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APOLLO COMMAND MODULE MOCKUP FLAMMABILITY TESTS

by Richard W. Bricker, Gary R. Primeaux, James P. Crabb, and Calvin Schomburg

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Houston, Texas

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Flammability tests were conducted in an interior mockup of the Apollo command module in three different atmospheres (100 percent oxygen at 6.2 psia, 60 percent oxygen/40 percent nitrogen at 16.2 psia, and 100 percent oxygen at 16.2 psia). The command module, with minor changes in materials and configuration, was determined to be firesafe in the 6.2-psia atmosphere or in the oxygen/nitrogen atmosphere.

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APOLLO COMMAND MODULE MOCKUP FLAMMABILITY TESTS

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SUMMARY

An interior mockup of a command module was used to conduct a series of 102 flammability tests. Thirty-seven tests were conducted in a 6.2-psia 100-percent-oxygen atmosphere to duplicate the flight atmosphere. Thirty-five tests were conducted in a 16.2-psia 60-percent-oxygen/40-percent-nitrogen atmosphere, and 30 tests were conducted in a 16.2-psia 100-percent-oxygen atmosphere. The latter two series of tests represented optional launch atmospheres. Fires were deliberately started in the command module mockup at locations selected as representative of potential ignition hazards. For each test, data were recorded to determine possible propagation paths and to identify any potentially toxic products which might evolve.

It was determined that, with minor changes in materials or configuration, the command module is firesafe in the 6.2-psia 100-percent-oxygen flight atmosphere and in the 16.2-psia 60-percent-oxygen/40-percent-nitrogen launch atmosphere. Although much progress has been made in reducing the flammability hazard in a 16.2-psia 100-percent-oxygen atmosphere, the results of these tests indicate that significant design changes are necessary to eliminate all hazardous areas. Consequently, a launch atmosphere of 16.2 psia 60 percent oxygen/40 percent nitrogen and an orbital atmosphere of 6.2 psia 100 percent oxygen were selected for the Apollo missions.

INTRODUCTION

The selection of an ideal space-cabin atmosphere requires a thorough analysis of physiological, physical, and engineering factors. Since the beginning of the United States manned space program, the cabin atmosphere of a spacecraft has been 100 percent oxygen at 16.5 psia on the launch pad and 100 percent oxygen at 6.2 psia while in the vacuum of space. There were sound reasons for the selection of these pressures and atmospheres. A one-gas system both in the suit loop and in the cabin was selected for manned flight because of its simplicity, light weight, and physiological desirability. A pressure of 16.5 psia while on the launch pad was selected to help seal the cabin hatch and to assure that any leakage would be outward rather than inward. A pressure of 6.2 psia was chosen for the spacecraft while in the vacuum of space for several reasons: (1) the spacecraft structure would be lighter because of the small pressure differential; (2) for lower pressures, less oxygen would have to be stored on board the

spacecraft; and (3) at a pressure of 6.2 psia, sufficient oxygen would be available to sustain human life with no adverse physiological effects.

A need for reevaluation of this system arose from the catastrophic fire in the Apollo command module (CM) 012 at John F. Kennedy Space Center in January 1967. This disaster clearly demonstrated the need for greatly increased resistance to fire in the CM. In the months that followed the accident, thousands of material flammability tests and hundreds of component and subsystem tests were conducted to determine the degree of fire hazard associated with individual components and, through subsequent testing of modified components, to evaluate the efficacy of the changes that had been made to reduce the potential hazards found in these tests. This work culminated in full-scale CM mockup flammability tests designed to verify the acceptability, from the standpoint of firesafety, of the redesigned CM interior with a pure and oxygen-enriched atmosphere. A Flammability Test Review Board was created by the Director of the Manned Spacecraft Center (MSC) to review flammability test programs and to establish if the lunar module (LM) and the CM were acceptable from a flammability standpoint for manned testing and flight.

Early in the redesign program, it was recognized that complete elimination of ignition sources from the CM was not possible; hence, the approach adopted for design and testing had to consist of eliminating as much combustible material as possible consistent with operation requirements; protecting remaining combustibles against fires; and arranging combustibles so that any accidental fire would be self-limiting and of limited magnitude in the test, launch, and flight atmospheres.

From a physiological standpoint, 100 percent oxygen is the optimum atmosphere for short-duration flights; however, from a flammability standpoint, 100 percent inert gas is the optimum atmosphere. For obvious reasons, neither a 100-percent-oxygen nor a 100-percent-inert-gas atmosphere is satisfactory as a spacecraft atmosphere during the period of launch. After careful and extensive evaluation, it was determined that a 60-percent-oxygen/40-percent-nitrogen mixture would satisfy both physiological and flammability requirements for the cabin atmosphere during the launch phase. To avoid redesigning the suit-loop system, the suit loop would contain 16.5 psia 100 percent oxygen while on the launch pad, and the pressure would be reduced to 6.2 psia in space after the cabin pressure had dropped and the cabin atmosphere had phased into a 100-percent-oxygen condition.

The investigation reported here consisted of three series of full-scale-mockup flammability tests. The atmospheres associated with these series were as follows:

1. Series 100 — 100 percent oxygen at 6.2 psia
2. Series 200 — 60 percent oxygen/40 percent nitrogen at 16.2 psia
3. Series 300 — 100 percent oxygen at 16.2 psia

The tests were conducted in an accurately configured interior mockup of the CM which contained essentially all the exposed nonmetallic materials (those used in more than minute quantities) currently used in construction or as auxiliary equipment used in flight or test operations (space suits, flight-data files, food, etc.).

A total of 102 separate and deliberate ignitions were made to observe the nature of fire propagation in the reconfigured CM. During these tests, data were obtained of combustion history, temperatures, pressures, and generation of smoke and potentially toxic products. This report presents and discusses the results of each test (appendix A). Included are detailed descriptions of the test articles (appendix B), quality assurance provisions (appendix C), and additional supporting information.

APPROACH SELECTED

There are two basic conditions necessary for any catastrophic fire within the CM. First, a fire must be ignited. Second, the fire must propagate beyond its immediate ignition point. Both of these factors have been, and continue to be, carefully examined from a preventative and protective standpoint. However, one of the two factors must be essentially eliminated to make the probability of a catastrophic fire so remote that it can be considered negligible.

The prediction of potential ignition sources is, at best, a highly speculative endeavor and is distinctly related to the knowledge of the predictor about the numerous types of ignition mechanisms, the minute details of vehicle design and construction, and the crew actions which may disturb or alter the interior cabin arrangement. Because all CM wiring is a potential ignition source, the only positive means of removing all potential electrical ignition sources is to eliminate all onboard electrical power, which, for obvious reasons, is impractical. Because there are also other sources of ignition, the alternative is to demonstrate that any fire which might possibly occur will not and cannot propagate beyond the discrete region of ignition. This approach was selected for the validation test series. It was assumed that accidental fires are possible even in the best of designs and that the basic means of avoiding catastrophe is the elimination of propagation. Therefore, in the boilerplate (BP) 1224 mockup tests, fires were started deliberately in various suspect locations, using selected CM flammable materials as the ignition sources.

Once this approach was adopted, the following ground rules were established to ensure the validity of the test results.

1. The BP 1224 CM was configured carefully to yield true, worst-case, composite simulation of CM Block II test vehicle number 1 (2TV-1) and of spacecraft (SC) 101.

2. The test ignition points were selected to represent all ignition possibilities within the CM.

3. The test environment-control and data-acquisition networks were carefully designed and were composed of proven components.

4. Detailed quality assurance monitoring was required to verify all buildup, checkout, testing, and data-acquisition procedures.

TEST OBJECTIVES

The objectives of the test program centered about the deliberate ignition of fires at all selected locations while the interior atmosphere was controlled to match realistic flight conditions. For each ignition, sufficient data were acquired for the following purposes.

1. To determine if the fire would propagate, and, if so, to determine the degree of propagation and the magnitude of the fire

2. To identify and understand the nature of all propagation paths and fire hazards

3. To determine the effects of combustion on the rate and magnitude of temperature and pressure increases within the CM

4. To identify any stable toxic product evolving from combustion

5. To determine the degradation of crew visibility caused by combustion (smoke, etc.)

Before the investigation, a detailed test plan for achieving these objectives was reviewed and approved by the Flammability Test Review Board. The tests were conducted in accordance with this approved test plan.

TEST ARTICLE

The test article (fig. 1), designated BP 1224, was a full-scale BP mockup of the CM cabin interior fabricated specifically for this test program. The design requirements for the test article required a high degree of fidelity in simulating the interior, geometrically, electrically, and with respect to flight hardware and crew equipment. The BP 1224 mockup was a composite simulation of 2TV-1 and SC 101, both of which represented the current CM flight configuration. A detailed description of the test article and comparative figures which indicate its similarity to these vehicles are contained in appendix B.

TEST FACILITY AND INSTRUMENTATION

The CM BP 1224 flammability tests were conducted at the MSC Auxiliary Propulsion Test Facility located in the Thermochemical Test Area. This facility is primarily a rocket-engine test facility; however, the existing data-acquisition and mechanical equipment, controlled access, and flexibility of operation make it readily adaptable to many types of hazardous testing conditions.

The requirement for evacuating BP 1224 for fire-extinguishing and test-article atmosphere-control purposes was met by using the three-stage steam-ejector altitude-simulation system of the facility.

The facility instrumentation display, the data-acquisition system (DAS), and the control equipment are housed in a central control room. The test-article control wiring and instrumentation cables are connected to the control console and DAS through patch panels, thereby permitting maximum flexibility in the use of the various components of the system. The primary DAS used for this test was a Systems Engineering Laboratories Model SEL 600 50-channel digital system which digitizes and records 50 channels of input data on magnetic tape at the rate of 40 000 samples per second. The magnetic tapes are processed on the CDC 3800 computer of the MSC Computation and Analysis Division using the PULSOO data-reduction program. This program averages the values of samples taken over a specified time period and plots the data for graphic presentation. Secondary instrumentation included six two-pen Mosely strip charts for real-time analysis of critical measurements.

All the temperature-measuring transducers were Chromel/Alumel thermocouples, which have a temperature-measuring range of 0° to 2500° F. The cabin-pressure measurements were made with Taber strain-gage-type pressure transducers, which have a pressure-measuring range of 0 to 50 psia. The locations of the sensing elements are shown in figures 2 and 3.

All critical control functions were operated remotely to minimize hazardous exposure to personnel during testing.

The ignition sites were monitored via two COHU Electronic Company series 2000 television cameras located inside the test vehicle. The viewing monitors were located in the central control room. Video tape recordings were made on a Machtronics Model MVR-15 video recorder and on an Ampex Model 1100 video recorder. Color motion pictures were made of each ignition, using several Milliken Model 5-A motion-picture cameras and Eastman type EF-B film. The motion-picture cameras were located inside the test vehicle. Pretest and post-test still photographs were taken of each ignition, using a Hasselblad Model 500 C camera and a Hasselblad Model Superwide C camera with Ektacolor type CPS-120 film. For selected tests, a Hasselblad 500 EL 70-millimeter sequence camera was used.

Data-acquisition components are listed in the following table.

Parameter	Sensor	Model
Pressure	Strain-gage transducer	Taber 227-SA
Temperature	Chromel/Alumel thermocouple	Not applicable
Television	Vidicon camera	COHU series 2000
	Video recorder	Machtronics MVR-15
	Video recorder	Ampex 1100
Motion pictures	24-fps silent camera	Milliken 5-A
Still photographs	2-1/4- by 2-1/4-inch single-lens reflex (SLR)	Hasselblad 500 C

Parameter	Sensor	Model
	2-1/4- by 2-1/4-inch SLR	Hasselblad Superwide C
Sequence still photographs	2-1/4- by 2-1/4-inch SLR	Hasselblad 500 EL 70-mm sequence camera

SYNTHETIC MATERIALS USED FOR TESTING PURPOSES

The following materials were used in the tests.

1. Teflon — A polyfluorocarbon plastic, Teflon is a series of completely fluorinated resins comprising two structurally distinct types of products: TFE (polytetrafluoroethylene) and FEP (a copolymer of tetrafluoroethylene and hexafluoropropylene). The chemical formulas for TFE and FEP are $(-CF_2-CF_2-)_n$ and $(-CF_2CF_2-CF_2CF-CF_3)_n$, respectively.

2. Kynar — A polyfluorocarbon plastic, Kynar is polyvinylidene fluoride. The chemical formula is $(-CH_2-CF_2-)_n$.

3. Neoprene — A rubber compound, neoprene is a homopolymer of chloroprene or chlorobutadiene, of which 2 chloro -1, 3- butadiene is the base monomer.

4. Fluorel — A rubber or polyfluorocarbon elastomer, Fluorel is a linear copolymer of vinylidene fluoride and hexafluoropropylene having a 50-percent composition of asbestos for combustion retardation. The chemical formula is $(-CF_2CH_2CF_2CF-)CF_{3n}$.

5. Polyolefin — Polyolefin plastics, which are polymers consisting of polyethylene, polypropylene, polybutenes, and polyisoprene are formed from the corresponding olefins by an additive polymerization process.

6. Silicone-laminate cover — Silicone-laminate cover is an organopolysiloxane resin reinforced with 181 "E" glass cloth.

7. Ladicote — Ladicote is a Fluorel rubber-based compound, or polyfluorocarbon elastomer, with inorganic flame-retardant compounds and fillers and a topcoat of carboxy nitrosyl rubber (CNR).

TEST PROCEDURES

Test Atmosphere

Three series of tests were conducted under different atmospheric conditions. Series 100 consisted of tests at flight atmosphere; series 200 and series 300 consisted of tests at launch and prelaunch atmospheres. Where possible, the same ignition locations were used for the three test atmospheres.

Test Series 100

A cabin pressure level of 6.2 ± 0.1 psia was established as representative of the maximum pressure which would occur during the major portion of the manned 2TV-1 ground tests and during the actual Apollo missions. This pressure level is maintained in the flight CM by a cabin pressure relief valve which vents when the pressure is between 5.8 and 6.2 psia. The BP 1224 test vehicle used a flight-hardware cabin pressure relief valve which vented the vehicle to a vacuum commensurate both with chamber tests and space flight. Before ignition, the pressure level was adjusted to approximately 6.2 psia and was maintained at this level by replenishment from an oxygen-makeup system. Quantitative measurements of cabin pressure increases resulting from the combustion process could not be obtained because of the venting of the cabin pressure relief valve. However, the amount of venting was noted in an effort to estimate an increase in pressure through the effect of the pressure in increasing the amount of gases vented.

The specified minimum oxygen concentration of 95 percent was based on an assumed minimum CM requirement for launch, on the minimum requirement for testing materials in an oxygen atmosphere, and on the desire to have the highest oxygen concentration within the capability of the test equipment. Before each test, the BP 1224 test vehicle was evacuated and then backfilled with pure oxygen until a cabin-pressure level of approximately 6.2 psia was reached. Gas chromatograph readings were then taken to ensure that the oxygen concentration was 95 percent or greater before the test was started. If the desired concentration was not attained, the evacuation, backfilling, and verification procedures were repeated until the minimum-acceptable concentration was achieved.

Test Series 200

A cabin atmosphere of 60 percent oxygen and 40 percent nitrogen at a total pressure of 16.2 psia was being considered for manned chamber tests before pumpdown and for prelaunch. Before each test, the proper gas mixture and pressure level were established and were maintained in the test vehicle until the test was initiated.

The test vehicle, BP 1224, was evacuated before each test and then backfilled with nitrogen to approximately 6.5 psia. The vehicle was then backfilled with oxygen to 16.2 psia. When the pressure reached approximately 5 psia during the nitrogen backfill, the cabin fan was started to increase circulation and to assist later in mixing while oxygen was being added to the atmosphere. After the pressure reached 16.2 psia, gas chromatograph readings were made to verify that the oxygen concentration was 62 ± 2 percent before the test was begun. If the required concentration was not attained, the test vehicle was purged and vented until the specified mixture was achieved.

Test Series 300

A cabin atmosphere of 95 to 100 percent oxygen at a total pressure of 16.2 psia was tested because it was a possible cabin atmosphere for manned chamber tests and for prelaunch. Before each test, the proper oxygen content and pressure level were established and were maintained in the test vehicle until the test was initiated.

The test vehicle, BP 1224, was evacuated before each test and then backfilled with oxygen to 16.2 ± 0.1 psia. After the pressure reached 16.2 psia, gas chromatograph readings were made to verify that the oxygen concentration was 95 percent or greater before the test was started. If the required concentration had not been attained, the test vehicle was purged and vented until the specified oxygen concentration was achieved.

Ignition Technique

Each test used either an external or an internal dc coil igniter. The source for internal ignition of electrical panels consisted of a Nichrome coil of 12 to 14 turns of 26-gage wire wound on a 0.12-inch-diameter rod (fig. 4). The coil was buried in the RTV conformal coating and covered with Ladicote. For external ignition conditions, the coil consisted of eight turns of 20-gage Nichrome wire mounted in contact with the nonmetallic material under test (fig. 5). In this case, a small amount of RTV was inserted in the center of the coil to provide an adequately controlled heat-energy input to the test item. Internal ignition was indicated by the increased output of adjacent thermocouples. The external ignition sources were capable of providing a visible flame for 20 to 30 seconds.

The specific type of ignition source and the ignition location for each test are given in the individual test results (appendix A). The general criteria used for the selection of ignition locations included the following factors.

1. Proximity of ignition source to flammable materials (i.e., silicone clamps, spacers, etc.)

2. Apparent propagation paths, such as vertical configurations of wire bundles, connectors, or terminal boards

3. Large masses of nonmetallic materials

4. Evaluation of replacement or substitute materials

5. Proximity to stowage areas containing flammable materials

The panel locations for the internal igniters are listed in table I. Internal igniters were installed for testing in all three test series. Chromel/Alumel thermocouples having a maximum range of 2500° F were embedded in the silicone rubber approximately one-eighth to one-fourth inch from each of the internal igniters. External Nichrome-coil igniters were installed in the locations identified in table II. All igniter locations are shown in figures 6 to 13.

Test Criteria

Test concluded (successfully).- The flames self-extinguished, and temperatures of adjacent materials had decreased to ambient or well below the nonmetallic ignition temperature.

Test terminated (unsuccessful). - Continuing flame propagation was apparent, and the test was terminated by evacuation of the test vehicle.

Test-Termination Criteria

Test termination was based on visual observation and on indications obtained from control thermocouples located in the area of ignition. The general criteria for test termination for each of the various possible test conditions are given in the following paragraphs.

No apparent ignition. - The test condition was maintained for a minimum of 2 minutes to verify that the thermocouples at the igniter did not indicate increasing temperature. If there was no indication of flame from the ignition source, the ignition sequence was repeated.

Flame self-extinguishing. - The test condition was maintained for a minimum of 5 minutes after the flame extinguished to verify that all temperatures were at ambient or below the nonmetallic-material ignition temperatures.

Flame propagation. - In some cases, the test was terminated when the flame propagated a specified distance, as determined by visual observation, or when temperature limits were reached on specific control thermocouples located in the test area. Specific test-termination criteria for each individual test are included in the detailed test plan.

Egress time. - This criterion was used only for the ground-test and prelaunch atmospheres (series 200 and series 300). The test was usually terminated 125 seconds after smoke was observed in the crew compartment (crew egress time plus a 50-percent safety factor) unless a catastrophic fire occurred. If the fire remained localized after test-termination time (based on the preceding criteria), the test was terminated based on temperatures and on propagation to adjacent combustibles according to the test guidelines.

Water-Glycol Flow Conditions

Water-glycol flow rates and pressures for each of the test locations are given in table III. The water-glycol system was included as a factor in testing primarily for the purposes of validating the structural reliability of the lines and of observing the flammability effects of the water-glycol solution if rupture occurred.

Gas Sampling

Well-mixed gas samples from the area that would be surrounding the commander's head were obtained at specified intervals during all tests and after those tests which did not involve forced termination. The location and sampling were chosen to provide information of the types and quantities of stable gases which might be present after an accidental fire in which the flightcrew would be expected to survive and perform until the gas products could be removed by the environmental control system or by venting the spacecraft.

It was recognized before the test program that complete quantitative and qualitative determination of the gaseous products resulting from the test fires would be limited by the following factors.

1. The products which evolve depend markedly on the conditions of combustion and, as a result, many of the products are not predictable on either a quantitative or a qualitative basis unless complete combustion occurs. Complete combustion is rarely possible under conditions other than those found in a carefully controlled laboratory where pure compounds are used.

2. The concentration of toxic products at any given point in time and at any location depends upon the degree of mixing of the sampled product. Post-test samples were taken as soon as possible after test termination, but these samples did not necessarily represent quantitative peaks.

3. Reactive intermediates would not be detected because they would react with sampling systems, spacecraft materials, atmospheric constituents, or analytical instrumentation. Hence, only stable or metastable products are detectable in the gas samples.

The gas samples were collected in a sampling bomb and analyzed in the following manner.

1. A CEC Model 21-103C mass spectrometer was used to analyze all constituents present in concentrations greater than 0.2 percent.

2. An Instruments Inc. Model C-40 gas chromatograph was used to analyze carbon monoxide in the low parts per million range.

3. A Perkin-Elmer Model 521 infrared spectrophotometer equipped with a variable-path-length gas cell was used to analyze all other trace components (those with concentrations less than 0.2 percent) using infrared techniques.

DISCUSSION OF RESULTS

Detailed results of each of the 102 tests are presented separately in appendix A. Photographs of test damage are presented in figures 14 to 50. The results of test series 100 indicate that most areas of the CM interior are adequately protected against the propagation of an accidental fire in a 100-percent-oxygen atmosphere at 6.2 psia. Likewise, the results of test series 200 indicate that most areas of the CM interior are protected against extensive propagation of an accidental fire in an atmosphere of 60 percent oxygen/40 percent nitrogen at a pressure of 16.2 psia. The results of test series 300 indicate that approximately 50 percent of the tests produced fires which did not self-extinguish in a 100-percent-oxygen atmosphere at a pressure of 16.2 psia. In three tests of test series 300, insufficient egress time remained after smoke was detected, and the available egress time was marginal in four other tests.

Test Series 100

The first test series (series 100) was conducted in a 100-percent-oxygen atmosphere at 6.2 psia. Fires that were produced in five of the tests were of sufficient magnitude to require further study and consideration. In tests 103 and 104, propagation occurred despite the addition of Ladicote (a proposed fire-resistant coating) to the instrumentation panels. In both of these tests, the internal igniter was placed on a switch which was close to other switches that provided a propagation path. The switches on panel 3 had plastic cases, whereas the switches on panels 1 and 2 had metal cases. This difference in materials was probably the cause of the greater severity of the fire in panel 3 as compared to the fire in panel 2. The other ignition points in panels 1 and 2 were isolated components that did not provide propagation paths. In addition, all circuit-breaker (CB) panels had two applications of Ladicote (nominal 90-mil thickness), whereas panels 1, 2, and 3 had only a single application of Ladicote (nominal 45-mil thickness). The thickness of Ladicote on these panels was the same as that applied in 2TV-1 and SC 101. Propagation did not occur in any of the CB panels. However, whether this nonpropagation can be attributed to the double layer of Ladicote or to the geometrical configuration of the components is not known.

In test 116, a serious fire occurred because significant quantities of Fluorel sponge were used for acoustic insulation in the area of the cabin fan. Large quantities of smoke and soot were produced, and the cabin free-air temperature rose from 87° to 150° F. The two cabin fans were rendered inoperative, and wire bundles in that area were damaged because of the loss of Teflon insulation on individual wires.

In test 135, the coaxial cable ignited and burned from the point of ignition to a point approximately 18 inches away, where the fire self-extinguished. In similar tests (tests 119, 128, and 134), ignition was initiated on a saddle clamp which held, in addition to electrical wire, a small bundle of coaxial cables. In these tests, the coaxial cable did not ignite. A significant result of test 135 was that no smoke was evident in the cabin even at the conclusion of the 16-minute test. The burning polyolefin produced much dripping of flaming particles, and adjacent wires were damaged because of the loss of Teflon insulation. The slight amount of smoke resulting from the fire was significant from the standpoint of detection. In the unsuited condition, the crew would smell the products of combustion even though no smoke would be seen; and, therefore, the crew could take the required action. However, with the crew suited and with the closed-loop suit circuits in operation, the products of combustion would not be detected by odor. Therefore, no adequate means would exist for early detection by the crew of a coaxial-cable fire. Although the coaxial cable does not carry sufficient power to constitute a primary ignition source, it is located near wires that do carry sufficient current.

In test 136, the Fluorel sponge (very similar to the Fluorel-sponge acoustic insulation in the fan duct) around a guidance and navigation (G&N) eyepiece was ignited. The resulting fire propagated from the eyepiece to star charts and maps placed below the eyepiece and used in conjunction with it.

The maps, star charts, and plastic overlays burned rapidly and provided a propagation path to a procedures manual located at the foot of the right-hand (RH) couch. The cabin ambient temperature rose to 165° F at 115 seconds after the time (T) of application of power to the igniter, indicating a rapid heat buildup. The Fluorel material surrounds the eyepiece heater; therefore, a flammability hazard exists in this region.

The results of the gas analyses are presented in summary form in table IV. Gases having potential toxicological implications were found in 21 of the 37 tests conducted. The principal potentially hazardous gases were carbon tetrafluoride, silicon tetrafluoride, carbon monoxide, carbonyl fluoride, and carbon dioxide.

Test Series 200

The second test series (series 200) was conducted in a 60-percent-oxygen/40-percent-nitrogen atmosphere at 16.2 psia. The results indicate that, in all but two tests, the damage resulting from ignition was more extensive than when the same test was conducted in a 100-percent-oxygen atmosphere at 6.2 psia. Specific examples of this increased damage were noted in test 212 (silicone-laminate cover), test 226 (Teflon wrap on wire bundle), test 202 (meter coated with Ladicote), and test 217 (saddle clamp with silicone spacers). The two tests in which less apparent damage occurred were associated with ignition regions newly coated with Ladicote, namely, panel 1 switches in tests 201 and panel 2 switches in test 203. In these two tests, minor damage occurred in the ignition areas; however, in the same type tests conducted in a 100-percent-oxygen atmosphere at 6.2 psia (series 100), significant propagation occurred. In both series of tests, the igniters were located in identical regions. Results of the two series of tests indicate a possible Ladicote aging effect that results in less protection with increased age.

Four of the tests produced fires of sufficient magnitude to require additional investigation. In tests 206 and 207, despite the double application of Ladicote to CB panels, the ignition resulted in a fire that produced considerable damage. In the series 100 tests conducted on these panels, all fires self-extinguished without significant propagation.

In test 216, a serious fire resulted because of the Fluorel sponge used for acoustic insulation in the area of the cabin fans. Large quantities of smoke, sparks, and soot were produced. The cabin free-air temperature increased from 85° F to a peak temperature of 155° F. The pressure rose from 16.2 psia to a peak pressure of 16.9 psia. The two cabin fans were rendered inoperative, and wire bundles in this region received severe damage through the loss of Teflon insulation on individual wires. The possibility existed for ignition of the Lexan helmets, oxygen hoses, or cobra cables before completion of egress because sparks were blown from the fan area before the required time for egress (125 seconds) after smoke was first observed in the cabin.

In test 219, the coaxial cable ignited, and an area extending approximately 48 inches above the ignition location burned before the test was terminated. The fire and heat resulting from this test produced considerable damage to adjacent wire bundles. A significant result was that smoke was not produced in visible quantities until after the fire had become fairly large. In this environment, the crew would be suited; therefore, the products of combustion would not be detected by odor, and the fire probably would not be detected until smoke was observed in the cabin.

Test Series 300

The third test series (series 300) was conducted in a 100-percent-oxygen atmosphere at 16.2 psia. Results indicated that, in all but two tests, the damage resulting from ignition was more extensive, or occurred more rapidly, than when the same type test was conducted in the alternate launch atmosphere of 60 percent oxygen/40 percent nitrogen at a total pressure of 16.2 psia.

A pronounced increase in damage was noted in test 302 (meter in panel 2), test 303 (switch in panel 2), test 306 (CB in panel 225), test 312 (silicone-laminate cover on panel 8), test 326 (wire bundle leading to ground-support-equipment (GSE) window), and test 330 (Teflon wrap on wire bundle exiting from forward end of RH floor tray).

Test 332 (internal igniter in the commander's rotation controller) and test 342 (Teflon-wrapped wire bundle leading to left-hand (LH) couch rotational controller), in contrast with other tests in series 300, resulted in less severe burning than the same type tests in series 200. The reason for this decreased burning is that, in test 232 (60 percent oxygen/40 percent nitrogen), a bellows on the hand controller was forced out of place by internal pressure shortly after ignition, permitting the ingress of fresh oxygen into an otherwise tightly sealed container. The same incident did not occur during test 332, in which self-extinguishment occurred. In test 242, the igniter was located adjacent to a silicone-rubber Adel clamp which was near a Dacron restraint harness. Shortly after ignition, the resulting fire propagated to the restraint harness, and the test was terminated to avoid ignition of the suit. However, in test 342, the igniter was located several inches from the Adel clamp on the Teflon-wrapped wire bundle, and the slight change in the ignition location resulted in greatly decreased propagation and in self-extinguishment of the fire.

Several tests of this series resulted in propagation to adjacent or remote ignition locations, and these areas were damaged or destroyed. The fire in test 312 (silicone-laminate cover on panel 8) damaged or destroyed the ignition locations for test 314 (saddle clamp adjacent to panel 8), test 305 (igniter on CB in panel 8), test 316 (saddle clamp in cabin heat-exchanger compartment), and test 340 (igniter in wire bundles leading to panel 8). Propagation resulting from test 312 was extensive and took place along the Teflon wrap on wire bundles leading to the heat-exchanger compartment, which had Fluorel sponge insulation. A severe fire resulted in that region and damaged wire bundles, rendered the cabin fans inoperative, and melted aluminum panels surrounding the heat-exchanger compartment. Molten aluminum and flaming particles dripped from this region onto the suit on the LH couch and caused ignition of the suit and a considerably intensified fire.

In test 326 (wire bundle leading to GSE window), propagation took place on the Teflon-wrapped wire and ignited the Teflon-wrapped wire bundle leading to the RH bulkhead floodlamp, the ignition location for test 339.

During test 330 (Teflon wrap on wire bundle exiting from forward end of RH floor tray), propagation took place in the RH floor tray, traveled from the ignition point to the sequencer bay, and resulted in a large fire in that region. This region included the ignition location for test 329. (The igniter was to be located near a connector in the sequencer bay.)

Three tests in this series resulted in ignition of a suit, of one or more pairs of oxygen hoses, and of one or more cobra cables. Test 312, previously described, resulted in extensive damage to the left arm, torso, and helmet of the suit. The fire in test 303 (ignition of a switch in panel 2) propagated to two pairs of oxygen hoses. The suit was also ignited during this test, either because of the dripping of flaming particles from panel 2 or because of propagation along the oxygen hoses to the suit. The Dacron restraint-harness straps burned rapidly and provided a propagation path across the suit chest and over the left shoulder of the suit to the underside of the center couch. Test 341 (connector under silicone-laminate cover on cabin floodlight on RH couch aft strut) resulted in ignition of one pair of oxygen hoses and, subsequently, in ignition of the right foot of the suit on the center couch. The fire burned through the pressure garment assembly and destroyed the pressure integrity of the suit. The left foot of the suit on the RH couch also incurred damage during the test.

In test 319 (igniter adjacent to coaxial cable in the lower equipment bay (LEB)), significant quantities of coaxial cable in the test region burned, and a large fire resulted which destroyed the Teflon insulation on approximately 75 percent of the wires in this region. Propagation took place along the coaxial cable to the region above the girth shelf where the coaxial cables are wrapped individually with aluminum tape to provide fire protection. The aluminum tape was ineffective in preventing propagation in this atmosphere, and the fire proceeded up the vertical bundle of coaxial cable until the test was terminated.

The results of all tests associated with main display panels 1, 2, 3, and 8 indicate that a crewmember would have considerable difficulty in determining where a fire was located even after smoke was observed in the cabin. In some cases, smoke came out of the front of the panel; however, in several tests, the only visible smoke was in the fan stream, and no smoke actually came out of the panel face until a large fire was burning behind the panel.

In test 339 (igniter on switch in panel 3) and test 303 (igniter on switch in panel 2), a means for injecting Apollo fire-extinguishing foam into the panel area was provided. In test 339, very little if any foam reached the panel area because of line restrictions in the extinguishing system. In test 303, as evidenced by television, by color motion-picture film coverage, and by rapidly reduced temperatures in the region, the foam was effective in putting out the fire behind the panel. Because the fire had propagated to the electroluminescent (EL) overlay and oxygen hoses before the foam was injected, the test had to be terminated because the fire was outside the area into which the foam had been injected.

Summary of Test-Program Results

A flammability comparison for the three test series is given in table V. During the test program, unacceptable fire damage occurred in several areas of the CM mock-up. A thorough analysis was conducted of all these fires to determine the problem materials or problem components and to determine what action would be necessary to eliminate the problems. All corrective actions were verified by additional testing before final acceptance. The components or component configurations which constituted the hazards and the corrective actions that were taken are discussed in the

following section. The atmosphere in which the hazard first became evident in testing is listed with each component.

Main display console (MDC) panels (6.2 psia 100 percent oxygen). - Conformal coating used in the CM is flammable and was therefore covered with a fire-resistant coating to prevent fire propagation. The coating used in the CM was Ladicote. Ladicote was applied to the MDC panels at a minimum thickness of 0.045 inch. Early tests at NR indicated that this thickness was adequate for these panels. During the BP 1224 tests in a 100-percent-oxygen atmosphere at 6.2 psia, propagation occurred on two MDC panels (panels 2 and 3). The switch configuration of panel 3 was that of 2TV-1 (plastic-covered switches on the back of the panel). Propagation occurred on panel 3 after ignition on the back of the panel, and the fire burned through the panel and resulted in test termination at T + 29 minutes 45 seconds. The switch configuration of panel 2 was that of SC 101 (metal-covered switches on the back of the panel). Fire propagated to a number of switches after ignition on the back of panel 2. This fire self-extinguished. Silicone-laminate scuff covers had been placed on the backs of the MDC panels and other electrical panels. The scuff covers are intended to prevent damage to wiring during manufacturing operations and during installation of the electrical panels. The fire did not propagate to the covers or ignite them. Component tests of the cover have demonstrated that it will not burn in a 6.2-psia, 100-percent-oxygen atmosphere.

Corrective action — Fire-extinguisher access holes were provided in the MDC panels in 2TV-1 and SC 101. Considering the propagation rate of the fire during the BP 1224 tests in the 2TV-1 configuration, the crew would have had sufficient time for egress from the spacecraft. (In the SC 101 configuration, no action would have been required because the fire self-extinguished.) Use of the fire extinguisher would also have been feasible. Spacecraft 103 and subsequent spacecraft have a 0.090-inch thickness of Ladicote on the backs of the panels in addition to the fire-extinguisher access holes.

Cabin heat-exchanger acoustic insulation (6.2 psia 100 percent oxygen). - After the Fluorel was installed in the cabin heat-exchanger enclosure, the material was found to be flammable. The burning rate was increased considerably by the rapid circulation of oxygen through the heat exchanger by the cabin fans.

Corrective action — Acoustic tests had revealed that the Fluorel insulation could be deleted with no adverse effects on cabin noise level; therefore, the insulation was removed from SC 101 and subsequent vehicles. Tests conducted in BP 1224 showed that the crew could safely egress 2TV-1 if a fire occurred; therefore, the material was retained for this vehicle. Tests at NR had also demonstrated that the fire could be extinguished in approximately 5 seconds with the foam fire-extinguisher agent provided in 2TV-1.

Coaxial cable (6.2 psia 100 percent oxygen). - After fabrication of SC 101 and 2TV-1 was almost completed, it was discovered that the Kynar-polyolefin coaxial cable in the CM was flammable. Extensive testing was executed at the component level to define the ignition and propagation characteristics of the cable assembly. Testing in BP 1224 was conducted to determine if ignition would occur under worst-case electrical-failure modes and to examine propagation if ignition did occur. The test results showed that the cable is difficult to ignite and that propagation is unlikely except

in vertical runs of the cable. During the testing at 6.2 psia, there were five ignitions in close proximity to the coaxial cable. In one test, the coaxial cable ignited and burned from the point of ignition to a point approximately 18 inches away, where it self-extinguished. In the other four tests, flames did not propagate along the intended ignition path from the igniter to the cable.

Corrective action — Because additional component testing indicated that the coaxial cable would present a flammability problem, especially at higher oxygen contents, it was decided to wrap all accessible portions of the coaxial cable with aluminum tape before any additional tests were run. Aluminum tape was observed not to prevent propagation in test 319; however, tests 119 and 219 indicated that the tape would be effective at the lower pressure of 6.2 psia or in a 60-percent-oxygen/40-percent-nitrogen atmosphere.

Guidance-and-navigation eyepieces (6.2 psia 100 percent oxygen). - Fluorel insulation over the heater on the G&N eyepiece was ignited, burned with considerable dripping of flaming particles, and resulted in secondary ignition of Mylar-covered maps on the worktable.

Corrective action — The Fluorel insulation was replaced by a metallic strap. Various materials are under investigation as a substitute for the Mylar map overlay. Housekeeping procedures will be developed to reduce to a minimum any hazard associated with the crew flight-data file.

Circuit-breaker panels (16.2 psia 60 percent oxygen/40 percent nitrogen). - All CB panels and terminal strips were coated with Ladicote to a minimum thickness of 0.090 inch. Initial NR tests indicated that this thickness was adequate to make fires self-extinguishing even in the worst-case 16.5-psia 100-percent-oxygen atmosphere. Following ignition on the back of a CB panel in the 16.2-psia 60-percent-oxygen/40-percent-nitrogen atmosphere, fire propagated to adjacent circuit breakers, and excessive smoke resulted in test termination after 6 minutes 15 seconds. Ignition on the back of another CB panel resulted in test termination after 13 minutes because of excessive smoke. No fire propagation ever occurred for the 6.2-psia-oxygen condition with the 0.090-inch Ladicote thickness.

Corrective action — The protection already used is adequate for all spacecraft. The only propagation that could occur is during prelaunch operations in a 16.2-psia 60-percent-oxygen/40-percent-nitrogen atmosphere. In this situation, the crew has adequate time to egress. This protection is sufficient to limit propagation during the launch phase of the mission while the cabin pressure is above 6.2 psia.

Cabin heat-exchanger acoustic insulation (16.2 psia 60 percent oxygen/40 percent nitrogen). - The Fluorel acoustic insulation in the cabin heat exchanger previously ignited during the 6.2-psia tests was also ignited during the 60-percent-oxygen/40-percent-nitrogen 16.2-psia tests.

Corrective action — This material was removed from SC 101 and subsequent spacecraft.

Coaxial cable (16.2 psia 60 percent oxygen/40 percent nitrogen). - The flame propagated to the left and right of the ignition point, and the coaxial cable started to

burn locally. At T + 1 minute 20 seconds, a large flame was observed to the left and right of the ignition point. The fire began to diminish, and, at T + 3 minutes 25 seconds, the only fire remaining visible was at the right clamp. At T + 6 minutes 30 seconds, there was no visible flame. The test was concluded at T + 12 minutes.

Corrective action — It was verified that the corrective action taken (the proper configuration of Teflon and aluminum tape) was adequate to stop fire propagation along the coaxial cable in the LEB.

Main display console (16.2 psia 100 percent oxygen). - The igniter was located under the conformal coating of a switch on panel 2. A 0.045-inch thickness of Ladicote was applied over the conformal coating. Flame became visible within 1 minute, and the fire propagated to the front of the panel in 2 minutes 35 seconds. The foam fire extinguisher, which was directed toward the back of the panel, was actuated at T + 2 minutes 39 seconds. At T + 2 minutes 45 seconds, the fire had propagated to the suit oxygen umbilicals and to the space suit. The test was terminated at T + 2 minutes 55 seconds. The foaming agent from the fire extinguisher caused a considerable reduction in temperatures behind the panel. The umbilicals were destroyed, and the suit was burned severely. The Ladicote did not provide adequate fire protection. During the oxygen/nitrogen tests at 16.2 psia, there had been no significant propagation, and the fire self-extinguished.

Corrective action — No satisfactory replacement materials or alternate systems have been found to replace critical components in the main display console; therefore, these results were instrumental in the decision to use a 60-percent-oxygen/40-percent-nitrogen launch atmosphere in the Apollo command module.

Circuit-breaker panel (16.2 psia 100 percent oxygen). - The igniter was located under the conformal coating. A 0.090-inch thickness of Ladicote was applied over the conformal coating. Light smoke was observed 38 seconds after ignition. Heavy smoke was observed at T + 2 minutes 20 seconds. At T + 3 minutes 15 seconds, the fire had propagated to the upper LH corner of the EL panel and had become quite intense. The test was terminated at T + 4 minutes 27 seconds. The silicone-laminate back cover was completely destroyed, and the wiring and circuit breakers were severely damaged. The Ladicote did not prevent the propagation of the fire. During the oxygen/nitrogen tests at 16.2 psia, fire propagation occurred at a slower rate. The test was terminated at T + 6 minutes 15 seconds.

Corrective action — No satisfactory replacement materials or alternate systems have been found to replace critical components in the circuit-breaker panel; therefore, these results were instrumental in the decision to use a 60-percent-oxygen/40-percent-nitrogen launch atmosphere in the Apollo command module.

