling drum peel Kg-cm/7.62 cm (lb-in/3 in.)		26.5 (23)	10.4 (9)	20.7 (18)

Table 3.—Summary of Verification Test Data (Concluded)

Verification tests		Panel number and fabricator		
		No. 8 Nordam	No. 9 Air Logistics	No. 14 Boeing
Warpage cm/m (in/ft)		0.38 (.03)	0.13 (.01)	0.38 (.03)
Weight gain after humidity enclosure, %	Unsealed	23	15	20
	Sealed	19	12	16
Peel strength after humidity exposure, %	Unsealed	None	56	61
	Sealed	70	55	67
Flexure strength after humidity exposure, %	Unsealed	20	87	72
	Sealed	73	—	75

Table 4.—Impact Strength Test Data

Panel	Fabricator	Impact test, failure load Kg-m (in-lb)					
		Specimen no. 1	Specimen no. 2	Specimen no. 3	Specimen no. 4	Specimen no. 5	Specimen no. 6
1	Boeing	0.772 (66)	0.842 (72)	0.725 (62)	—	—	—
2	Boeing	0.632 (54)	0.749 (64)	0.725 (62)	—	—	—
3	General Veneer	0.702 (60)	0.749 (64)	0.772 (66)	—	—	—
4	Deco	0.608 (52)	0.608 (52)	0.538 (46)	—	—	—
5	Deco	0.468 (40)	0.445 (38)	0.491 (42)	—	—	—
6q	Deco	1.381 (118)	1.334 (114)	1.182 (101)	—	—	—
7	Boeing	0.514 (44)	0.445 (38)	0.515 (44)	—	—	—
8	Nordam	0.936 (80)	0.866 (74)	0.889 (76)	0.913 (78)	0.889 (76)	0.936 (80)
9	Air Logistics	0.445 (38)	0.445 (38)	0.445 (38)	0.491 (42)	0.421 (36)	0.421 (36)
10	Ciba Geigy	0.819 (70)	0.796 (68)	0.842 (72)	—	—	—
11	Ciba Geigy	0.749 (64)	0.866 (74)	0.772 (66)	—	—	—
12	Boeing	0.234 (20)	0.234 (20)	0.234 (20)	—	—	—
13	Boeing	1.193 (102)	0.959 (82)	1.006 (86)	—	—	—
14	Boeing	0.772 (66)	0.749 (64)	0.772 (66)	0.725 (62)	0.796 (68)	0.749 (64)

Table 5.—FAR 25-32 Flame Test Data

Panel	Fabricator	12 Sec vertical		60 Sec vertical		30 sec, 45 degree	
		Burn time sec	Burn length cm (in)	Burn time sec	Burn length cm (in)	Burn time sec	Flame penetration
1	Boeing	0.0	0.25 (0.1)	0.0	1.27 (0.5)	–	–
2	Boeing	0.0	0.25 (0.1)	0.0	1.27 (0.5)	–	–
3	General Veneer	0.0	3.81 (1.5)	0.0	6.35 (2.5)	–	–
4	Deco	0.0	0.25 (0.1)	13.4	3.05 (1.2)	–	–
5	Deco	1.2	0.25 (0.1)	10.4	2.29 (0.9)	–	–
6	Deco	0.0	1.27 (0.5)	0.0	0.25 (0.1)	–	–
7	Boeing	0.0	0.25 (0.1)	0.0	1.52 (0.6)	–	–
8	Nordam	8.1	1.27 (0.5)	12.6	4.83 (1.9)	1.9	None
9	Air Logistics	0.0	1.02 (0.4)	0.0	4.06 (1.6)	0.0	None
10	Ciba Geigy	0.0	2.29 (0.9)	1.9	5.33 (2.1)	–	–
11	Ciba Geigy	0.0	4.32 (1.7)	0.0	5.33 (2.1)	–	–
12	Boeing	0.0	3.81 (1.5)	0.0	6.35 (2.5)	–	–
13	Boeing	0.0	0.25 (0.1)	0.0	3.36 (1.4)	–	–
14	Boeing	0.0	0.762 (0.3)	3.3	2.29 (0.9)	0.0	None

Table 6.—Burn-Through Test Data

Panel	Fabricator	Back Face Temperature @ 10 min °C (°F)					
		Specimen no. 1	Specimen no. 2	Specimen no. 3	Specimen no. 4	Specimen no. 5	Specimen no. 6
1	Boeing	393 (740)	349 (660)	376 (709)	—	—	—
2	Boeing	338 (640)	367 (692)	351 (663)	—	—	—
3	General Veneer	439 (822)	436 (817)	430 (806)	—	—	—
4	Deco	278 (533)	317 (602)	298 (569)	—	—	—
5	Deco	381 (717)	392 (737)	372 (703)	—	—	—
6	Deco	383 (722)	371 (700)	382 (720)	—	—	—
7	Boeing	231 (447)	239 (462)	232 (450)	—	—	—
8	Nordam	328 (623)	322 (612)	324 (616)	311 (592)	317 (603)	313 (595)
9	Air Logistics	416 (781)	410 (770)	407 (765)	408 (767)	423 (793)	418 (785)
10	Ciba Geigy	365 (689)	378 (713)	383 (722)	—	—	—
11	Ciba Geigy	418 (784)	399 (750)	397 (746)	—	—	—
12	Boeing	434 (814)	431 (807)	432 (809)	—	—	—
13	Boeing	328 (622)	331 (627)	355 (671)	—	—	—
14	Boeing	311 (592)	309 (588)	302 (575)	284 (544)	307 (584)	303 (578)

Table 7.—Smoke and Toxic Gas Generation Test Data

Panel	Fabricator	Toxicity ppm @ 4.0 min						Smoke emission D_S					
		HCN	HCl	HF	CO	SO_2	NO_X	Run no. 1		Run no. 2		Run no. 3	
								@ 4 min	max	@ 4 min	max	@ 4 min	max
1	Boeing	—	—	—	—	—	—	—	—	—	—	—	—
2	Boeing	2	None	None	150	None	8	3	14	4	13	8	19
3	General Veneer	1	None	None	110	None	2	10	32	18	36	12	27
4	Deco	2	None	None	146	None	12	20	31	11	26	1	15
5	Deco	2	None	None	86	None	5	1	7	1	3	1	5
6	Deco	2	0	None	101	8	7	1	4	1	4	1	3
7	Boeing	Trace	None	None	60	None	3	5	14	13	22	6	14
8	Nordam	17 20	None None	None None	60 120	None None	Trace 25	1 27	2 43	1 28	3 30	1 12	3 45
9	Air Logistics	Trace Trace	None None	None None	50 80	None None	6 7	1 3	2 16	1 2	2 7	1 3	2 7
10	Ciba Geigy	Trace	None	None	100	20	5	1	5	1	5	1	4
11	Ciba Geigy	Trace	None	None	130	None	4	10	16	19	34	17	32
12	Boeing	Trace	None	None	80	None	7	2	7	3	7	3	6
13	Boeing	5	Trace	None	None	60	None	27	56	38	56	40	65
14	Boeing	Trace Trace	None None	None None	60 112	None None	4 6	8 18	16 36	23 13	42 29	3 27	12 41

Table 8.—Limiting Oxygen Index Test Data

Panel	Fabricator	Screening tests %			Verification tests %		
		Face sheet	Face sheet & adhesive	Core	Face sheet	Face sheet & adhesive	Core
1	Boeing	—	—	32	—	—	—
2	Boeing	100	58	32	—	—	—
3	General Veneer	100	—	32	—	—	—
4	Deco	100	—	32	—	—	—
5	Deco	100	—	32	—	—	—
6	Deco	100	—	32	—	—	—
7	Boeing	100	58	50	—	—	—
8	Nordam	81	36	50	100	35	50
9	Air Logistics	76	57	33	75	58	33
10	Ciba Geigy	57	44	33	—	—	—
11	Ciba Geigy	57	44	33	—	—	—
12	Boeing	48	44	33	—	—	—
13	Boeing	32	32	33	—	—	—
14	Boeing	100	58	45	100	58	40

Table 9.—Thermogravimetric Test Data

Panel	Fabricator	Screening tests °C				Verification tests °C			
		Start of wt loss	5% wt loss	10% wt loss	Wt loss ceased	Start of wt loss	5% wt loss	10% wt loss	Wt loss ceased
1	Boeing	–	–	–	–	–	–	–	–
2	Boeing	70	340	460	–	–	–	–	–
3	General Veneer	80	320	425	820	–	–	–	–
4	Deco	135	330	445	–	–	–	–	–
5	Deco	145	420	520	–	–	–	–	–
6	Deco	75	415	485	765	–	–	–	–
7	Boeing	155	410	505	680	–	–	–	–
8	Nordam	85	353	410	740	90	367	420	–
9	Air Logistics	50	410	473	675	45	390	502	–
10	Ciba Geigy	70	380	435	760	–	–	–	–
11	Ciba Geigy	–	–	–	–	–	–	–	–
12	Boeing	65	415	473	800	–	–	–	–
13	Boeing	50	380	425	750	–	–	–	–
14	Boeing	40	410	490	690	47	377	453	–

Table 10.—Rolling Drum Peel Test Data

Panel	Fabricator	Rolling drum peel Kg-cm/7.62 cm (lb-in/3 in.)				
		Specimen no. 1	Specimen no. 2	Specimen no. 3	Specimen no. 4	Specimen no. 5
8	Nordam	26.5 (23)	28.8 (25)	23.0 (20)	28.8 (25)	26.5 (23)
9	Air Logistics	11.5 (10)	11.5 (10)	11.5 (10)	8.1 (7)	8.1 (7)
14	Boeing	20.7 (18)	18.43 (16)	20.7 (18)	21.9 (19)	20.7 (18)

Table 11.—Flexure and Core Shear-Test Data

Panel	Fabricator	Long beam flexure Kg (lb)					Core shear Kg (lb)				
		Specimen no. 1	Specimen no. 2	Specimen no. 3	Specimen no. 4	Specimen no. 5	Specimen no. 1	Specimen no. 2	Specimen no. 3	Specimen no. 4	Specimen no. 5
1	Boeing	—	—	—	—	—	127 (280)	159 (350)	149 (329)	142 (313)	171 (378)
2	Boeing	203 (448)	193 (426)	191 (422)	192 (423)	177 (391)	290 (640)	333 (735)	317 (698)	324 (714)	342 (753)
3	General Veneer	143 (316)	154 (339)	147 (323)	175 (385)	168 (370)	316 (696)	311 (686)	324 (714)	317 (698)	338 (746)
4	Deco	1.17 (257)	123 (272)	129 (284)	144 (318)	158 (348)	177 (391)	188 (414)	185 (408)	175 (386)	175 (386)
5	Deco	162 (358)	137 (303)	142 (314)	153 (337)	159 (351)	147 (324)	161 (354)	121 (266)	126 (278)	151 (333)
6	Deco	67 (147)	70 (155)	86 (190)	64 (141)	87 (192)	147 (325)	270 (596)	223 (492)	155 (342)	295 (650)
7	Boeing	128 (282)	177 (390)	146 (321)	123 (271)	175 (386)	184 (406)	149 (328)	165 (364)	215 (474)	217 (478)
8	Nordam	161 (355)	173 (381)	108 (238)	108 (237)	136 (300)	376 (828)	377 (832)	350 (772)	350 (772)	360 (794)
9	Air Logistics	156 (343)	161 (356)	170 (374)	199 (438)	141 (310)	252 (556)	283 (624)	297 (654)	357 (788)	255 (563)
		174 (388	137 (302)	144 (317)	162 (358)	118 (260)	281 (620)	294 (648)	305 (672)	268 (590)	335 (738)
10	Ciba Geigy	81 (179)	86 (190)	88 (195)	97 (213)	98 (215)	309 (682)	336 (740)	259 (570)	249 (550)	288 (636)
11	Ciba Geigy	—	—	—	—	—	—	—	—	—	—
12	Boeing	—	—	—	—	—	—	—	—	—	—
13	Boeing	181 (400)	137 (303)	117 (258)	119 (263)	103 (226)	—	—	—	—	—
14	Boeing	155 (342)	128 (282)	176 (387)	165 (363)	177 (390)	357 (786)	360 (794)	402 (886)	378 (883)	371 (820)