Silicone-laminate cover (16.2 psia 100 percent oxygen). - The igniter was placed on the edge of a silicone-laminate cover. Within 1 minute after ignition, visible flames were observed, and there was a rapid buildup of smoke in the crew compartment. The fire propagated to the heat-exchanger area, and dripping particles were observed coming from that area. At T + 2 minutes 50 seconds, the space suit ignited, and the fire propagated rapidly to the helmet region of the suit. The test was terminated at T + 2 minutes 57 seconds. A number of switches and several circuit breakers on the front of the panel were severely damaged. There was extensive damage in the area of

the heat-exchanger compartment and to the space suit. The silicone-laminate covers and Fluorel in the heat-exchanger area provided a propagation path for the fire. During the oxygen/nitrogen tests at 16.2 psia, limited propagation of the fire occurred along the silicone-laminate cover, and the fire subsequently self-extinguished.

Corrective action — These test results prompted replacement of the material used in the silicone-laminate cover. These results also were instrumental in the decision to use a 60-percent-oxygen/40-percent-nitrogen launch atmosphere in the Apollo command module.

Teflon wire wrap (16.2 psia 100 percent oxygen). - The igniter was located on a saddle clamp on a vertical wire bundle. Visible flames were observed 13 seconds after ignition. At T + 1 minute 24 seconds, the fire had propagated upward along the Teflon wrap. The fire continued to propagate to adjacent small Teflon-overwrapped wire bundles. Flames were observed coming from the floor area at T + 3 minutes 20 seconds. The test was terminated at T + 4 minutes 27 seconds. Post-test inspection indicated that the fire had propagated to a sleep pad below the LH couch and had destroyed approximately one-fourth of the pad. During the oxygen/nitrogen tests at 16.2 psia, there was no significant propagation, and the fire self-extinguished.

Corrective action — No satisfactory replacement materials or alternate systems have been found to replace the Teflon wire wrap; therefore, these results were instrumental in the decision to use a 60-percent-oxygen/40-percent-nitrogen launch atmosphere in the Apollo command module.

Coaxial cable (16.2 psia 100 percent oxygen). - After 45 seconds, the fire propagated to the coaxial cable, which was near the ignition point. Within 2 minutes 40 seconds, the fire had propagated along the coaxial cable above the girth shelf. Within 4 minutes 30 seconds, general fires were observed in the area above and below the girth shelf, and it was necessary to terminate the test at T + 5 minutes. There was major wire damage on the lower-right and upper-right sides of the LEB. During the oxygen/nitrogen tests at 16.2 psia, there was significant propagation; however, the fire remained localized below the girth shelf and eventually self-extinguished.

Corrective action — No satisfactory replacement materials or alternate systems have been found to replace critical materials in the coaxial cable; therefore, these results were instrumental in the decision to use a 60-percent-oxygen/40-percent-nitrogen launch atmosphere in the Apollo command module.

CONCLUDING REMARKS

Because most of the nonmetallic materials found in the command module had been previously tested at a component level and found acceptable, the high degree of flammability of some materials and the substantial areas affected by some of the fires were unexpected. For example, in a 100-percent-oxygen 16.2-psia atmosphere, the degree of flame propagation along the Ladicote flame-retardant coating on the back of the electrical panels was much greater than expected. Before full-scale testing was begun, a number of component tests had indicated that Ladicote was a satisfactory flame retardant; however, during full-scale testing, the Ladicote failed to prevent excessive propagation. Other tests which showed the components to be unacceptable in the spacecraft

configuration, although individual component tests had shown them to be acceptable, were those associated with the silicone-laminate scuff covers, with the Teflon chafe-guard, and with the silicone wire-bundle spacers. These variations in the results of component tests as opposed to the results of full-scale tests indicate that, although the need for individual component testing remains a necessary first step in the test program, the results cannot be taken as conclusive when applied to the entire spacecraft configuration. Such variables as location, heat-sink characteristics, airflow patterns, proximity to other materials, and so forth, which can only be represented by full-scale testing, apparently play an important role in determining the flammability characteristics of individual and composite components.

As a result of information obtained from the three full-scale flammability test series, the Flammability Test Review Board concluded that, with the presently available materials, no space flights should be made with a 16.2-psia 100-percent-oxygen atmosphere. However, the material changes and other changes that have been made in the command module have resulted in a firesafe configuration in the 6.2-psia 100-percent-oxygen inflight atmosphere and in the 16.2-psia 60-percent-oxygen/40-percent-nitrogen launch atmosphere. Consequently, these two atmospheres were selected for flight.

Although there remains a substantial flammability hazard in a 16.2-psia 100-percent-oxygen atmosphere, the hazard has been greatly reduced from that of Spacecraft 012 and preceding configurations. This remaining hazard, however, is significantly greater than that in a 60-percent-oxygen/40-percent-nitrogen atmosphere at the same pressure or in a 6.2-psia 100-percent-oxygen atmosphere. The fire hazard in a 16.2-psia 60-percent-oxygen/40-percent-nitrogen atmosphere, as measured by self-extinguishment, by reduced rate of propagation, and by reduced magnitude of the fires, is essentially equivalent to that of 100 percent oxygen at 6.2 psia, which is the maximum pressure that will be used in space flight. Based on the boilerplate 1224 testing, the use of the oxygen/nitrogen atmosphere also provides adequate crew egress time in case of a fire on the launch pad. There is a hazard associated with the boost phase of flight; however, this hazard is deemed acceptable because boost phase is short in duration and because, with the crew suited, the crew-compartment atmosphere can be vented to extinguish a fire.

Manned Spacecraft Center
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TABLE I. - INTERNAL IGNITER LOCATIONS

Test	Igniter location
101, 201, 301	Under conformal coating of switch S53 on MDC panel 1
102, 202, 302	Under conformal coating of meter M12 on MDC panel 2
103, 203, 303	Under conformal coating of switch S47 on MDC panel 2
104, 204	Under conformal coating of switch adjacent to R1 control on MDC panel 3
105	Under conformal coating of CB 30 on panel 8, which is the side display console above girth shelf adjacent to environmental-control-unit (ECU) controls
106, 206, 306	Under conformal coating of CB 5 on panel 225, which is on RH side of vehicle under liferaft stowage compartment
107, 207, 307	Under conformal coating of CB 12 on panel 226, which is on right side of vehicle above girth shelf near waste-disposal opening
108, 308	Under conformal coating of CB 17 on panel 250, which is on right side of vehicle below girth shelf and above fecal canister
109, 309	Under conformal coating of CB 20 on panel 275, which is on right side of vehicle below girth shelf and above sequencer bay

TABLE II. - EXTERNAL IGNITER LOCATIONS

Test	Igniter location
110, 210, 310	Silicone-cushioned Adel clamps on water-glycol lines under wire bundle entering the upper-deck feedthrough plate behind panel 2
111, 211	Edge of silicone-laminate cover on back of display panel 2
112, 212, 312	Edge of silicone-laminate cover on back of panel 8 side display console
113, 213, 313	Neoprene-coated saddle clamp securing wire bundle penetrating through the LH shelf behind food-storage compartment B1
114, 214	Neoprene-coated saddle clamp above LH girth shelf and behind control and display panel 8 adjacent to suit supply duct and on LH equipment bay (LHEB)
115, 215, 315	Sleeve over wiring entering electrical connector to electronic-control-unit amplifier under lithium hydroxide canisters
116, 216	Neoprene-coated saddle clamp with pink silicone spacers in RH side of cabin heat-exchanger compartment on bulkhead
117, 217, 317	Saddle clamp with pink silicone fillers on vertical wire bundle where bundle leaves LH floor-harness tray in LEB
118, 218, 318	Kynar sleeves of wires in wire bundle entering connector (second from RH edge) on bottom row of RH circuit-interrupter feed-through plate assembly
119, 219, 319	External igniter on Neoprene-coated saddle clamp securing horizontal wire bundle at RH side of RH circuit-interrupter feedthrough plate assembly on LEB (Coaxial cables are routed through this region.)
219A	Neoprene-coated saddle clamp securing large horizontal wire bundle at RH side of circuit-interrupter feedthrough plate assembly
120, 220, 320	Neoprene-coated saddle clamp mounted horizontally on LEB bulkhead
121, 221, 321	Adjacent to potting compound on connector 56P21 of G&N "G" harness
122, 222, 322	Adjacent to potting compound on connector 56P27 of the G&N control panel
123, 223, 323	Against the silicone-rubber-covered clamp attaching G&N "S" harness to rear of guidance computer
124, 224, 324	Unwrapped portion of wire bundle going into connector J22 on GSE feedthrough panel approximately 3 inches from back of connector

TABLE II. - EXTERNAL IGNITER LOCATIONS - Concluded

Test	Igniter location
125, 225, 325	On insert in back of connector J20 on GSE feedthrough panel in RH equipment bay (RHEB)
126, 226, 326	Under the Teflon wrap on large-diameter GSE wire bundle (from GSE feedthrough plate) 6 inches above point of bundle entry to RH floor tray
127	Gray silicone-filled saddle clamp (LH) located behind the procedure-manual stowage compartment R1
128, 228, 328	Gray silicone-filled saddle clamp located behind and to right of survival-equipment stowage compartment R4
129, 229	On Teflon overwrap approximately 2 inches away from bottom inboard connector located in sequencer bay
130, 230, 330	Edge of Teflon wrap on wire bundle that leaves forward end of RH floor tray and is then routed into LEB
131, 231, 331	Neoprene-coated saddle clamp (with gray silicone fillers) behind sanitation-supply stowage compartment R10
232, 332	Inside metal case on potted terminal board in lower portion of commander's rotational controller
133, 233, 333	Center of cabin approximately 3 feet above cabin floor
134	Neoprene-coated saddle clamp securing horizontal wire bundle at RH side of RH circuit-interrupter feedthrough plate assembly on LEB
135	Neoprene-coated saddle clamp securing horizontal wire bundle at RH side of RH circuit-interrupter feedthrough plate assembly
136	Fluorel-wrapped eyepiece (space sextant) located in upper portion of G&N area
137, 237	Small Teflon-wrapped wire bundle going to electrical connector on RH bulkhead floodlight
138, 238, 338	On 5-foot length of 12-gage SC wire in cable in RH floor tray
339	Under conformal coating of switch SW63 on panel 3 on RH side of MDC
240	Adjacent to wire bundles in which individual wires are covered with Teflon shrink tubing
341	On silicone-rubber insert of electrical connector on cabin floodlight
242, 342	In Teflon-wrapped wire bundle coming from LH-couch rotational controller

TABLE III. - WATER-GLYCOL FLOW RATES AND PRESSURES

Location	Flow rate, lb/hr	GSE pressure, psia
MDC flight director attitude indicator (FDAI)	40	28
Liferaft stowage compartment R4	NA[a]	NA
ECU controller (LHEB), inertial measurement unit (IMU)	33	32
Food stowage compartment B1 (LEB)	NA	NA
Cabin heat exchanger	167	29
Panel 8 (LHEB)	NA	NA
Food stowage compartment L3 (overhead equipment bay), ECU (LHEB)	NA	NA

[a]Not applicable.

TABLE IV. - GAS ANALYSIS SUMMARY

Test	Sample	Time after T = 0, min	O_2, percent	N_2, percent	Ar, percent	CO_2, percent	CO, ppm	COF_2, ppm	CF_4, ppm	SiF_4, ppm
101	1	3	79.3	20.2	0.3	0.2	--	--	--	--
101	2	10	77.2	22.3	.3	.2	--	--	--	--
101	3	15	73.4	26.1	.3	.2	--	--	--	--
201	1	5.5	55.3	44.7	--	--	--	--	--	5.4
201	2	8	54.1	45.8	.1	--	--	--	--	6
201	3	14	53.7	46.2	.1	--	--	--	--	6.5
301	1	1	99.3	.7	--	--	--	--	--	3.3
301	2	2	99.4	.6	--	--	--	83.3	<1	15.3
301	3	3.5	99	.6	--	.4	--	583.3	410	370
102	1	2	92.8	7.2	--	--	--	--	--	--
202	1	4.25	60.8	39.2	--	--	--	66.6	1.3	3.3
202	2	8.5	58	41.9	.1	--	--	228.4	21.6	15.4
302	1	2.25	99.1	.6	.2	.1	--	153.8	21.1	11.5
302	2	4	98.7	.9	.1	.3	--	500	158.8	54
103	1	1	92.3	7.5	.2	--	--	--	--	<1
103	2	5	91.6	8.2	.2	--	--	--	--	16
103	3	6	52.8	46.7	.5	--	--	--	--	17.4
103	4	12	91	8.5	.3	.2	0.64	100	2	51
103	5	18	90.2	9.3	.3	.2	.70	155	6	70
103	6	28	81.5	18	.3	.2	.75	188	8	128
203	1	1	58.1	41.8	.1	--	--	--	--	--
203	2	5	57.2	42.7	.1	--	--	--	--	--
203	3	11	57.2	42.7	.1	--	--	--	--	--
303	1	1.5	99.4	.6	--	--	--	137.6	1.5	37.8
303	2	2.75	98.5	.6	--	.9	--	1020	857.1	678.5
104	1	3	92.1	7.9	--	--	--	--	8	--
104	2	11	82	16.7	.2	1.1	4.2	287	13	106
104	3	16	75.3	22.7	.2	1.8	5.9	563	95	240
104	4	23	71.3	25.4	.3	3	20.1	944	248	739
104	5	29	68	27.1	.3	4.6	36.7	951	397	937
204	1	1	62	38	--	--	--	--	--	2.7
204	2	2.75	62	38	--	--	--	78.1	3.9	3.9
204	3	5	61.9	38.1	--	--	--	147.1	13.2	13.9
204	4	7.25	61.7	38	--	.3	--	376.8	143.2	64.5
105	1	5	88	11.9	.1	--	--	--	--	3.8
105	2	18	79	20.7	.3	--	--	--	--	4.9
106	1	3	93.1	6.9	--	--	--	--	--	--
206	1	2	56.8	43.1	.1	--	--	--	--	<1
206	2	5	56.4	43.3	.1	.2	--	187.5	3.9	13.3
306	1	3	88.3	11.2	.3	.2	--	81.9	13.1	45
306	2	3.5	96.4	3	.3	.3	--	138.8	35.1	115.7
306	3	4	96.2	3.1	.3	.4	--	142.8	118.4	368.4

TABLE IV.- GAS ANALYSIS SUMMARY - Continued

Test	Sample	Time after T = 0, min	O_2, percent	N_2, percent	Ar, percent	CO_2, percent	CO, ppm	COF_2, ppm	CF_4, ppm	SiF_4, ppm
107	1	5	94	6	--	--	--	--	--	--
107	2	8	83.9	15.9	0.2	--	--	--	--	--
207	1	1.25	49.5	50.2	.3	--	--	--	--	--
207	2	2.75	58.3	41.6	.1	--	--	--	--	--
207	3	5	58.5	41.4	.1	--	--	--	--	--
207	4	6.75	58.8	41.1	.1	--	--	--	--	--
207	5	8.75	58.1	48.7	.1	--	--	--	--	--
207	6	13.75	21.1	78	.9	--	--	--	--	--
307	1	2.5	85.5	13.9	.3	--	--	102.7	1	4.7
307	2	4.25	94.1	5.4	.3	0.2	--	121.9	21.9	35.9
307	3	5	81.5	17.8	.4	.3	--	217.3	121	126.3
108	1	3	94	5.9	.1	--	--	--	--	--
308	1	1.25	89.9	9.8	.3	--	--	--	--	--
308	2	3.5	96.9	2.6	.3	.2	--	280.3	90	38.6
308	3	4	98.2	1.3	.3	.2	--	561.4	180	105.2
109	1	1.5	95	5	--	--	--	--	--	--
309	1	2	29	70.2	.8	--	--	--	--	--
309	2	3.75	97.3	2.2	.3	.2	--	157.5	13	54.3
110	1	2	91.9	7.9	.2	--	--	--	--	--
110	2	5	90.5	9.3	.2	--	--	--	--	--
210	1	1	61.9	38	.1	--	--	--	--	--
210	2	3	61.7	38.2	.1	--	--	--	--	<1
210	3	11	61.6	38.3	.1	--	--	--	--	<1
310	1	1.5	99.2	.6	.2	--	--	--	<1	1
310	2	3	96.3	3.5	.2	--	--	--	1	2.2
310	3	5	98.8	1	.2	--	--	--	2.7	4.5
111	1	2	88	11.8	.2	--	--	--	--	--
111	2	5	87.3	12.4	.3	--	--	--	--	--
211	1	2	59.9	40	.1	--	--	--	--	--
211	2	8	59.1	40.7	.2	--	--	--	--	--
112	1	1.5	89.1	10.7	.2	--	--	--	42.7	6.7
112	2	5	77.6	22	.2	.2	--	--	80.2	9
212	1	2	58.7	41.2	.1	--	--	--	2	1
212	2	5	59	40.9	.1	--	--	--	3.1	1
212	3	9	58.6	41.3	.1	--	--	--	3	1
312	1	1.5	99.1	.7	.2	--	--	288.8	44.4	62.2
312	2	2.5	98.7	.8	--	.5	--	431.8	163.6	463.6
113	1	2	91.1	8.5	.2	.2	--	--	--	--
113	2	5	90.8	8.9	.2	.2	--	--	--	--

TABLE IV. - GAS ANALYSIS SUMMARY - Continued

Test	Sample	Time after T = 0, min	O_2, percent	N_2, percent	Ar, percent	CO_2, percent	CO, ppm	COF_2, ppm	CF_4, ppm	SiF_4, ppm
213	1	1	60.6	39.3	0.1	--	--	--	--	--
213	2	3	60	39.9	.1	--	--	--	--	--
213	3	5	60.3	39.6	.1	--	--	--	--	--
313	1	1	98.7	1.1	.2	--	--	--	--	--
313	2	3	96.3	3.5	.2	--	--	--	--	--
313	3	5.5	99.3	.5	.2	--	--	--	--	--
114	1	1.5	70.8	28.8	.4	--	--	--	29.5	--
114	2	4.5	--	--	--	--	--	--	30.9	--
214	1	2.5	60.7	39.2	.1	--	--	50.5	3	1.1
214	2	5.25	60.7	39.2	.1	--	--	101	5	1.4
115	1	3	84.5	15	.2	0.2	--	--	--	--
115	2	5	83.8	15.8	.2	.2	--	--	--	--
215	1	2	60	39.9	.1	--	--	79.2	7.4	2.9
215	2	5	59.3	40.6	.1	--	--	98	8.8	4.4
315	1	1	99.2	.8	--	--	--	118	9	4.8
315	2	4	97.2	2.8	--	--	--	131.5	27.6	5.2
116	1	6	93.6	5.6	--	.8	--	568	100	705
116	2	9	91.5	5.9	--	2.6	7.9	887	166	2415
216	1	2	61.3	38.6	.1	--	--	--	--	2.2
216	2	5	60.4	39.5	.1	--	--	--	--	9.5
216	3	7	60.3	39.2	.1	.4	--	511.1	81.3	531.2
216	4	8	58.6	40.9	.1	.4	--	620	93.7	706
117	1	2	81.9	17.7	.2	.2	--	219	26	17
217	1	.75	59	40.9	.1	--	--	110.7	11.3	2.3
217	2	2.75	58.2	41.7	.1	--	--	246	66.1	13.8
217	3	10.75	58.1	41.7	.1	.1	--	289	78.4	15.1
317	1	3	98.9	.9	--	.2	--	2081.9	750	66 6
317	2	4	98.6	.9	--	.5	--	2162	828.5	103.3
118	1	2	95.6	4.2	.2	--	--	--	3.9	--
118	2	5	70.8	28.8	.4	--	--	--	4.4	2.5
218	1	2	59.4	40.6	--	--	--	--	--	--
218	2	5	59.3	40.6	.1	--	--	--	--	--
318	1	1	86.9	12.9	.2	--	--	30	3	3
318	2	4.5	93.9	5.9	.1	.1	--	57.5	7.7	3.2
119	1	2	86.9	12.8	.3	--	--	--	--	--
119	2	5	82.6	17	.4	--	--	--	--	--
219	1	2	61.9	38.1	--	--	--	--	--	--
219	2	5	61.1	38.9	--	--	--	--	--	--
219	3	12	60.2	39.5	.1	.2	--	204	44.8	38.7

TABLE IV - GAS ANALYSIS SUMMARY - Continued

Test	Sample	Time after T = 0, min	O_2, percent	N_2, percent	Ar, percent	CO_2, percent	CO, ppm	COF_2, ppm	CF_4, ppm	SiF_4, ppm
219A	1	1	62.8	37.2	--	--	--	--	<1	2.3
219A	2	2	63	37	--	--	--	--	2.6	4.7
219A	3	5	62.7	37.2	--	0.1	--	--	4.4	6.3
219A	4	9	62.4	37.5	--	.1	--	--	5.3	8.9
219A	5	11	62.1	37.8	--	.1	--	--	6.8	11.9
319	1	2	90.4	9.2	0.2	.2	--	485.7	115	66.4
319	2	3	97	2.5	--	.5	--	1350	420	284.6
120	1	1.5	85.7	14	.3	--	--	--	--	--
120	2	5	80.7	19	.3	--	--	--	--	--
220	1	2	59.6	40.2	.2	--	--	--	8.3	--
220	2	5	59.5	40.4	.1	--	--	--	9.4	--
320	1	2	85.9	13.5	.4	.2	--	184.7	30.4	3.8
320	2	5	93.9	5.5	.3	.3	--	226.6	40.6	6.6
121	1	1	--	--	--	--	--	--	--	--
121	2	3	--	--	--	--	--	--	--	--
221	1	5.5	61.2	38.6	.2	--	--	--	--	--
321	1	4.5	79	20.5	.3	.2	--	--	--	--
321	2	6.75	28.4	70.7	.8	.1	--	--	--	--
321	3	9.5	90.8	8.7	.2	.3	--	--	4.2	--
321	4	11.5	91.7	7.8	.2	.3	--	--	4.2	--
122	1	1	93.7	6.2	.1	--	--	--	--	--
222	1	1.5	59.9	39.9	.2	--	--	--	--	--
222	2	5.5	59.7	40.1	.2	--	--	--	--	--
322	1	1	89.9	9.7	.2	.2	--	--	--	--
322	2	4.5	96.2	3.4	.2	.2	--	--	--	--
123	1	1	88	11.8	.2	--	--	--	--	--
223	1	1.5	60.1	39.8	.1	--	--	--	--	--
323	1	2	81.8	17.7	.3	.2	--	--	--	--
323	2	3	90.9	8.6	.3	.2	--	--	--	--
124	1	2	93.6	6.2	--	.2	--	--	≤1	--
124	2	5	76.7	22.9	.2	.2	--	--	1	<1
224	1	2	58.5	41.3	.2	--	--	140.4	23.7	10.5
224	2	5	57.9	41.9	.2	--	--	144.6	25.6	10.9
324	1	2	86	13.8	.2	--	--	217.3	34.7	7.1
324	2	4	94.9	5	.1	--	--	237.5	36	8.7
324	3	5.75	94.5	5.4	.1	--	--	305.2	43.8	14.9
125	1	2	94.5	5.3	--	.2	--	--	2.1	2
125	2	4	88.9	10.8	--	.3	--	--	4.5	11.6

TABLE IV. - GAS ANALYSIS SUMMARY - Continued

Test	Sample	Time after T = 0, min	O_2, percent	N_2, percent	Ar, percent	CO_2, percent	CO, ppm	COF_2, ppm	CF_4, ppm	SiF_4, ppm
225	1	2	60.5	39.4	0.1	--	--	--	.1	<1
225	2	5	58.7	41.2	.1	--	--	--	1.2	1
325	1	2	91.9	7.9	.2	--	--	93	23.7	6.9
325	2	5	97.5	2.5	--	--	--	109.1	25.9	6.9
126	1	2	96.3	3.5	--	0.2	--	--	--	<1
126	2	4	95.4	4.4	--	.2	--	--	<1	6.7
226	1	2	56.7	43.1	.2	--	--	489.4	128.8	29.3
226	2	5	59	40.8	.2	--	--	890.6	255	38.5
226	3	13	58.4	41.2	.2	.2	--	2425	700	260
226	4	16	58.1	41.5	.2	.2	--	2750	825	412.5
326	1	1	93.3	6.6	.1	--	--	193.8	36.7	10.2
326	2	2.25	98	1.9	.1	--	--	1944.4	620	105.2
127	1	4	94.6	5.2	.2	--	--	118	10.1	2.5
127	2	10	93	6.8	.2	--	--	144	11.8	3
128	1	2	95.3	4.5	.2	--	--	--	--	--
128	2	2.5	94.6	5.2	.2	--	--	--	--	--
128	3	8.5	92	7.6	.2	.2	--	--	--	5.7
228	1	2	64.3	35.6	.1	--	--	--	--	<1
228	2	5	60.6	39.3	.1	--	--	--	--	<1
228	3	15	62.2	37.6	.1	.1	--	--	--	2.8
328	1	1	98.7	1.3	--	--	--	--	--	--
328	2	2.75	99	.8	--	.2	--	64.9	1.3	1.9
328	3	5	96.7	3.1	--	.2	--	121.2	22.7	15.2
129	1	1.5	97.9	2.1	--	--	--	103	15.1	21.4
129	2	3.5	97	3	--	--	--	138	27.6	27.5
129	3	6	96.2	3.6	--	.2	--	245	35.9	29.3
229	1	2	60.5	39.4	.1	--	--	105	30	5.8
229	2	5	59.1	40.8	.1	--	--	165.2	36.5	19.8
130	1	2	92.4	7.5	.1	--	--	89.2	42.8	5.9
130	2	5	92.9	6.9	.2	--	--	108	53.8	26
230	1	1	59.3	40.6	.1	--	--	--	1	--
230	2	4	59.7	40.2	.1	--	--	670	251	13.8
230	3	6	60.1	39.8	.1	--	--	775	340	47.5
230	4	9.5	59.3	40.5	.1	.1	--	802	350	51.2
330	1	1.5	83.8	16	.2	--	--	126.8	35	<1
330	2	3	93	6.7	.1	.2	--	1110.2	418.1	26.5
330	3	7	96.8	2.9	--	.3	--	4842.1	1216.6	133.3
330	4	12.5	92.6	6.8	.2	.4	--	7142.8	2353.3	285.7
131	1	4	88.2	11.6	.2	--	--	--	--	--

TABLE IV. - GAS ANALYSIS SUMMARY - Continued

Test	Sample	Time after T = 0, min	O_2, percent	N_2, percent	Ar, percent	CO_2, percent	CO, ppm	COF_2, ppm	CF_4, ppm	SiF_4, ppm
231	1	1	56.2	43.7	0.1	--	--	--	--	--
231	2	5.5	59.2	40.7	.1	--	--	--	--	<1
231	3	11 5	59.2	40.7	.1	--	--	--	--	1.5
331	1	1	93.5	6.3	.2	--	--	--	--	--
331	2	4	35.1	64.2	.7	--	--	--	--	1.8
331	3	8	91	8.8	.2	--	--	--	--	2.3
331	4	14	93.7	6.2	.1	--	--	--	--	3.7
232	1	2	60.4	39.5	.1	--	--	--	--	1.1
232	2	4	60	39.9	.1	--	--	--	--	1.2
232	3	8	59.9	39.9	.1	0.1	--	--	--	2.8
232	4	14	59.6	40.1	.1	.2	--	--	--	3.1
232	5	20	58.7	40.9	.1	.3	--	--	--	3
332	1	1	99	1	--	--	--	--	--	--
332	2	2.25	99	1	--	--	--	--	--	4
332	3	5.5	98.9	1.1	--	--	--	--	--	4.3
133	1	1.5	81.4	18.3	.3	--	--	--	--	--
233	1	.5	63	36.9	.1	--	--	--	--	--
233	2	1	63.3	36.6	.1	--	--	--	--	--
333	1	1.25	99.5	.5	--	--	--	--	--	--
134	1	2	94.8	5	.2	--	--	--	--	--
134	2	5	93.7	6.1	.2	--	--	--	--	<1
134	3	9	93.5	6.3	.2	--	--	--	<1	2.8
135	1	2	95.3	4.5	.2	--	--	--	--	--
135	2	5	92.6	7.2	.2	--	--	--	3.6	--
135	3	7.5	92.1	7.3	.3	.3	--	--	15.7	--
135	4	11.5	91.6	7.5	.3	.6	--	157	33.7	113.7
135	5	15	91.5	7.6	.3	.6	--	315	43.4	126.7
136	1	1	94.2	5.6	.2	--	--	220	16.6	363
137	1	.5	96.4	3.3	.3	--	--	--	--	--
137	2	1.5	89.9	9.8	.3	--	--	--	13	--
137	3	4	88	11.7	.3	--	--	--	14.2	--
237	1	1	61.9	40	.1	--	--	148	10.9	3
237	2	4	61.5	38.3	.2	--	--	179.5	30.7	6.4
138	1	2.5	95.2	4.5	.3	--	--	340	74.7	5
138	2	5.5	77.6	21.9	.3	.2	--	438	120	10
238	1	2	61.2	38.7	.1	--	--	32	<1	≤1
238	2	3	60.9	39	.1	--	--	101	23.3	1
283	3	4	34.6	64.8	.6	--	--	128.8	28.4	1.2
238	4	9	58.9	40.9	.2	--	--	340	126.3	1.7
238	5	14	59.9	40	.1	--	--	354.6	207.5	3.2

TABLE IV. - GAS ANALYSIS SUMMARY - Concluded

Test	Sample	Time after T = 0, min	O_2, percent	N_2, percent	Ar, percent	CO_2, percent	CO, ppm	COF_2, ppm	CF_4, ppm	SiF_4, ppm
338	1	1.25	99.5	.5	--	--	--	64.3	--	≤1
338	2	3.75	99.3	.7	--	--	--	131.5	14.2	1.5
338	3	13	99.2	.8	--	--	--	161.4	33.8	3.6
339	1	5	96.8	1.6	--	1.6	--	2258	837.5	375
240	1	1	61.6	38.3	0.1	--	--	64.1	3.2	<1
240	2	6	61.6	38.3	.1	--	--	98.2	5.8	1.1
242	1	1.5	72	28	--	--	--	--	4.5	5.6
341	No sample									
342	1	.25	99.4	.6	--	--	--	--	--	--
342	2	.66	98.3	1.7	--	--	--	44.6	<1	2.6
342	3	1.15	97.3	2.7	--	--	--	111.9	7.4	5.2
342	4	2	99.7	.3	--	--	--	424.5	92.4	6.6
342	5	5.75	99.4	.5	--	.1	--	701.9	200	9.6

TABLE V. - THE BP 1224 TEST-PROGRAM SURVEY

Test series	Atmosphere	Number of tests		
		Total	Fire self-extinguished	Termination required
100	100 percent oxygen at 6.2 psia	37	34	3
200	60 percent oxygen/ 40 percent nitrogen at 16.2 psia	34	30	4
300	100 percent oxygen at 16.2 psia	30	15	15

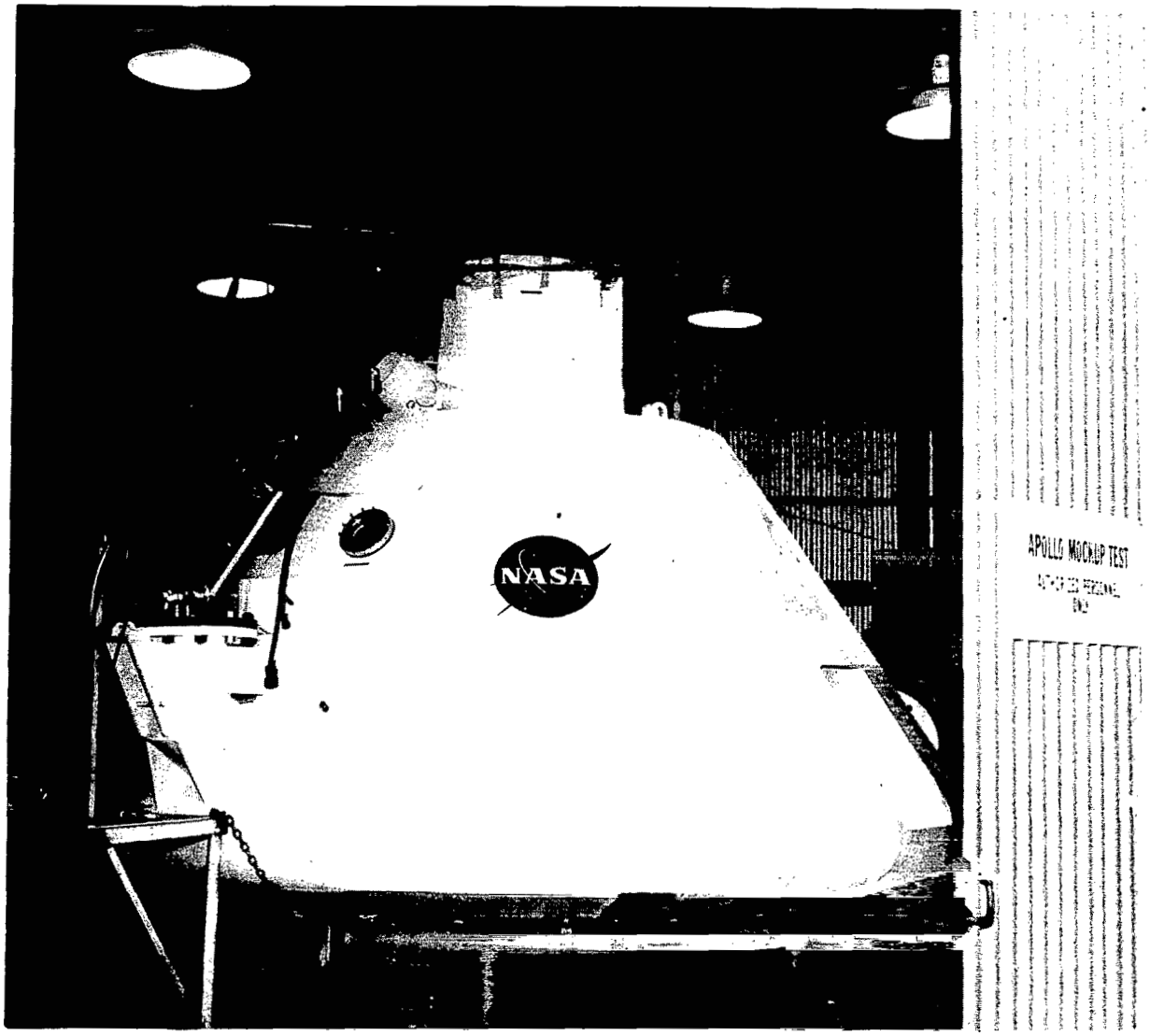
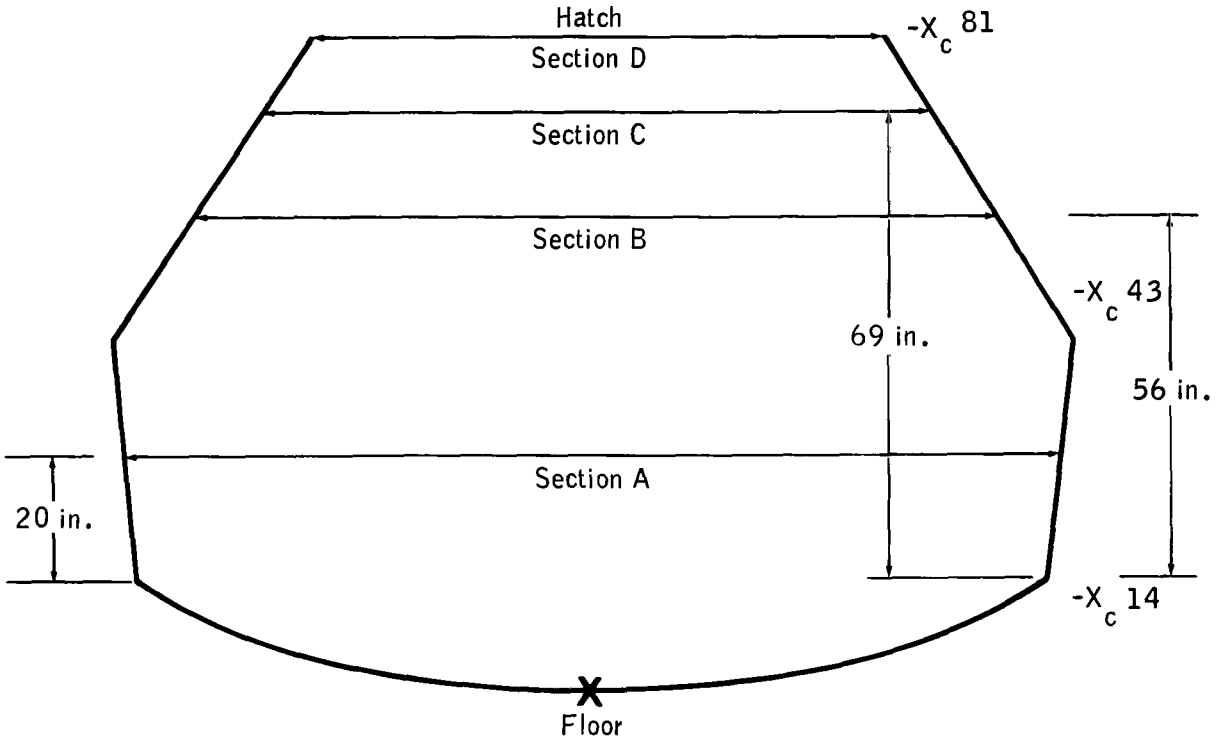


Figure 1. - Exterior view of BP 1224.



Note: Location of sensing elements in each section is shown in figure 3

Figure 2. - Front elevation of mockup test article, showing sensor location sections.

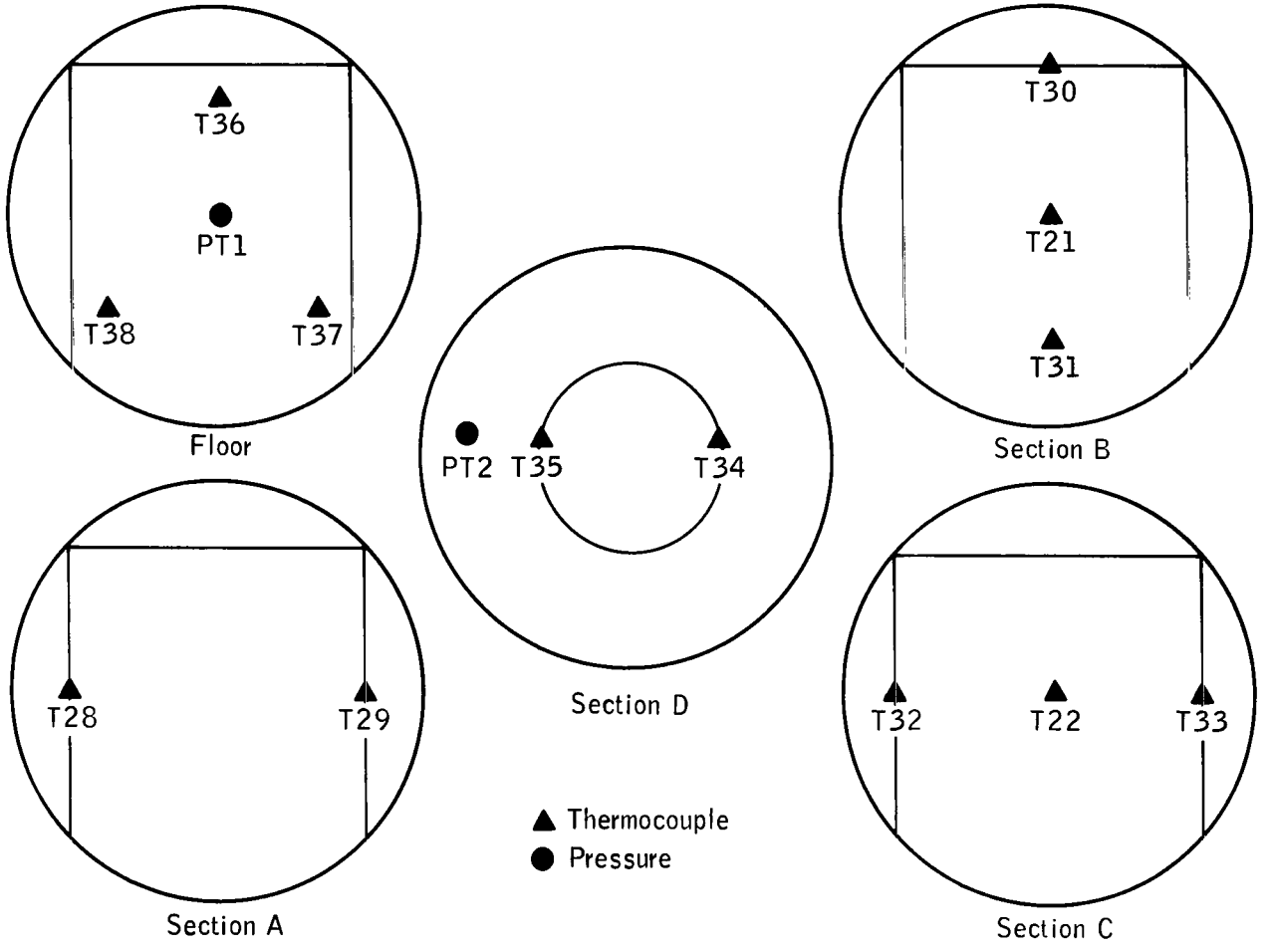


Figure 3. - Location of sensing elements on mockup sections.