Table 12.—Insert Pullout (Shear) Data

Panel	Fabricator	Insert pullout ultimate load Kg (lb)				
		Specimen no. 1	Specimen no. 2	Specimen no. 3	Specimen no. 4	Specimen no. 5
8	Nordam	528.4 (1165)	560.2 (1235)	530.7 (1170)	594.2 (1310)	573.4 (1264)
9	Air Logistics	326.6 (720)	347.4 (766)	393.7 (868)	309.4 (682)	274.0 (604)
14	Boeing	554.3 (1222)	560.6 (1236)	750.2 (1654)	656.8 (1448)	680.4 (1500)

Table 13.—Panel In-Plane Shear Test Data

Panel	Fabricator	In-plane shear ultimate load Kg (lb)		
		Specimen no. 1 closed frame	Specimen no. 2 closed frame	Specimen no. 3 open frame
14	Boeing	3690.5 (8136)	3433.8 (7570)	1188.4 (2620)

Table 14.—Environmental Exposure Test Data

Environmental tests		Panel no. and fabricator		
		No. 8 Nordam	No. 9 Air Logistics	No. 14 Boeing
Weight gain %				
Unsealed specimens no.	1	25	18	19
	2	18	10	15
	3	26	11	24
	4	19	16	24
	5	22	20	18
Sealed edge specimens no.	1	21	9	16
	2	23	12	20
	3	13	11	19
	4	24	16	13
	5	14	12	12
Peel Kg-cm/7.62 cm (lb-in/3 in.)				
Unsealed specimens no.	1	1.2 (1)	4.6 (4)	11.5 (10)
	2	1.2 (1)	4.6 (4)	13.8 (12)
	3	1.2 (1)	5.8 (5)	11.5 (10)
	4	1.2 (1)	5.8 (5)	12.7 (11)
	5	1.2 (1)	5.8 (5)	13.8 (12)
Sealed edge specimens no.	1	17.3 (15)	5.8 (5)	13.8 (12)
	2	17.3 (15)	5.8 (5)	13.8 (12)
	3	17.3 (15)	5.8 (5)	15.0 (13)
	4	19.6 (17)	5.8 (5)	15.0 (13)
	5	18.4 (16)	5.8 (5)	13.8 (12)
Long beam flexure Kg (lb)				
Unsealed specimens no.	1	28.1 (62)	121.6 (268)	121.6 (268)
	2	22.2 (49)	141.5 (312)	117.9 (260)
	3	25.4 (56)	131.5 (290)	107.0 (236)
	4	34.0 (75)	133.4 (294)	120.6 (266)
	5	29.5 (65)	115.2 (254)	105.7 (233)
Sealed edge specimens no.	1	94.3 (208)	—	122.5 (270)
	2	112.9 (249)	—	111.1 (245)
	3	96.6 (213)	—	126.1 (278)
	4	101.1 (223)	—	131.5 (290)
	5	98.0 (216)	—	106.1 (234)

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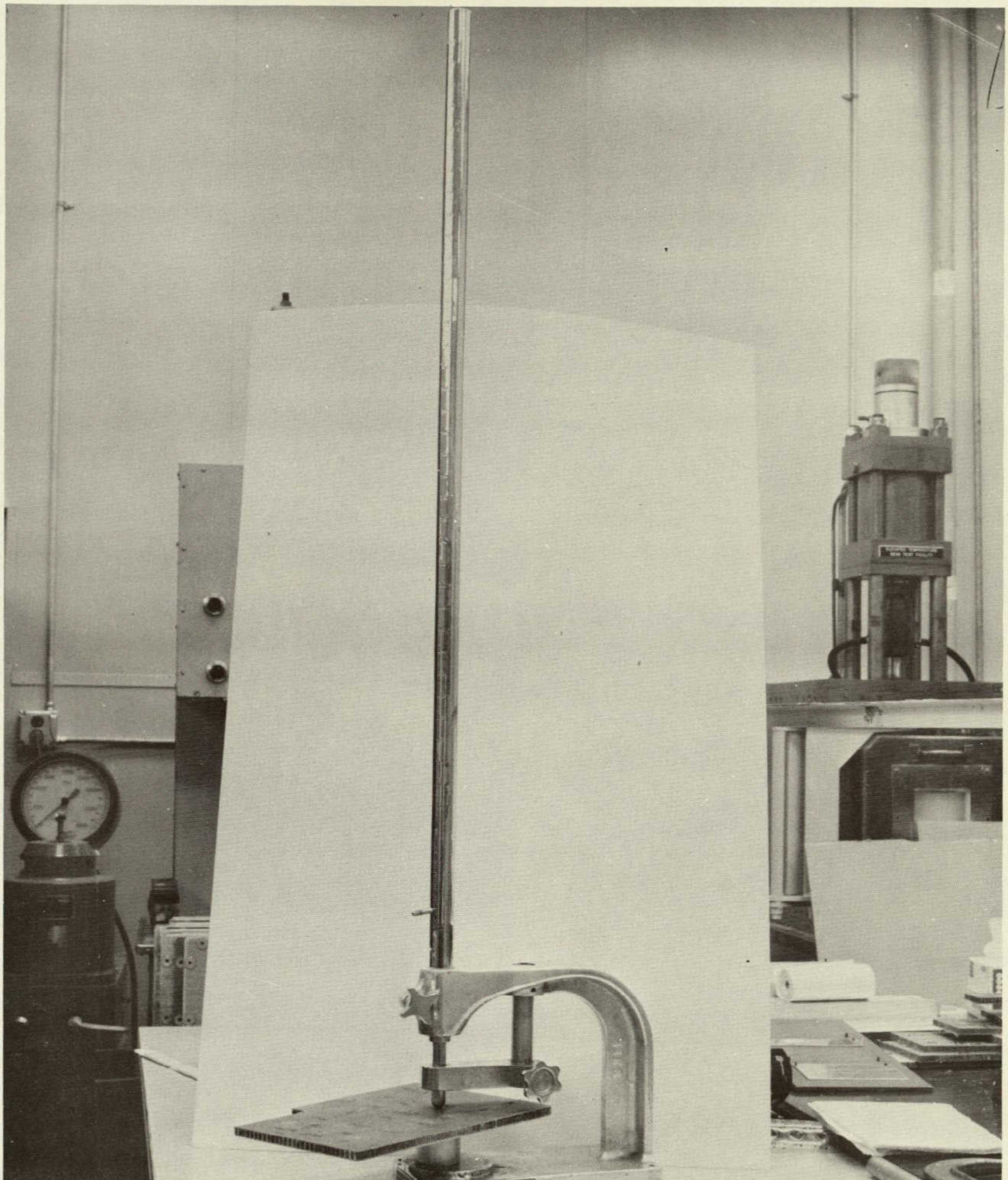
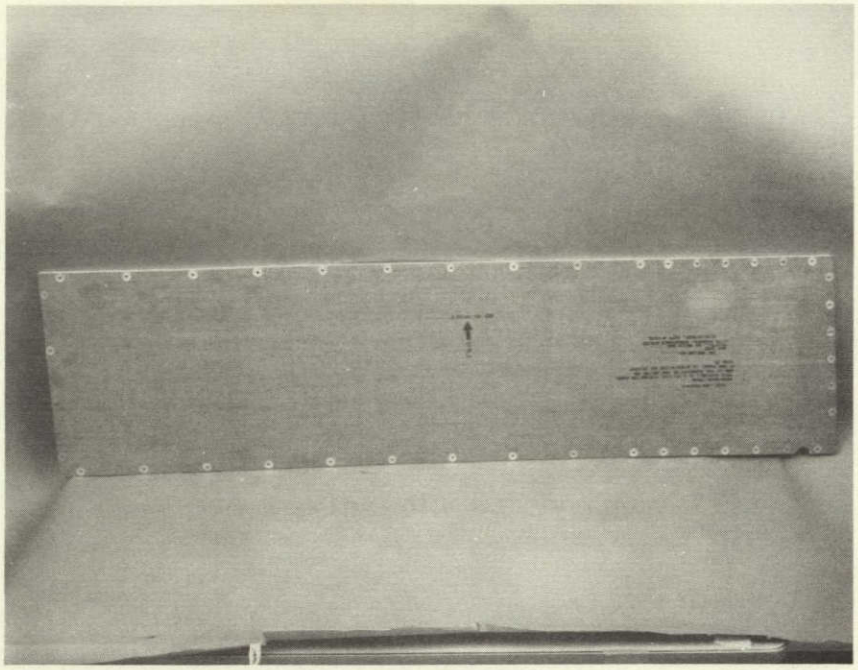
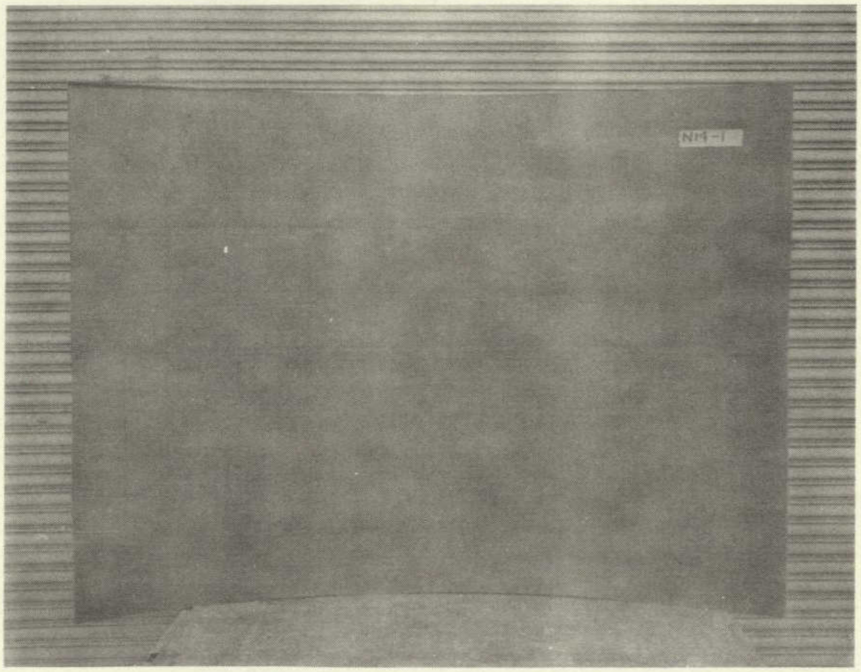


Figure 1.—Gardener Impact Test Fixture



747 Service Evaluation Panel



One of the Two Curved Panels

Figure 2.—Fabricated End Items

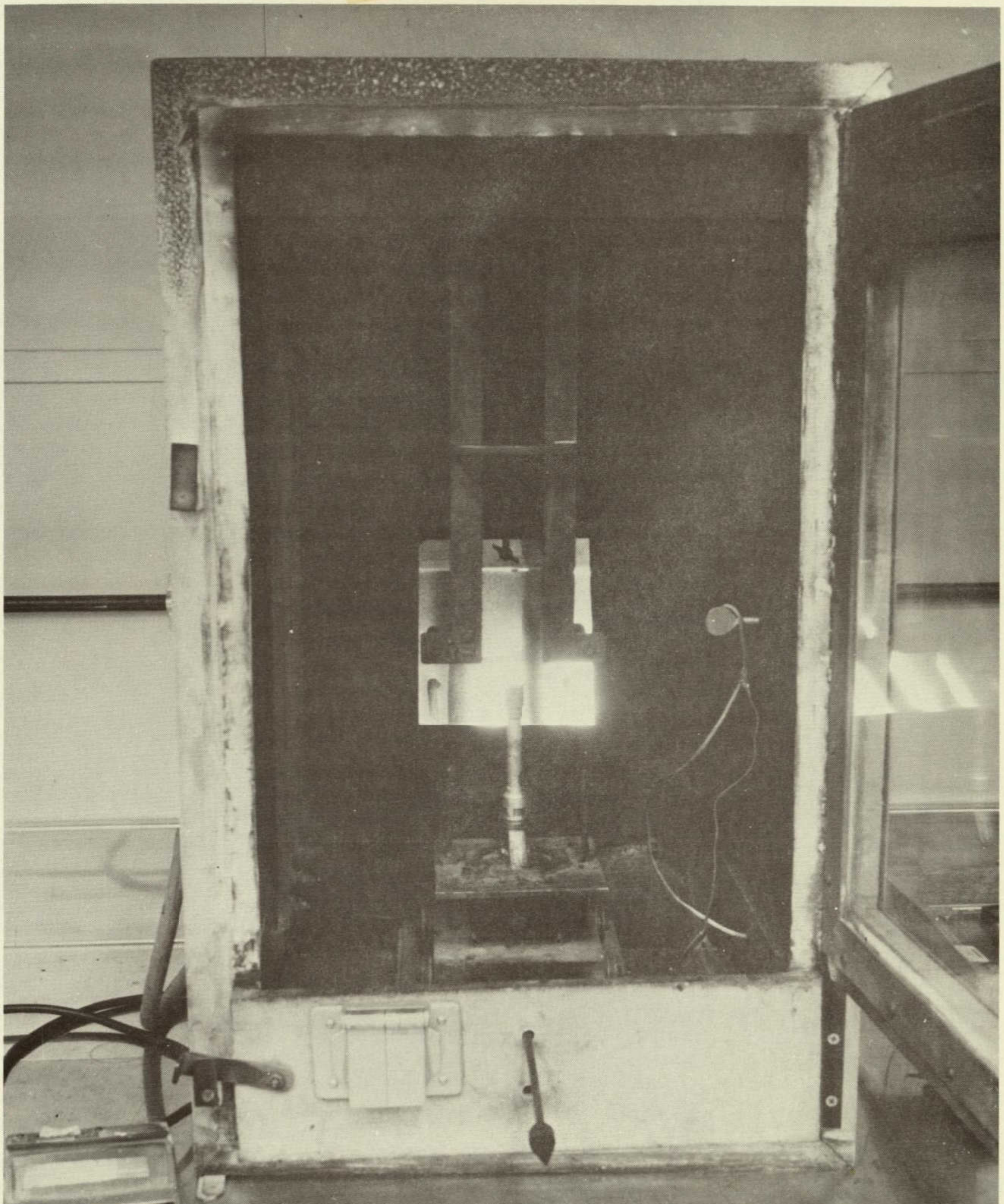


Figure 3.—Vertical Burn Test Chamber, FAR 25-32 Type

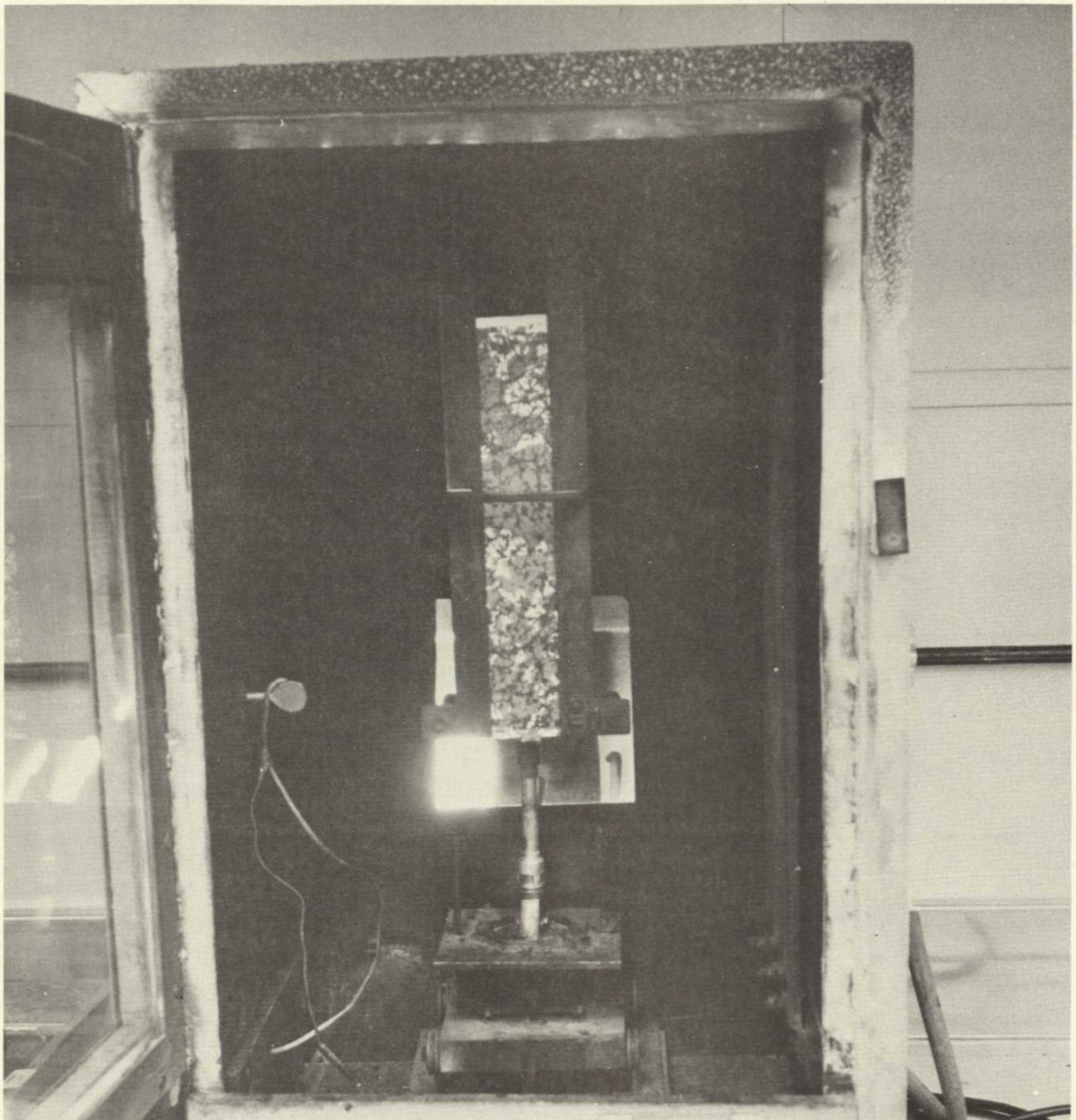


Figure 4.—Vertical Burn Test Chamber Showing Specimen and Burner Flame Positioning