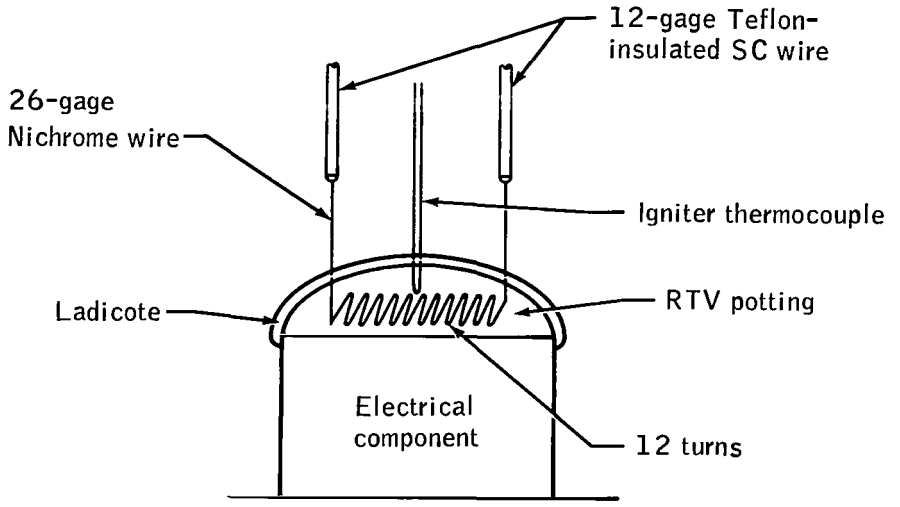


Figure 4. - Internal (hidden) igniter configuration.

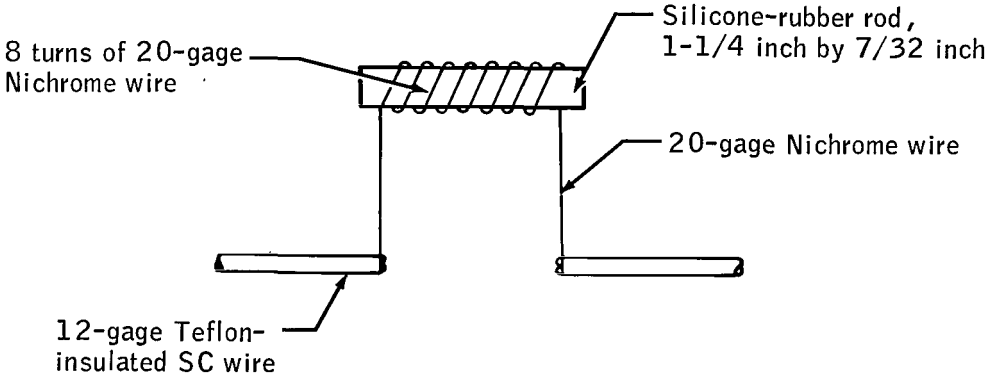


Figure 5. - External igniter configuration.

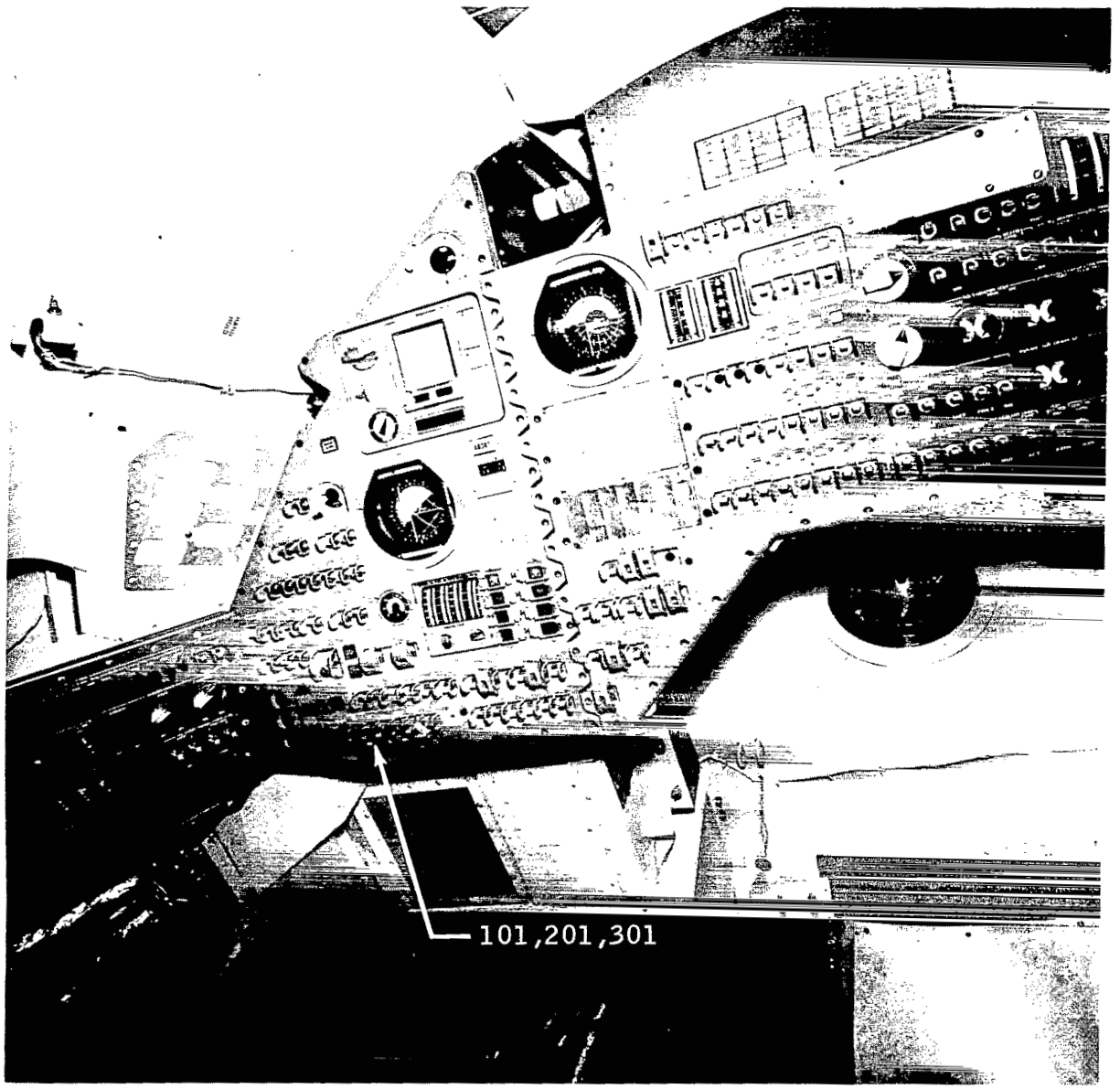


Figure 6. - Igniter locations on MDC panel 1 (tests 101, 201, and 301).

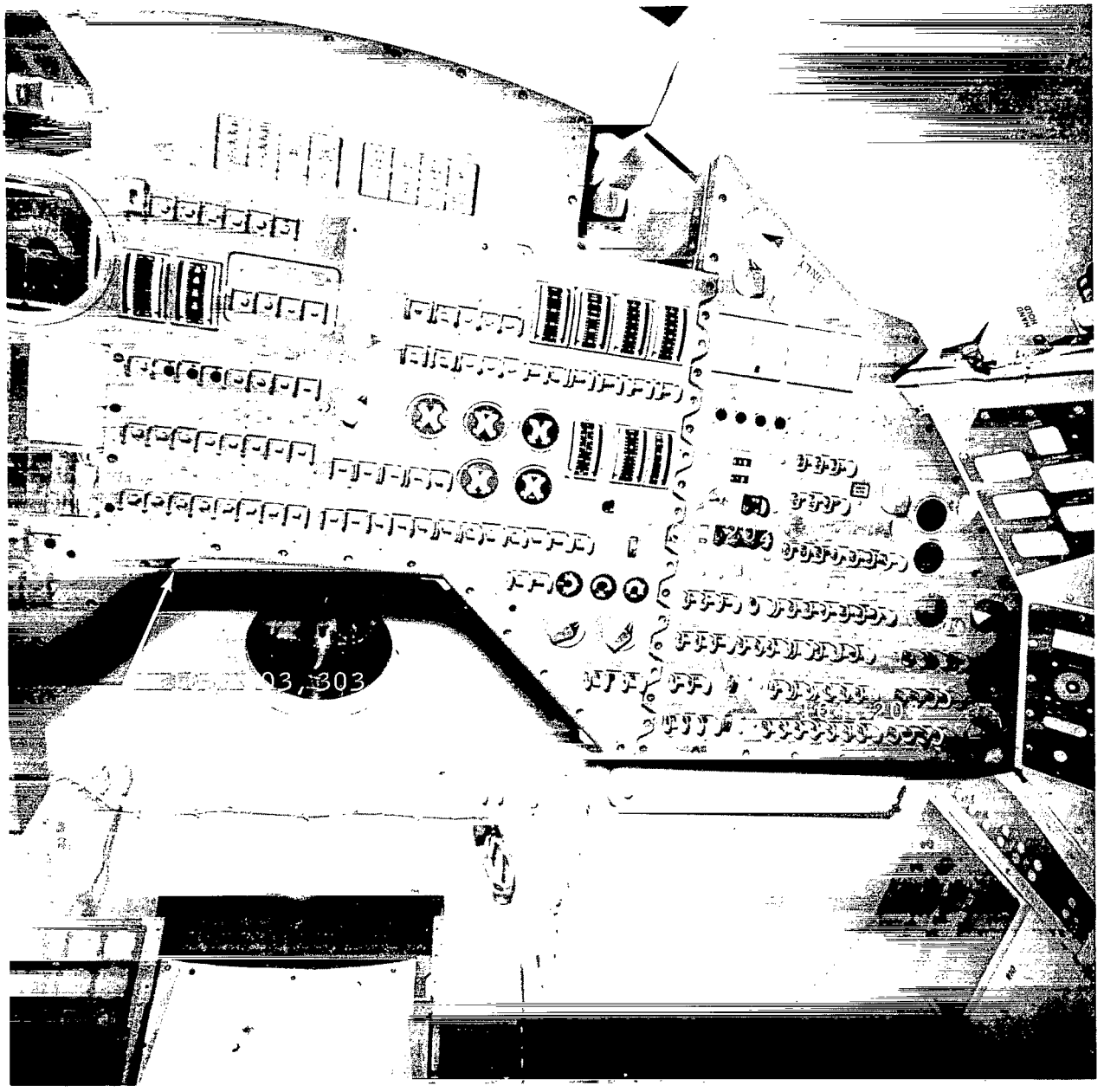


Figure 7. - Igniter locations on MDC panels 2 and 3 (tests 102, 202, 302, 103, 203, 303, 104, and 204).

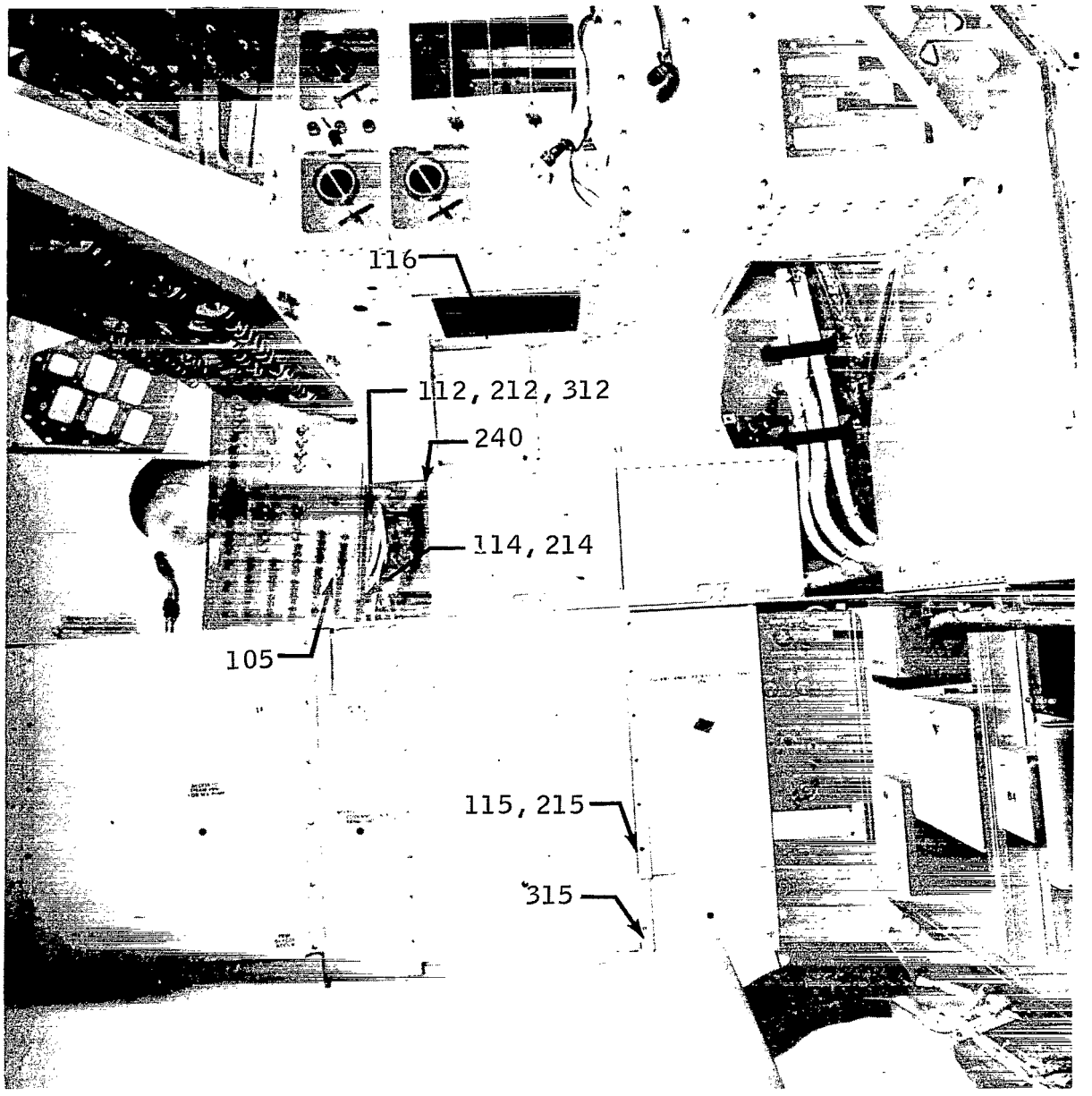


Figure 8. - Igniter locations in LHEB (tests 105, 112, 212, 312, 114, 214, 115, 215, 315, 116, and 240).

Figure 9. - Igniter locations in RHEB (tests 106, 206, 306, 107, 207, 307, 108, 308, 109, 309, 124, 224, 324, 125, 225, 325, 126, 226, 326, 127, 128, 228, 328, 129, 229, 330, 131, 321, 331, 138, 238, and 338).

Figure 10. - Igniter locations in rear access area to MDC (tests 110, 210, 310, 111, and 211).

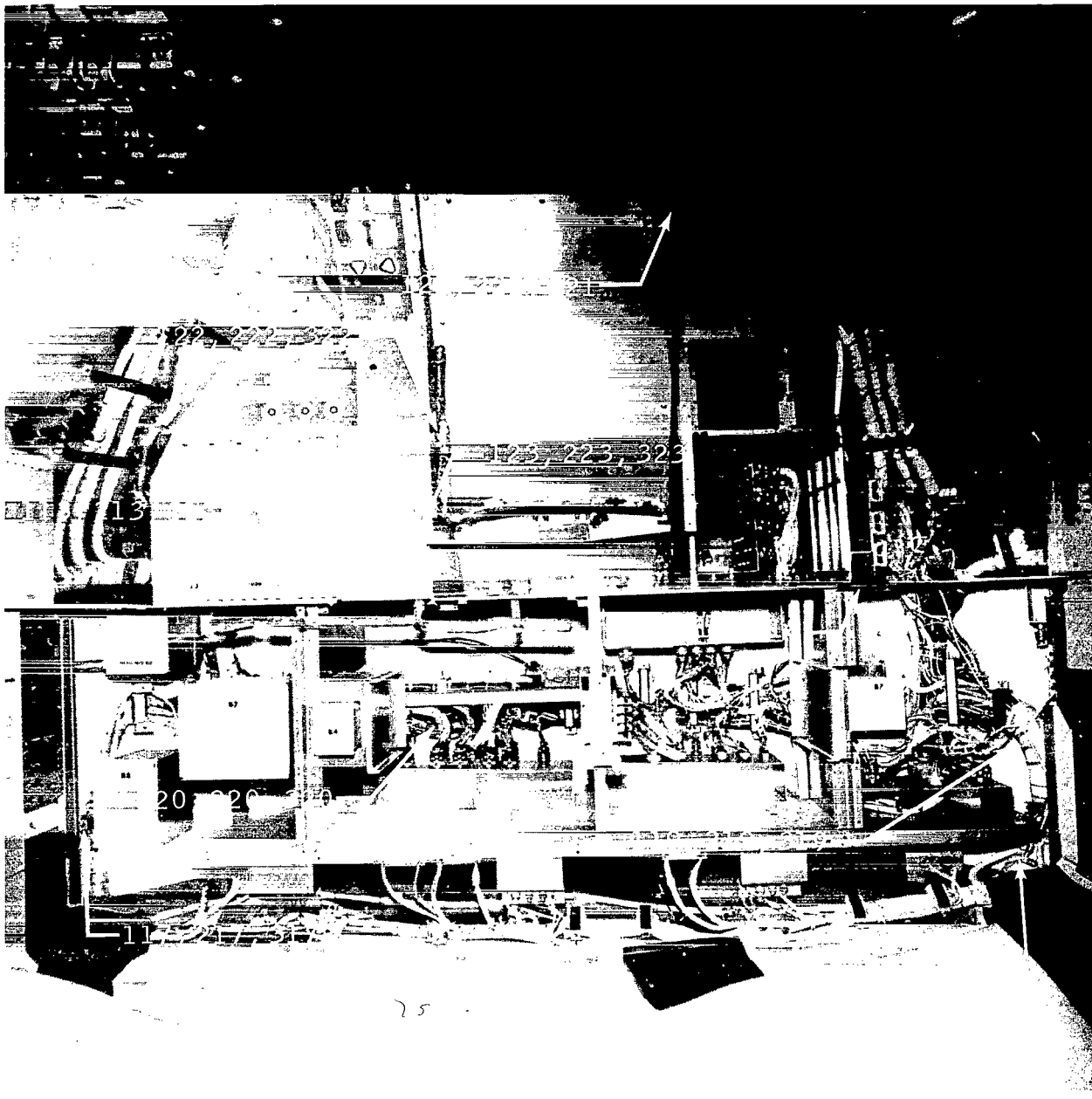


Figure 11. - Igniter locations in LEB (tests 113, 213, 313, 117, 217, 317, 118, 218, 318, 119, 219, 319, 120, 220, 320, 121, 221, 321, 122, 222, 322, 123, 223, 323, 130, 230, and 330).

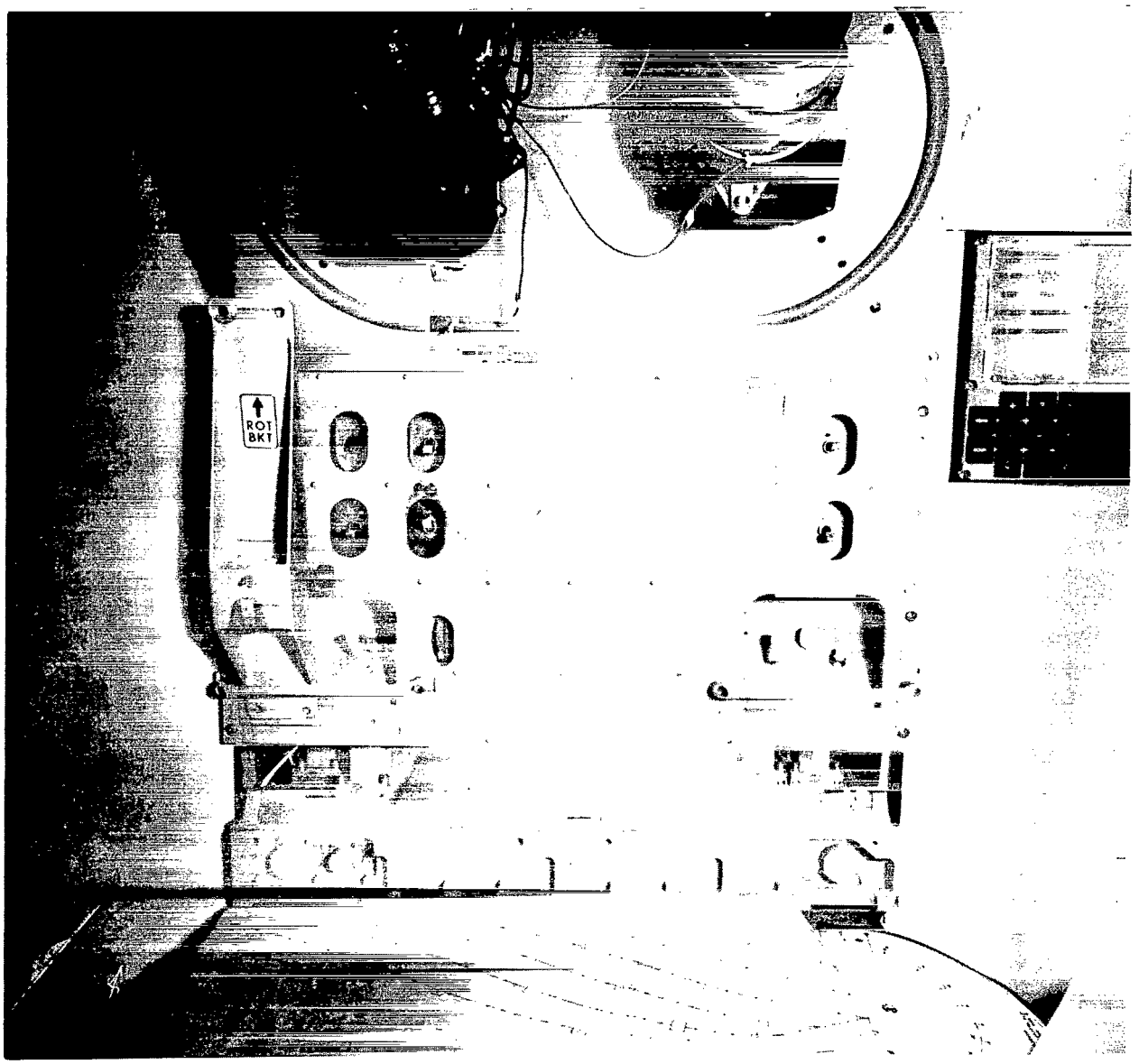


Figure 12. - Location of external igniter in G&N area (test 136).

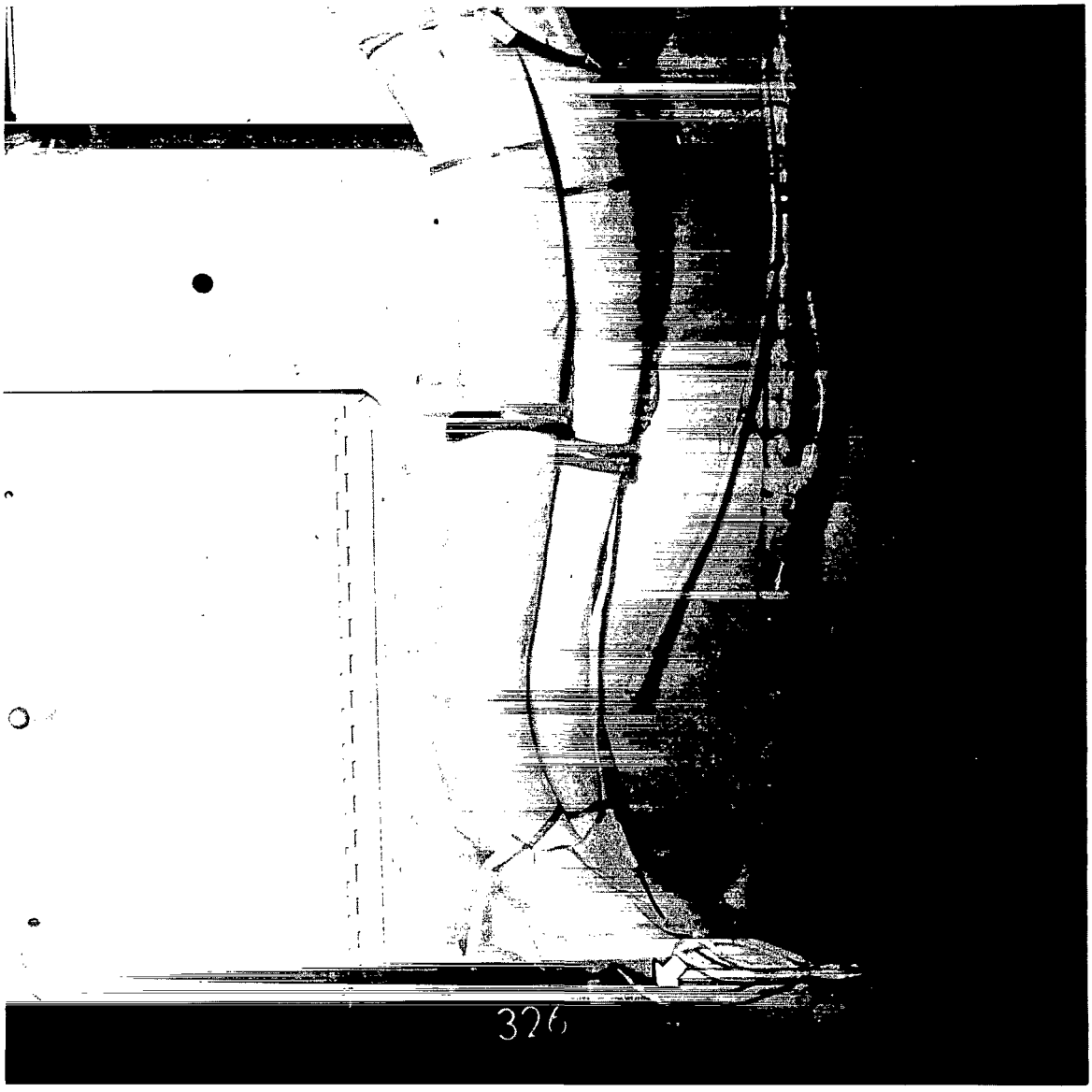


Figure 13. - Pretest igniter location (test 326).

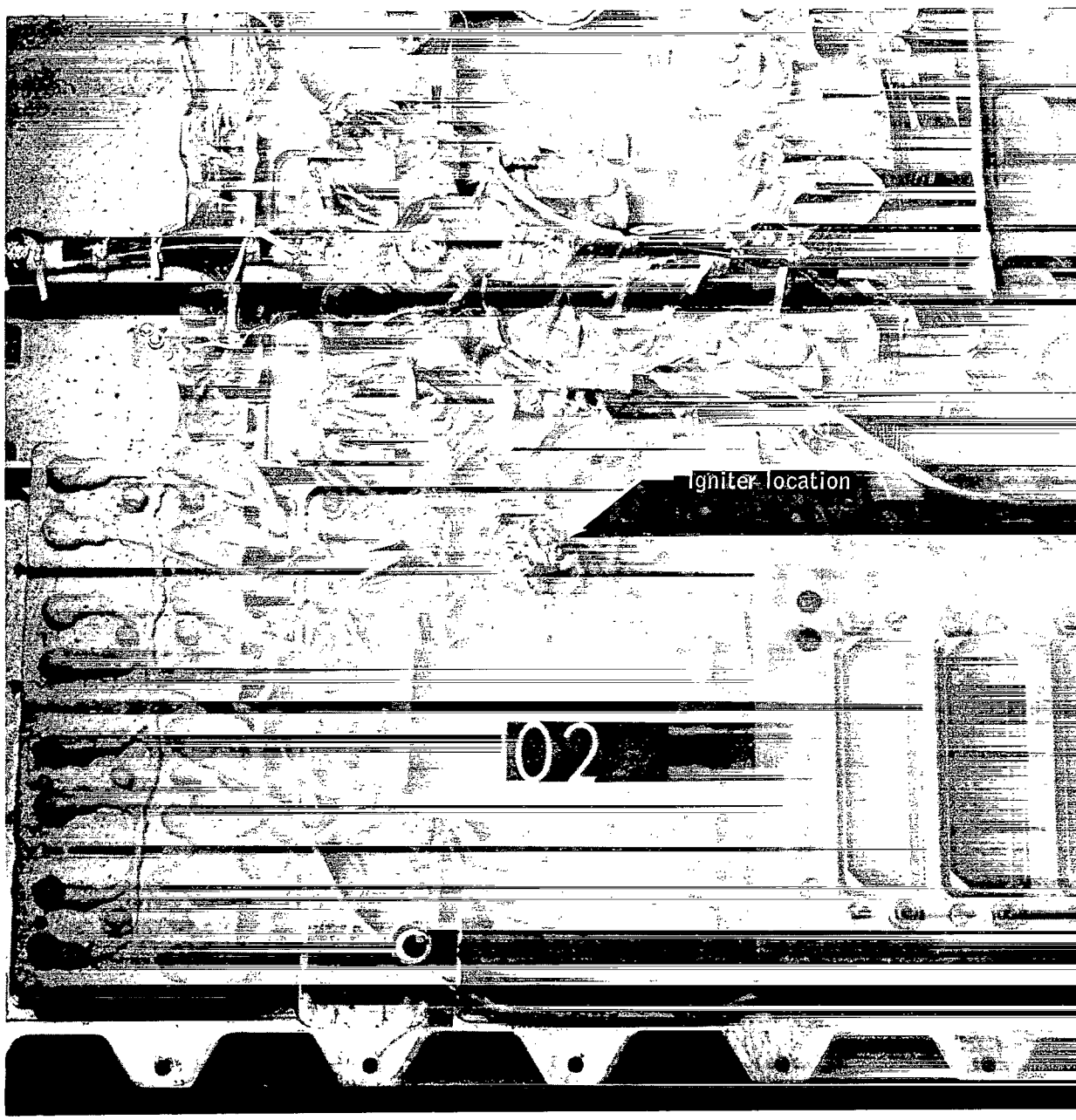
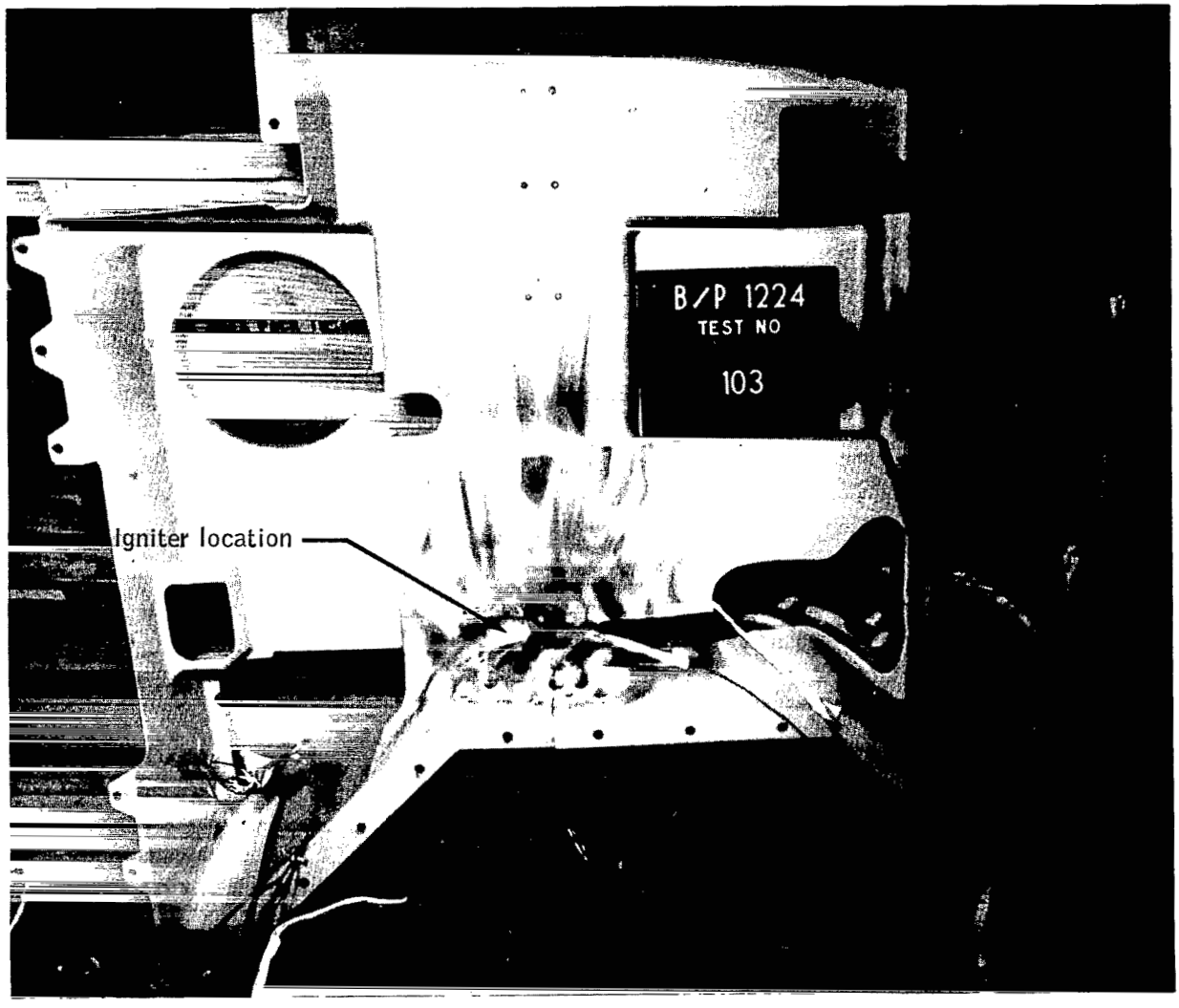
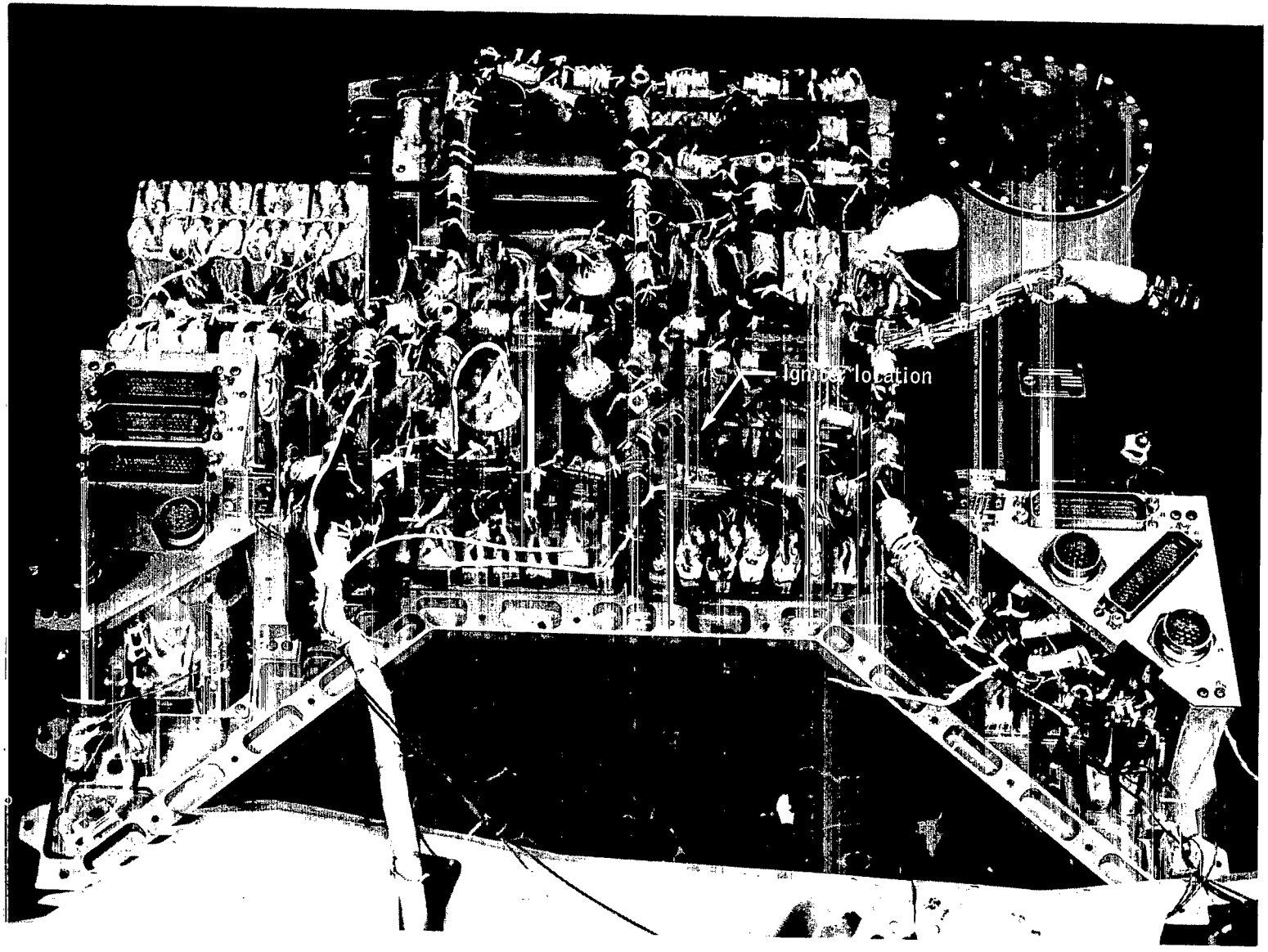


Figure 14. - Post-test damage (test 102).



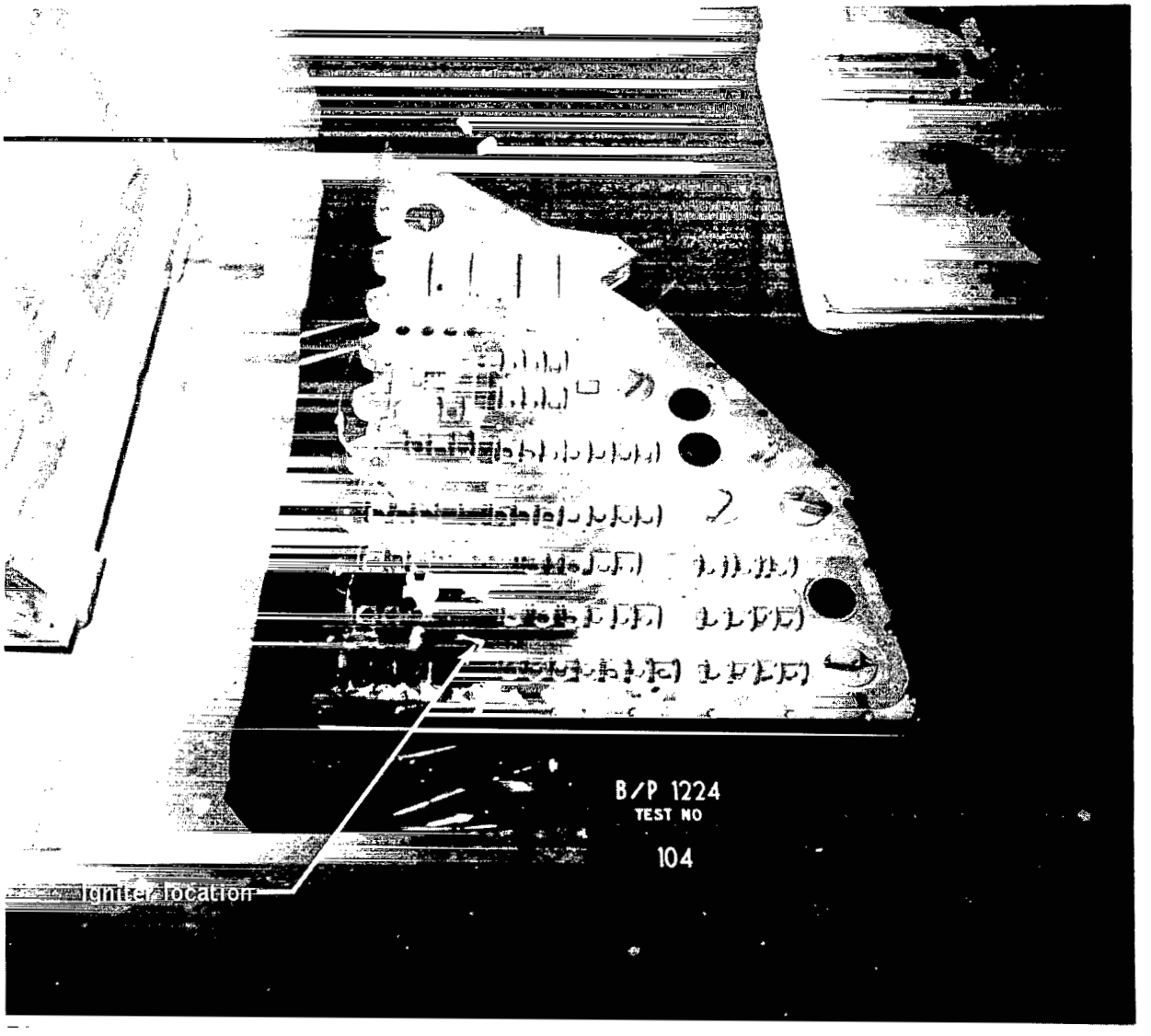
(a) View 1.

Figure 15. - Post-test damage (test 103).



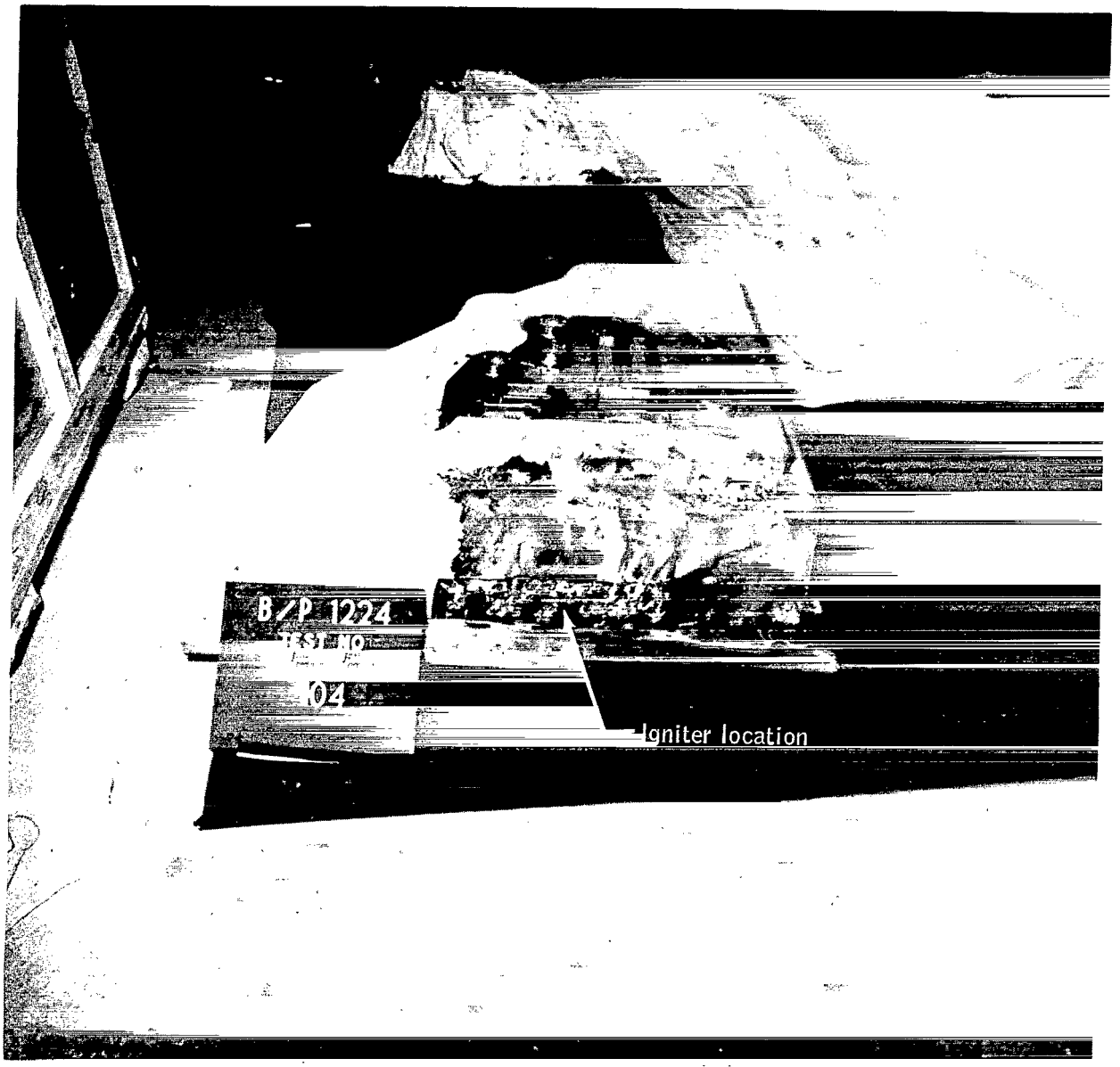
(b) View 2.

Figure 15. - Concluded.



(a) View 1.

Figure 16. - Post-test damage (test 104).



(b) View 2.

Figure 16. - Continued.

(c) View 3.

Figure 16. - Concluded.

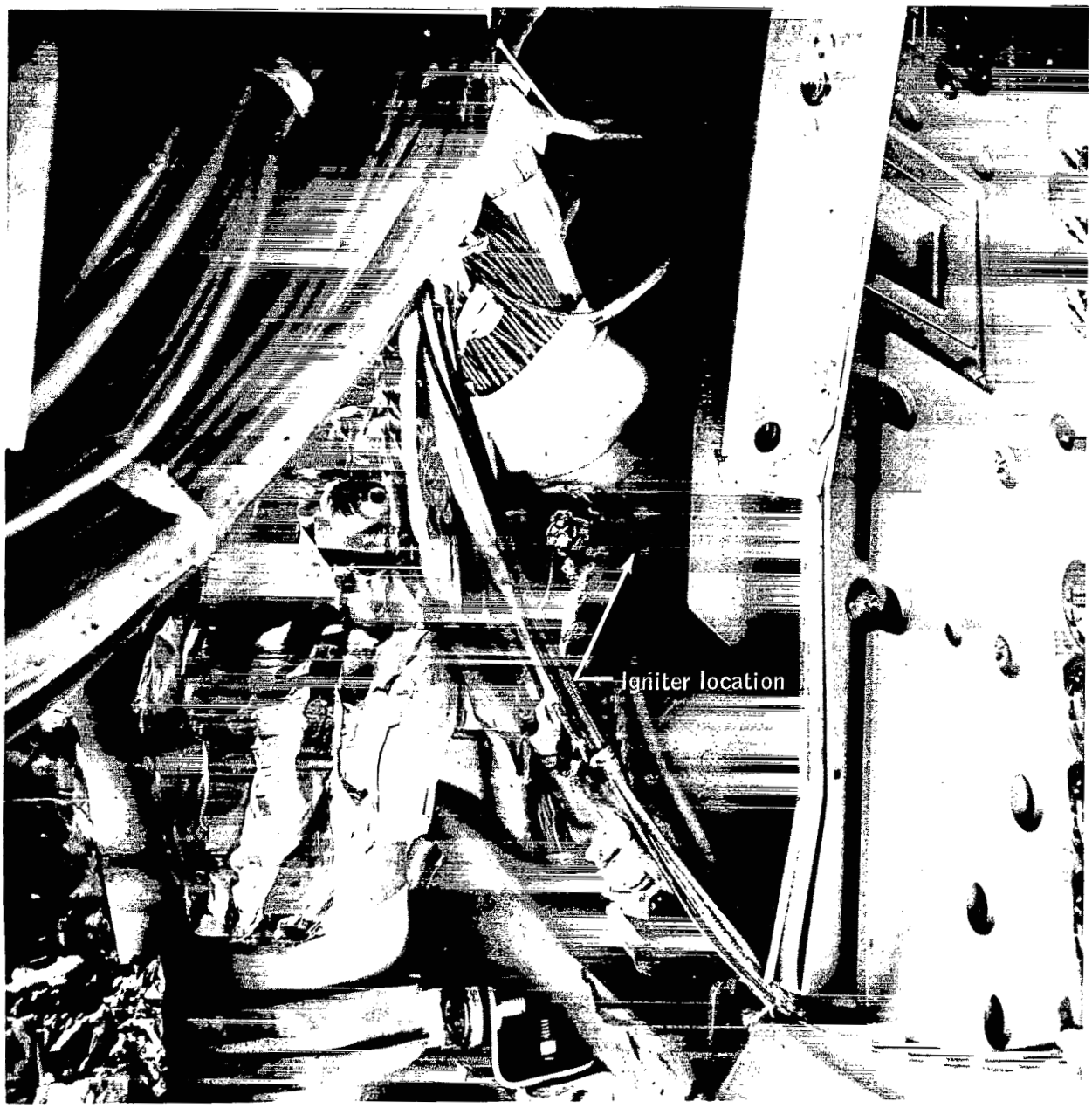


Figure 17. - Post-test damage (test 112).

Figure 18. - Post-test damage (test 115).

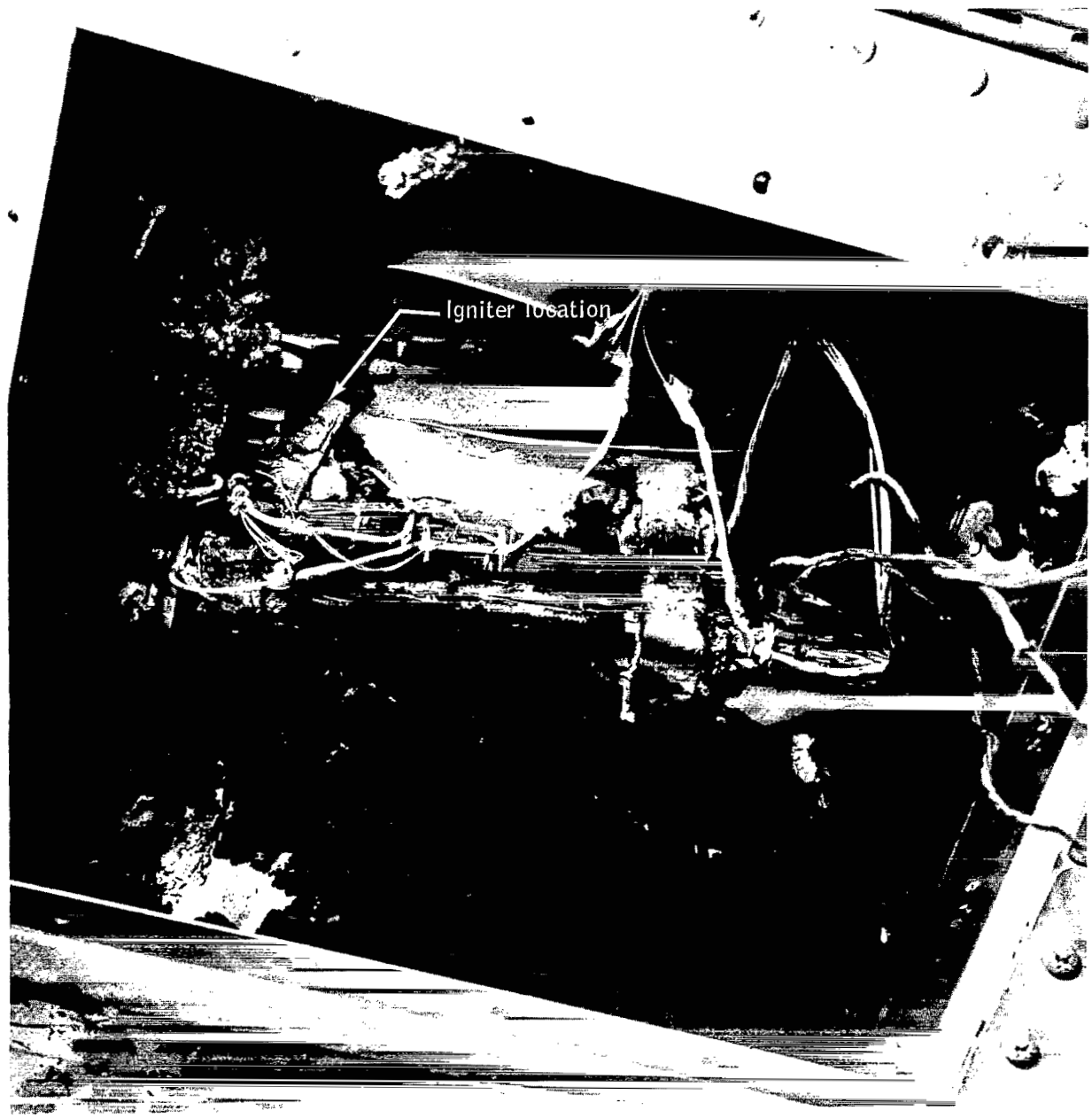


Figure 19. - Post-test damage (test 116).

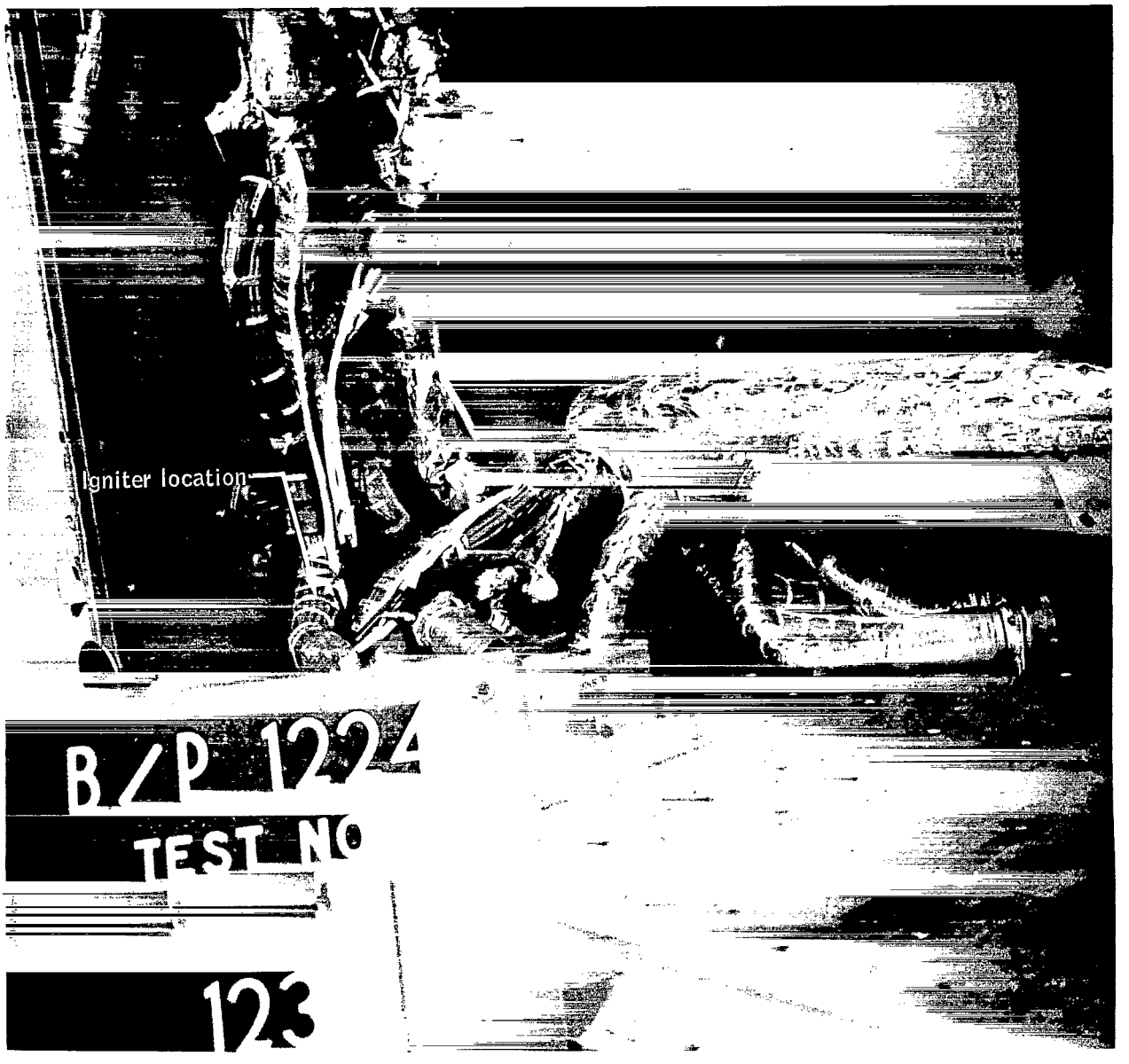


Figure 20. - Post-test damage (test 123).

Figure 21. - Post-test damage (test 125).

Figure 22. - Post-test damage (test 129).

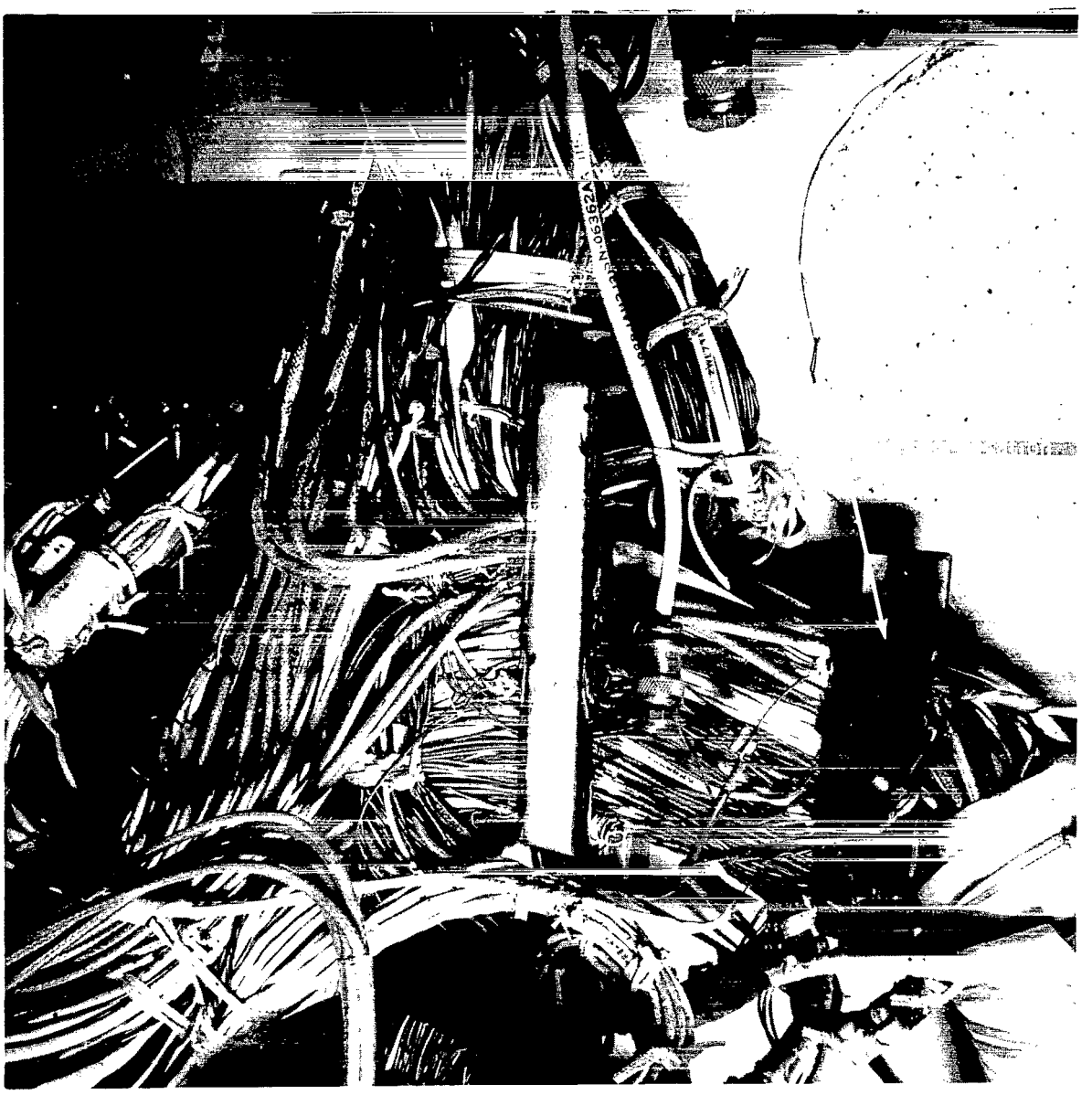


Figure 23. - Post-test damage (test 135).

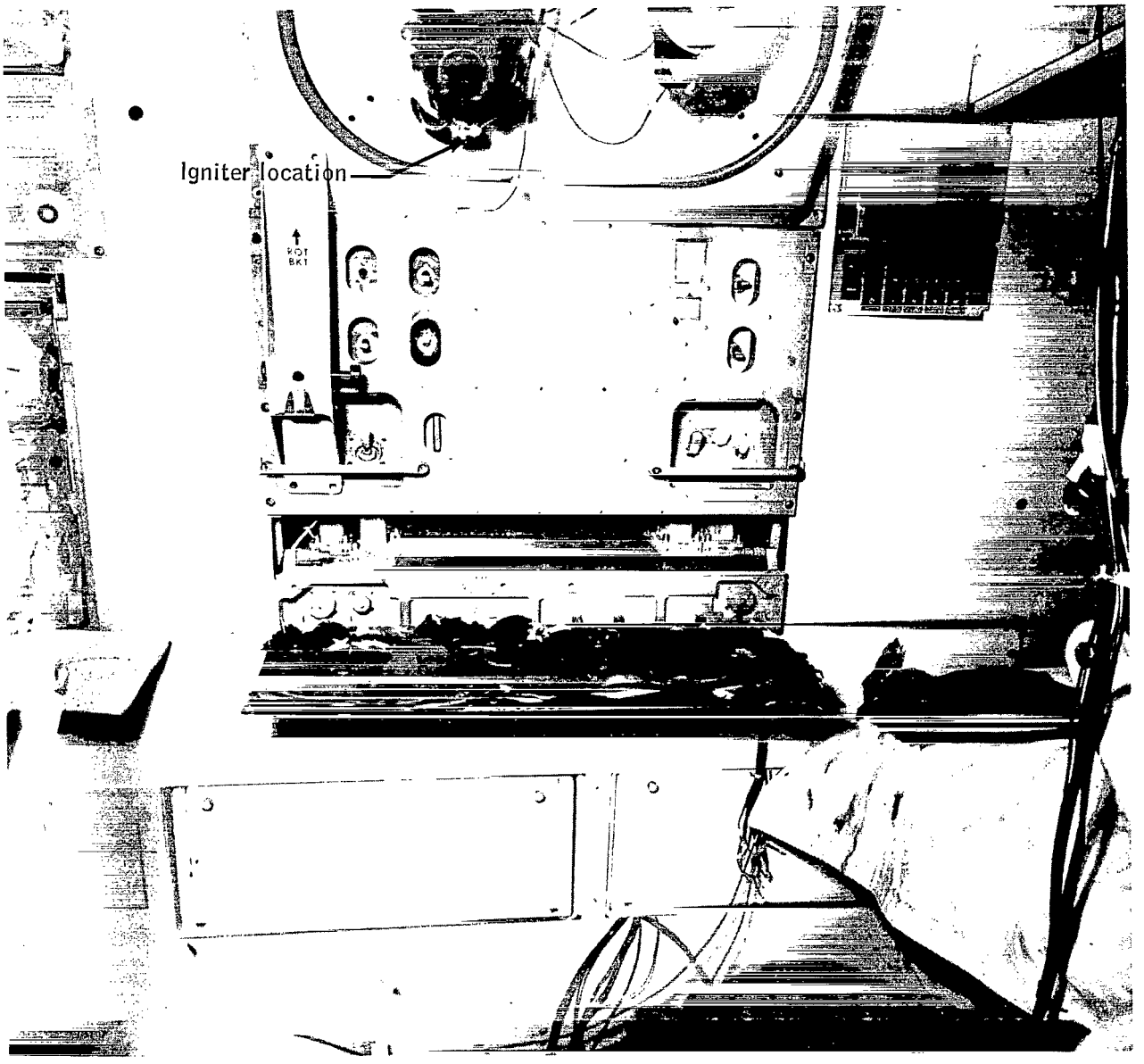


Figure 24. - Post-test damage (test 136).

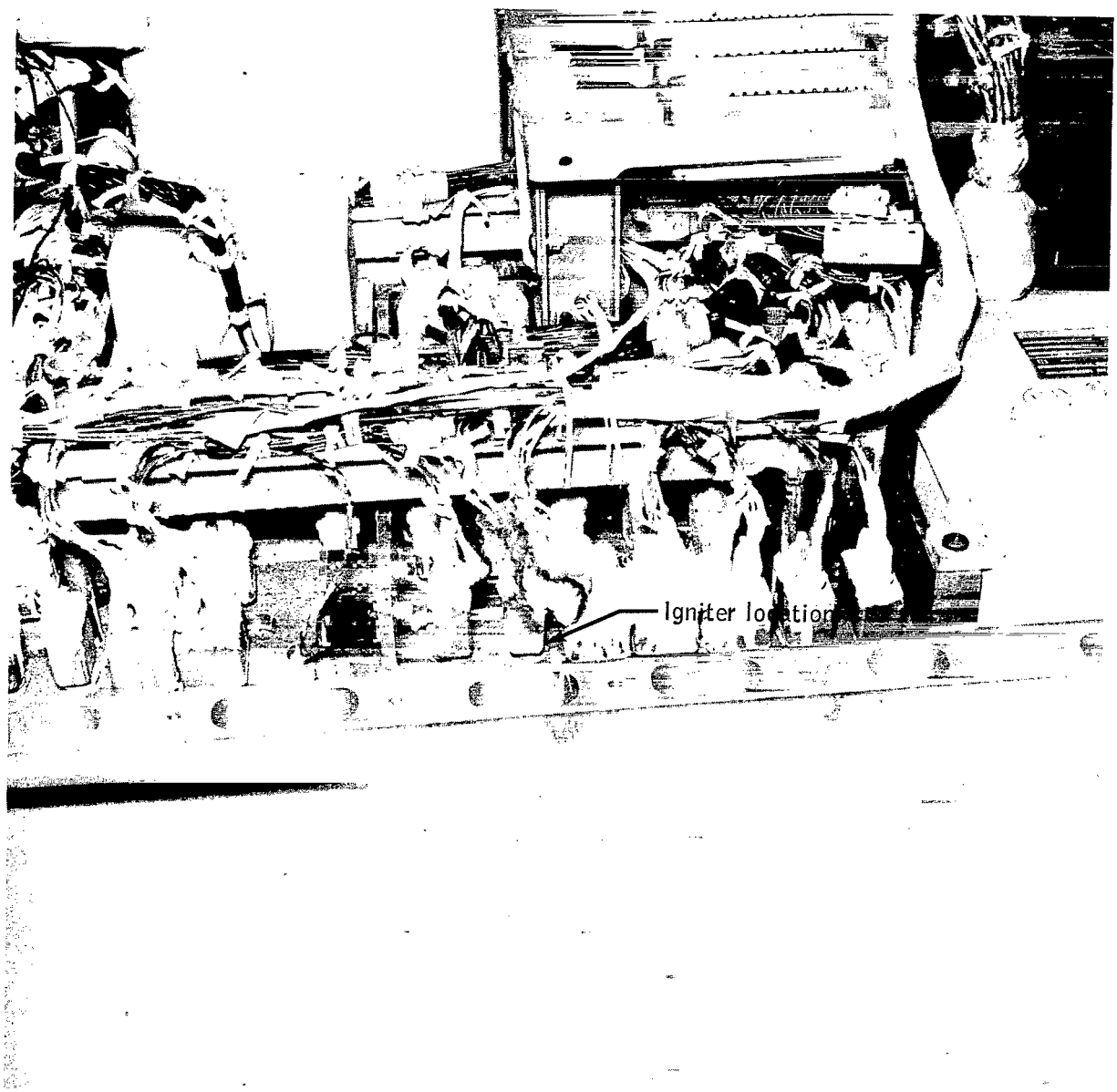


Figure 25. - Post-test damage (test 201).

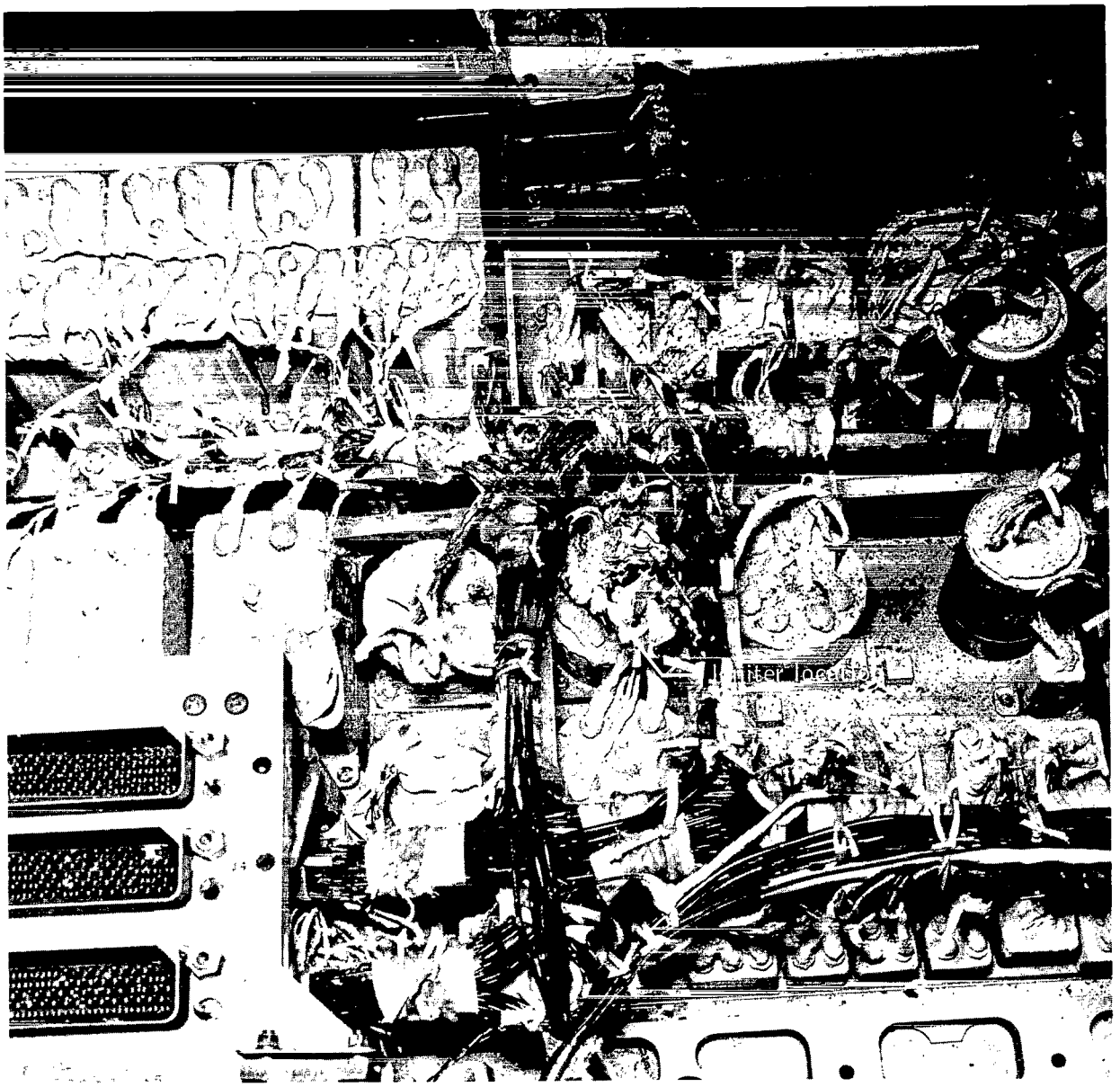


Figure 26. - Post-test damage (test 202).

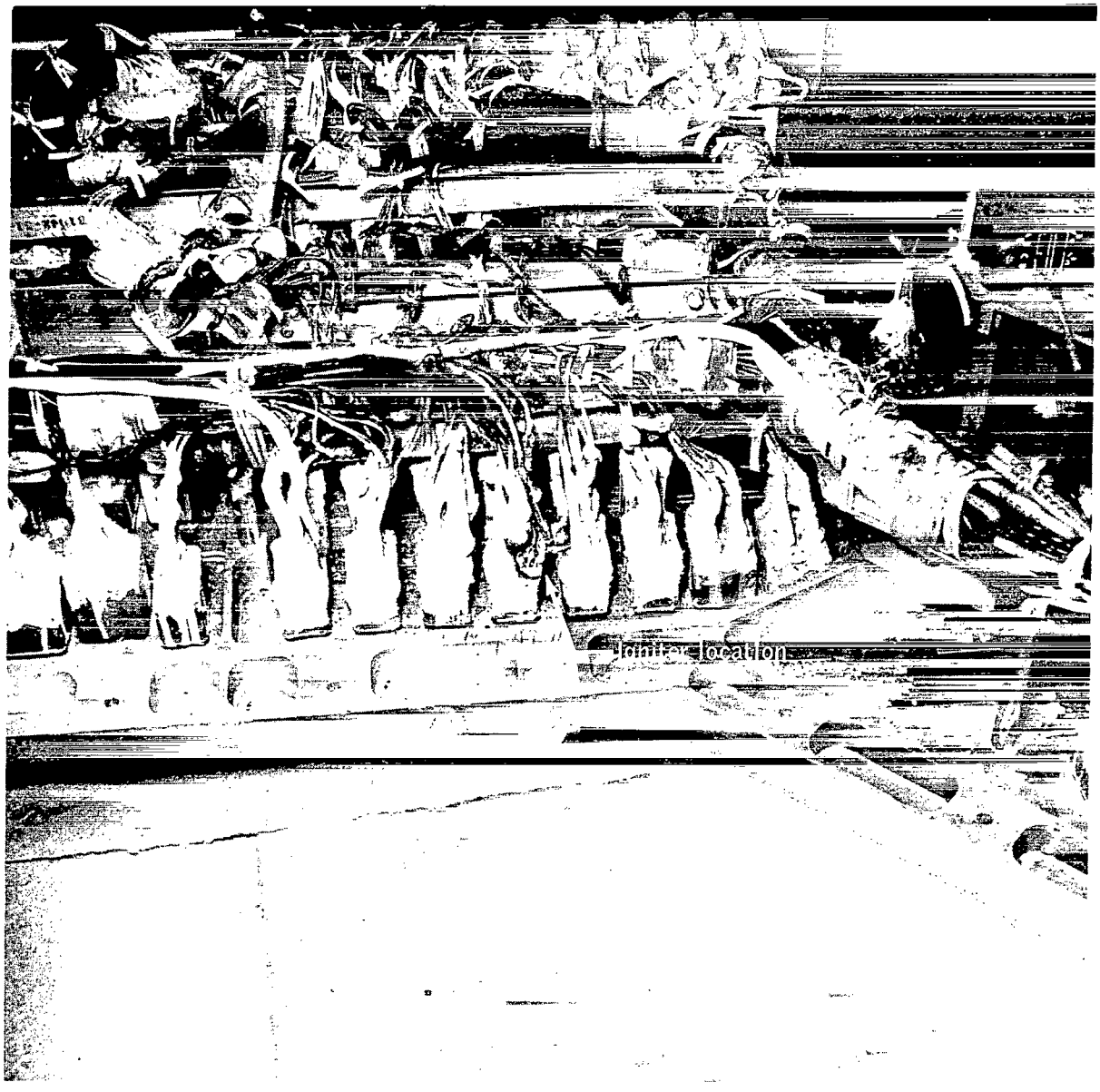


Figure 27. - Post-test damage (test 203).

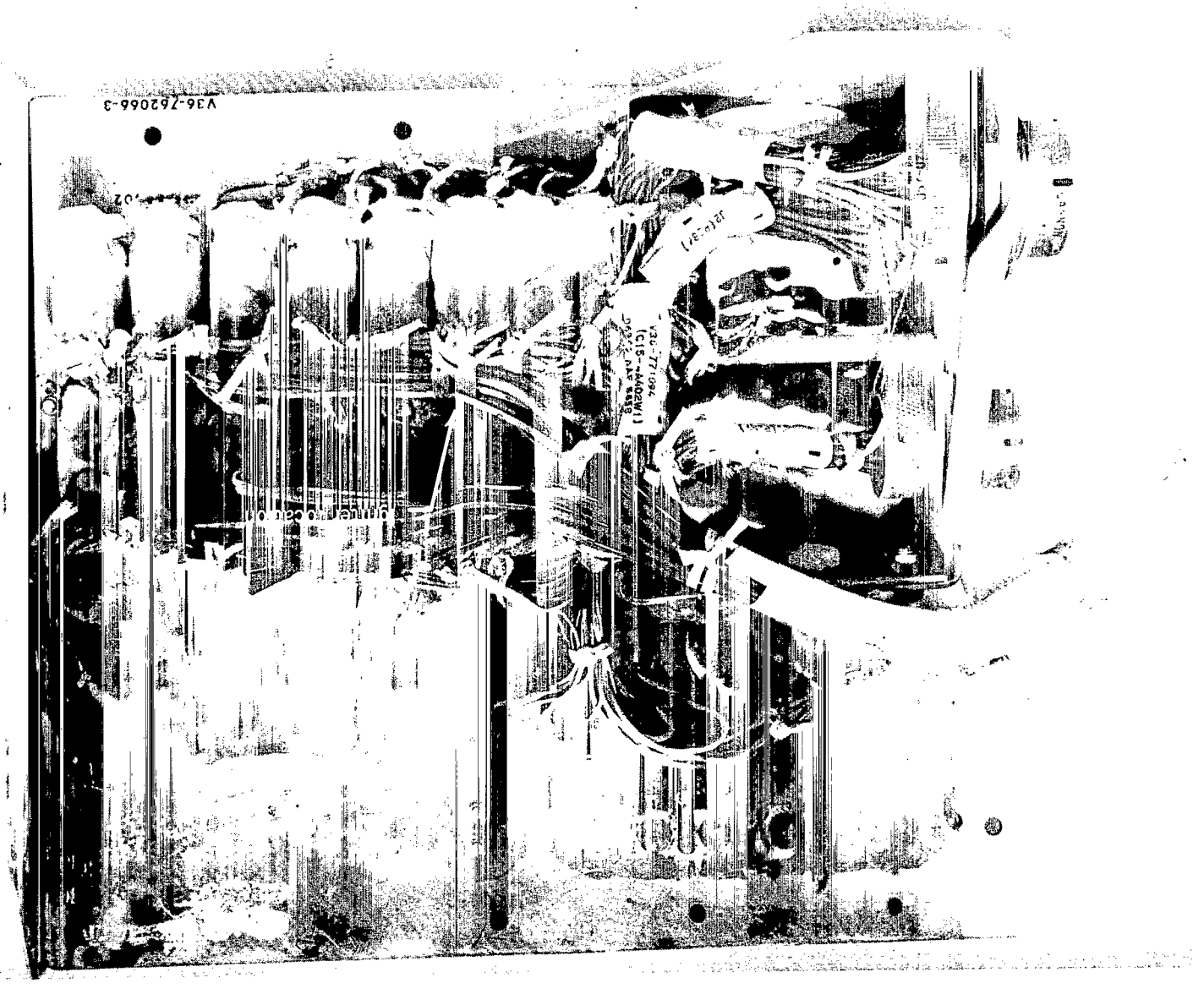


Figure 28. - Post-test damage (test 206).

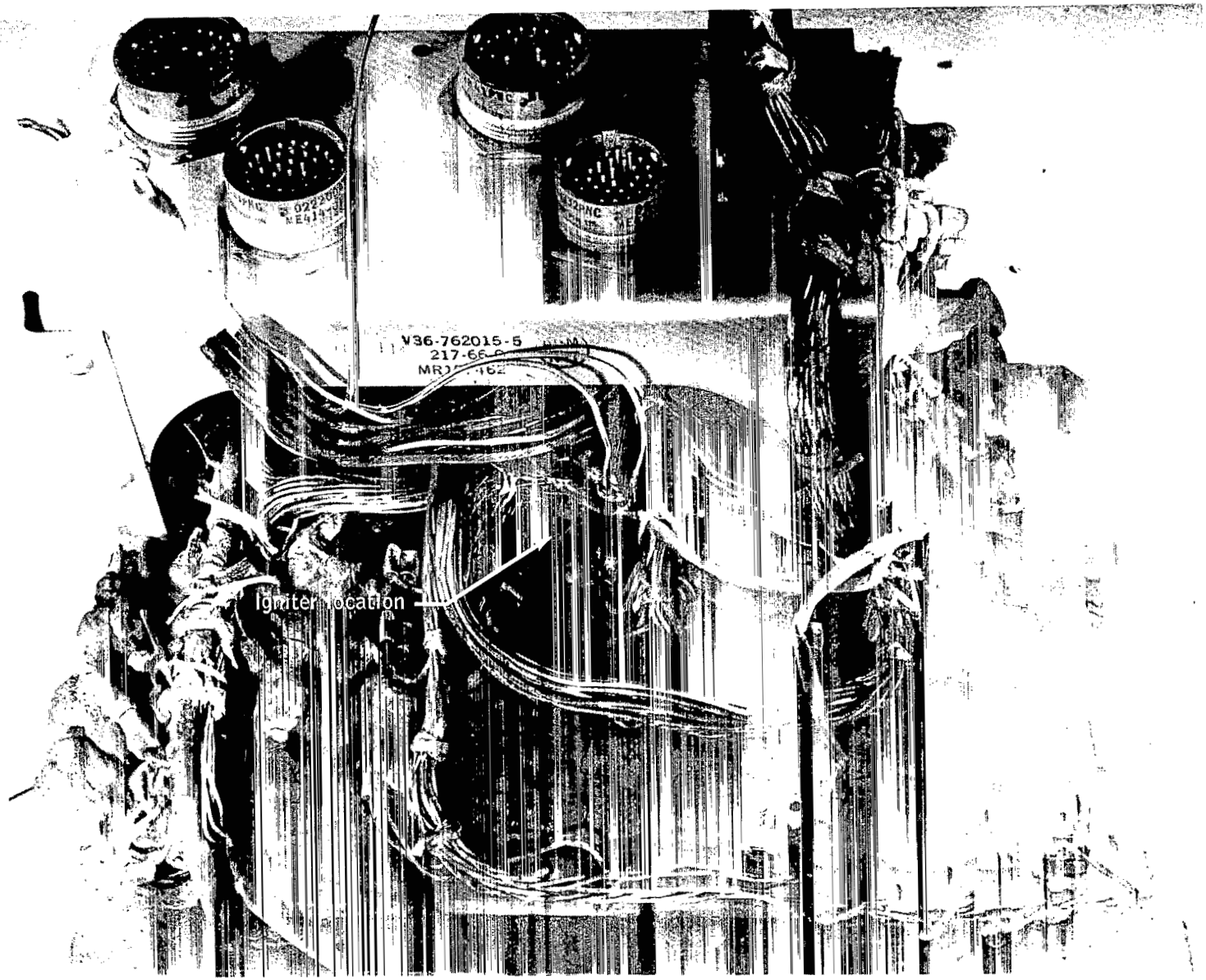


Figure 29. - Post-test damage (test 207).