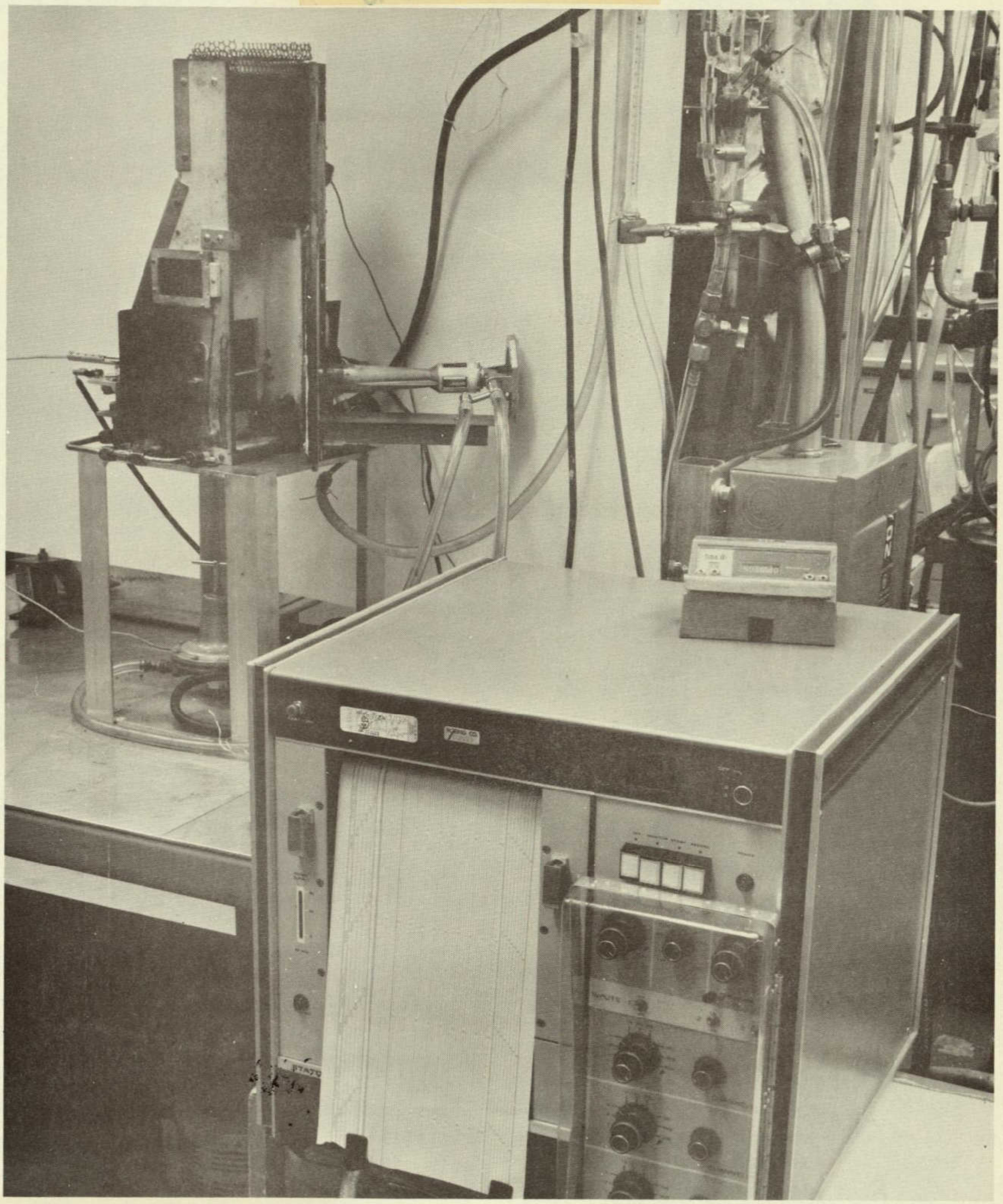


Figure 5.—Burn-Through Test Apparatus

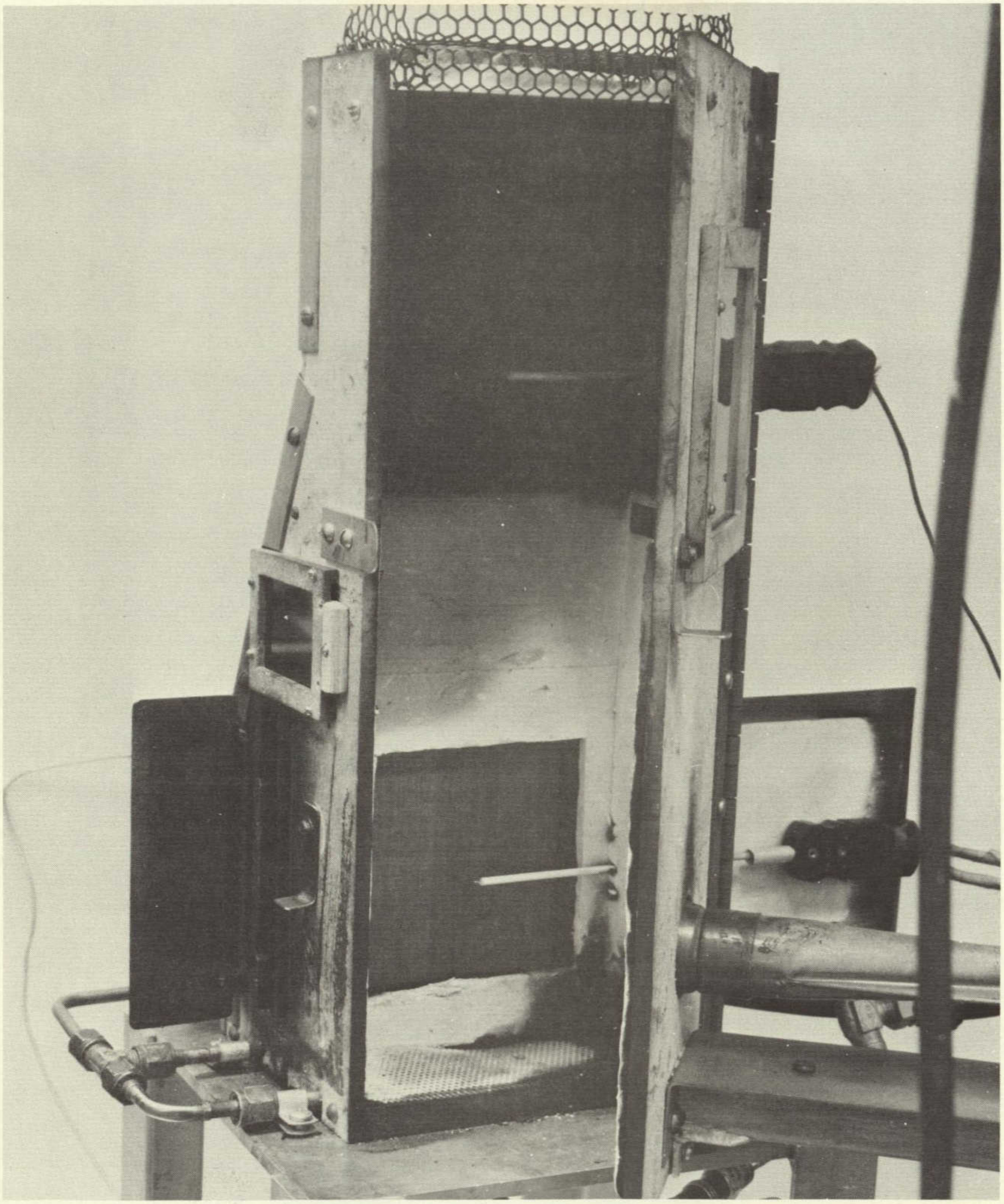


Figure 6.—Burn-Through Test Chamber Showing Specimen Test Window

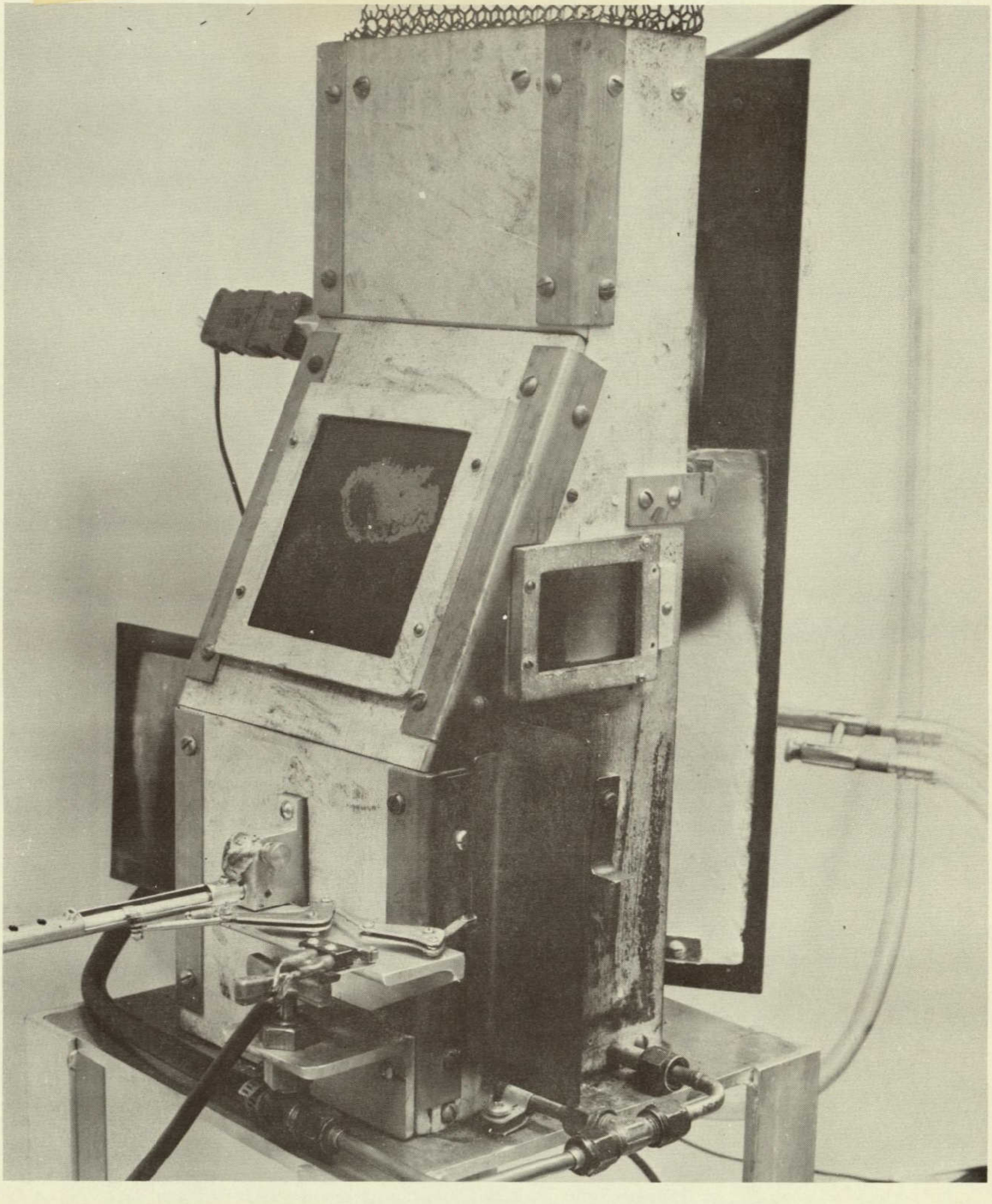


Figure 7.—Burn-Through Test Apparatus Showing Operation of Backface Thermocouple Levers

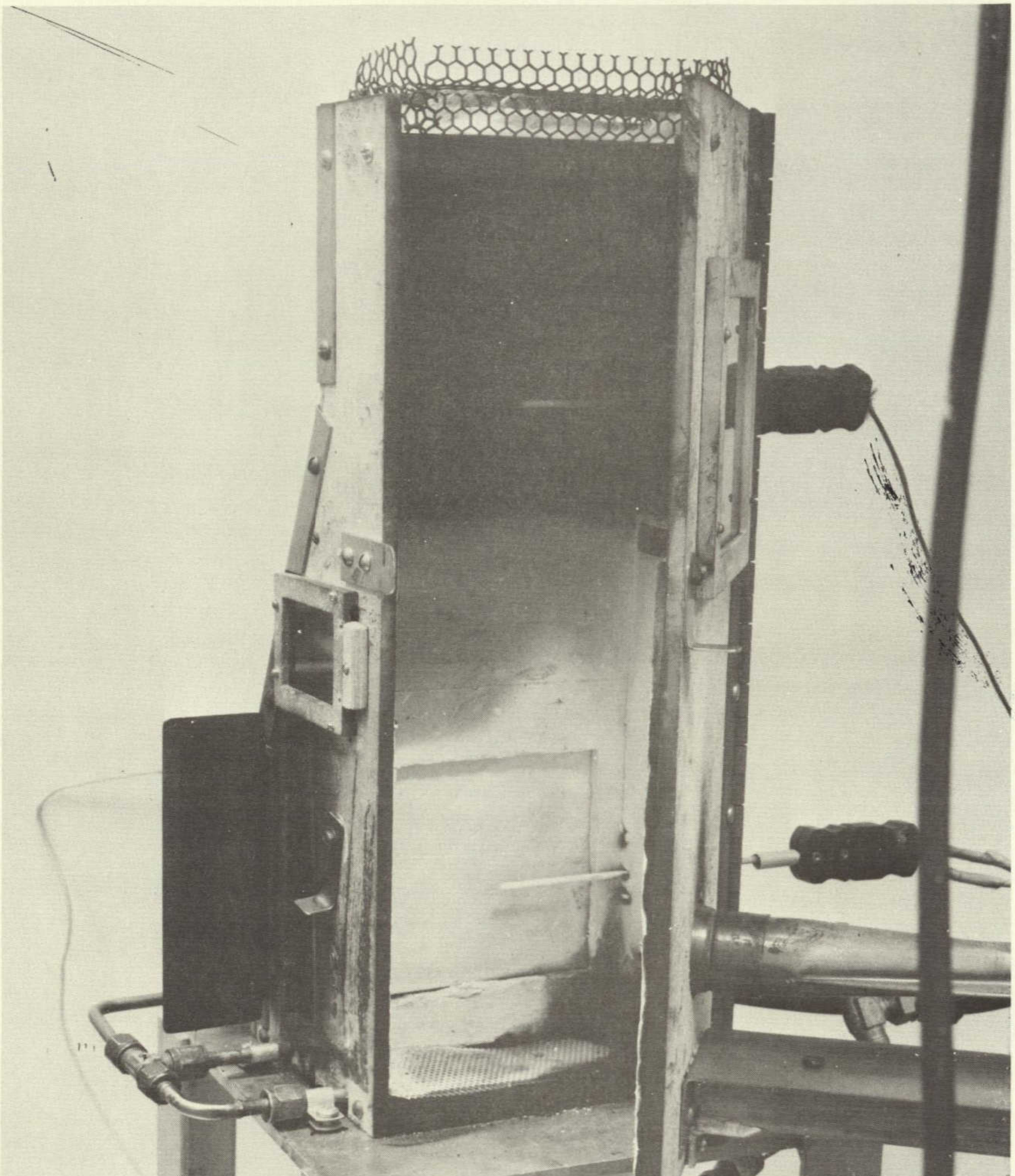


Figure 8.—Burn-Through Test Apparatus Showing Baffle Positioned in Test Window Preparatory to Starting the Burner