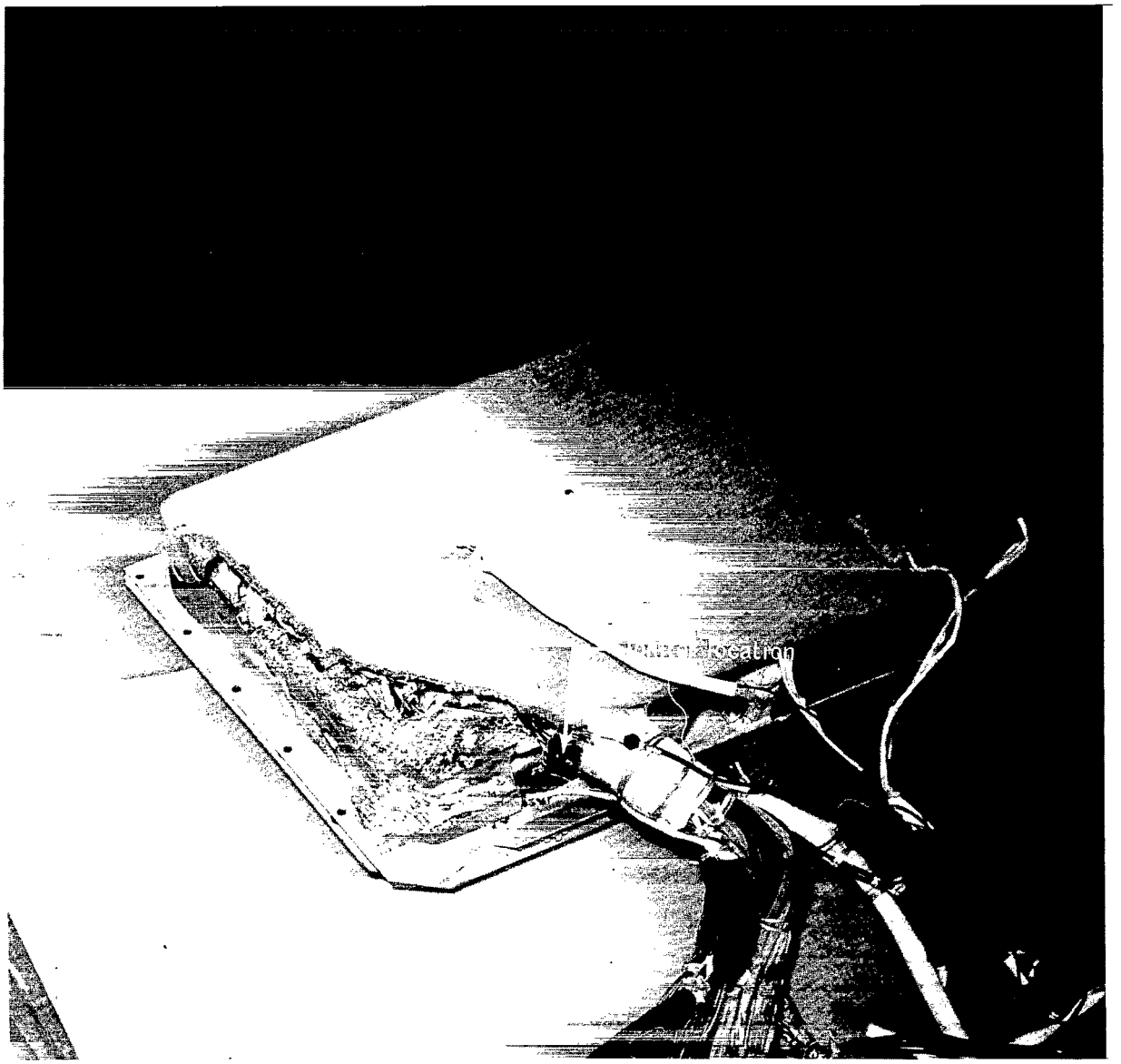


Figure 30. - Post-test damage (test 212).

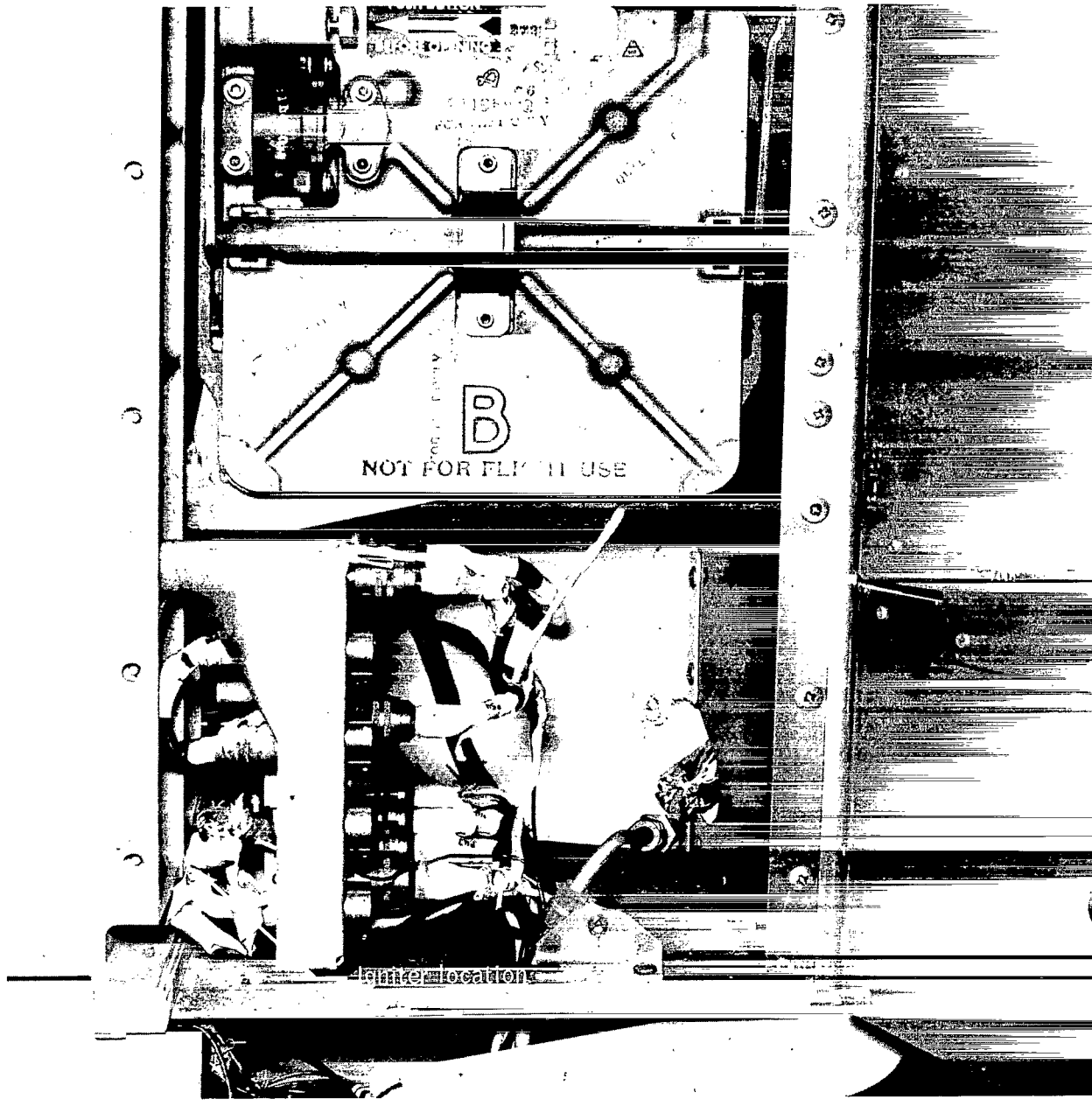


Figure 31. - Post-test damage (test 215).

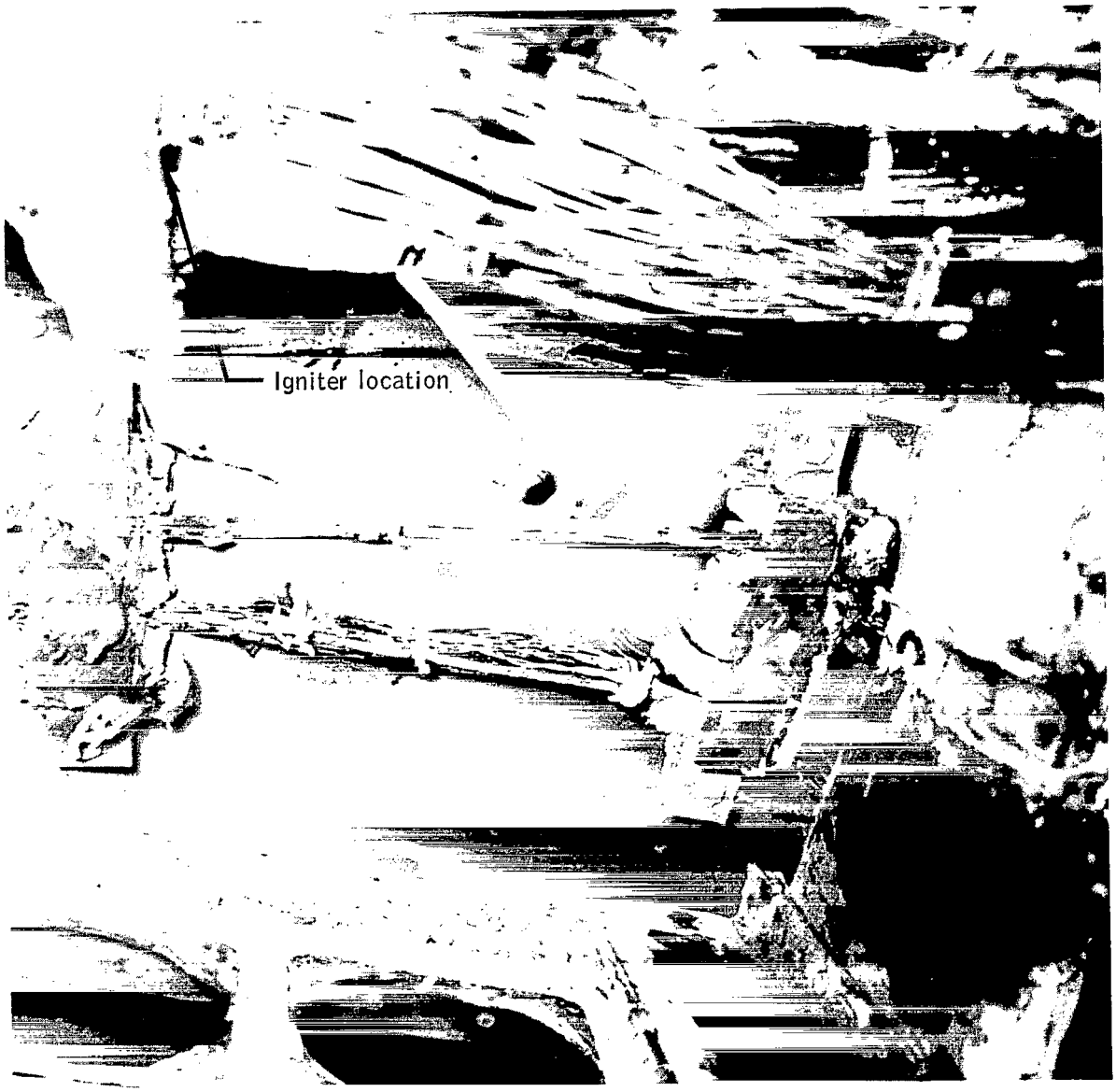


Figure 32. - Post-test damage (test 216).

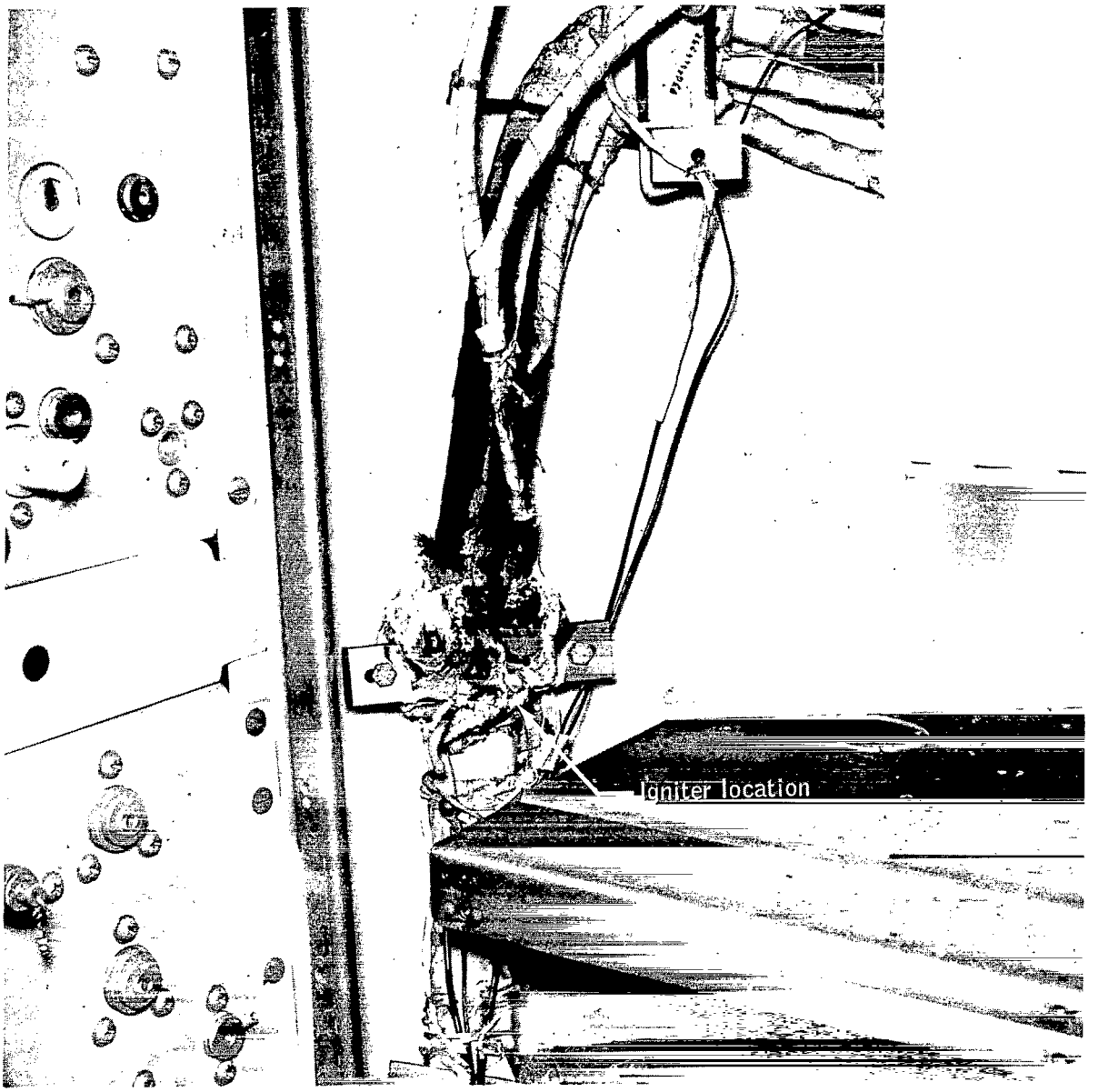


Figure 33. - Post-test damage (test 217).

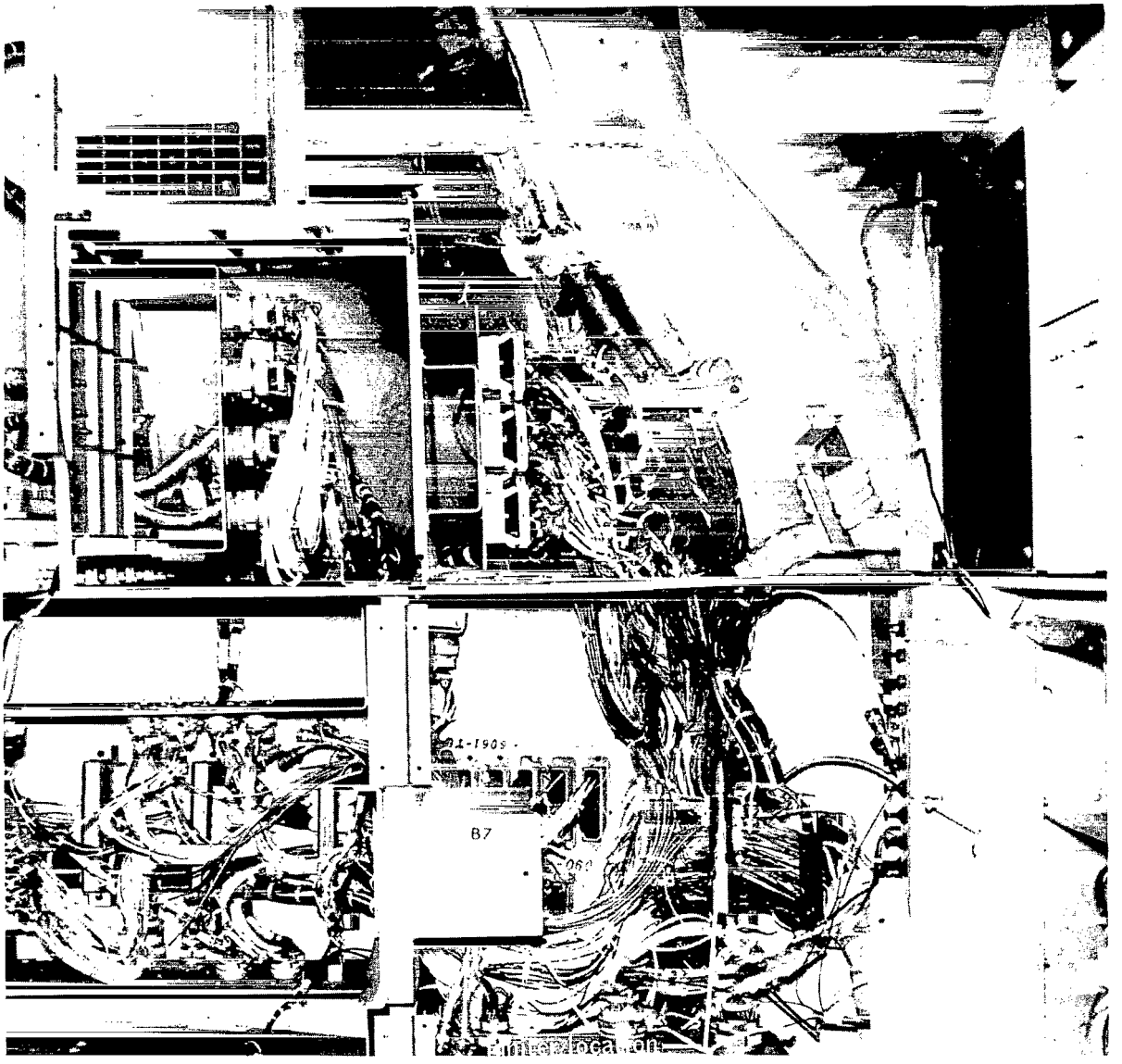


Figure 34. - Post-test damage (test 219).

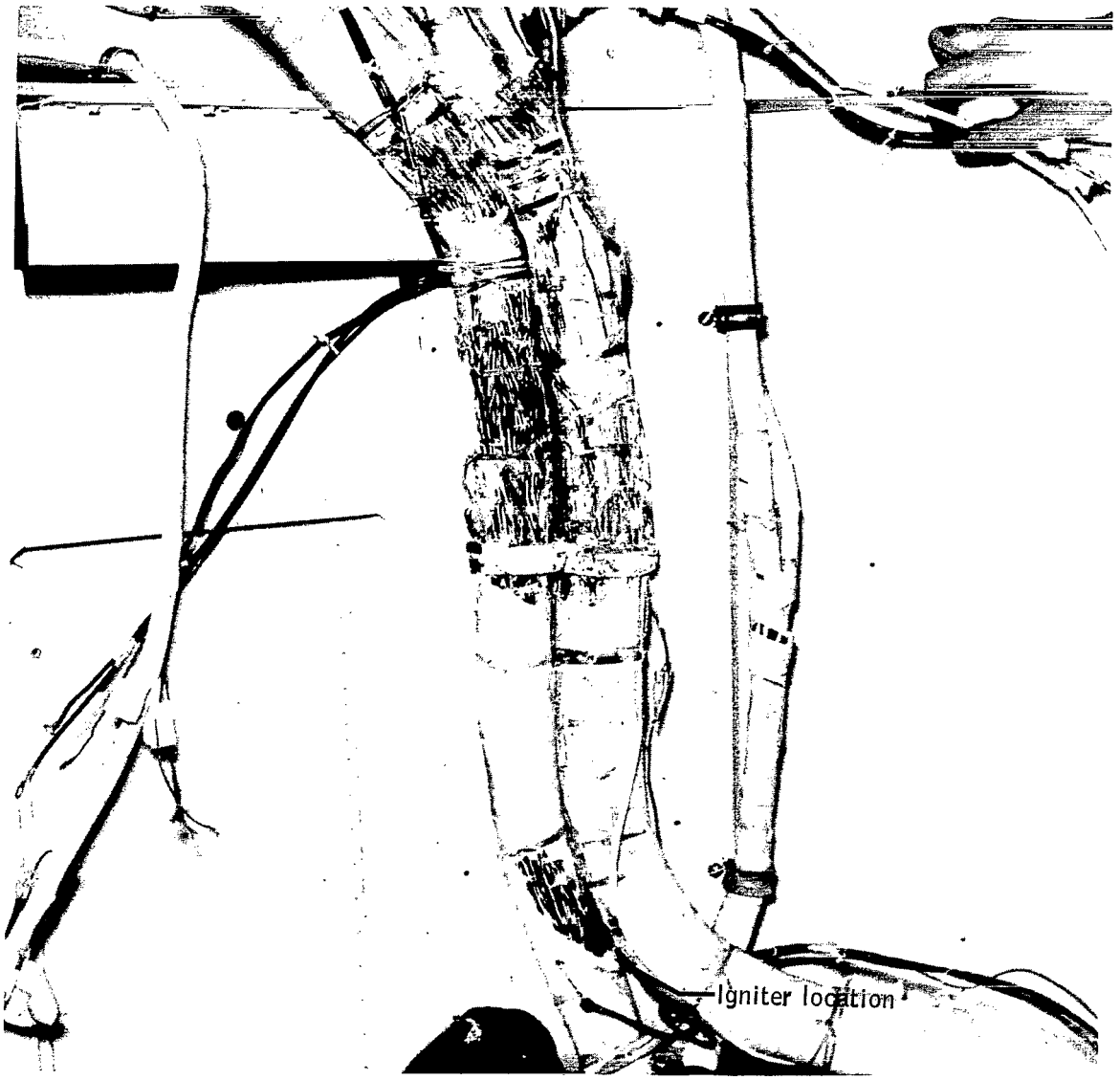


Figure 35. - Post-test damage (test 226).

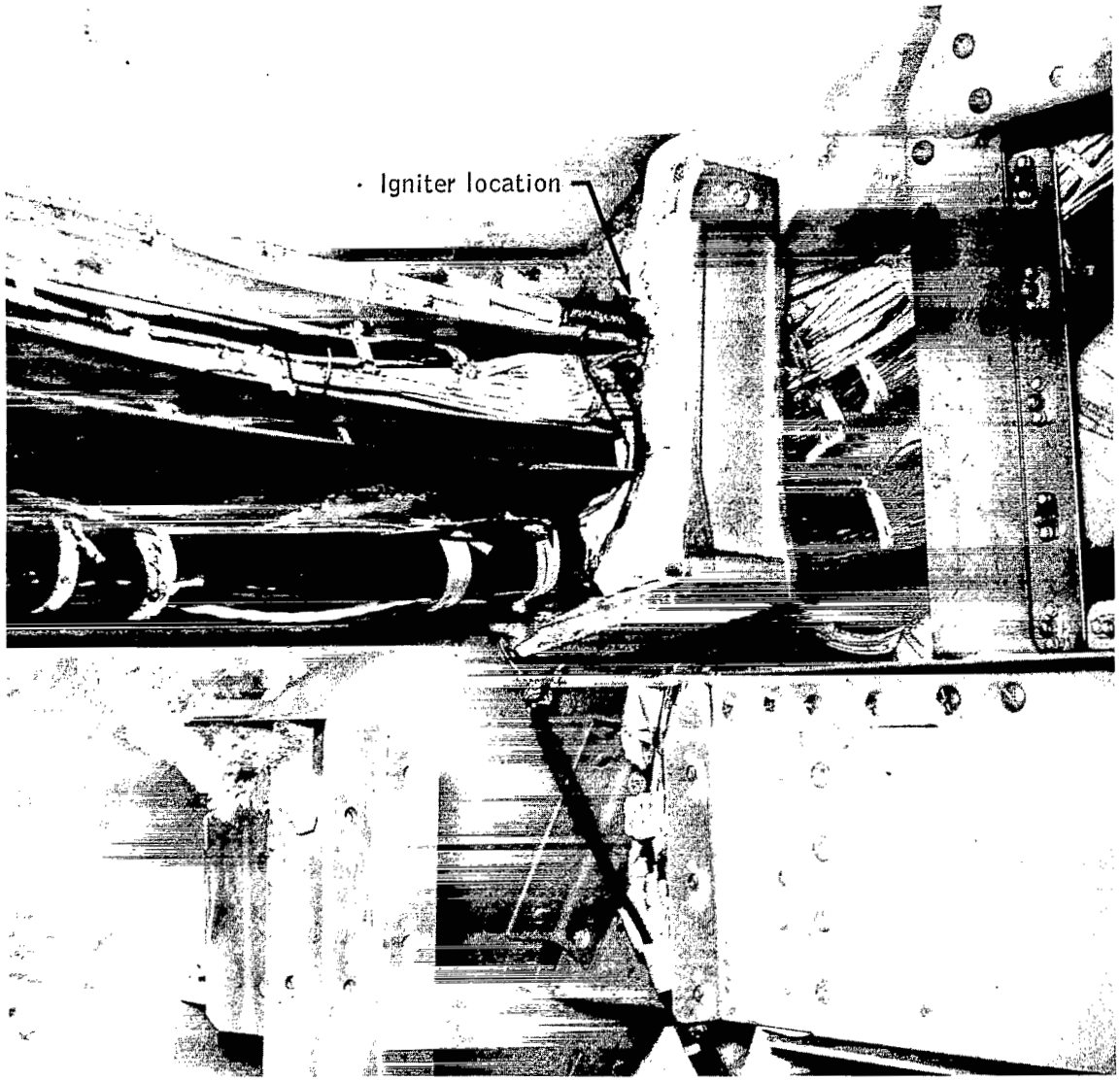


Figure 36. - Post-test damage (test 228).

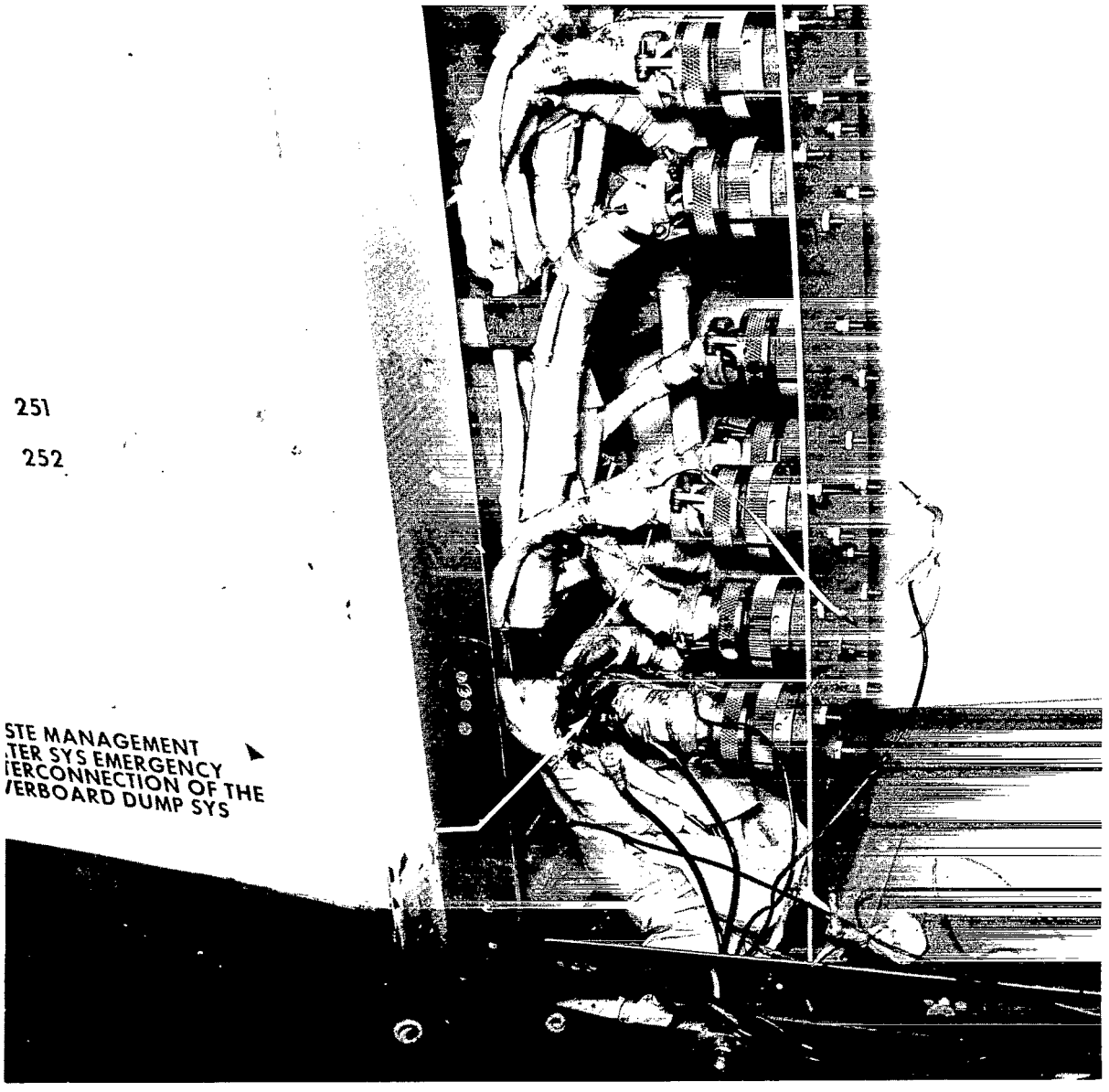


Figure 37. - Post-test damage (test 229).

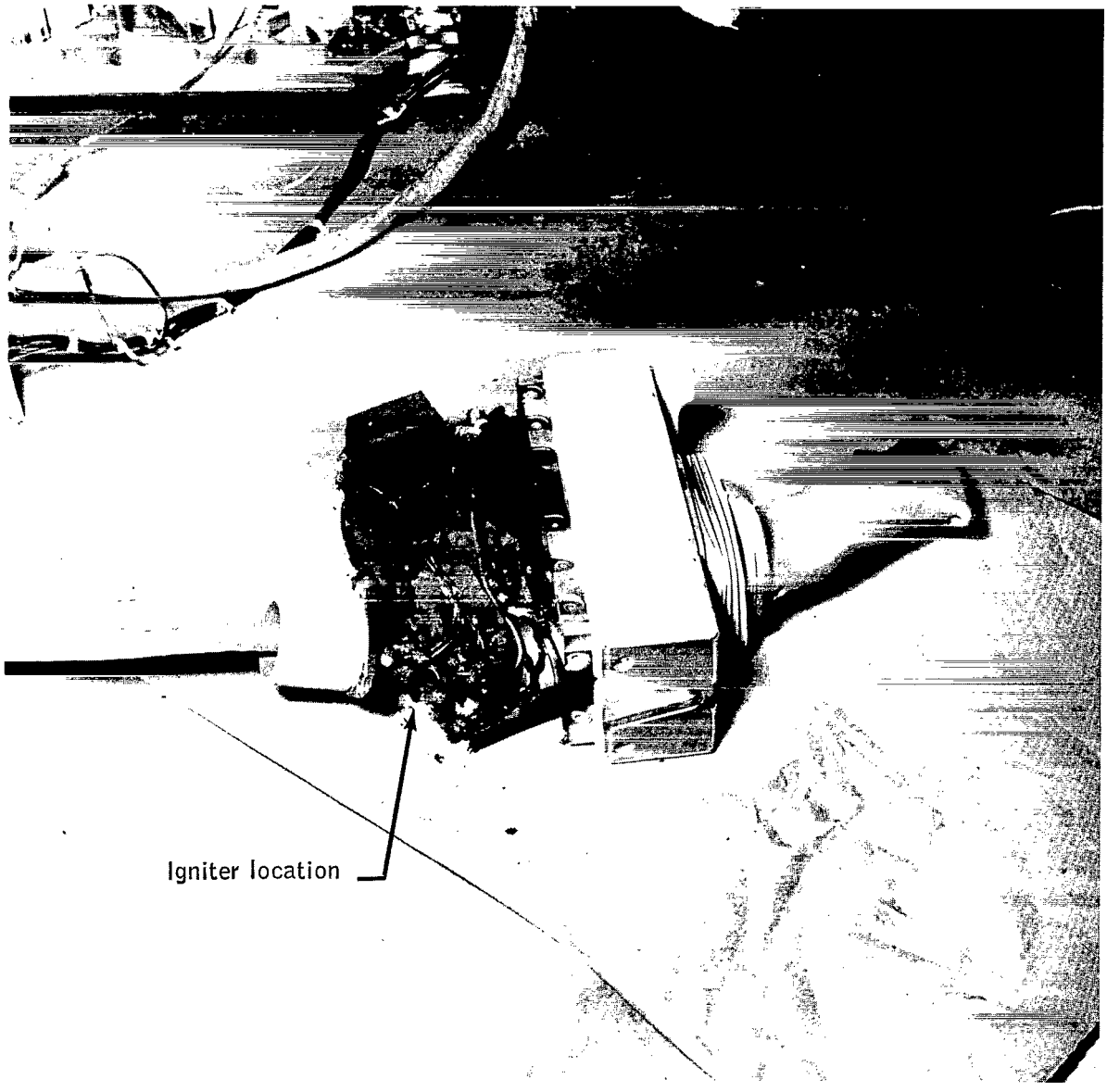


Figure 38. - Post-test damage (test 232).

Figure 39. - Post-test damage, rear of panel 2 (test 302).

Figure 40. - Post-test damage (test 303).

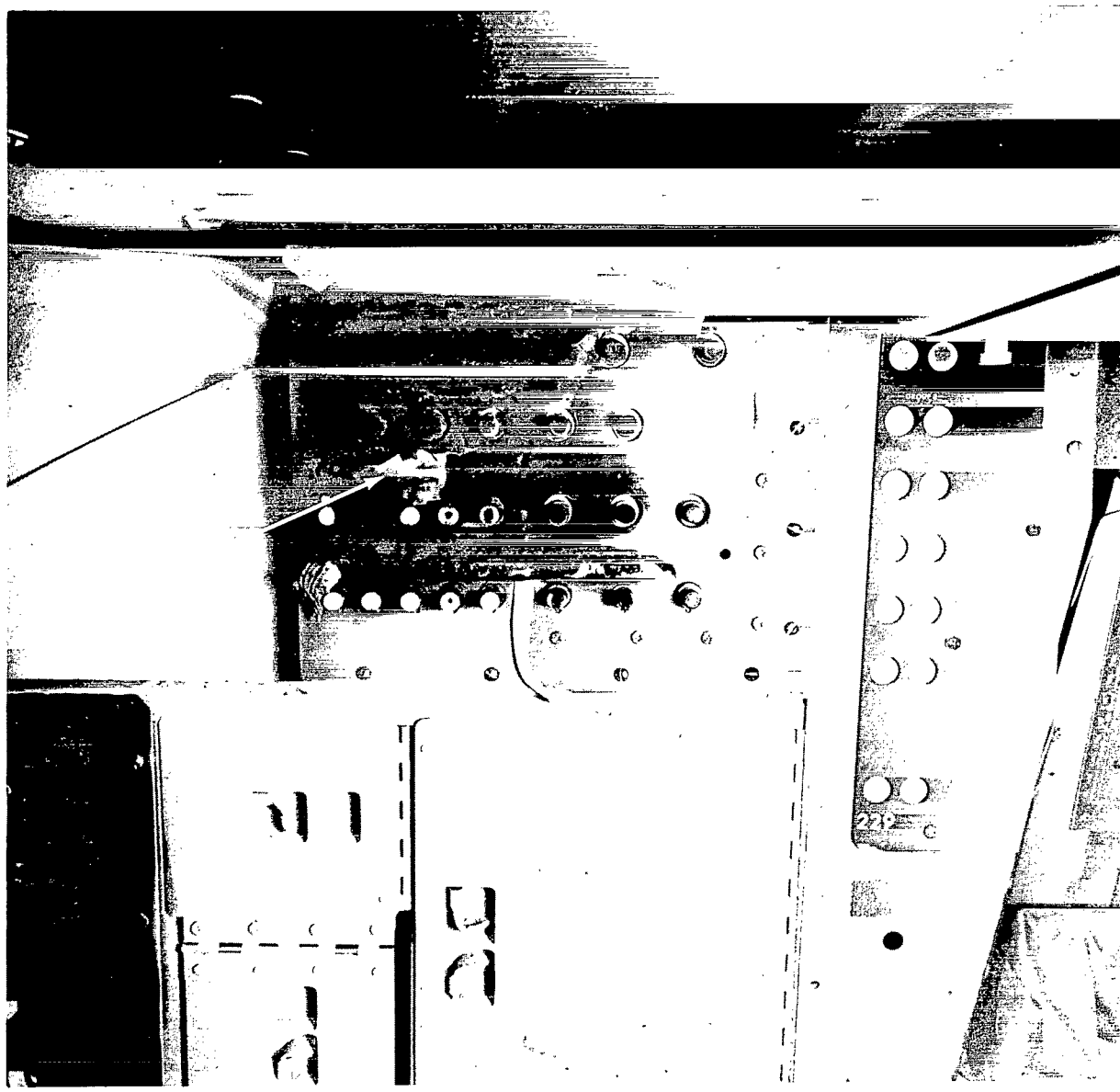


Figure 41. - Post-test damage, face of panel 225 (test 306).

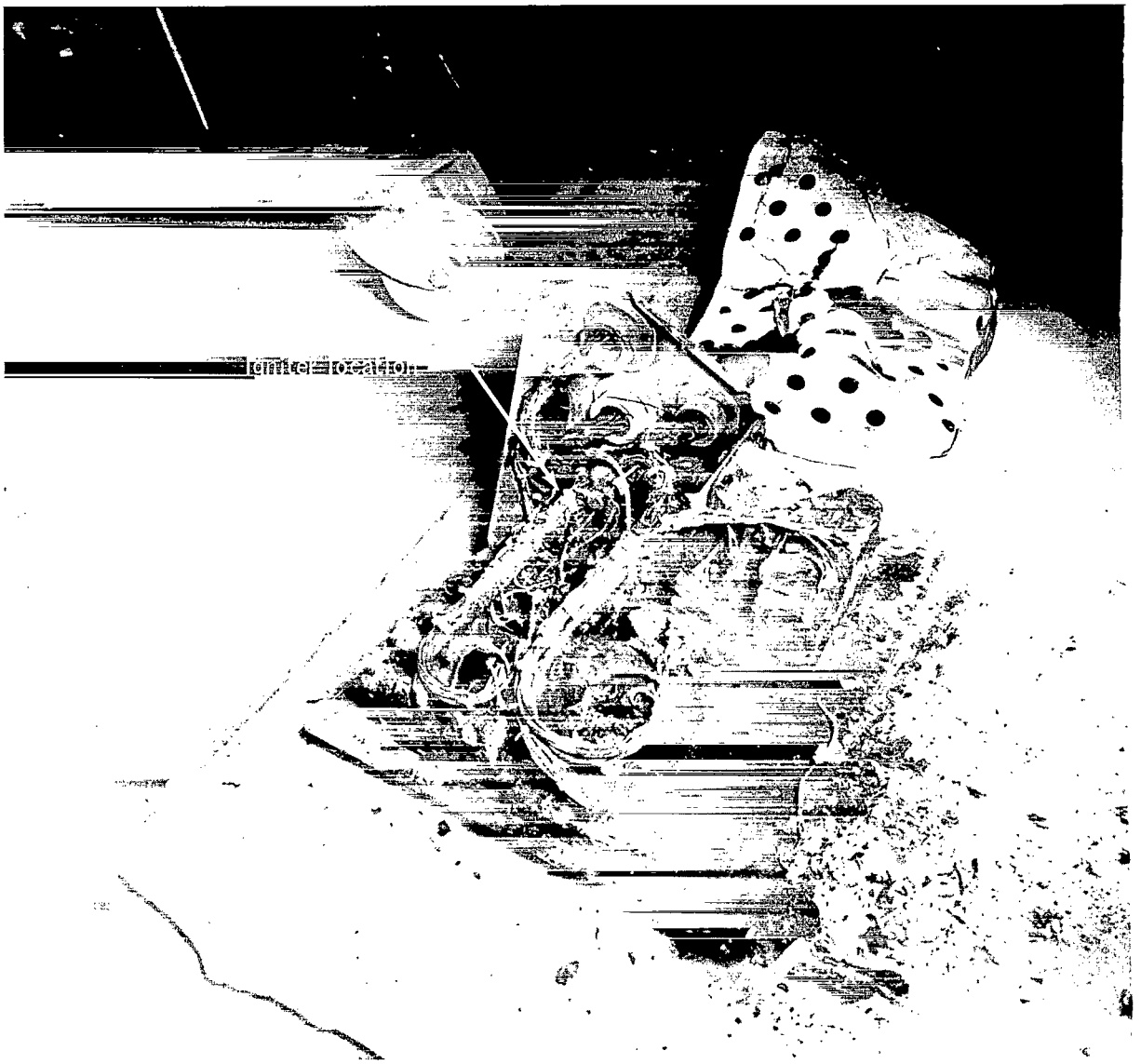


Figure 42. - Post-test damage, rear of panel 225 (test 306).

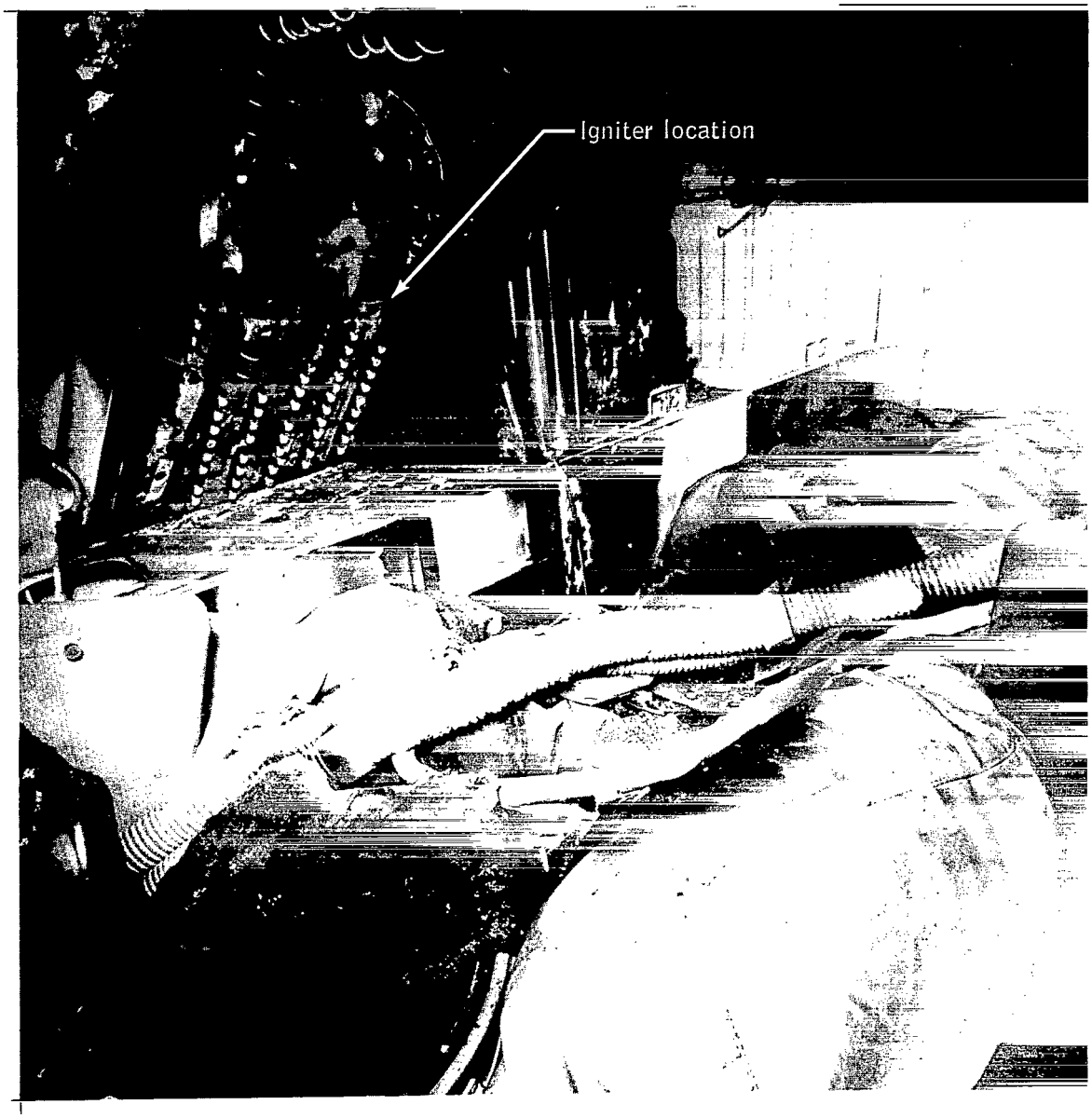
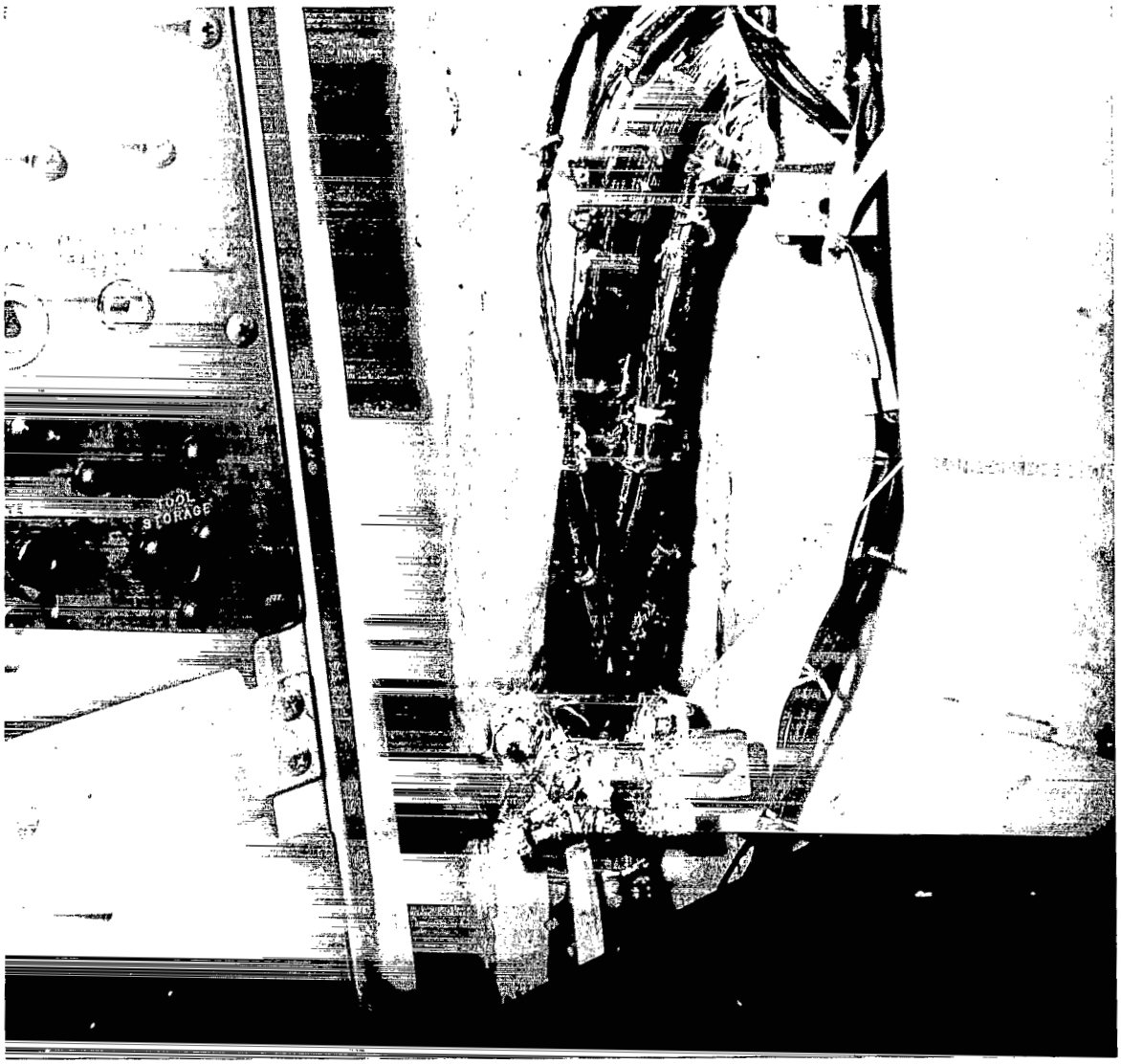
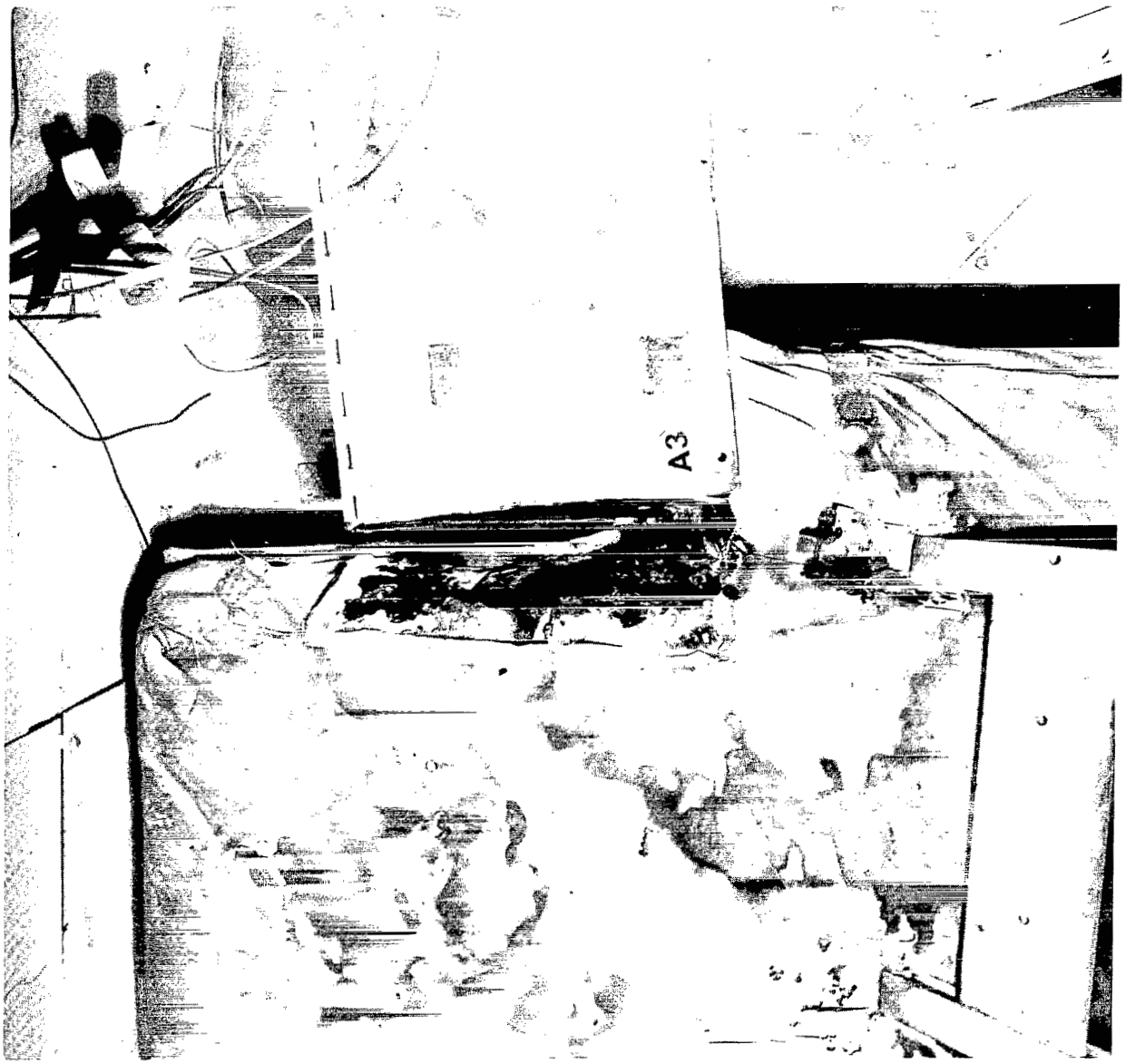


Figure 43. - Post-test damage (test 312).



(a) View 1.

Figure 44. - Post-test damage (test 317).



(b) View 2.

Figure 44. - Concluded.

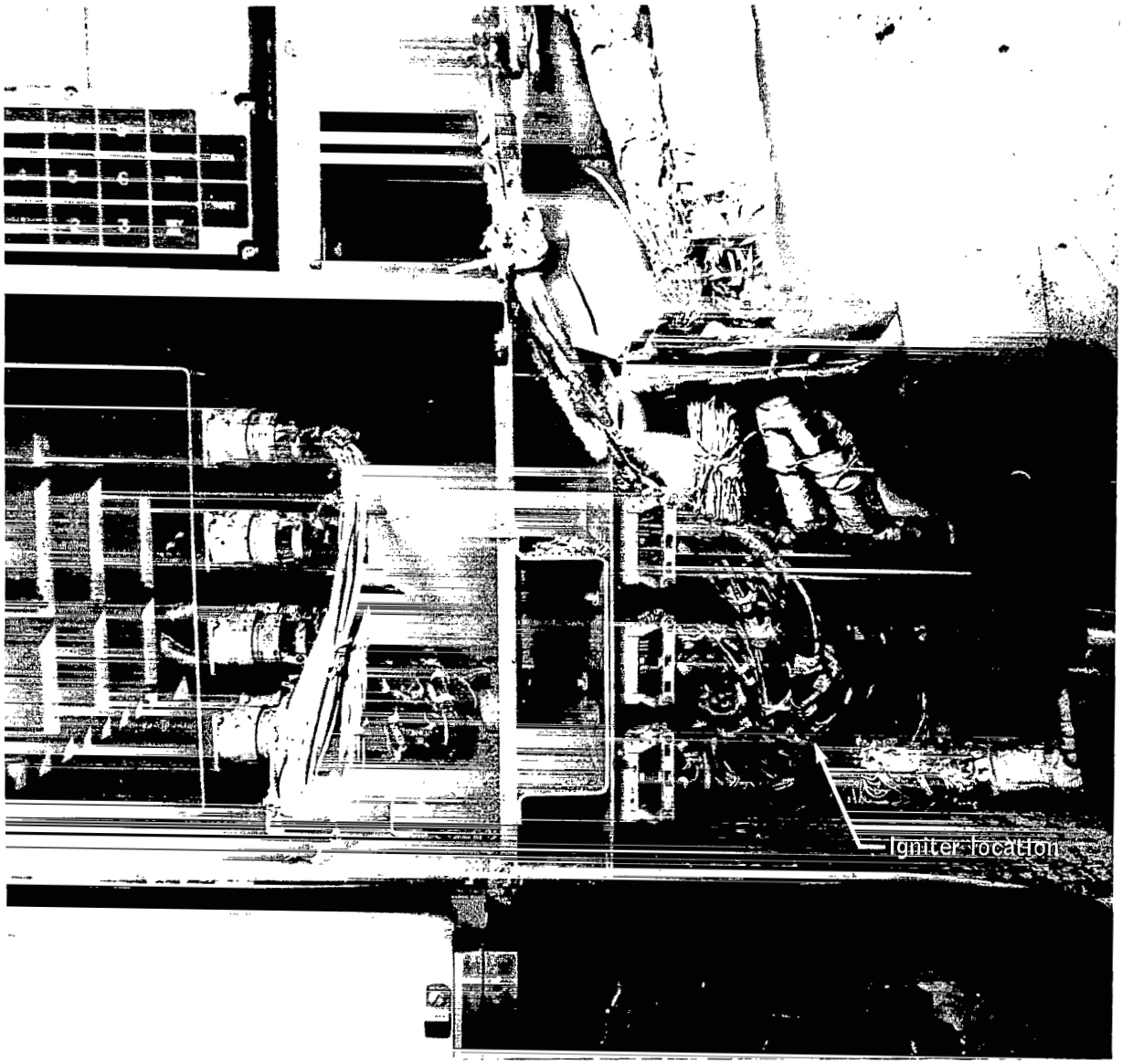


Figure 45. - Post-test damage above girth shelf (test 319).

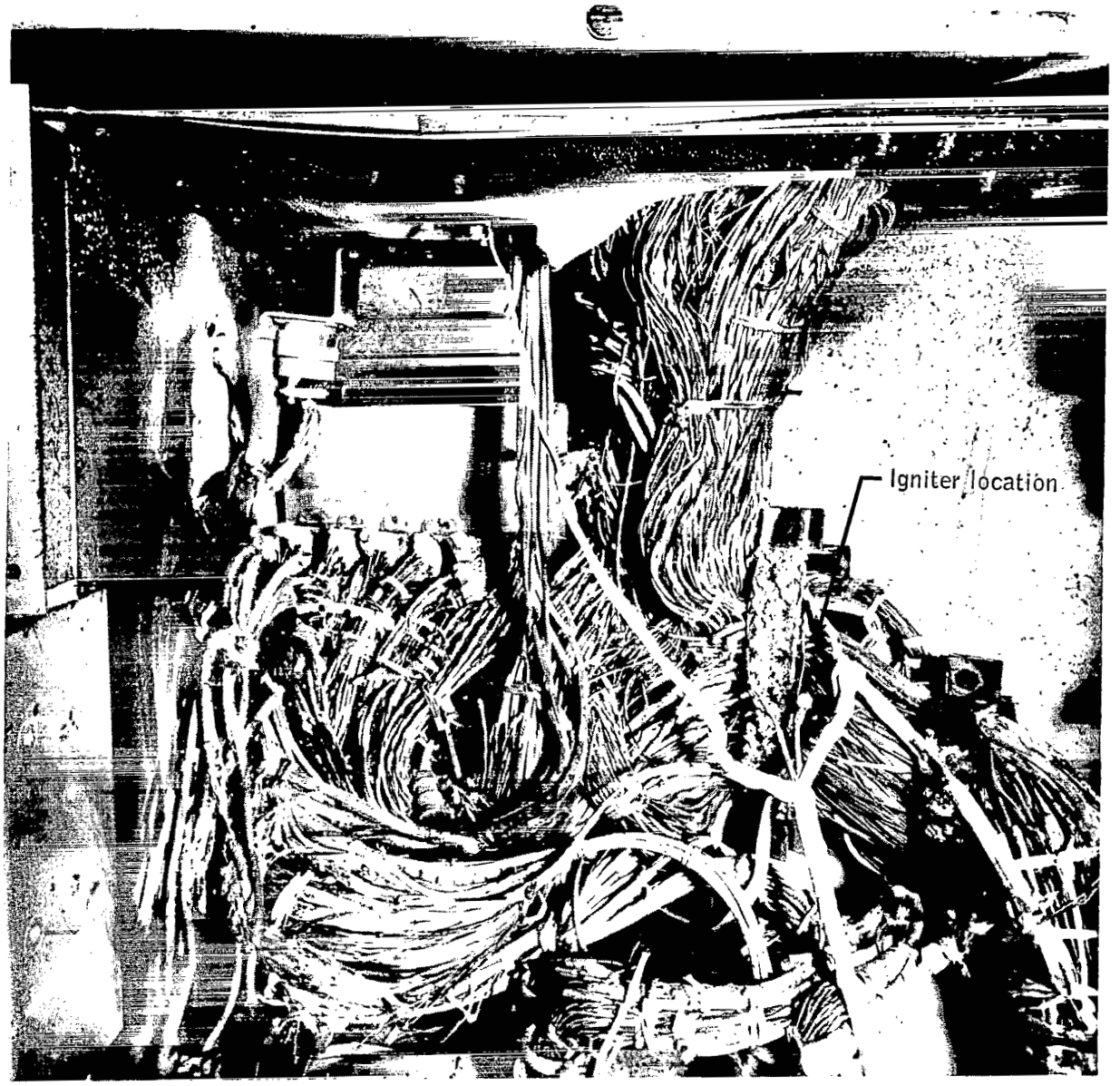


Figure 46. - Post-test damage below girth shelf (test 319).

Figure 47. - Post-test damage (test 326).

Figure 48. - Post-test damage (test 330).

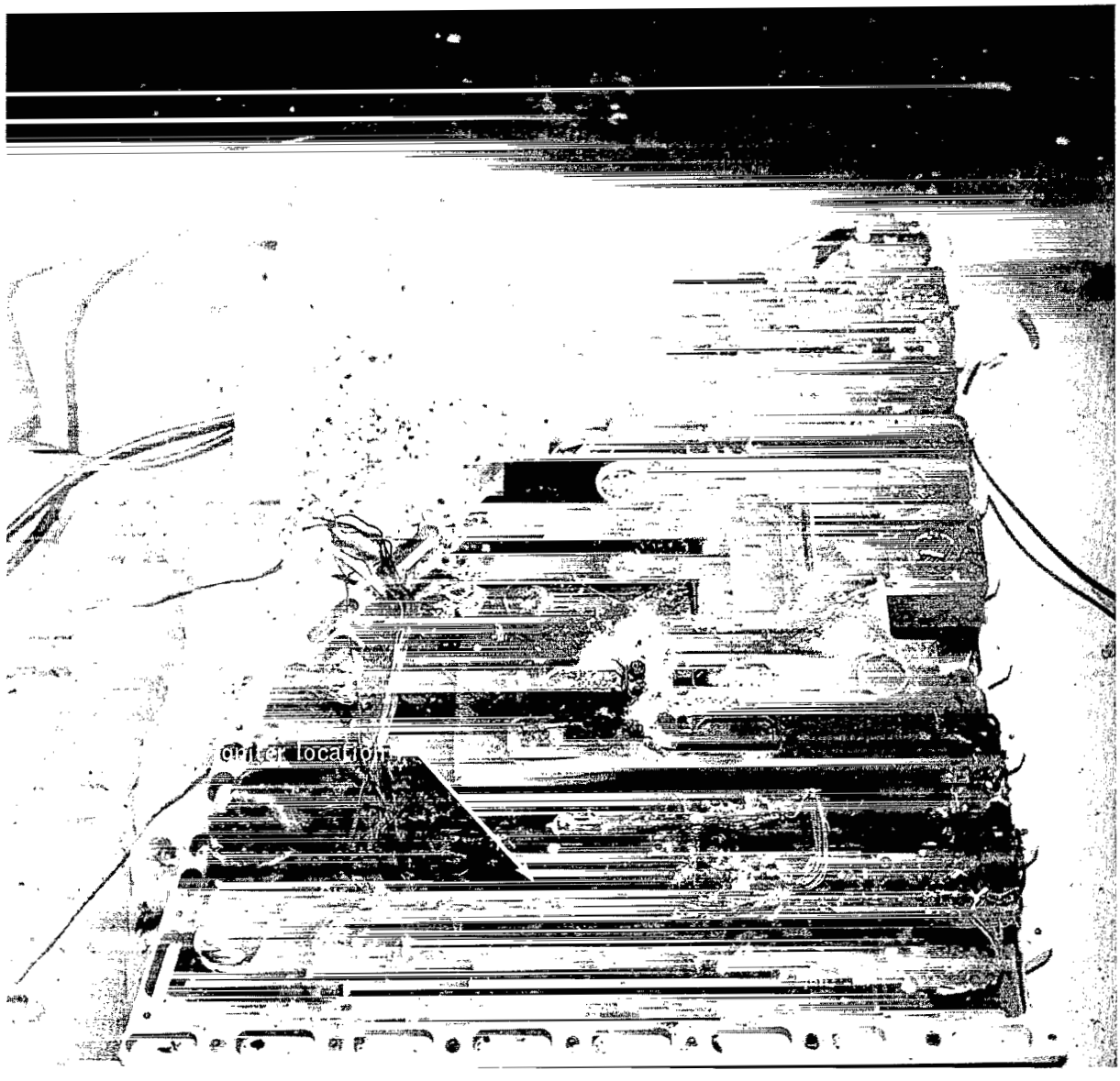


Figure 49. - Post-test damage, rear of panel 3 (test 339).

Figure 50. - Post-test damage (test 341).

APPENDIX A

DETAILS OF INDIVIDUAL TESTS

INTRODUCTION

In this appendix, each test is individually described in such a manner as to allow the combustion history, cabin pressure and temperature changes, visibility deterioration, and subsequent gas analysis to be considered as results of the ignition of a specific material at a specific point within the CM. The ignition location and test purpose are common to tests having the same sequential number in each series (for example, tests 105, 205, and 305 in series 100, series 200, and series 300, respectively).

Tests 101, 201, and 301

Ignition location. - An internal igniter was located under the conformal coating of switch S53 on panel 1 of the MDC (fig. 6). This panel had metal-enclosed switches which were representative of SC 101 and subsequent vehicles.

Purpose. - The purpose of tests 101, 201, and 301 was to determine the flammability characteristics of the nonmetallic materials used in the panels and to evaluate the protection provided by Ladicote.

Test descriptions. - The following descriptions are of tests 101, 201, and 301.

Test 101: Burnthrough of the igniter occurred at T + 2 minutes. Smoke was visible from T + 50 seconds to T + 5 minutes; the maximum output of smoke was at T + 3 minutes. Related thermocouples indicated no propagation. The test was concluded at T + 7 minutes.

Test 201: Smoke was observed as a light haze from T + 5 minutes to T + 9 minutes. Burnthrough of the igniter occurred at T + 5 minutes 30 seconds. Related thermocouples indicated no propagation. The test was concluded at T + 15 minutes.

Test 301: Significant smoke was observed coming from the panel at T + 1 minute 55 seconds. Igniter burnthrough occurred at T + 2 minutes 8 seconds. Dense smoke was observed coming out of the face of the panel at T + 2 minutes 30 seconds; smoke increased steadily and became very dense at approximately T + 3 minutes 40 seconds. At T + 3 minutes 45 seconds, flame was observed coming out of the lower aft side of panel 1. The test was terminated at T + 4 minutes.

Visibility. - Visibility in the cabin was not affected during test 101 or 201, but was considerably reduced during test 301.

Temperature and pressure. - There was no significant increase in free-air temperature or cabin pressure during tests 101, 201, or 301.

Gas analysis. - The following data are gas-sample-analysis results for tests 101, 201, and 301.

Test 101: No potentially toxic products were detected in the gas sample.

Test 201: The gas analysis indicated 6.5 ppm silicon tetrafluoride present in the gas sample.

Test 301: The gas analysis indicated 583.3 ppm carbonyl fluoride, 410.0 ppm carbon tetrafluoride, and 370.0 ppm silicon tetrafluoride present in the gas sample.

Post-test inspections. - The following data are the results of the post-test inspections for tests 101, 201, and 301.

Test 101: Visual inspection indicated only localized burning of the RTV and Ladicote. The burned portion of the panel covered an area approximately 1-1/2 inches in diameter.

Test 201: Visual inspection indicated burning of the RTV and Ladicote at the point of ignition with propagation to only one adjacent switch. The burned portion of the panel covered an area approximately 2 inches in diameter (fig. 25).

Test 301: The entire lower half of the silicone-laminate cover was burned. All switches and meter cases in the lower part of the panel were burned or severely damaged. The insulation on all wiring and connector plugs on and above the panel was burned off.

Summaries. - The following notes are summaries of tests 101, 201, and 301.

Test 101: Propagation did not occur, indicating that the Ladicote provided adequate protection.

Test 201: This test was conducted in a region having newly applied Ladicote and of a configuration similar to areas which suffered severe damage in tests in a 6.2-psia 95-percent-oxygen atmosphere. The results of this test indicate that Ladicote may provide less protection with age.

Test 301: The results of this test indicated that the Ladicote did not provide adequate fire protection for electrical components.

Tests 102, 202, and 302

Ignition location. - An internal igniter was located under the conformal coating of meter M12 on display panel 2, which is the center panel on the MDC and the largest of the three major panels on the MDC (fig. 7).

Purpose. - The purpose of tests 102, 202, and 302 was to determine the flammability characteristics of the nonmetallic materials used in the panels and to evaluate the protection provided by Ladicote.

Test descriptions. - The following notes are descriptions of tests 102, 202, and 302.

Test 102: The igniter burned through at T + 2 minutes. Although the igniter thermocouple reached a maximum temperature of 796° F at T + 3 minutes 30 seconds, no smoke or fire was observed. At T + 8 minutes with all temperatures decreasing or at ambient, the test was concluded.

Test 202: At T + 4 minutes, a moderate amount of smoke was observed for approximately 15 seconds. Igniter burnthrough occurred at T + 4 minutes 12 seconds. The test was concluded at T + 12 minutes.

Test 302: Smoke was observed at T + 35 seconds and continued to be observed throughout the test. At T + 1 minute 28 seconds, flame was observed burning the silicone-laminate cover. The flame propagated outward in all directions from a point on the cover above the ignition area. A very light-colored smoke was observed coming from the panel; however, the smoke became very dense at T + 3 minutes 30 seconds. The test was terminated at T + 4 minutes.

Visibility. - The following remarks are visibility summaries for tests 102, 202, and 302.

Test 102: Visibility was not affected.

Test 202: A light, smoky haze was observed in the cabin; however, visibility in the cabin was not significantly affected.

Test 302: Visibility in the cabin was severely reduced.

Temperature and pressure. - There was no significant increase in free-air temperature or cabin pressure during test 102, 202, or 302.

Gas analysis. - The following data are gas-sample-analysis results for tests 102, 202, and 302.

Test 102: No potentially toxic products were detected in the gas sample.

Test 202: The gas analysis indicated 228.4 ppm carbonyl fluoride, 21.6 ppm carbon tetrafluoride, and 15.4 ppm silicon tetrafluoride present in the gas sample.

Test 302: The gas analysis indicated 500.0 ppm carbonyl fluoride, 158.8 ppm carbon tetrafluoride, and 54.0 ppm silicon tetrafluoride present in the gas sample.

Post-test inspections. - The following data are the results of the post-test inspections for tests 102, 202, and 302.

Test 102: Visual inspection of the meter indicated burning of the RTV and Ladicote in a localized area approximately 1-1/2 inches in diameter. There was no propagation to adjacent components or wire bundles; however, there was some burning of the insulation on wires leading to the meter (fig. 14).

Test 202: Visual inspection of the meter indicated burning of the RTV and Ladicote. No propagation to adjacent components or wire bundles occurred, although there was some charring of the wire insulation. The area of the silicone-laminate cover above the ignition point was scorched (fig. 26).

Test 302: Approximately two-thirds of the silicone-laminate cover was burned. Visual inspection indicated that eight meters to the left and above the ignition point were severely damaged. All wiring insulation leading to these components was destroyed. Some burning occurred on the insulation of other wiring under and in close proximity to the burned portion of the silicone-laminate cover (fig. 39).

Summaries. - The following notes are the summaries of tests 102, 202, 302.

Test 102: Propagation did not occur, indicating that the Ladicote offered adequate protection.

Test 202: The RTV and Ladicote on the back side of the meter were badly burned. There was no propagation to other components; however, because of the panel configuration, no propagation paths existed among the surrounding components.

Test 302: The results of this test indicated that Ladicote does not provide sufficient protection for electrical components from either an internal or an external fire. The silicone-laminate back cover provided a significant fire propagation path.

Tests 103, 203, and 303

Ignition location. - An internal igniter was located under the conformal coating of switch S47 on panel 2, the center panel on the MDC and the largest of the three major panels on the MDC (fig. 7). This panel had metal-enclosed switches which were representative of SC 101 and subsequent vehicles.

Purpose. - The purpose of tests 103, 203, and 303 was to determine the flammability characteristics of the nonmetallic materials used in the panel, to evaluate the protection provided by Ladicote, and to determine the effectiveness of the foam extinquishing agent.

Test descriptions. - The following descriptions are of tests 103, 203, and 303.

Test 103: At approximately T + 2 minutes, temperatures in the ignition region indicated fire and some propagation. A significant amount of smoke coming from the back of the panel was observed between T + 6 minutes and T + 15 minutes. On two occasions, smoke emanated from the panel front. Based on temperature data, it is concluded that the fire self-extinguished at approximately T + 15 minutes. The test was concluded at T + 30 minutes.

Test 203: Smoke was observed at T + 54 seconds, although three quick flashes behind the panel were seen at T + 35 seconds. Smoke continued until T + 3 minutes. The test was concluded at T + 12 minutes.

Test 303: Light smoke was observed in the ignition area at T + 40 seconds. Flame became visible in the ignition area at T + 1 minute; at T + 1 minute 7 seconds, the egress count was started. At T + 2 minutes, heavy smoke was observed in the cabin, and the fire had intensified and propagated to the right-side wire bundles. Fire propagated to the face of the panel at T + 2 minutes 35 seconds. At T + 2 minutes 39 seconds, the extinguishing agent valve opened, and foam was visible behind the panel. Drippings were observed, and at T + 2 minutes 45 seconds, the suit oxygen hoses caught fire. Flames were observed coming from below the hoses, apparently from the suit. Temperatures behind the panel had reduced considerably as a result of the foam; however, because the fire had propagated out of the panel, the test was terminated by pumpdown of the BP at T + 2 minutes 55 seconds.

Visibility. - The following visibility summaries are for tests 103, 203, and 303.

Tests 103 and 203: A very light, smoky haze was observed in the cabin; however, visibility was not significantly affected.

Test 303: Visibility in the cabin was severely reduced.

Temperature and pressure. - There was no significant increase in free-air temperature or cabin pressure during test 103, 203, or 303.

Gas analysis. - The following data are gas-sample-analysis results for tests 103, 203, and 303.

Test 103: The gas analysis indicated 0.75 ppm carbon monoxide, 188 ppm carbonyl fluoride, 8 ppm carbon tetrafluoride, and 128 ppm silicon tetrafluoride present in the gas sample.

Test 203: No potentially toxic products were detected in the gas sample.

Test 303: The gas analysis indicated 1020.0 ppm carbonyl fluoride, 857.1 ppm carbon tetrafluoride, and 678.5 ppm silicon tetrafluoride present in the gas sample.

Post-test inspections. - The following results are for the post-test inspections for tests 103, 203, and 303.

Test 103: The fire propagated across four switches to the left of the ignition point where propagation apparently stopped because of a break in the switch spacing. The fire propagated to only one switch to the right of the ignition point, possibly because of a very small amount of RTV on the two adjacent switches. The entire row of six annunciators above the ignition row was burned. The fire had no apparent propagation path beyond this row. The wire bundle above the ignition area was badly damaged, and some insulation was burned off (fig. 15(b)). Considerable soot and loose debris were desposited in this area. The area of the silicone-laminate cover adjacent to the ignition point was scorched (fig. 15(a)).

Test 203: Visual inspection indicated only localized burning of the RTV and Ladicote at the igniter location. The fire did not propagate to any adjacent switch or along the wire bundles. The back side of the silicone-laminate cover did not show any evidence of burning (fig. 27).

Test 303: Approximately one-half of the silicone-laminate back cover was burned. The fire propagated outward in all directions, and a total of 35 switches, annunciators, and meters were destroyed or severely damaged. The insulation on all the wiring leading to these components was destroyed. The left arm, hand, and chest area of the center suit were severely burned. The oxygen hoses and communications cable were destroyed. The Dacron tiedown harness was burned and apparently contributed to the rapid fire propagation on the suit (fig. 40).

Summaries. - The following are summaries of tests 103, 203, and 303.

Test 103: The results of this test indicated that a single coat of Ladicote was not adequate protection in an area where several electrical components are close to each other. Propagation was significant, and severe damage resulted to 12 switches.

Test 203: Although test 203 was conducted in a somewhat more severe environment than test 103, test 203 damage was negligible compared to damage in test 103. A fresh coat of Ladicote had been applied to the region prior to test 203. Test results imply that aging lessens the effectiveness of the Ladicote coating.

Test 303: The results of this test indicated that the Ladicote did not provide adequate fire protection. The adequacy of the foam extinguishing agent could not be evaluated because of the severe propagation outside the panel area.

Tests 104 and 204

Ignition location. - The igniter was located under the conformal coating of a switch adjacent to control R1 on MDC panel 3. This panel had plastic-enclosed switches which were representative of 2TV-1.

Purpose. - The purpose of tests 104 and 204 was to determine the flammability characteristics of the nonmetallic materials used in the panels and to evaluate the protection provided by the Ladicote to switches in the 2TV-1 configuration. Test 304 was not conducted because panel 3 was destroyed in a previous test series.

Test descriptions. - The following descriptions are of tests 104 and 204.

Test 104: Burnthrough of the igniter occurred at T + 2 minutes 30 seconds. Smoke was observed at approximately T + 1 minute and continued for the duration of the test. Temperatures in the region of the igniter started to rise at approximately T + 3 minutes 24 seconds. Starting at T + 5 minutes and continuing throughout the test, intermittent dripping of an unidentified liquid (not water-glycol) was observed coming from several places on the panel. At T + 5 minutes, sparks and flame were observed for several seconds along the bottom of the panel. Temperatures and smoke continued to increase, and at approximately T + 29 minutes, the EL overlay ignited and began to propagate upward. In accordance with the test-termination criteria, the test was terminated at T + 29 minutes 45 seconds.

Test 204: Smoke was observed coming out of the face of the panel at T + 47 seconds and subsided 15 seconds later. No definite smoke pattern was observed until a

light haze formed in the cabin. At T + 6 minutes 40 seconds, flame was observed above the ignition point; it subsided, however, at T + 6 minutes 50 seconds. At T + 7 minutes 10 seconds, heavy smoke was observed in the cabin, and the test was terminated at T + 7 minutes 45 seconds.

Visibility. - Visibility in the cabin was severely reduced during tests 104 and 204.

Temperature and pressure. - The following notes are temperature and pressure data for tests 104 and 204.

Test 104: The free-air temperature rose from 72° to 78° F. There was no detectable pressure rise.

Test 204: There was no significant increase in free-air temperature or cabin pressure.

Gas analysis. - The following summaries are gas-sample-analysis results for tests 104 and 204.

Test 104: The gas analysis indicated 36.5 ppm carbon monoxide, 951 ppm carbonyl fluoride, 397 ppm carbon tetrafluoride, and 937 ppm silicon tetrafluoride present in the gas sample.

Test 204: The gas analysis indicated 376.8 ppm carbonyl fluoride, 143.2 ppm carbon tetrafluoride, and 64.5 ppm silicon tetrafluoride present in the gas sample.

Post-test inspections. - The following results are for the post-test inspections for tests 104 and 204.

Test 104: Fire propagated outward in all directions from the ignition point (fig. 16). Twenty switches were severely damaged. All wiring leading to these switches was destroyed. Extensive heat damage occurred on panel connectors 12 inches from the ignition point. The entire back side of the panel was covered with a thick layer of soot. The silicone-laminate panel back cover was burned in the region around the ignition point. The fire did not appear to propagate over the silicone-laminate back cover. Approximately one-third of the EL overlay on the front of the panel burned. The fire propagation path was to the face of the panel from behind the panel around the lower LH corner. However, no known flammable material existed in this region.

Test 204: The fire propagated outward in all directions from the ignition point. Visual inspection indicated that 29 switches were severely damaged. All wiring leading to these components was destroyed. Six of the 10 electrical connector plugs were also destroyed.

Summaries. - The following summaries are of tests 104 and 204.

Test 104: The results of this test indicated that a single coat of Ladicote was not adequate protection in an area where several electrical components are in close proximity to one another.

Test 204: The results of this test indicated that the Ladicote did not provide adequate fire protection for the switches.

Test 105

Ignition location. - An internal igniter was located under the conformal coating of CB 30 on panel 8, which is the side display console just above the girth shelf on the LH side of the BP and adjacent to the ECU controls.

Purpose. - The purpose of test 105 was to determine the flammability characteristics of the nonmetallic materials used in panel 8 and to evaluate the protection provided by Ladicote. Test 205 was not conducted because of the large fires that resulted in similar tests 206 and 207. Test 305 was not conducted because panel 8 was partially destroyed in test 312.

Test description. - No flame was observed, and all temperature data indicated that little or no propagation occurred. The test was concluded at T + 6 minutes.

Visibility. - Visibility was not affected.

Temperature and pressure. - There was no significant increase in free-air temperature or cabin pressure during test 105.

Gas analysis. - The gas analysis indicated 4.9 ppm of silicon tetrafluoride present in the gas sample.

Post-test inspection. - Visual inspection of the ignition area indicated that the RTV and Ladicote burned in a localized region approximately 1 inch in diameter. One adjacent CB showed partial burning; however, no further propagation occurred to adjacent components or wire bundles.

Summary. - The results of this test indicated that the application of double Ladicote on circuit breakers provides sufficient protection to prevent flame propagation.

Tests 106, 206, and 306

Ignition location. - An internal igniter was placed under the conformal coating of CB 5 on panel 225, which is on the right side of the test vehicle just below the liferaft stowage compartment (fig. 9).

Purpose. - The purpose of tests 106, 206, and 306 was to determine the flammability characteristics of the nonmetallic materials used in panel 225 and to evaluate the protection provided by Ladicote.

Test descriptions. - The following descriptions are of tests 106, 206, and 306.

Test 106: At T + 30 seconds, smoke was observed at the lower LH corner of the panel. At T + 2 minutes 45 seconds, smoke was observed at the upper LH corner of the panel. Igniter burnthrough occurred at T + 12 minutes 58 seconds. No flame was

observed, and all temperature data indicated that little or no propagation occurred. The test was concluded at T + 7 minutes.