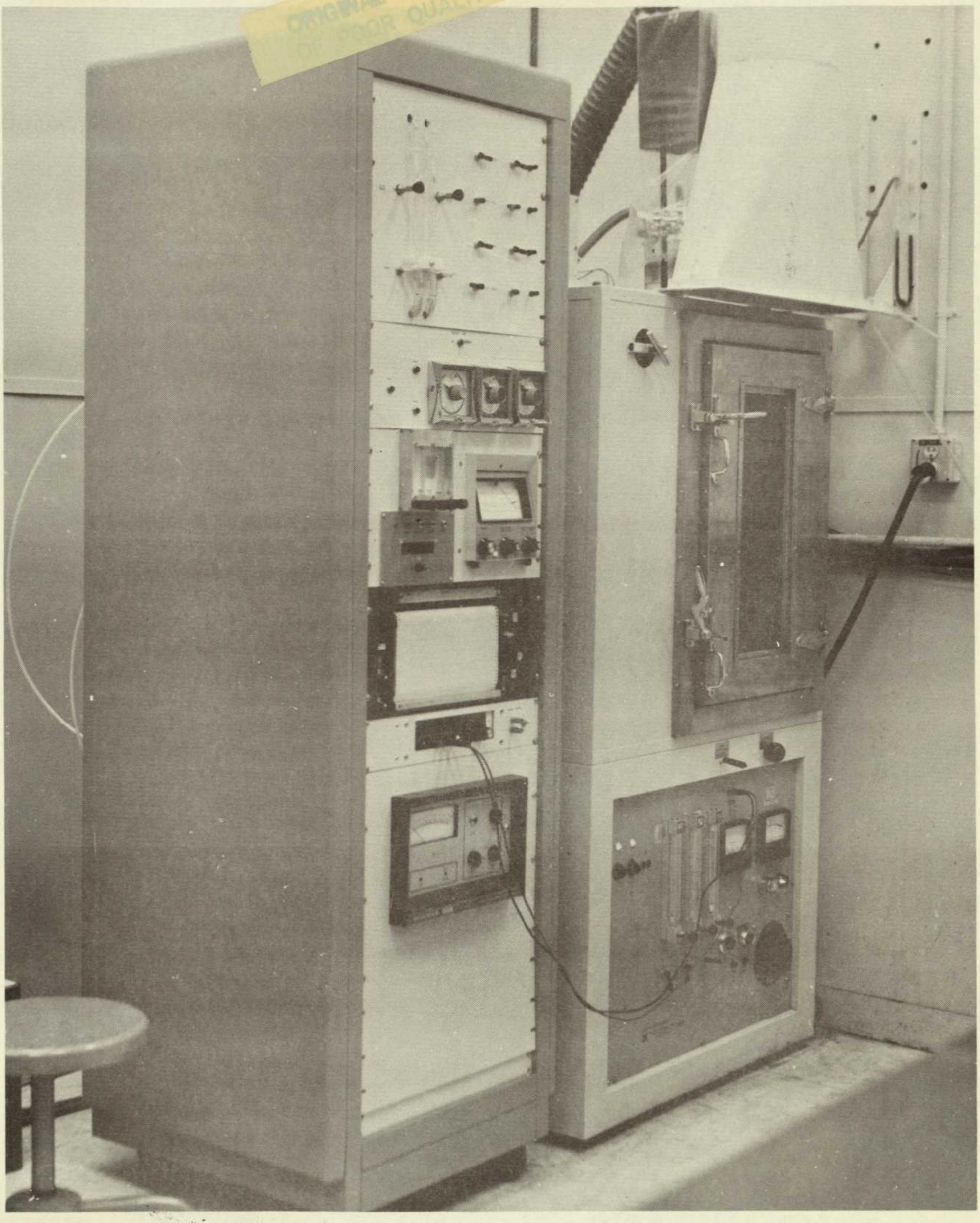


Figure 9.—AMINCO-NBS Smoke Test Chamber

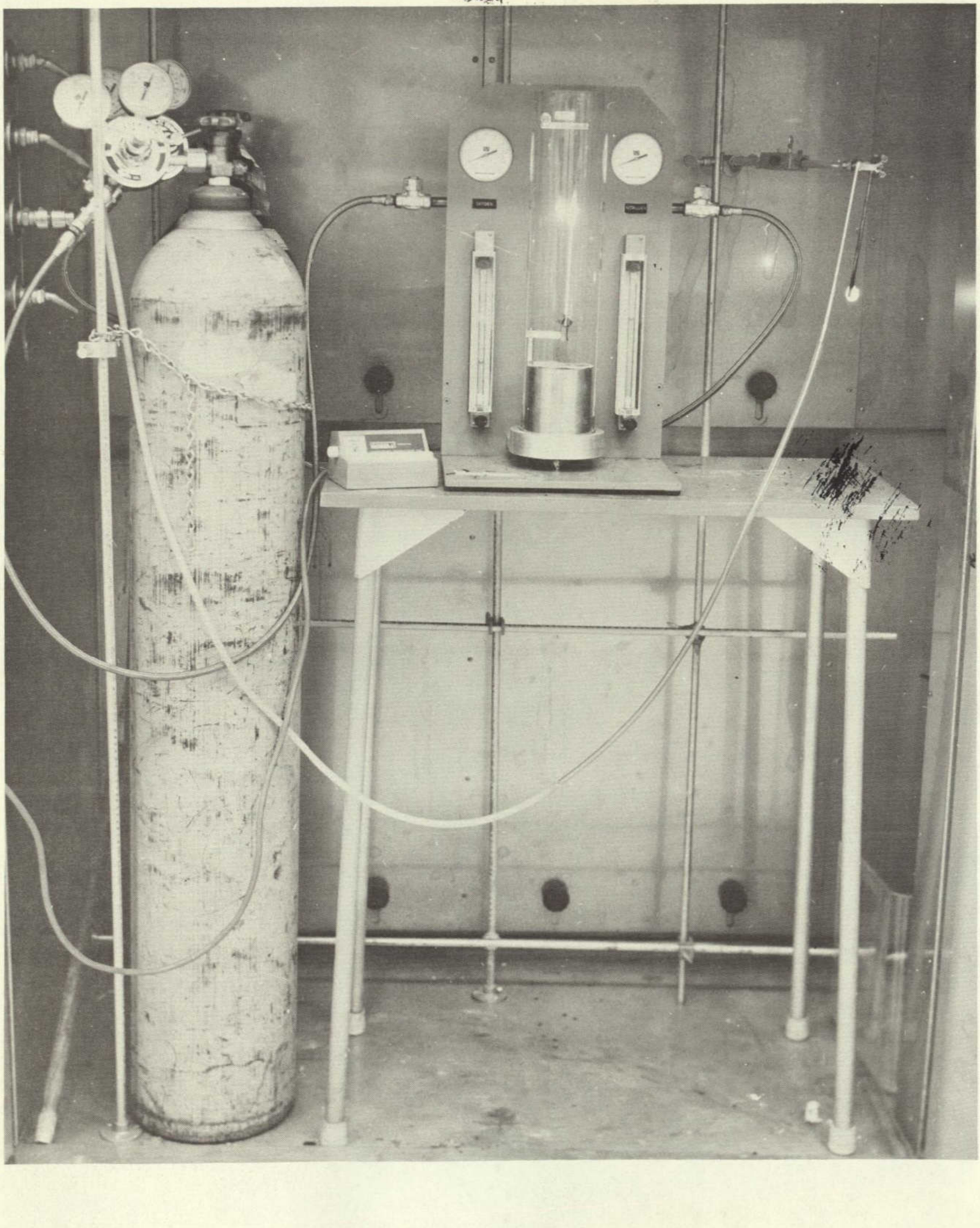


Figure 10.—ONI Limiting Oxygen Index Tester

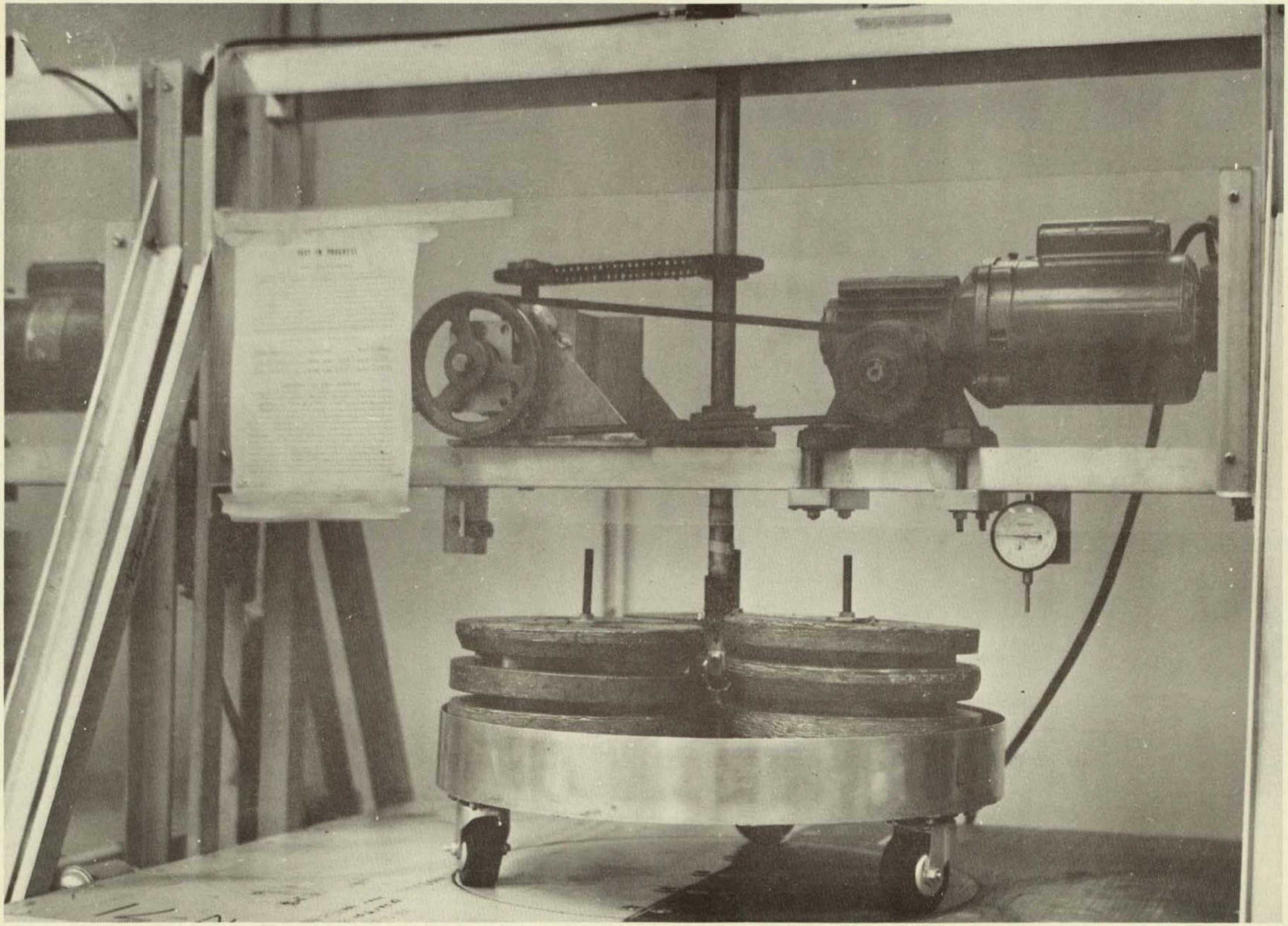


Figure 11.—Fatigue Tester (Food Cart Roller Test)

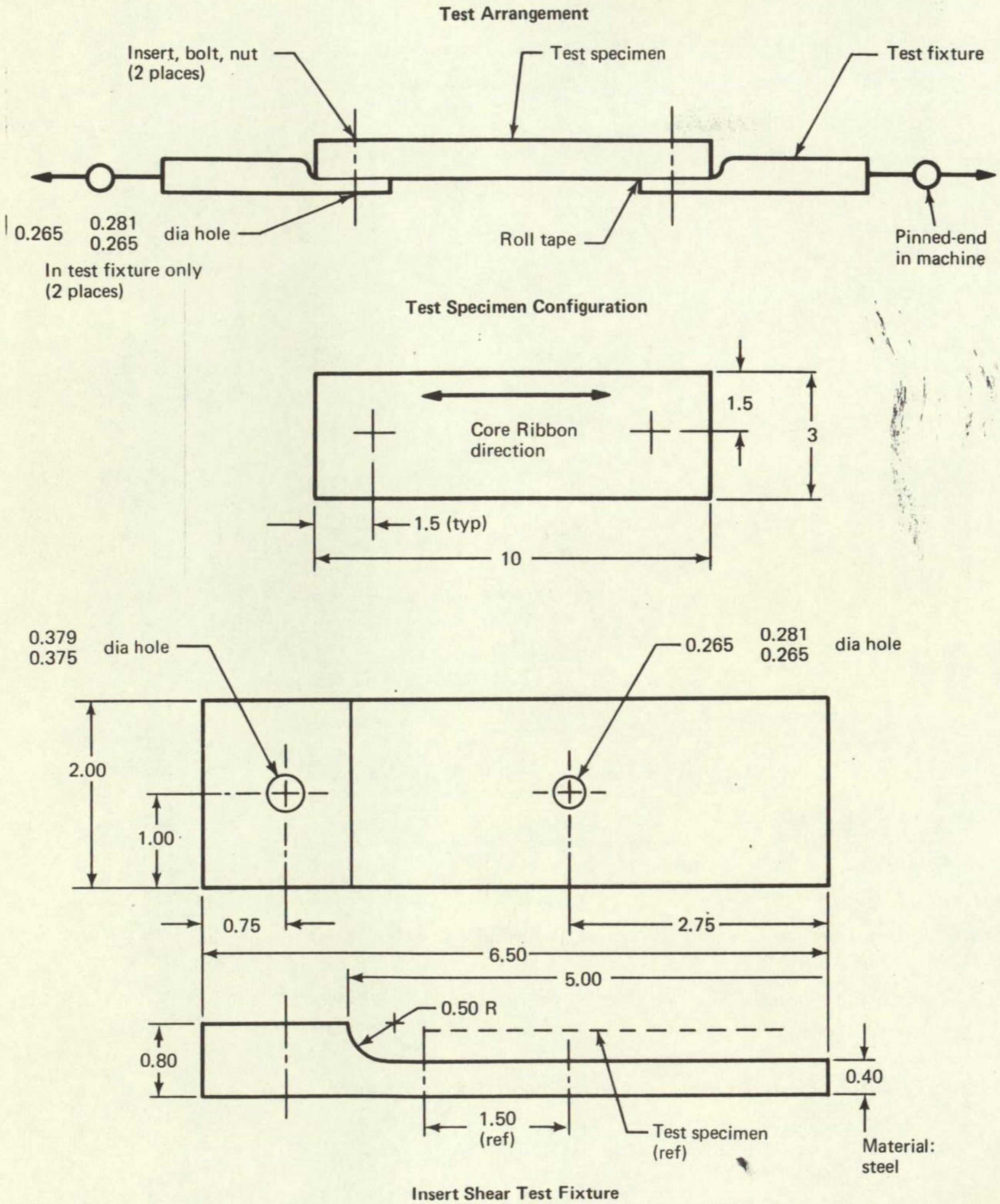
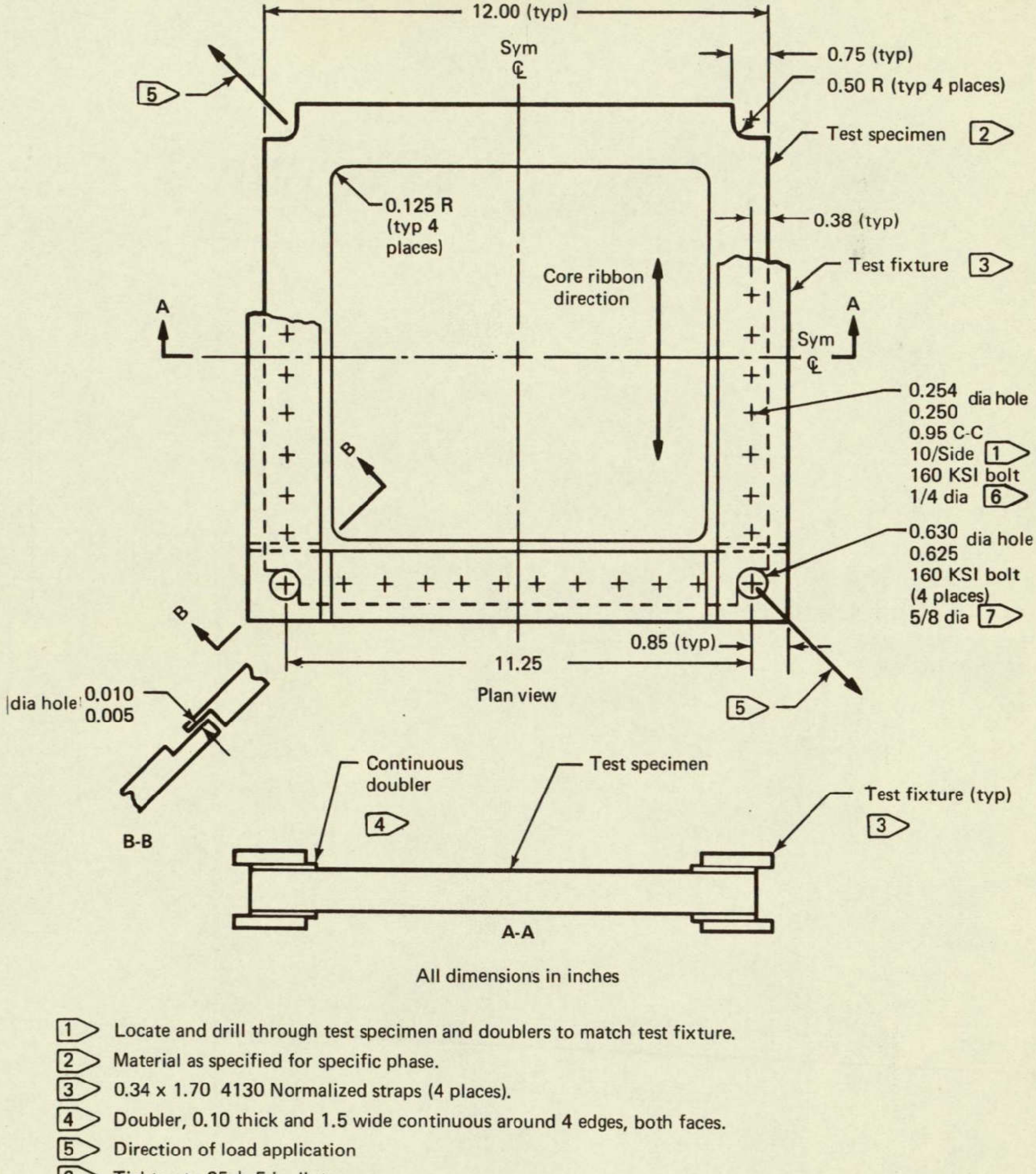


Figure 12.—Boeing Insert Shear Test Fixture



All dimensions in inches

1. Locate and drill through test specimen and doublers to match test fixture.
2. Material as specified for specific phase.
3. 0.34 x 1.70 4130 Normalized straps (4 places).
4. Doubler, 0.10 thick and 1.5 wide continuous around 4 edges, both faces.
5. Direction of load application
6. Tighten to 35 ± 5 in.-lb torque.
7. Finger tighten only.

NOTE: All tolerances ± 0.030 inch except as shown.