Test 206: Smoke was observed at T + 45 seconds and increased steadily before forced termination of the test at T + 6 minutes 15 seconds. At termination, thermocouples between and on top of circuit breakers indicated temperatures of 1780° and 1231° F, respectively.

Test 306: Light smoke was observed coming from the lower LH corner of the panel at T + 38 seconds. At T + 1 minute 5 seconds, a flash was observed in the panel area. At T + 1 minute 20 seconds, light smoke rose from the top of the panel. Heavy smoke from the panel was observed at T + 2 minutes 20 seconds and caused a light haze throughout the cabin. At T + 2 minutes 50 seconds, flame emanated from the upper LH corner of the panel. At T + 3 minutes 15 seconds, the fire ignited the upper LH corner of the EL panel and began propagating downward and to the right. At T + 3 minutes 20 seconds, the fire was very intense, and dense smoke was visible throughout the cabin. Dripping was observed at T + 4 minutes 20 seconds. The test was terminated at T + 4 minutes 27 seconds in accordance with test-termination criteria. Just before termination, the fire had propagated across approximately 75 percent of the EL panel; all related temperatures were very high and rising.

Visibility. - The following visibility summaries are for tests 106, 206, and 306.

Test 106: Visibility in the cabin was not affected.

Test 206: A light haze observed in the cabin created a slight reduction in visibility.

Test 306: A large amount of smoke was observed throughout the test. By T + 3 minutes 20 seconds, visibility in the cabin was greatly reduced.

Temperature and pressure. - There was no significant increase in free-air temperature or cabin pressure during test 106, 206, or 306.

Gas analysis. - The following gas-sample-analysis results are from tests 106, 206, and 306.

Test 106: No potentially toxic products were detected in the gas sample.

Test 206: The gas analysis indicated 187.5 ppm carbonyl fluoride, 3.9 ppm carbon tetrafluoride, and 13.3 ppm silicon tetrafluoride.

Test 306: The gas analysis indicated 142.8 ppm carbonyl fluoride, 118.4 ppm carbon tetrafluoride, and 368.4 ppm silicon tetrafluoride present in the gas sample.

Post-test inspections. - The following data are the results of the post-test inspections for tests 106, 206, and 306.

Test 106: Visual inspection of the ignition area indicated burning of the RTV and Ladicote on two circuit breakers. Burning covered a region approximately 1-1/4 inches in diameter. No further propagation to other components or wire bundles occurred.

Test 206: All circuit breakers above and to each side of the ignition point were severely damaged. All wiring leading to these circuit breakers was destroyed. The upper half of the silicone-laminate cover was burned. Inspection of individual circuit breakers indicated damage ranging from complete burning to only top-surface burning, depending upon the location of the circuit breakers relative to the ignition point. The fire did not propagate to the bottom row of circuit breakers, probably because of forced termination of the test (fig. 28).

Test 306: The silicone-laminate back cover was completely destroyed. All 22 circuit breakers, electrical wiring, and connector plugs were severely burned or damaged (figs. 41 and 42).

Summaries. - The following summaries are for tests 106, 206, and 306.

Test 106: The results of this test indicated that the application of double Ladicote on circuit breakers provided sufficient protection to prevent flame propagation.

Test 206: The results of this test indicated that the Ladicote was not sufficient protection for the circuit breakers.

Test 306: The results of this test indicated that the Ladicote did not provide adequate fire protection for a CB panel.

Tests 107, 207, and 307

Ignition location. - An internal igniter was located under the conformal coating of CB 12 on panel 226, which is on the right side of the test vehicle just above the girth shelf and next to the waste-disposal opening (fig. 9).

Purpose. - The purpose of tests 107, 207, and 307 was to determine the flammability characteristics of the nonmetallic materials used in panel 226 and to evaluate the protection provided by Ladicote.

Test descriptions. - The following descriptions are of tests 107, 207, and 307.

Test 107: A small amount of smoke was seen at T + 1 minute 30 seconds. Igniter burnthrough occurred at T + 1 minute 37 seconds. The smoke subsided shortly after igniter burnthrough, and no flame was observed. All temperature data indicated that little or no propagation occurred. The test was concluded at T + 6 minutes.

Test 207: Smoke was observed at T + 55 seconds and progressively intensified a high haze throughout the cabin. At T + 13 minutes, the panels could not be seen clearly. The thermocouple at the lower right of the panel reached 1650° F at T + 16 minutes. The test was terminated at T + 20 minutes primarily because of lack of visibility in the cabin.

Test 307: Smoke was observed coming out of the upper LH corner of panel 226 at T + 42 seconds. Significant smoke was visible in the panel area at T + 1 minute 30 seconds, and a light haze was detected throughout the cabin. At T + 3 minutes 50 seconds, the smoke in the cabin had progressively increased in thickness, and

clear definition of the panel was difficult. Visibility of the panel was almost lost at T + 5 minutes. Flame was observed at the upper LH corner of the panel at T + 5 minutes 16 seconds. The test was terminated at T + 5 minutes 30 seconds in accordance with test-termination criteria. The flame was still visible at termination.

Visibility. - The following visibility summaries are for tests 107, 207, and 307.

Test 107: Visibility in the cabin was not affected.

Test 207: A large amount of smoke was produced throughout the test. Visibility in the panel area was lost at T + 15 minutes, and complete loss of cabin visibility occurred at T + 18 minutes.

Test 307: A large amount of smoke was produced throughout the test. Panel visibility was lost at T + 5 minutes. Cabin visibility was considerably reduced.

Temperature and pressure. - There was no significant increase in free-air temperature or cabin pressure during test 107, 207, or 307.

Gas analysis. - The following gas-sample-analysis results are for tests 107, 207, and 307.

Tests 107 and 207: No potentially toxic products were detected in the gas sample.

Test 307: The gas analysis indicated 217.3 ppm carbonyl fluoride, 121.0 ppm carbon tetrafluoride, and 126.3 ppm silicon tetrafluoride present in the gas sample.

Post-test inspections. - The following data are the results of the post-test inspections for tests 107, 207, and 307.

Test 107: Visual inspection of the ignition area indicated burning of the RTV and Ladicote in a localized region approximately 1-1/2 inches in diameter. There was no propagation to adjacent components or wire bundles.

Test 207: All circuit breakers were severely damaged. All wiring leading to the circuit breakers was destroyed. The entire back side of the panel was covered with a thick layer of soot. Individual CB inspection indicated damage ranging from complete burning to only partial burning, depending upon CB location relative to the ignition point (fig. 29).

Test 307: Visual inspection showed that 26 out of 34 circuit breakers were severely damaged. Burning occurred on both the Ladicote and the plastic CB cases. All electrical wiring on the panel was destroyed. The silicone-rubber inserts on three connector plugs were destroyed.

Summaries. - The following summaries are for tests 107, 207, and 307.

Test 107: Results of this test indicated that the application of double Ladicote to circuit breakers provided sufficient protection to prevent flame propagation.

Test 207: The results of this test indicated that the Ladicote was not sufficient protection for the circuit breakers.

Test 307: The results of this test indicated that the Ladicote did not provide adequate fire protection for a CB panel.

Tests 108 and 308

Ignition location. - An internal igniter was located under the conformal coating of CB 17 on panel 250, which is on the right side of the test vehicle in the corner below the girth shelf and above the fecal canister (fig. 9).

Purpose. - The purpose of tests 108 and 308 was to determine the flammability characteristics of the nonmetallic materials used in panel 250 and to evaluate the protection provided by Ladicote. Test 208 was not conducted because of the large fires that resulted in similar tests 206 and 207.

Test descriptions. - The following descriptions are for tests 108 and 308.

Test 108: Igniter burnthrough occurred at T + 1 minute 30 seconds. No smoke or fire was observed during the test. Temperature data indicated that little or no propagation occurred. The test was concluded at T + 6 minutes.

Test 308: Light smoke was observed at the upper edge of the panel at T + 40 seconds. The smoke became significant at T + 53 seconds and continued to increase until termination. Flame was observed in the lower portion of the panel at T + 4 minutes 8 seconds, and approximately 10 seconds later, the flame became visible in the middle and upper portions of the edge of the panel. The test was terminated at T + 4 minutes 30 seconds in accordance with test-termination criteria. Flame was still visible at termination.

Visibility. - The following visibility summaries are for tests 108 and 308.

Test 108: Visibility in the cabin was not affected.

Test 308: A moderate haze was observed; however, cabin visibility was not appreciably reduced.

Temperature and pressure. - There was no significant increase in free-air temperature or cabin pressure during test 108 or 308.

Gas analysis. - The following results are from gas-sample-analysis for tests 108 and 308.

Test 108: No potentially toxic products were detected in the gas sample.

Test 308: The gas analysis indicated 561.4 ppm carbonyl fluoride, 180.0 ppm carbon tetrafluoride, and 105.2 ppm silicon tetrafluoride present in the gas sample.

Post-test inspections. - The following notes are the results of the post-test inspections for tests 108 and 308.

Test 108: Visual inspection of the ignition area indicated burning of the RTV and Ladicote in a localized region approximately 2-1/4 inches in diameter. There was no propagation to adjacent components or wire bundles.

Test 308: Seven out of nine circuit breakers were severely burned. All insulation on wires leading to these circuit breakers was destroyed.

Summaries. - The following summaries are for tests 108 and 308.

Test 108: The results of this test indicated that the application of double Ladicote to circuit breakers provided sufficient protection to prevent flame propagation.

Test 308: The results of this test indicated that the Ladicote did not provide adequate fire protection for a CB panel.

Tests 109 and 309

Ignition location. - An internal igniter was located under the conformal coating of CB 20 on panel 275, which is on the right side of the test vehicle just below the girth shelf and above the sequencer bay (fig. 9).

Purpose. - The purpose of tests 109 and 309 was to determine the flammability characteristics of the nonmetallic materials used in panel 275 and to evaluate the protection provided by Ladicote. Test 209 was not conducted because of the large fires that resulted in similar tests 206 and 207.

Test descriptions. - The following descriptions are for tests 109 and 309.

Test 109: Igniter burnthrough occurred at T + 1 minute 25 seconds. Smoke emanated from the right side of the panel at T + 1 minute 16 seconds and lasted for approximately 15 seconds. Temperature data indicated that little or no propagation occurred. The test was concluded at T + 5 minutes.

Test 309: Smoke and flame were observed simultaneously along the upper edge of the panel at T + 50 seconds. Smoke became significant at T + 1 minute 10 seconds and continued to increase throughout the test. Igniter burnthrough occurred at T + 2 minutes. The smoke and flame had become more severe by T + 4 minutes 45 seconds. The test was terminated at T + 5 minutes in accordance with test-termination criteria.

Visibility. - The following visibility summaries are for tests 109 and 309.

Test 109: Visibility in the cabin was not affected.

Test 309: Visibility in the cabin was considerably reduced.

Temperature and pressure. - There was no significant increase in free-air temperature or cabin pressure during test 109 or 309.

Gas analysis. - The following notes are from gas-sample-analysis results for tests 109 and 309.

Test 109: No potentially toxic products were detected in the gas sample.

Test 309: The gas analysis indicated 157.5 ppm carbonyl fluoride, 13.0 ppm carbon tetrafluoride, and 54.3 ppm silicon tetrafluoride present in the gas sample.

Post-test inspections. - The following notes are the results of the post-test inspections for tests 109 and 309.

Test 109: Visual inspection of the ignition area indicated burning of the RTV and Ladicote in a localized region approximately one-half inch in diameter. No propagation to adjacent components or wire bundles occurred.

Test 309: Ten out of 13 circuit breakers were severely damaged. Most of the insulation on wires leading to the circuit breakers was destroyed.

Summaries. - The following summaries are for tests 109 and 309.

Test 109: The results of this test indicated that the application of double Ladicote to circuit breakers provided sufficient protection to prevent flame propagation.

Test 309: The results of this test indicated that the Ladicote did not provide adequate fire protection for a CB panel.

Tests 110, 210, and 310

Ignition location. - An external igniter was located on the silicone-cushioned Adel clamps on the water-glycol lines that are under the wire bundle that goes to the RH upper-deck feedthrough plate behind panel 2 (fig. 10).

Purpose. - The purpose of tests 110, 210, and 310 was to determine if flame impingement would damage the water-glycol line and to determine the fire hazard if rupture occurred in the area of a fire.

Test descriptions. - The following descriptions are for tests 110, 210, and 310.

Test 110: Ignition occurred at approximately T + 30 seconds. At T + 35 seconds, one particle was observed to drop from the ignition site. The fire self-extinguished at approximately T + 3 minutes 30 seconds. At T + 3 minutes 40 seconds, all temperatures started to decrease. At T + 7 minutes, all temperatures were at a nominal level, and the test was concluded. There was no indication that the water-glycol line was affected as a result of this test.

Test 210: Ignition occurred at T + 23 seconds. At T + 4 minutes 30 seconds, the fire self-extinguished. No smoke or haze in the cabin was observed during the test. There were no visible indications that the glycol line was affected. The test was concluded at T + 12 minutes.

Test 310: Flame was first observed at T + 22 seconds. The fire self-extinguished at T + 2 minutes 45 seconds. No smoke was visible at any time during the test. The test was concluded at T + 8 minutes.

Visibility. - Visibility in the cabin was not affected during test 110, 210, or 310.

Temperature and pressure. - There was no significant increase in free-air temperature or cabin pressure during test 110, 210, or 310.

Gas analysis. - The following data are gas-sample-analysis results for tests 110, 210, and 310.

Test 110: No potentially toxic products were detected in the gas sample.

Test 210: The gas analysis indicated less than 1.0 ppm silicon tetrafluoride present in the gas sample.

Test 310: The gas analysis indicated 2.7 ppm carbon tetrafluoride and 4.5 ppm silicon tetrafluoride present in the gas sample.

Post-test inspections. - The following results are from the post-test inspections for tests 110, 210, and 310.

Test 110: The Adel clamp was ignited, but no propagation to other materials occurred. Post-test checkout of the glycol system indicated no leaks or other damage.

Test 210: The silicone-cushioned Adel clamp was ignited and burned completely; however, there was no propagation to other materials. No glycol-line damage was noted.

Test 310: The silicone-cushioned Adel clamp was burned; however, there was no propagation to other materials and no damage to the water-glycol lines.

Summaries. - The following summaries are for tests 110, 210, and 310.

Test 110: No propagation or damage to the glycol line occurred as a result of this test.

Tests 210 and 310: Direct flame impingement did no apparent damage to the water-glycol lines.

Tests 111 and 211

Ignition location. - An external igniter was located at the edge of the silicone-laminate cover on the back of display panel 2, which is the center panel on the MDC and largest of the three major panels on the MDC (fig. 10).

Purpose. - The purpose of tests 111 and 211 was to determine the flammability and flame-propagation properties of the silicone-laminate cover mounted on the back of display panel 2. The inside surface of the cover was in close proximity to the

igniter, which was located on a wire bundle of the panel. Test 311 was not conducted because the silicone-laminate cover on panel 2 was destroyed in tests 302 and 303.

Test descriptions. - The following descriptions are for tests 111 and 211.

Test 111: Ignition occurred at T + 15 seconds. The flame self-extinguished at T + 2 minutes. Temperature data indicated no flame propagation. The test was concluded at T + 6 minutes after the igniter thermocouple had fallen from a maximum of 1100° to 172° F.

Test 211: Smoke was observed at T + 13 seconds, and flame was visible at T + 18 seconds. Flame continued for approximately 1 minute. Smoke and flame were localized to the area of ignition. No smoke was seen in the cabin. The test was concluded at T + 9 minutes.

Visibility. - Visibility in the cabin was not affected during test 111 or 211.

Temperature and pressure. - There was no significant increase in free-air temperature or cabin pressure during test 111 or 211.

Gas analysis. - No potentially toxic products were detected in the gas samples from tests 111 and 211.

Post-test inspections. - The following results are from the post-test inspections for tests 111 and 211.

Test 111: Only a very small portion of the silicone-laminate cover in an area immediately over the ignition point was burned.

Test 211: Only a small portion of the silicone-laminate cover in the area immediately over the ignition point was burned. There was no propagation.

Summary. - The results of tests 111 and 211 indicated that the silicone-laminate cover did not support combustion.

Tests 112, 212, and 312

Ignition location. - An external igniter was located at the edge of the silicone-laminate cover on the back of the panel-8 side display console. The console was just above the girth shelf on the LH side of the test vehicle and was adjacent to the ECU controls (fig. 8).

Purpose. - The purpose of tests 112, 212, and 312 was to determine flammability and flame-propagation properties resulting from an ignition source at the junction of a wire bundle and a cutout in the silicone-laminate cover of panel 8.

Test descriptions. - The following descriptions are for tests 112, 212, and 312.

Test 112: Ignition occurred at approximately T + 1 minute 30 seconds. At T + 2 minutes 20 seconds, the temperature 6 inches above the igniter reached 1500 °F. At T + 5 minutes, the test was concluded after temperature data indicated burning had stopped.

Test 212: The reflection of a flame was seen at T + 35 seconds behind the upper RH corner of panel 8. The reflection of the flame lasted approximately 1 minute. No smoke was visible at the ignition point or in the cabin. The test was concluded at T + 6 minutes.

Test 312: At T + 27 seconds, the temperature in the ignition area had risen to 1900° F. Igniter burnthrough occurred at T + 40 seconds. At T + 1 minute, fire was observed behind the upper RH corner of panel 8. Sufficient smoke to start the 125-second egress count was observed at T + 1 minute 45 seconds. Intermittent dripping of particles from the heat-exchanger area started at T + 1 minute 50 seconds and continued throughout the test. The buildup of smoke in the cabin continued at a rapid rate. At approximately T + 2 minutes 50 seconds, the left arm or left edge of the suit ignited, and the fire rapidly propagated to the suit torso and helmet region. The test was terminated at T + 2 minutes 57 seconds by opening the BP to the vacuum system.

Post-termination data (test 312). - Because the BP outlet to the vacuum system is adjacent to panel 8, the directional gas flow around panels 8 and 1 caused flames to sweep across the panel faces and ignite the EL overlays on both panels. The pumpdown of the BP was relatively slow because of the quantities of gases produced and because of the expansion of gases resulting from the large fire that existed for several minutes after test termination. At T + 11 minutes, burning was still observed in the region of the helmet, and the cabin pressure was approximately 0.81 psia. At T + 5 minutes 55 seconds, the water-glycol circulating pump was turned off. At T + 8 minutes 10 seconds, large quantities of steam or light-colored smoke, believed to be water-glycol vapor, were seen sweeping across the cabin from the region of the heat exchanger toward the vacuum-exhaust line. At T + 8 minutes 30 seconds, a liquid was seen dripping from the same region onto the LH couch.

Visibility. - Visibility in the cabin was not affected during test 112 or 212, but was greatly reduced during test 312.

Temperature and pressure. - The following temperature and pressure data are for tests 112, 212, and 312.

Tests 112 and 212: There was no significant increase in free-air temperature or cabin pressure.

Test 312: The cabin free-air temperature rose 180° F above ambient, and cabin pressure increased 1.3 psig.

Gas analysis. - The following results are from gas-sample analysis for tests 112, 212, and 312.

Test 112: The gas analysis indicated 80.2 ppm carbon tetrafluoride and 9 ppm silicon tetrafluoride present in the gas sample.

Test 212: The gas analysis indicated 3.0 ppm carbon tetrafluoride and 1.0 ppm silicon tetrafluoride present in the gas sample.

Test 312: The gas analysis indicated 431.8 ppm carbonyl fluoride, 163.6 ppm carbon tetrafluoride, and 463.6 ppm silicone tetrafluoride present in the gas sample.

Post-test inspections. - The following data are the results of the post-test inspections for tests 112, 212, and 312.

Test 112: Inspection indicated that some propagation occurred vertically and horizontally on the surface of the silicone-laminate cover (fig. 17).

Test 212: Inspection indicated that propagation occurred vertically and horizontally on the surface of the silicone-laminate cover (fig. 30).

Test 312: The fire propagated up and outward from the ignition point across the silicone-laminate cover of panel 8. The upper one-third of the silicone-laminate cover was completely burned. The fire propagated to and severely damaged eight switches and several circuit breakers on the upper portion of the panel. Much of the insulation on the wiring leading to these components was destroyed. A small area (approximately 2 by 4 inches) of the silicone-laminate cover on panel 1 was also burned. Post-test inspection indicated that the fire reached the heat-exchanger Fluorel by propagating up a vertical wire bundle which ran along the left inner bulkhead behind panel 8. This bundle intersected a horizontal wire bundle which was on the upper bulkhead and which went through the heat-exchanger compartment and through both adjacent compartments; all of the Fluorel, wire insulation, silicone spacers, and clamps were destroyed in these areas. The aluminum inner structure in the heat-exchanger compartment melted in several locations. Aluminum drippings were found on the left couch, on the mattress below the couch, and on the floor. Both cabin fans were destroyed. The fans were severely distorted, and molten metal from the fan housing had dripped down onto the heat exchanger (fig. 43). A rupture occurred in a water-glycol line in front of and just above the heat exchanger. The rupture was at an unarmored solder splice and was apparently caused by high temperatures in the area.

Summaries. - The following summaries are for tests 112, 212, and 312.

Test 112: The results of this test indicated that the silicone-laminate cover would support combustion vertically and, to a lesser degree, horizontally; however, self-extinguishment did take place after the heat source was removed.

Test 212: The results of this test indicated that the silicone-laminate cover will support combustion vertically as well as horizontally.

Test 312: The results of this test indicated that materials in this region provided sufficient propagation paths for a fire to spread rapidly throughout the upper LHEB. Although direct visual observation was not possible, it is believed from motion pictures and post-test inspection that the suit ignited as a result of flaming sparks or molten metal dripping from the heat-exchanger area. Because of the very large fire, the test was terminated approximately 53 seconds before the required egress time of 2 minutes 5 seconds had elapsed. It should be reemphasized that the post-test damage to the EL overlays on panels 8 and 1 occurred as a result of evacuating the cabin after termination.

Tests 113, 213, and 313

Ignition location. - An external igniter was located on the neoprene-coated saddle clamp that secures the wire bundle that penetrates through the LH shelf behind food-storage compartment B1 (fig. 11).

Purpose. - The purpose of tests 113, 213, and 313 was to determine the extent of flame propagation resulting from ignition of neoprene coating on a saddle clamp to the adjacent wire bundle and through the Du Pont Pyrolin-laminate food container to the contents of the food container.

Test descriptions. - The following descriptions are for tests 113, 213, and 313.

Test 113: Ignition occurred at T + 15 seconds. A visible flame was observed for 60 seconds. A thermocouple located on the back side of the food box indicated a temperature rise of 31° F. A thermocouple inside the food box, 3 inches from the back side, indicated a temperature rise of 3° F.

Test 213: At T + 1 minute 45 seconds, a few sparks were visible below the ignition area. There was no visible flame or smoke throughout the test. The test was concluded at T + 8 minutes.

Test 313: At T + 30 seconds, the reflection of a flame was observed on the glass of panel 317 for approximately 5 seconds. A few sparks were observed falling from the ignition area. There was no visible flame or smoke throughout the test. The test was concluded at T + 6 minutes.

Visibility. - Visibility in the cabin was not affected during test 113, 213, or 313.

Temperature and pressure. - There was no significant increase in free-air temperature or cabin pressure during test 113, 213, or 313.

Gas analysis. - No potentially toxic products were detected in the gas samples from tests 113, 213, and 313.

Post-test inspections. - The following results are from the post-test inspections for tests 113, 213, and 313.

Test 113: The neoprene coating on the saddle clamp was burned. Wire bundles under the saddle clamp sustained minor surface damage.

Tests 213 and 313: The neoprene coating on the saddle clamp was burned. The fire did not propagate along the wire bundles going through the clamp; however, there was some localized burning of wire insulation. No damage was done to the food box or to the contents of the food box.

Summaries. - The following summaries are for tests 113, 213, and 313.

Test 113: The results of this test indicated that the aluminum food box provided adequate protection for the contents from an external ignition source.

Tests 213 and 313: The results of these tests indicated that the Du Pont Pyrolin-laminate food container provided adequate protection for the contents from an external ignition source.

Tests 114 and 214

Ignition location. - An external igniter was located on a neoprene-coated saddle clamp above the LH girth shelf and behind control-and-display panel 8 adjacent to the suit supply duct and on the LHEB (fig. 8).

Purpose. - The purpose of test 114 was to determine the extent of flame propagation to adjacent wire bundles from the ignition of a neoprene-latex coating on a wire-bundle saddle clamp. Propagation could occur vertically up the bundle from the clamp. The purpose of test 214 was to determine the extent of flame propagation to adjacent vertical wire bundles from the ignition of a neoprene-coated saddle clamp. Test 314 was not conducted because the test location was destroyed by the severe propagation in test 312.

Test descriptions. - The following descriptions are for tests 114 and 214.

Test 114: Burnthrough of the igniter occurred at T + 17 seconds. There was no visible indication of fire or smoke.

Test 214: The reflection of a fire was observed in the area of the igniter at T + 25 seconds; flickering continued to be visible for approximately 1 minute. No smoke was observed during the test at the igniter area or in the cabin. The test was concluded at T + 6 minutes.

Visibility. - Visibility in the cabin was not affected during test 114 or 214.

Temperature and pressure. - There was no significant increase in free-air temperature or cabin pressure during test 114 or 214.

Gas analysis. - The following notes are gas-sample-analysis results for tests 114 and 214.

Test 114: The gas analysis indicated 30.9 ppm carbon tetrafluoride present in the gas sample.

Test 214: The gas analysis indicated 101.0 ppm carbonyl fluoride, 5.0 ppm carbon tetrafluoride, and 1.4 ppm silicon tetrafluoride present in the gas sample.

Post-test inspections. - The following results are from the post-test inspections for tests 114 and 214.

Test 114: The igniter burned but did not ignite the neoprene coating on the saddle clamp. A small wire bundle above the igniter was slightly damaged from the igniter flame.

Test 214: The neoprene coating on the saddle clamp was burned off; however, the fire did not propagate to the wire bundle going through the clamp. Only a small, localized part of the wire insulation adjacent to the ignition point was damaged.

Summaries. - The following summaries are for tests 114 and 214.

Test 114: No significant fire or propagation resulted from test 114.

Test 214: No propagation occurred, and only localized damage resulted from test 214.

Tests 115, 215, and 315

Ignition location. - An external igniter was placed on the sleeve over the wiring entering the electrical connector to the electronic-control-unit amplifier that is under the lithium-hydroxide canisters. The electronic-control-unit amplifier is in the LHEB (fig. 8).

Purpose. - The purpose of tests 115, 215, and 315 was to determine the flammability of nonmetallic materials on the electronic-control-unit amplifier panel and to determine the propagation of flame to adjacent components.

Test descriptions. - The following descriptions are for tests 115, 215, and 315.

Test 115: Flame was visible from T + 30 seconds to T + 1 minute 53 seconds. No significant propagation occurred.

Test 215: Smoke was observed at T + 19 seconds, at which time a small amount of soot was seen momentarily. Flame was observed at T + 27 seconds and continued to be visible until it self-extinguished at T + 1 minute 6 seconds. The test was concluded at T + 6 minutes.

Test 315: Flame 3 inches in height was observed at T + 14 seconds and continued at about the same intensity until T + 1 minute 15 seconds. At this time, flame began to progressively decrease until it self-extinguished at T + 1 minute 40 seconds. No smoke was observed at the ignition area or in the cabin. The test was concluded at T + 5 minutes.

Visibility. - Visibility in the cabin was not affected during test 115, 215, or 315.

Temperature and pressure. - There was no significant increase in free-air temperature or cabin pressure during test 115, 215, or 315.

Gas analysis. - The following notes are gas-sample-analysis results for tests 115, 215, and 315.

Test 115: No potentially toxic products were detected in the gas sample.

Test 215: The gas analysis indicated 98.0 ppm carbonyl fluoride, 8.8 ppm carbon tetrafluoride, and 4.4 ppm silicon tetrafluoride present in the gas sample.

Test 315: The gas analysis indicated 131.5 ppm carbonyl fluoride, 27.6 ppm carbon tetrafluoride, and 5.2 ppm silicon tetrafluoride present in the gas sample.

Post-test inspections. - The following data are the results of the post-test inspections for tests 115, 215, and 315.

Test 115: Damage was localized to the ignition area and was limited to the wire insulation and protective sleeve (fig. 18).

Test 215: Inspection indicated that the Teflon wrap and some of the Teflon-braid insulation were destroyed. The damage was localized in an area approximately 2 inches in diameter in the ignition region (fig. 31).

Test 315: Inspection indicated that the Teflon wrap and some of the Teflon-braid insulation were destroyed. The damage was localized in an area approximately 2 inches in diameter in the ignition region.

Summaries. - The following summaries are for tests 115, 215, and 315.

Test 115: No significant fire or propagation resulted from this test.

Tests 215 and 315: The results of these tests indicated that there was no significant propagation to adjacent components.

Tests 116 and 216

Ignition location. - An external igniter was located on a neoprene-coated saddle clamp with pink-silicone spacers. The saddle clamp was in the RH side of the cabin heat-exchanger compartment on the bulkhead (fig. 8).

Purpose. - The purpose of tests 116 and 216 was to determine the extent of flame propagation to adjacent wire bundles, to water-glycol lines, and to Fluorel insulation from the ignition of a neoprene-coated saddle clamp and of unwrapped silicone-rubber spacers. Test 316 was not conducted because the test location was destroyed by severe propagation in test 312.

Test descriptions. - The following descriptions are for tests 116 and 216.

Test 116: At T + 5 minutes, smoke and fire were observed in the fan area. All related thermocouples indicated a continuous temperature rise. At T + 9 minutes 40 seconds, the test was terminated in accordance with the test-termination criteria when a thermocouple on an adjacent clamp indicated a temperature in excess of 1000° F.

Test 216: Smoke was observed at T + 4 minutes 50 seconds in the fan area. Sparks of burning material were seen coming from the cabin fan exit at T + 5 minutes 20 seconds. Heavy smoke was observed at T + 5 minutes 40 seconds. Smoke became dense throughout the cabin at T + 6 minutes. A considerable amount of soot was seen floating in the cabin at T + 7 minutes 15 seconds. At T + 8 minutes 19 seconds, the

test was terminated; however, all related thermocouples were indicating a rapid increase in temperature.

Visibility. - The following visibility summaries are for tests 116 and 216.

Test 116: Visibility was severely affected by considerable smoke and soot.

Test 216: Visibility in the cabin was greatly reduced.

Temperature and pressure. - The following temperature and pressure data are for tests 116 and 216.

Test 116: This test produced an increase in cabin free-air temperature from 87° to 150° F. Temperatures on two adjacent saddle clamps went to 950° F, while the temperature at a third clamp had reached 1350° F by test termination. There was no detectable increase in cabin pressure, although intermittent venting of the cabin-pressure relief valve was noted.

Test 216: The cabin free-air temperature rose from 85° F to a peak of 155° F. The cabin pressure rose from 16.2 psia to a peak pressure of 16.9 psia and then leveled off at 16.5 psia.

Gas analysis. - The following results are from gas-sample analysis for tests 116 and 216.

Test 116: The gas analysis indicated 7.9 ppm carbon monoxide, 887 ppm carbonyl fluoride, 166 ppm carbon tetrafluoride, and 2415 ppm silicon tetrafluoride present in the gas sample.

Test 216: The gas analysis indicated 620.0 ppm carbonyl fluoride, 93.7 ppm carbon tetrafluoride, and 706.0 ppm silicon tetrafluoride present in the gas sample.

Post-test inspections. - The following notes are the results of the post-test inspections for tests 116 and 216.

Test 116: Major damage occurred as a result of this fire. Both cabin fans were rendered inoperable; wire insulation was destroyed; silicone-rubber spacers were burned; and the Fluorel acoustic insulation in the duct burned. Large quantities of soot and debris were deposited throughout the cabin interior (fig. 19).

Test 216: Inspection indicated that severe damage had occurred. Both cabin fans were rendered inoperable. Wires, insulation, silicone-rubber spacers, and the Fluorel acoustic insulation in the fan compartment were completely destroyed. Fire propagated to the compartments on the right and left of the fan compartment; wire insulation, silicone spacers, and clamps were destroyed in these areas. Further propagation occurred beyond the compartment adjacent to the left and into the area above panel 1. No significant damage occurred in this area because the test was terminated. The aluminum inner structure in the heat-exchanger compartment was severely distorted and melted in several locations (fig. 32).

Summaries. - The following summaries are for tests 116 and 216.

Test 116: The results of this test indicated that the materials in this region, particularly the Fluorel acoustic insulation, provided a significant quantity of flammable material which resulted in an extensive fire.

Test 216: The results of this test indicated that materials in this region, particularly the Fluorel acoustic insulation, are highly flammable and that significant propagation can occur to adjacent areas.

Tests 117, 217, and 317

Ignition location. - An external igniter was placed on a saddle clamp (with pink-silicone fillers) on a vertical wire bundle where the bundle exits from the LH floor-harness tray in the LEB (fig. 11).

Purpose. - The purpose of tests 117, 217, and 317 was to determine the extent of flame propagation to adjacent wire bundles from the ignition of a neoprene-coated saddle clamp and unwrapped silicone-rubber spacers.

Test descriptions. - The following descriptions are of tests 117, 217, and 317.

Test 117: No fire or smoke was visible during this test. All related thermocouples indicated no significant propagation.

Test 217: Smoke at the igniter was observed at T + 16 seconds, and flame was observed at T + 27 seconds. The flame reached a maximum height of approximately 12 inches from the igniter. Maximum flame was observed at T + 45 seconds. The flame self-extinguished at T + 4 minutes 35 seconds. The test was concluded at T + 12 minutes.

Test 317: Flame was observed at T + 13 seconds. At T + 1 minute 24 seconds, the flame had propagated upward along the Teflon wrap to the clamp approximately 12 inches above the ignition point. Fire propagated 3 to 4 inches past the clamp. A significant amount of smoke was observed in the cabin at T + 2 minutes 20 seconds. At T + 3 minutes, flame had diminished; however, it had propagated to adjacent small Teflon-overwrapped wire bundles. At T + 3 minutes 20 seconds, additional smoke was observed coming from the floor area below the ignition point; also, flame was observed simultaneously coming from the floor area. At T + 4 minutes 5 seconds, heavy smoke and flickering flame from the floor area were observed. At T + 4 minutes 27 seconds, the test was terminated in accordance with the test-termination criteria.

Visibility. - Visibility in the cabin was not affected during test 117 or 217, but was considerably reduced during test 317.

Temperature and pressure. - The following temperature and pressure data are for tests 117, 217, and 317.

Tests 117 and 217: There was no significant increase in free-air temperature or cabin pressure.

Test 317: Cabin free-air temperature rose to 155° F above ambient. There was no increase in cabin pressure.

Gas analysis. - The following data are gas-sample-analysis results for tests 117, 217, and 317.

Test 117: The gas analysis indicated 219 ppm carbonyl fluoride, 26 ppm carbon tetrafluoride, and 17 ppm silicon tetrafluoride present in the gas sample.

Test 217: The gas analysis indicated 289 ppm carbonyl fluoride, 78.4 ppm carbon tetrafluoride, and 15.1 ppm silicon tetrafluoride present in the gas sample.

Test 317: The gas analysis indicated 2162 ppm carbonyl fluoride, 828.5 ppm carbon tetrafluoride, and 103.3 ppm silicon tetrafluoride present in the gas sample.

Post-test inspections. - The following notes are the results of the post-test inspections for tests 117, 217, and 317.

Test 117: All of the exposed neoprene and silicone-rubber spacers were severely burned. The Teflon wrapping and wire insulation was burned in a localized area next to the clamp.

Test 217: Inspection indicated that the saddle clamp and silicone spacers were completely burned. Flame impingement from the clamp burned about 6 inches of Teflon overwrap and wire insulation above the clamp. No propagation occurred (fig. 33).

Test 317: The saddle clamp and all silicone spacers were completely burned. The fire propagated upward past a neoprene-coated saddle clamp along an undetermined path. The fire also propagated downward to the sleep pad below the LH couch. Approximately one-fourth of the pad was burned. The exact propagation path to the sleep pad could not be determined. However, it is believed that the fire propagated inside the LH electrical floor tray (fig. 44).

Summaries. - The following summaries are for tests 117, 217, and 317.

Test 117: No propagation occurred in the test region.

Test 217: The results of this test indicated no propagation and only localized damage to wire insulation.

Test 317: The results of this test indicated that the Teflon overwrap provided a propagation path for a localized fire to become widespread.

Tests 118, 218, and 318

Ignition location. - An external igniter was located on the Kynar sleeves of wires in the bundle going into the connector (second from RH edge) on the bottom row of the RH circuit-interrupter feedthrough plate assembly (fig. 11).

Purpose. - The purpose of tests 118, 218, and 318 was to determine the extent of flame propagation resulting from the ignition of wire bundle Kynar identification sleeves to adjacent wire bundles and to the silicone-rubber insert in the connector on the feedthrough plate assembly.

Test descriptions. - The following descriptions are for tests 118, 218, and 318.

Test 118: The reflection of a flame was seen on the television monitor for approximately 45 seconds. The igniter thermocouple reached 1600° F, indicating ignition. Related thermocouples did not show any temperature rise, indicating that no propagation occurred. The test was concluded at T + 5 minutes.

Test 218: Ignition occurred at T + 30 seconds, at which time the igniter thermocouple indicated approximately 1030° F. It was not possible to determine visually when the flame went out; however, the thermocouple temperature drop would indicate that the flame went out at T + 2 minutes 15 seconds. The test was concluded at T + 6 minutes.

Test 318: Flame and light smoke were observed simultaneously at T + 21 seconds. Smoke was visible for approximately 5 seconds. Igniter burnthrough occurred at T + 30 seconds. The flickering of flames remained visible until T + 45 seconds. At T + 1 minute 15 seconds, there was no visible flame or smoke. At T + 5 minutes, the test was concluded.

Visibility. - Visibility in the cabin was not affected during test 118, 218, or 318.

Temperature and pressure. - There was no significant increase in free-air temperature or cabin pressure during test 118, 218, or 318.

Gas analysis. - The following results are from gas-sample analysis for tests 118, 218, and 318.

Test 118: The gas analysis indicated 4.4 ppm carbon tetrafluoride and 2.5 ppm tetrafluoride present in the gas sample.

Test 218: No potentially toxic products were detected in the gas sample.

Test 318: The gas analysis indicated 57.5 ppm carbonyl fluoride, 7.7 ppm carbon tetrafluoride, and 3.2 ppm silicon tetrafluoride present in the gas sample.

Post-test inspections. - The following notes are the results of the post-test inspections for tests 118, 218, and 318.

Test 118: Damage was localized to the Teflon wire insulation in the igniter region.

Test 218: Inspection indicated that damage was localized to the Kynar sleeves in the area of ignition. There was some charring of the Teflon wire insulation.

Test 318: Visual inspection indicated that damage was localized to the ignition area. The Kynar sleeves and some wire insulation were burned.

Summaries. - The following summaries are for tests 118, 218, and 318.

Test 118: No significant propagation occurred during this test.

Tests 218 and 318: The Kynar identification sleeves burned; however, there was no propagation along the wire bundle or to adjacent components.

Tests 119, 219, and 319

Ignition location. - An external igniter was located on the neoprene-coated saddle clamp securing a large horizontal wire bundle at the RH side of the RH circuit-interrupter feedthrough plate assembly which is located on the LEB. Coaxial cables are routed through this region. On tests 219 and 319, the igniter was placed directly under and in contact with the coaxial cable (fig. 11). For test 219, the cable was placed in the SC 101 configuration.

Purpose. - The purpose of tests 119, 219, and 319 was to determine the extent of flame propagation to adjacent wire bundles from the ignition of a neoprene-coated saddle clamp. Because the coaxial cable will burn, knowledge of the ease of ignition and of the extent of propagation was required. An additional purpose of test 319 was to determine if the aluminum-tape overwrap on the coaxial cables above the girth shelf would stop vertical propagation.

Test descriptions. - The following descriptions are for tests 119, 219, and 319.

Test 119: The igniter burned; however, the neoprene on the saddle clamp did not ignite. No visible flames were seen after approximately T + 1 minute.

Test 219: Smoke was observed at T + 18 seconds at the igniter area, and fire occurred at T + 35 seconds with flame coming out from both sides of the clamp. The current to the igniter was turned off at T + 40 seconds. The fire propagated to the clamp at the right of the igniter at T + 1 minute 50 seconds and remained visible at the clamp area for 20 seconds. At T + 3 minutes, the fire appeared to have self-extinguished. At T + 4 minutes, the igniter current was turned on again, and flame reappeared at T + 4 minutes 40 seconds. The flame increased at T + 5 minutes 30 seconds, and the clamp burned more severely than after the first ignition. At T + 6 minutes, propagation had taken place to both sides of the clamp; and 35 seconds later, the coaxial cable was flaming at the clamp. At T + 6 minutes 45 seconds, the fire propagated to the left of the ignition area along the coaxial cable. At T + 7 minutes 20 seconds, smoke was observed in the compartment above the girth shelf, and the flame continued to propagate to the left of the coaxial cable. The flame reached approximately halfway to the girth shelf at this time. At T + 8 minutes 50 seconds, propagation occurred to the right along the coaxial cable; and at T + 9 minutes 40 seconds, the flame reached the clamp to the right of the ignition point.