In-Plane Panel Shear Test Specimen and Test Fixture Arrangement

Figure 13.—Boeing "Picture Frame" Test Fixture

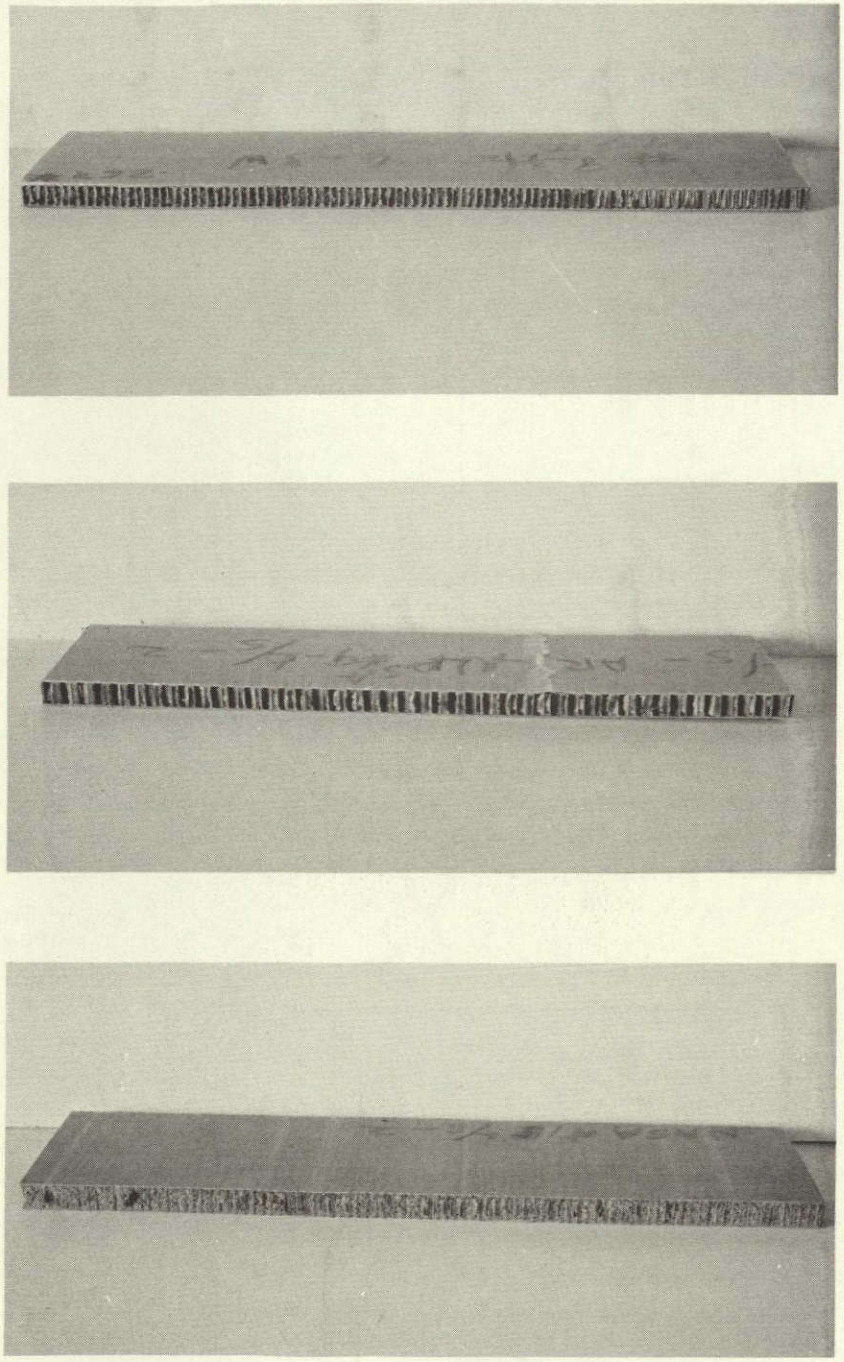
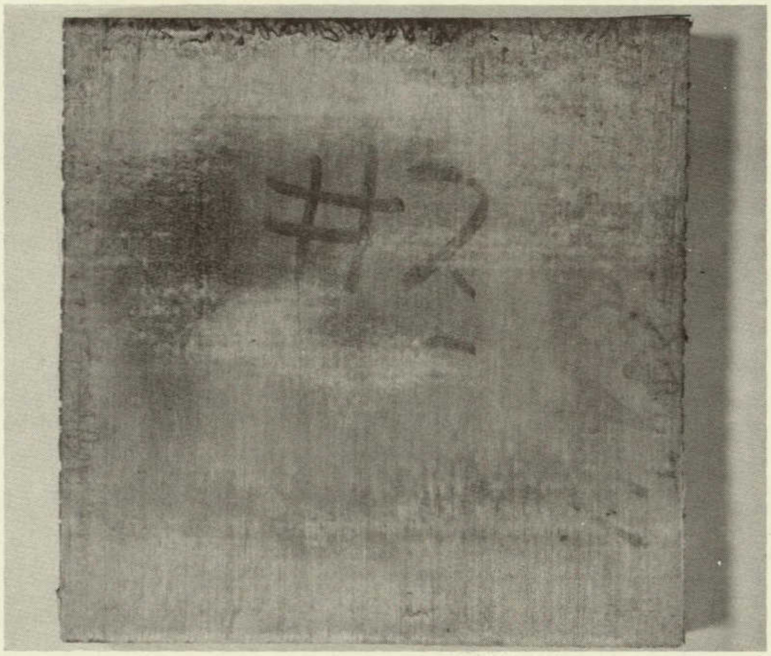
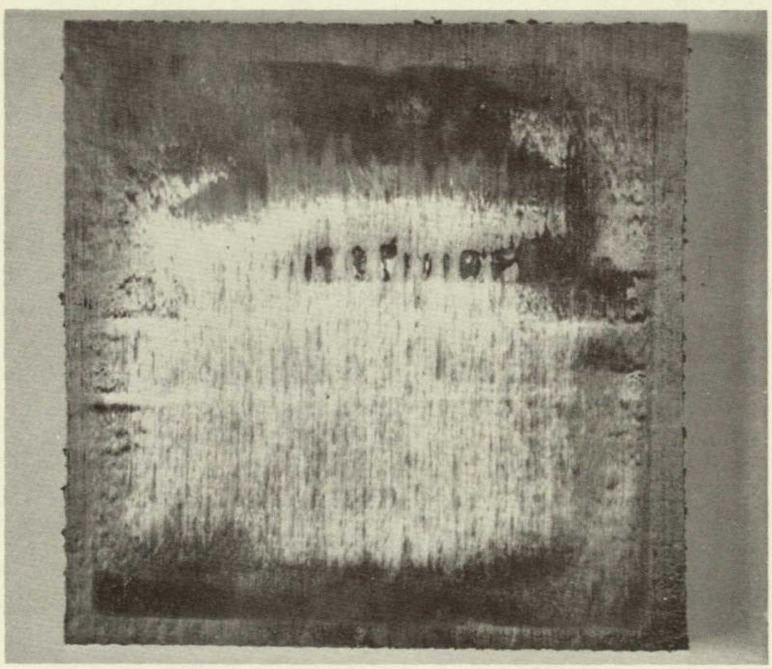


Figure 14.—Verification Phase Panels

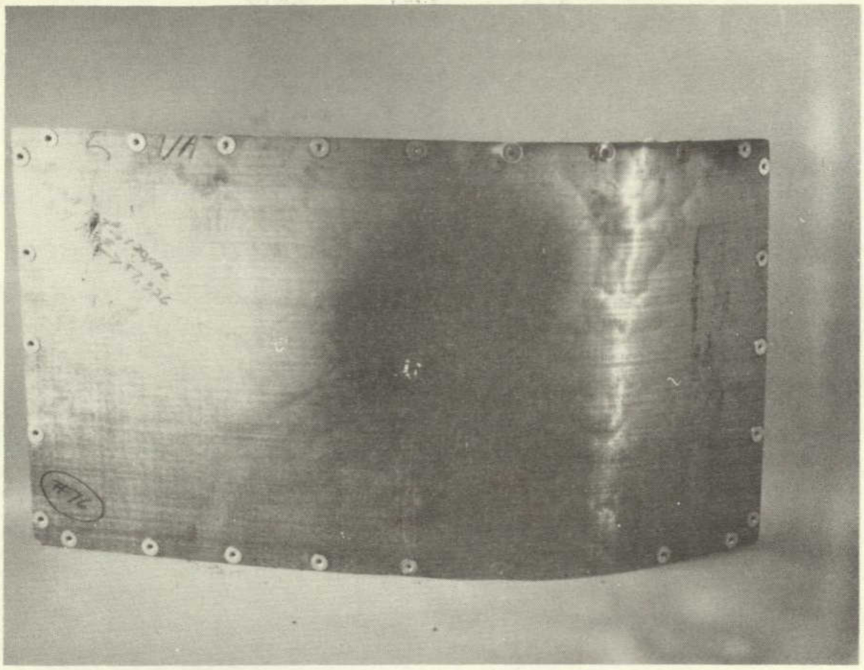


Unexposed Face

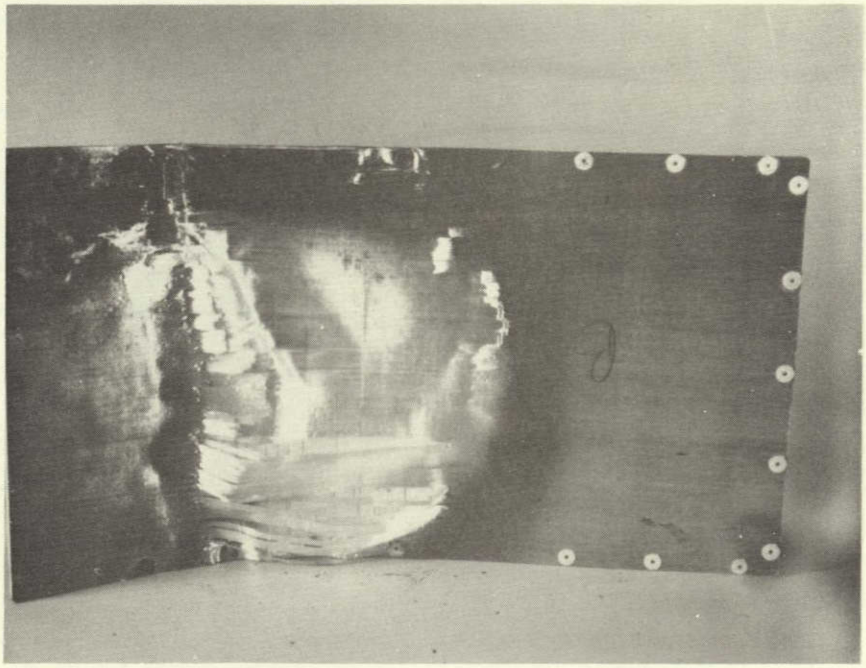


Exposed Face

Figure 15.—Panel Number 14 Burn-Through Specimen



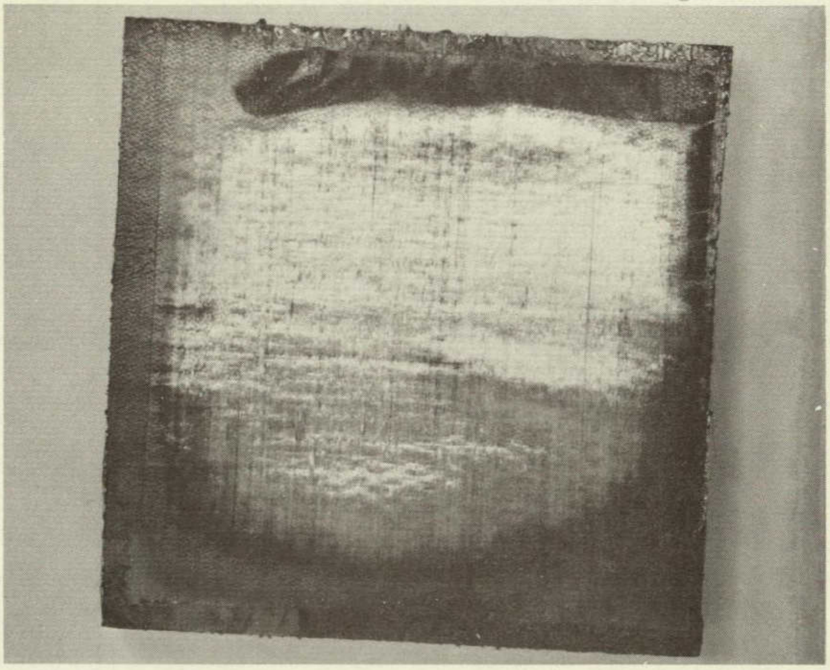
Unexposed Face



Exposed Face

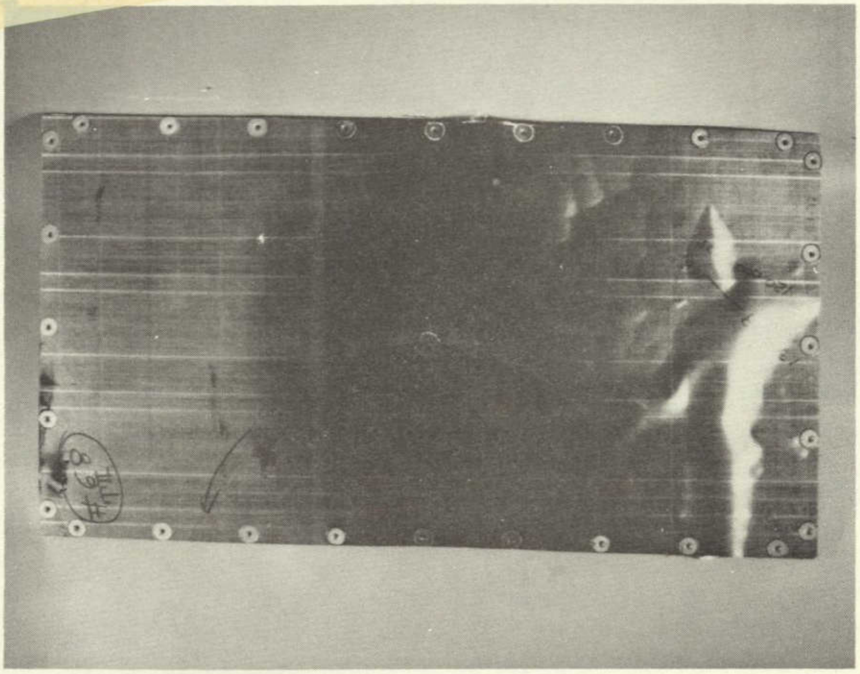
Figure 16.—Panel Number 14 Oil Burner Specimen

Unexpected Face

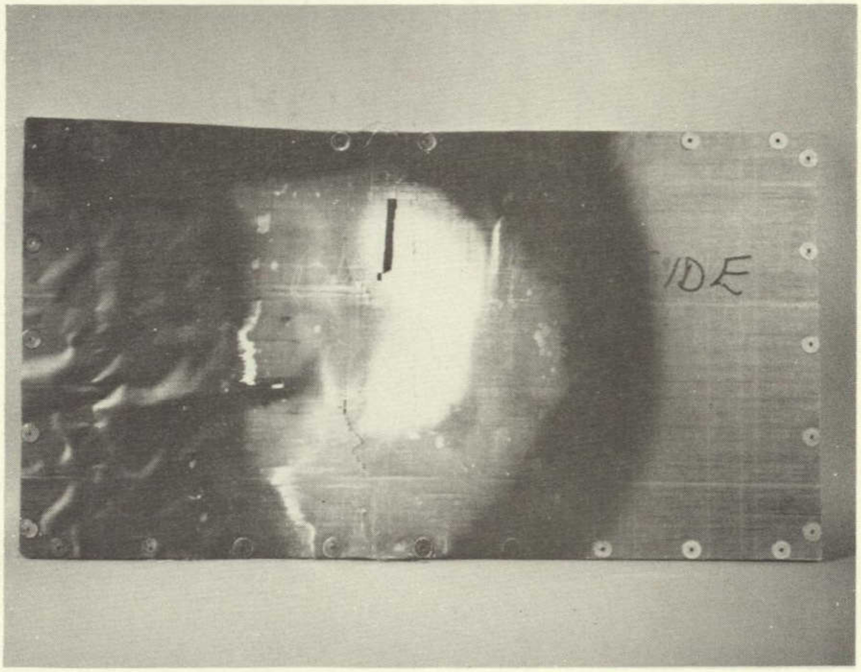


Exposed Face

Figure 17.—Panel Number 8 Burn-Through Specimen

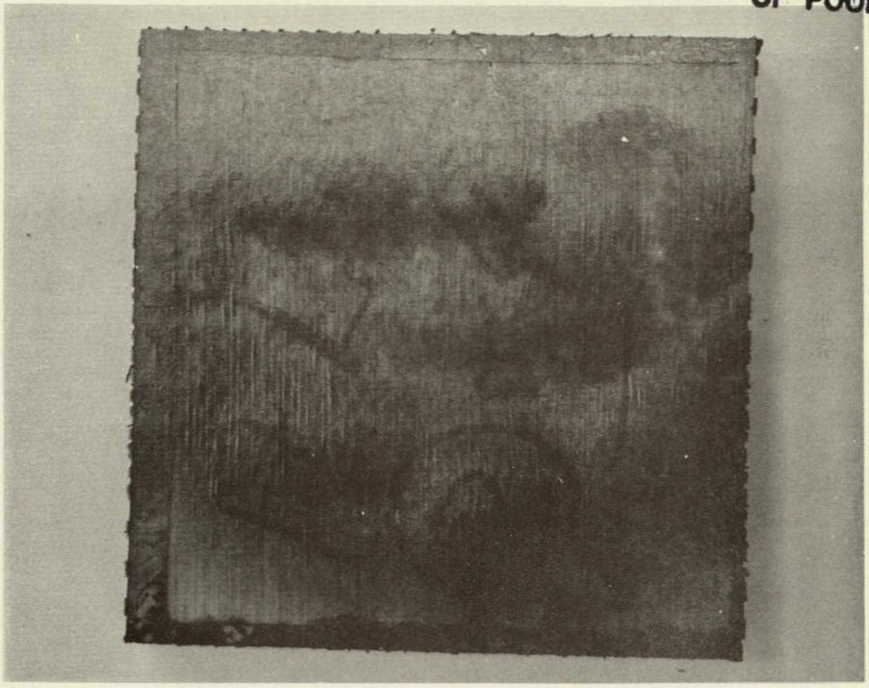


Unexposed Face

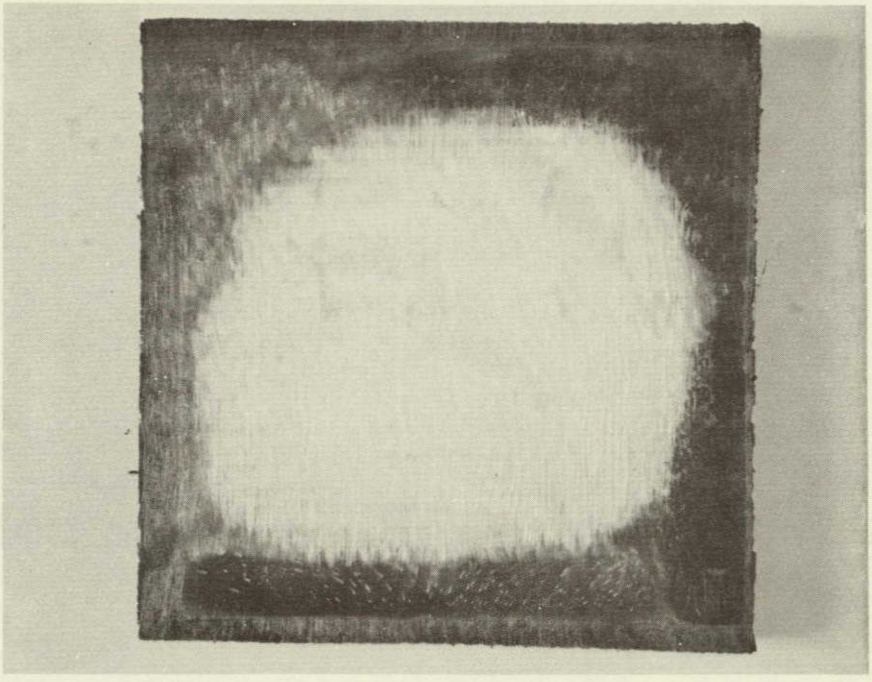


Exposed Face

Figure 18.—Panel Number 8 Oil Burner Specimen

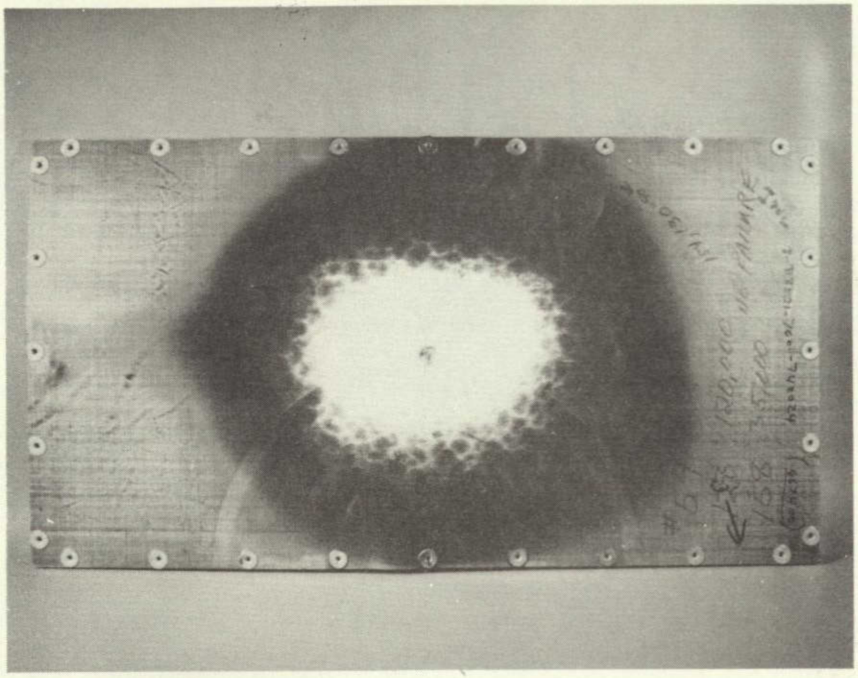


Unexposed Face

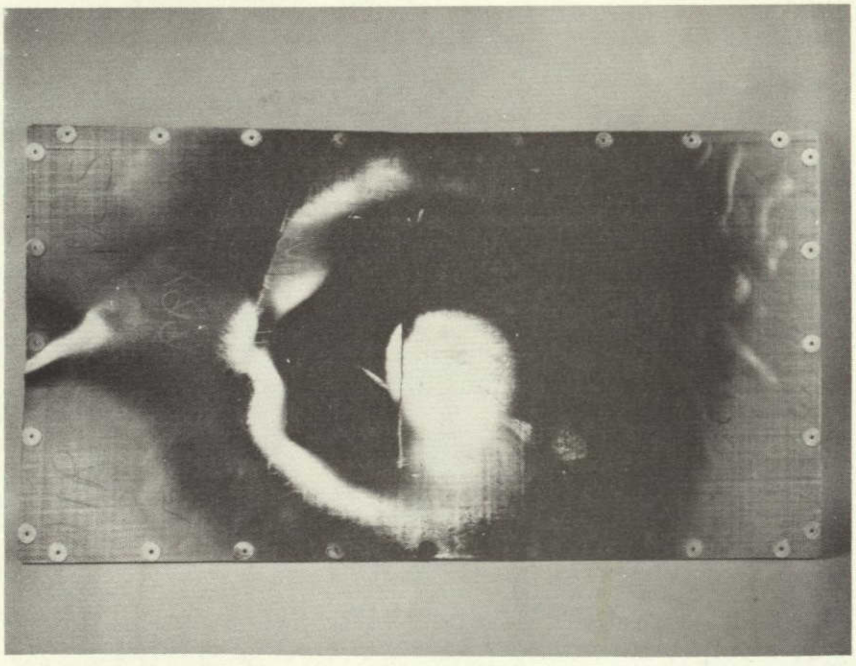


Exposed Face

Figure 19.—Panel Number 9 Burn-Through Specimen



Unexposed Face



Exposed Face

Figure 20.—Panel Number 9 Oil Burner Specimen