Test 319: Flame was observed at T + 13 seconds. At T + 30 seconds, the clamp was burning. At T + 45 seconds, the coaxial cable was burning to the right and left of the clamp. Light smoke was observed coming from the top side of the glass panel above the girth shelf at T + 1 minute 10 seconds. At T + 1 minute 30 seconds, the coaxial cable was burning on the vertical run to the left of the ignition point. At

T + 2 minutes 30 seconds, the fire propagated on the coaxial cable to the right and upward toward the girth shelf. At T + 2 minutes 40 seconds, fire was observed at the saddle clamp and extended above the girth shelf. Significant soot and smoke were observed above the girth shelf and in the cabin area at T + 2 minutes 50 seconds. At T + 3 minutes 30 seconds, smoke and soot became heavy throughout the cabin. At T + 3 minutes 45 seconds, a group of coaxial cables to the left of the vertical bundle below the girth shelf was burning vigorously. At T + 4 minutes 20 seconds, fire propagated along the vertical coaxial cable above the girth shelf and reached the silicone-covered Adel clamp at T + 4 minutes 30 seconds. General fires occurred in the area above and below the girth shelf until the test was terminated at T + 5 minutes in accordance with test-termination criteria.

Visibility. - Visibility in the cabin was not affected during test 119, but was significantly reduced during tests 219 and 319.

Temperature and pressure. - The following temperature and pressure data are for tests 119, 219, and 319.

Test 119: There was no significant increase in free-air temperature or cabin pressure.

Test 219: Cabin free-air temperature rose from 78° to 81° F, and the cabin pressure increased from 16.3 to 16.8 psia.

Test 319: Free-air temperature rose 10° F above ambient. There was no increase in cabin pressure.

Gas analysis. - The following data are gas-sample-analysis results for tests 119, 219, and 319.

Test 119: No potentially toxic products were detected in the gas sample.

Test 219: The gas analysis indicated 204 ppm carbonyl fluoride, 44.8 ppm carbon tetrafluoride, and 38.7 ppm silicon tetrafluoride present in the gas sample.

Test 319: The gas analysis indicated 135 ppm carbonyl fluoride, 420.0 ppm carbon tetrafluoride, and 284.6 ppm silicon tetrafluoride present in the gas sample.

Post-test inspections. - The following notes are the results of the post-test inspections for tests 119, 219, and 319.

Test 119: Damage was localized to the igniter region.

Test 219: Considerable damage caused by flame impingement from the coaxial cable was observed. The coaxial cable was destroyed below and above the girth shelf. Fire propagated to all adjacent wire bundles above the girth shelf, primarily to the LH wire bundle and to a bundle of small conductors leading to a connector on the LH compartment. Soot was observed over the entire raceway area (fig. 34).

Test 319: The fire propagated throughout both the lower and the upper RH compartment of the LEB. All clamps, connector inserts, coaxial cables, and 75 percent

of the wiring in this area were severely burned. The fire had propagated up to the wire raceway behind cabinet R1 before the test was terminated. An 8-inch long rupture in the aluminum inner skin occurred approximately 14 inches above the girth shelf (figs. 45 and 46).

Summaries. - The following summaries are for tests 119, 219, and 319.

Test 119: No significant propagation occurred.

Test 219: Considerable burning of the coaxial cable occurred before smoke was observed. The vertical runs of coaxial cable produced a significant fire. The resulting fire did not self-extinguish.

Test 319: The coaxial cable provided a rapid propagation path for a fire to spread throughout the RH LEB. The aluminum-tape overwrap on the coaxial cable did not appear to inhibit fire propagation.

Test 219A

Ignition location. - An external igniter was located on a neoprene-coated saddle clamp that secured a large horizontal wire bundle at the RH circuit-interrupter feedthrough plate assembly on the LEB. Coaxial cables are routed through this region. The igniter was placed directly under and in contact with a coaxial cable placed in the 2TV-1 configuration. Test 219A was necessary because the coaxial-cable configuration was not the same for 2TV-1 as for SC 101. (The cable was placed in the SC 101 configuration in test 219.)

Purpose. - The purpose of test 219A was to determine the extent of propagation to adjacent wire bundles from the ignition of a neoprene-coated saddle clamp. It was already known that the coaxial cable was flammable, but information was needed as to the ease of ignition and extent of propagation.

Test description. - A significant amount of smoke was observed coming from the ignition area at T + 16 seconds; at T + 26 seconds, flame was observed. At T + 45 seconds, the flame propagated to the left and right of the ignition point, and the coaxial cable started to burn locally. At T + 1 minute 20 seconds, a large flame was observed to the left and right of the saddle clamp. This flame died down at T + 2 minutes 30 seconds. At T + 3 minutes, the flame appeared to flare up again and propagated a short distance to the right and left. At T + 3 minutes 25 seconds, the only fire remaining visible was at the right clamp. At T + 6 minutes 30 seconds, there was no visible smoke, although some soot was observed. The test was concluded at T + 12 minutes.

Visibility. - Visibility in the cabin was not significantly affected.

Temperature and pressure. - There was no significant increase in free-air temperature or cabin pressure.

Gas analysis. - The gas analysis indicated 6.8 ppm carbon tetrafluoride and 11.9 ppm silicon tetrafluoride present in the gas sample.

Post-test inspection. - The fire propagated along the coaxial cable approximately 6 inches to either side of the ignition point. The burning stopped on both sides at a point where the coaxial cable was overwrapped with Teflon. Two neoprene-coated saddle clamps were burned. Only slight damage occurred to the insulation of other wires in the immediate ignition area.

Summary. - Only minor propagation along the coaxial cable occurred, and the fire self-extinguished. The flame appeared to have been stopped by the Teflon overwrap.

Tests 120, 220, and 320

Ignition location. - The ignition locations for tests 120, 220, and 320 were as follows.

Test 120: An external igniter was located on the neoprene-coated saddle clamp securing the horizontal wire bundle at the LH side of the LH circuit-interrupter feedthrough plate assembly on the LH rear corner of the LEB.

Tests 220 and 320: An external igniter was located on the neoprene-coated saddle clamp mounted horizontally on a bulkhead in the LEB approximately 12 inches to the right of the LH circuit-interrupter feedthrough plate assembly (fig. 11).

Purpose. - The purpose of tests 120, 220, and 320 was to determine the extent of flame propagation to adjacent wire bundles from the ignition of a neoprene-coated saddle clamp.

Test descriptions. - The following descriptions are for tests 120, 220, and 320.

Test 120: There was no visible indication of burning during the test. All thermocouples indicated no significant propagation.

Test 220: Because of the igniter location, no positive visible identification was made of smoke or soot. The test was concluded at T + 5 minutes.

Test 320: The igniter location precluded visible flame identification. However, temperature data indicated that ignition occurred at approximately T + 25 seconds. Light smoke was observed coming from a slot around a storage box in front of the ignition point at T + 1 minute. The test was concluded at T + 5 minutes.

Visibility. - Visibility in the cabin was not affected during test 120, 220, or 320.

Temperature and pressure. - There was no significant increase in free-air temperature or cabin pressure during test 120, 220, or 320.

Gas analysis. - The following data are gas-sample-analysis results for tests 120, 220, and 320.

Test 120: No potentially toxic products were detected in the gas sample.

Test 220: The gas analysis indicated 9.4 ppm carbon tetrafluoride present in the gas sample.

Test 320: The gas analysis indicated 226.6 ppm carbonyl fluoride, 40.6 ppm carbon tetrafluoride, and 6.6 ppm silicon tetrafluoride present in the gas sample.

Post-test inspections. - The following data are the results of the post-test inspections for tests 120, 220, and 320.

Test 120: The neoprene coating on the saddle clamp was completely burned away. There was no evidence of propagation through the clamp in either direction on the wire bundle. The outer wires adjacent to the neoprene were covered with soot. An adjacent wire bundle behind the ignition point was not affected.

Test 220: The neoprene coating on the saddle clamp was completely destroyed. No propagation occurred from the clamp to the wire bundle. The insulation on the wires adjacent to the clamp was charred and covered with soot.

Test 320: The neoprene coating on the saddle clamp was completely destroyed. No propagation occurred from the clamp outward on the wire bundle. The insulation was burned on some of the wires going through the clamp.

Summaries. - The following summaries are for tests 120, 220, and 320.

Test 120: No significant propagation occurred.

Test 220: No propagation occurred, and there was only slight charring of wire insulation.

Test 320: No significant propagation occurred, and there was only slight charring of wire insulation directly above the clamp.

Tests 121, 221, and 321

Ignition location. - An internal igniter under aluminum tape was located adjacent to the potting compound on connector 56P21 of the G&N "G" harness behind the G&N control panel (fig. 11).

Purpose. - The purpose of tests 121, 221, and 321 was to determine the flammability of nonmetallic materials used in the G&N harness and to determine the propagation along wire bundles and to adjacent wire bundles and equipment of flame resulting from an ignition source located on a potted connector.

Test descriptions. - The following descriptions are for tests 121, 221, and 321.

Test 121: Ignition occurred at T + 17 seconds, and the flame went out approximately 1 minute later. The test was concluded at T + 6 minutes after all thermocouples indicated no remaining fire.

Test 221: The initial power to the igniter was 12 amperes. The current was increased 1 ampere every 30 seconds until burnthrough occurred at T + 4 minutes 15 seconds. There was no visible indication of flame or smoke at any time during the test. The test was concluded at T + 8 minutes.

Test 321: Flame was observed at T + 4 minutes 13 seconds. At T + 5 minutes, flame flared up to a height of 6 inches for a period of approximately 1 minute 25 seconds. Drippings were also observed during this time. The flame decreased steadily until it became small and localized at the end of the connector. The flame self-extinguished at T + 8 minutes. No smoke was visible during the test. The test was concluded at T + 12 minutes.

Visibility. - Visibility in the cabin was not affected during test 121, 221, or 231.

Temperature and pressure. - There was no significant increase in free-air temperature or cabin pressure during test 121, 221, or 321.

Gas analysis. - The following notes are gas-sample-analysis results for tests 121, 221, and 321.

Tests 121 and 221: No potentially toxic products were detected in the gas samples.

Test 321: The gas analysis indicated 4.2 ppm carbon tetrafluoride present in the gas sample.

Post-test inspections. - The following notes are the results of the post-test inspections for tests 121, 221, and 321.

Test 121: Damage was localized and resulted from igniter-flame impingement on the connector.

Test 221: Inspection of the visible area showed no significant damage.

Test 321: There was localized burning of the aluminum wrap and of the connector potting material. Some wire insulation was burned off in the igniter region; however, no propagation occurred either on the wire bundle or on the connector potting compound.

Summaries. - The following summaries are for tests 121, 221, and 321.

Tests 121 and 221: The results of these tests indicated that the aluminum-foil covering over the potted connector provided adequate protection.

Test 321: The results of this test indicated that wrapping the connector potting with aluminum tape did not prevent ignition of an internal fire; however, the tape did prevent propagation.

Tests 122, 222, and 322

Ignition location. - An external igniter was located adjacent to the potting compound on connector 56P27 of the G&N "H" harness behind the G&N control panel (fig. 11).

Purpose. - The purpose of tests 122, 222, and 322 was to determine the flammability of the nonmetallic materials used in the G&N harness and to determine propagation along wire bundles and to adjacent wire bundles and equipment of flame resulting from an ignition source located on a potted connector.

Test descriptions. - The following descriptions are for tests 122, 222, and 322.

Test 122: Ignition occurred at T + 15 seconds, and the flame went out approximately 1 minute later. A small amount of smoke was observed in the igniter region.

Test 222: Smoke followed by flame was observed at T + 25 seconds. The fire self-extinguished at approximately T + 1 minute 45 seconds. The test was concluded at T + 6 minutes.

Test 322: Flame was observed at T + 17 seconds. The fire self-extinguished at T + 50 seconds, and the test was concluded at T + 5 minutes. There was no smoke visible in the ignition area or in the cabin during the test.

Visibility. - Visibility in the cabin was not affected during test 122, 222, or 322, although localized smoke was observed at the time of ignition on test 222.

Temperature and pressure. - There was no significant increase in free-air temperature or cabin pressure during test 122, 222, or 322.

Gas analysis. - No potentially toxic products were detected in the gas sample from test 122, 222, or 322.

Post-test inspections. - The following data are the results of the post-test inspections for tests 122, 222, and 322.

Test 122: Damage was localized and resulted from igniter-flame impingement on the connector.

Test 222: Inspection of the visible area showed no significant damage.

Test 322: Visual inspection of the ignition area showed only a small amount of light-colored residue and no damage from burning.

Summary. - The results of tests 122, 222, and 322 indicated that the aluminum-foil covering over the potted connector provided adequate fire protection from an external ignition source.

Tests 123, 223, and 323

Ignition location. - An external igniter was located against the silicone-rubber-covered clamp attaching the G&N "S" harness to the rear of the guidance computer location (fig. 11).

Purpose. - The purpose of tests 123, 223, and 323 was to determine the flammability of the nonmetallic materials used in the G&N harness and the propagation along wire bundles and to adjacent wire bundles and equipment of flame resulting from an ignition source located on a potted connector.

Test descriptions. - The following descriptions are for tests 123, 223, and 323.

Test 123: Ignition occurred at T + 17 seconds, and the flame went out approximately 50 seconds later. The test was concluded at T + 5 minutes after all thermocouples indicated no remaining fire.

Test 223: Smoke was observed at T + 16 seconds, and visible flame was observed at T + 50 seconds. The fire self-extinguished at approximately T + 1 minute 45 seconds. The test was concluded at T + 5 minutes.

Test 323: Light smoke was observed at T + 10 seconds, and visible flame was observed at T + 15 seconds. The fire self-extinguished at approximately T + 1 minute. The test was concluded at T + 5 minutes.

Visibility. - Visibility in the cabin was not affected during test 123, 223, or 323.

Temperature and pressure. - There was no significant increase in free-air temperature or cabin pressure during test 123, 223, or 323.

Gas analysis. - No potentially toxic products were detected in the gas sample from test 123, 223, or 323.

Post-test inspections. - The following data are the results of the post-test inspections for tests 123, 223, and 323.

Test 123: Damage was localized (fig. 20) and resulted from igniter-flame impingement on the connector.

Test 223: Inspection of the visible area showed no significant damage or propagation.

Test 323: Visual inspection of the ignition area showed only a small amount of light-colored residue and no damage from burning.

Summary. - The results of tests 123, 223, and 323 indicated that the aluminum foil covering the potted connector provided adequate protection from an external ignition source.

Tests 124, 224, and 324

Ignition location. - An external igniter was placed on the unwrapped portion of the wire bundle going into connector J22 on the GSE feedthrough panel approximately 3 inches from the back of the connector (fig. 9).

Purpose. - The purpose of tests 124, 224, and 324 was to determine the flammability of an unwrapped portion of a wire bundle and to determine fire propagation (resulting from ignition at a source located just above the Teflon overwrapping) from the unwrapped portion of the wire bundle to the overwrapped portion and to an adjacent connector.

Test descriptions. - The following descriptions are for tests 124, 224, and 324.

Test 124: Ignition occurred at approximately T + 25 seconds. No fire was observed, but a small amount of smoke was observed behind the GSE cover. The test was concluded at T + 6 minutes after all related thermocouples indicated no remaining fire.

Test 224: Smoke and soot were observed in the GSE window at T + 15 seconds; smoke remained visible until approximately T + 1 minute. Because of the location of the igniter, no visual observation of flame was possible. The test was concluded at T + 8 minutes.

Test 324: Flame was observed in the ignition area at T + 25 seconds. The fire self-extinguished at T + 3 minutes. No smoke was observed during the test. The test was concluded at T + 6 minutes.

Visibility. - The following visibility summaries are for tests 124, 224, and 324.

Tests 124 and 324: Visibility in the cabin was not affected.

Test 224: A small amount of light smoke was observed in the RH upper area of the BP at approximately T + 2 minutes. Visibility in the cabin was not affected.

Temperature and pressure. - There was no significant increase in free-air temperature or cabin pressure during test 124, 224, or 324.

Gas analysis. - The following data are gas-sample-analysis results for tests 124, 224, and 324.

Test 124: The gas analysis indicated 1 ppm carbon tetrafluoride and less than 1 ppm silicon tetrafluoride present in the gas sample.

Test 224: The gas analysis indicated 144.6 ppm carbonyl fluoride, 25.6 ppm carbon tetrafluoride, and 10.9 ppm silicon tetrafluoride present in the gas sample.

Test 324: The gas analysis indicated 305.2 ppm carbonyl fluoride, 43.8 ppm carbon tetrafluoride, and 14.9 ppm silicon tetrafluoride present in the gas sample.

Post-test inspections. - The following notes are the results of the post-test inspections for tests 124, 224, and 324.

Test 124: Damage was localized and resulted from igniter-flame impingement on the wire bundle.

Test 224: Only localized damage to the Teflon overwrap and wire insulation occurred at the igniter location. No propagation occurred on the wire bundle.

Test 324: Visual observation indicated only localized damage to the wire insulation. There was no propagation along the wire bundle or to adjacent connectors.

Summary. - The results of tests 124, 224, and 324 indicated that the wire bundles leading into the GSE window did not provide a propagation path.

Tests 125, 225, and 325

Ignition location. - An external igniter was placed on the insert in the back of connector J20 on the GSE feedthrough panel in the RHEB (fig. 9).

Purpose. - The purpose of tests 125, 225, and 325 was to determine the flammability of a silicone-rubber connector insert and to determine the extent of propagation from the connector to adjacent wire bundles and other components of flame resulting from ignition at a source located at the connector insert.

Test descriptions. - The following descriptions are for tests 125, 225, and 325.

Test 125: The silicone-rubber insert in the connector burned. However, there was no propagation to adjacent connectors or wire bundles. Some spattering of the silicone was noted. The test was concluded at T + 5 minutes after all thermocouples indicated no remaining fire.

Test 225: Smoke and soot were observed at the ignition area behind the GSE window at T + 10 seconds, and flame was observed at T + 17 seconds. The flame self-extinguished at approximately T + 1 minute 40 seconds. The test was concluded at T + 5 minutes.

Test 325: Flame was observed at T + 11 seconds. At T + 30 seconds, fire propagated to insert J16 1-1/2 inches above the igniter. The flame self-extinguished at T + 1 minute 45 seconds. At T + 2 minutes 30 seconds, with cabin lights off, there was no visible flame. There was no visible smoke during the test. At T + 6 minutes, the test was concluded.

Visibility. - Visibility in the cabin was not affected during test 125, 225, or 325.

Temperature and pressure. - There was no significant increase in free-air temperature or cabin pressure during test 125, 225, or 325.

Gas analysis. - The following data are gas-sample-analysis results for tests 125, 225, and 325.

Test 125: The gas analysis indicated 4.5 ppm carbon tetrafluoride and 11.6 ppm silicon tetrafluoride present in the gas sample.

Test 225: The gas analysis indicated 1.2 ppm carbon tetrafluoride and 1.0 ppm silicon tetrafluoride present in the gas sample.

Test 325: The gas analysis indicated 109.1 ppm carbonyl fluoride, 25.9 ppm carbon tetrafluoride, and 6.9 ppm silicon tetrafluoride present in the gas sample.

Post-test inspections. - The following notes are the results of the post-test inspections for tests 125, 225, and 325.

Test 125: Damage was localized. The silicon-rubber insert and wire insulation in the region were damaged (fig. 21).

Test 225: Localized damage to the silicone-rubber insert occurred in the region of ignition. No propagation took place.

Test 325: Localized damage to the silicone-rubber insert occurred in the region of ignition. Propagation occurred to the connector directly above the ignition point.

Summaries. - The following summaries are for tests 125, 225, and 325.

Test 125: Ignition of one connector insert in the GSE window did not result in propagation to other connectors.

Test 225: Ignition of one connector insert in the wire bundles leading into the GSE window did not cause a fire of sufficient magnitude to propagate to adjacent connectors or wire bundles.

Test 325: Ignition of one connector insert on the GSE window caused fire propagation to one adjacent connector insert.

Tests 126, 226, and 326

Ignition location. - An external igniter was located under the Teflon wrap on a large-diameter GSE wire bundle (from the GSE feedthrough plate) 6 inches above the point of bundle entry to the RH floor tray (fig. 9).

Purpose. - The purpose of tests 126, 226, and 326 was to determine the flammability of a large, vertical, Teflon-overwrapped wire bundle and to determine the extent of fire propagation resulting from ignition at a source at the lower end of the Teflon overwrap.

Test descriptions. - The following descriptions are for tests 126, 226, and 326.

Test 126: A small amount of smoke was the only visible result of this test. Thermocouples in the igniter region did not indicate any temperature rise.

Test 226: Smoke was observed at T + 6 seconds, and flame at the ignition area was observed from T + 26 seconds to T + 3 minutes. There was no visible flame after T + 3 minutes; however, thermocouple data indicated continued burning. The test was concluded at T + 18 minutes 30 seconds.

Test 326: Flame was observed at T + 15 seconds. The fire increased in intensity at T + 1 minute 9 seconds, and drippings were noticed at T + 1 minute 20 seconds. At T + 1 minute 45 seconds, fire propagated around the back of the large bundle and ignited the right adjacent wire bundle. Fire continued to propagate upward, ignited both upper Adel clamps at T + 2 minutes 35 seconds, and continued to propagate upward to the GSE window. Fire on the right adjacent bundle propagated to the wiring on the cabin floodlight and above and behind panel 3. Dark smoke was observed in the cabin at T + 3 minutes 30 seconds, and soot was noticed throughout the cabin at T + 3 minutes 50 seconds. Fires were still visible when the test was terminated at T + 4 minutes 45 seconds in accordance with test-termination criteria.

Visibility. - The following visibility summaries are for tests 126, 226, and 326.

Test 126: Visibility in the cabin was not affected.

Test 226: Smoke haze was observed in the cabin; however, visibility was not affected.

Test 326: Heavy smoke and soot considerably reduced visibility in the cabin.

Temperature and pressure. - There was no significant increase in free-air temperature or cabin pressure during test 126, 226, or 326.

Gas analysis. - The following data are gas-sample-analysis results for tests 126, 226, and 326.

Test 126: The gas analysis indicated less than 1 ppm carbon tetrafluoride and 6.7 ppm silicon tetrafluoride present in the gas sample.

Test 226: The gas analysis indicated 2750.0 ppm carbonyl fluoride, 825.0 ppm carbon tetrafluoride, and 412.5 ppm silicon tetrafluoride present in the gas sample.

Test 326: The gas analysis indicated 1944.4 ppm carbonyl fluoride, 620.0 ppm carbon tetrafluoride, and 105.2 ppm silicon tetrafluoride present in the gas sample.

Post-test inspections. - The following notes are the results of the post-test inspections for tests 126, 226, and 326.

Test 126: Damage was localized to the edge of the Teflon wrap.

Test 226: Inspection indicated that the outer surface of the Teflon overwrap was severely damaged. Fire propagated upward on the Teflon overwrap to the silicone-rubber-covered Adel clamps 10 inches away from the ignition point. The fire propagated to the clamp on the adjacent bundle and continued to propagate upward from this point (fig. 35). The Teflon overwrap on both wire bundles was completely burned off

to approximately 12 inches above the clamps. Much of the insulation burned off the individual wires in both bundles.

Test 326: All of the Teflon overwrap on all of the wire bundles was completely burned. Much of the insulation on the outer wires of the bundles was destroyed (fig. 47).

Summaries. - The following summaries are for tests 126, 226, and 326.

Test 126: The results of this test indicated that the Teflon wrap did not provide a propagation path.

Test 226: The results of this test indicated that there was considerable burning of the Teflon wrap. The fire eventually self-extinguished.

Test 326: The results of this test indicated that the Teflon overwrap provided a propagation path whereby a localized fire could become widespread.

Test 127

Ignition location. - An external igniter was located on the LH gray, silicone-filled, saddle clamp behind the procedure-manual stowage compartment R1. This compartment is overhead on the RHEB (fig. 9).

Purpose. - The purpose of test 127 was to determine the flammability of gray, silicone-rubber spacers in a wire-bundle saddle clamp and to determine the extent of flame propagation to the wire bundle, to adjacent components (including coaxial cable), and to the procedure-manual compartment. Tests 227 and 327 were not conducted because the proximity of ignition points to the coaxial cable would have been identical to that in tests 219, 228, 319, and 328.

Test description. - The only visible indication of fire during this test was a small amount of smoke observed in the G&N region. The test was concluded at T + 12 minutes after all thermocouples indicated no remaining fire.

Visibility. - Visibility in the cabin was not affected during test 127.

Temperature and pressure. - There was no significant increase in free-air temperature or cabin pressure during test 127.

Gas analysis. - The gas analysis indicated 144 ppm carbonyl fluoride, 11.8 ppm carbon tetrafluoride, and 3 ppm silicon tetrafluoride present in the gas sample.

Post-test inspection. - Only minor surface burning of the gray silicone spacers occurred.

Summary. - The results of this test indicated that the gray silicone fillers burned with a very low-level flame that did not propagate to adjacent wire bundles.

Tests 128, 228, and 328

Ignition location. - An external igniter was located on the gray, silicone-filled saddle clamp located behind and to the right of survival-equipment stowage compartment R4 (fig. 9).

Purpose. - The purpose of tests 128, 228, and 328 was to determine the flammability of gray, silicone-rubber spacers in a wire-bundle saddle clamp and to determine the extent of flame propagation to the wire bundle (including coaxial cable) and to the survival-equipment stowage compartment.

Test descriptions. - The following descriptions are for tests 128, 228, and 328.

Test 128: Flame was observed from T + 23 seconds until T + 3 minutes 15 seconds. The test was concluded at T + 13 minutes after all related thermocouples indicated no remaining fire.

Test 228: Ignition occurred at T + 37 seconds, and flame was observed at the igniter location until T + 6 minutes. At T + 8 minutes, with cabin lights out, there was still a visible glow. At T + 12 minutes, with cabin lights off, there was no visible flame or glow. There was no visible smoke during the test, but a very light haze was detected. The test was concluded at T + 16 minutes when all related thermocouples indicated no remaining fire.

Test 328: Flame at the ignition area was observed at T + 27 seconds, and a significant amount of smoke was visible at T + 1 minute 55 seconds. At T + 2 minutes 30 seconds, the flame appeared to be approximately 6 inches in diameter. A light haze was observed in the cabin at T + 2 minutes 45 seconds. The fire appeared to have propagated to the left and right of the ignition point at T + 3 minutes 40 seconds. The test was terminated at T + 4 minutes.

Visibility. - Visibility in the cabin was not affected during test 128 or 228, but was partially reduced during test 328.

Temperature and pressure. - There was no significant increase in free-air temperature or cabin pressure during test 128, 228, or 328.

Gas analysis. - The following notes are gas-sample-analysis results for tests 128, 228, and 328.

Test 128: The gas analysis indicated 5.7 ppm silicon tetrafluoride present in the gas sample.

Test 228: The gas analysis indicated 2.8 ppm silicon tetrafluoride present in the gas sample.

Test 328: The gas analysis indicated 121.2 ppm carbonyl fluoride, 22.7 ppm carbon tetrafluoride, and 15.2 ppm silicon tetrafluoride present in the gas sample.

Post-test inspections. - The following data are the results of the post-test inspections for tests 128, 228, and 328.

Test 128: Only minor surface-burning of the gray silicone spacers occurred. The fire did not propagate to the coaxial cable, but burned approximately 4 inches along the outer Kynar insulation. The polyolefin inner insulation did not ignite.

Test 228: All of the gray silicone spacers were completely burned. The fire ignited the Kynar on the coaxial cable. Very little propagation occurred, however. The polyolefin inside the coaxial cable did not ignite. The Teflon insulation on the wires adjacent to the silicone spacers was partially destroyed (fig. 36).

Test 328: All of the gray silicone spacers were completely burned. The coaxial cable ignited, and the fire propagated in both directions along the coaxial cable. Some melting of the aluminum inner structure occurred. There was significant damage to wire-bundle insulation in the ignition area.

Summaries. - The following summaries are for tests 128, 228, and 328.

Test 128: Ignition of the gray silicone spacers caused flame to propagate to the coaxial cable. Because this region was not visible during the test, it is not known whether the fire extinguished itself or was extinguished when the vehicle was pumped down after the test.

Test 228: Fire resulting from the ignition of the gray silicone spacers propagated to the coaxial cable.

Test 328: Fire resulting from the ignition of the gray silicone spacers propagated to the coaxial cable, making it possible for the fire to propagate rapidly in two directions.

Tests 129 and 229

Ignition location. - An external igniter was placed on the Teflon overwrap approximately 2 inches away from the bottom inboard connector in the sequencer bay (fig. 9).

Purpose. - The purpose of tests 129 and 229 was to determine the flammability of the Teflon wrap on the wire bundle under the Teflon-clamp sleeve and to determine the extent of flame propagation to the connector, to adjacent connectors, to the wire bundle, and to adjacent wire bundles. Test 329 was not conducted because the test region had been destroyed in test 330.

Test descriptions. - The following descriptions are for tests 129 and 229.

Test 129: Flame was observed at T + 45 seconds and lasted approximately 4 minutes. The flame was localized, and no significant propagation occurred. The test was concluded at T + 8 minutes after all related thermocouples indicated no remaining fire.

Test 229: Smoke and soot at the igniter were observed at T + 15 seconds, and flame was observed at T + 20 seconds. The flame self-extinguished at T + 2 minutes 35 seconds. The test was concluded at T + 6 minutes.

Visibility. - Visibility in the cabin was not affected during test 129 or 229.

Temperature and pressure. - There was no significant increase in free-air temperature or cabin pressure during test 129 or 229.

Gas analysis. - The following data are gas-sample-analysis results for tests 129 and 229.

Test 129: The gas analysis indicated 245 ppm carbonyl fluoride, 35.9 ppm carbon tetrafluoride, and 29.3 ppm silicon tetrafluoride present in the gas sample.

Test 299: The gas analysis indicated 165.2 ppm carbonyl fluoride, 36.5 ppm carbon tetrafluoride, and 19.8 ppm silicon tetrafluoride present in the gas sample.

Post-test inspections. - The following results are for the post-test inspections for tests 129 and 229.

Test 129: Damage was localized. A portion of the Teflon wrap and some of the Teflon wire insulation were destroyed (fig. 22).

Test 229: Inspection indicated that the Teflon wrap and some of the wire insulation were destroyed. The damage was localized to an area approximately 3 inches in diameter at the point of ignition (fig. 37).

Summaries. - The following summaries are for tests 129 and 229.

Test 129: The results of this test indicated no propagation to adjacent connectors in a high-density area.

Test 229: The results of this test indicated only localized damage and very little propagation.

Tests 130, 230, and 330

Ignition location. - An external igniter was located at the edge of the Teflon wrap on a wire bundle exiting from the forward end of the RH floor tray and routed into the LEB (fig. 11).

Purpose. - The purpose of tests 130, 230, and 330 was to determine the flammability of a vertically oriented, Teflon-overwrapped wire bundle and to determine the extent of fire propagation resulting from ignition at the lower end of the overwrapping.

Test descriptions. - The following descriptions are for tests 130, 230, and 330.

Test 130: Some flame was visible, but no significant propagation occurred. The test was concluded at T + 6 minutes after all related thermocouples indicated no remaining fire.

Test 230: Smoke and flame were observed simultaneously at T + 55 seconds. Flame height was approximately 6 inches (up to the clamp on the wire bundles) at T + 1 minute 15 seconds. Flame disappeared at T + 2 minutes 25 seconds and reappeared 10 seconds later. This flame self-extinguished at T + 2 minutes 45 seconds.

The clamp above the igniter broke into flame at T + 3 minutes and burned for approximately 40 seconds. There was a slight flame visible to the left of the igniter at T + 5 minutes 15 seconds. No smoke or flame was visible at T + 6 minutes. The test was concluded at T + 10 minutes.

Test 330: Flame was observed at T + 42 seconds in the general area of the igniter. Fire propagated upward on the Teflon wrap of the large wire bundle and ignited the neoprene-coated saddle clamp 12 inches above the igniter. At T + 3 minutes 15 seconds, the clamp was burning vigorously; however, the fire did not propagate above the saddle clamp. At T + 4 minutes 50 seconds, there was no visible flame at the ignition area. At T + 5 minutes, fire was observed propagating downward and to the left of the ignition area. Flame remained visible until T + 14 minutes 30 seconds. During this period, the flame appeared to flare up intermittently. At T + 15 minutes 30 seconds, soot was observed at the ignition area. At T + 17 minutes 30 seconds, a light haze was noted behind the glass panel in front of the wire bundle. A significant amount of smoke was observed in the area above the wire tray to the right of the ignition point, and a haze was seen throughout the cabin. At T + 18 minutes 40 seconds, smoke and soot were observed coming out of the tray area. The intensity of smoke and soot progressively increased. The test was terminated at T + 20 minutes 35 seconds based on termination criteria. Before test termination, the source of smoke could not be observed because this area was not in the field of view of the television cameras or of the observers.

Visibility. - Visibility in the cabin was not affected during test 130 or 230, but was significantly reduced during test 330.

Temperature and pressure. - There was no significant increase in free-air temperature or cabin pressure during test 130, 230, or 330.

Gas analysis. - The following gas-sample-analysis results were obtained for tests 130, 230, and 330.

Test 130: The gas analysis indicated 108 ppm carbonyl fluoride, 53.8 ppm carbon tetrafluoride, and 26 ppm silicon tetrafluoride present in the gas sample.

Test 230: The gas analysis indicated 802 ppm carbonyl fluoride, 350.0 ppm carbon tetrafluoride, and 51.2 ppm silicon tetrafluoride present in the gas sample.

Test 330: The gas analysis indicated 7142.8 ppm carbonyl fluoride, 2353.3 ppm carbon tetrafluoride, and 285.7 ppm silicon tetrafluoride present in the gas sample.

Post-test inspections. - The following notes are the results of the post-test inspections for tests 130, 230, and 330.

Test 130: Damage was localized and consisted of some melting or burning of the Teflon overwrap in the region of the igniter.

Test 230: The Teflon overwrap and outer wire insulation were severely burned approximately 10 inches beyond the ignition point. The neoprene-coated saddle clamp above the ignition point burned; however, the fire did not propagate any further.

Test 330: The Teflon overwrap and outer wire insulation were burned approximately 12 inches above the ignition point. The neoprene-coated saddle clamp above the ignition point burned; however, the fire did not continue to propagate upward. The fire propagated to the sequencer bay by burning along the Teflon liner inside the RH floor tray. The Teflon liner and the outer wire insulation on one wire bundle were burned. All of the Teflon overwrap, wire insulation, and connector inserts in the sequencer bay were completely destroyed (fig. 48).

Summaries. - The following summaries are for tests 130, 230, and 330.

Test 130: The results of this test indicated that the Teflon overwrap neither burned significantly nor provided a propagation path.

Test 230: The results of this test indicated that a large area of the Teflon wrap did burn and would support combustion to some degree.

Test 330: The results of this test indicated that the Teflon overwrap and the Teflon liner inside the floor tray provided an adequate propagation path whereby a localized fire could become widespread.

Tests 131, 231, and 331

Ignition location. - An external igniter was located on the neoprene-coated saddle clamp (with gray silicone fillers) behind sanitation-supply stowage compartment R10 (above the girth shelf) (fig. 9).

Purpose. - The purpose of tests 131, 231, and 331 was to determine the flammability of gray silicone-rubber spacers in a wire-bundle saddle clamp and to determine the extent of flame propagation to the wire bundle, to adjacent components, and to the sanitation-supply stowage compartment.

Test descriptions. - The following descriptions are for tests 131, 231, and 331.

Test 131: Smoke was observed for 3 minutes after T + 50 seconds. The test was concluded at T + 7 minutes after all related thermocouples indicated no remaining flame.

Test 231: Light smoke was observed in the ignition area at T + 45 seconds. Thermocouple readings indicated that a fire started and then self-extinguished at approximately T + 5 minutes. The test was concluded at T + 15 minutes.

Test 331: Based on temperature readings, a fire started at T + 1 minute and self-extinguished at approximately T + 10 minutes. Very light smoke was observed intermittently during the test. The test was concluded at T + 15 minutes.

Visibility. - Visibility in the cabin was not affected during test 131, 231, or 331.

Temperature and pressure. - There was no significant increase in free-air temperature or cabin pressure during test 131, 231, or 331.

Gas analysis. - The following data are gas-sample-analysis results for tests 131, 231, and 331.

Test 131: No potentially toxic products were detected in the gas sample.

Test 231: The gas analysis indicated 1.5 ppm silicon tetrafluoride present in the gas sample.

Test 331: The gas analysis indicated 3.7 ppm silicon tetrafluoride present in the gas sample.

Post-test inspections. - The following results are for the post-test inspections for tests 131, 231, and 331.

Test 131: Only minor surface-burning of the gray silicone spacers occurred. The fire did not propagate along the wire bundles, and only minor damage was observed on the wire insulation.

Test 231: The gray silicone spacers were completely burned; however, the fire did not propagate along the wire bundles, and only minor damage was observed on the wire insulation adjacent to the spacers. No damage was done to the items in the storage compartment.

Test 331: The gray silicone spacers were completely burned; however, the fire did not propagate along the wire bundles, and only minor damage was observed on the wire insulation adjacent to the spacers.

Summaries. - The following summaries are for tests 131, 231, and 331.

Test 131: The results of this test indicated that no significant hazard existed because of the gray fillers.

Tests 231 and 331: The results of these tests indicated that no significant propagation resulted from ignition of the gray silicone spacers.

Tests 232 and 332

Ignition location. - An igniter was placed inside the metal case on a potted terminal board in the lower portion of the commander's rotational controller. This controller is on the RH armrest of the LH couch.

Purpose. - The purpose of tests 232 and 332 was to determine the flammability of the silicone-rubber boot on the couch-mounted rotational controller and to determine the extent of fire propagation to adjacent clothing, furnishings, and equipment from an ignition source located on the boot. Test 132 was not conducted because the choice of igniter location was not valid. It was not considered necessary to conduct test 132 because the results of the hand-controller tests in the 200 series were satisfactory.

Test descriptions. - The following descriptions are for tests 232 and 332.

Test 232: Smoke was observed at T + 1 minute 25 seconds, at which time the silicone bellows separated from the lower portion of the controller. At T + 5 minutes, a considerable amount of smoke was coming from the controller, and a moderate haze was noticed throughout the cabin. At T + 24 minutes 20 seconds, a slight flame was observed inside the controller. At this time, the test was concluded because of decreasing visibility, verification of more than adequate egress time, and lack of flame propagation outside the hand-controller assembly.

Test 332: Very light smoke was observed at T + 24 seconds. At T + 44 seconds, a significant amount of smoke was visible coming from the top of the rotational controller. The gloved hand of the suit was pulled away from the controller at this time. Intermittent light smoke from the controller was observed between T + 1 minute 45 seconds and T + 3 minutes. There was no visible flame during the test. All related thermocouples were decreasing when the test was concluded at T + 7 minutes.

Visibility. - The following visibility summaries are for tests 232 and 332.

Test 232: Considerable smoke came from the controller and became increasingly heavy throughout the test. Visibility in the cabin was greatly reduced but was not completely lost.

Test 332: Visibility in the cabin was not affected.

Temperature and pressure. - There was no significant increase in free-air temperature or cabin pressure during test 232 or 332.

Gas analysis. - The following data are gas-sample-analysis results for tests 232 and 332.

Test 232: The gas analysis indicated 3 ppm silicon tetrafluoride present in the gas sample.

Test 332: The gas analysis indicated 4.3 ppm silicon tetrafluoride present in the gas sample.

Post-test inspections. - The following notes are the results of the post-test inspections for tests 232 and 332.

Test 232: Inspection indicated that severe damage took place inside the metal case of the rotational controller. The potting compound around the ignition point was completely destroyed; wire insulation in the bottom portion was burned off; and the encapsulated resistors in the potted compound were partially exposed. Large deposits of soot and melted potting were found inside the controller case (fig. 38).

Test 332: The potting compound and electrical components around the ignition point were destroyed. There was a significant amount of soot over all of the controller.

Summaries. - The following summaries are for tests 232 and 332.

Test 232: The hand-controller cover appeared adequate for containing the fire and stopping outside propagation to adjacent clothing or equipment.

Test 332: The hand-controller cover appeared adequate for containing a fire and preventing propagation to adjacent materials.

Tests 133, 233, and 333

Ignition location. - An external igniter was located in the center of the cabin approximately 3 feet above the cabin floor.

Purpose. - The purpose of tests 133, 233, and 333 was to determine a standard background for the gas analysis, to provide photographic coverage of an igniter, and to determine burn time for an igniter.

Test descriptions. - The following descriptions are for tests 133, 233, and 333.

Test 133: The igniter burned for approximately 1 minute and glowed for an additional 45 seconds.

Test 233: Smoke was observed at T + 18 seconds, and flame was observed at T + 28 seconds. Flame was visible for approximately 1 minute 10 seconds, and the igniter glowed for an additional 15 seconds. The test was concluded at T + 4 minutes 30 seconds.

Test 333: Flame at the igniter was observed for 30 seconds.

Visibility. - Visibility in the cabin was not affected during test 133, 233, or 333.

Temperature and pressure. - There was no significant increase in free-air temperature or cabin pressure during test 133, 233, or 333.

Gas analysis. - No potentially toxic products were detected in the gas sample from test 133, 233, or 333.

Post-test inspections. - The igniter burned and left a gray residue in each test.

Summary. - Data were obtained for use in interpreting gas-analysis results.

Test 134

Ignition location. - An external igniter was located on the neoprene-coated saddle clamp that secured a horizontal wire bundle at the RH side of the RH circuit-interrupter feedthrough plate assembly on the LEB. Coaxial cables are routed through this region.

Purpose. - The purpose of test 134 was to determine the extent of flame propagation to adjacent wire bundles from the ignition of a neoprene-coated saddle clamp. Because the coaxial cable is flammable, knowledge was required of the ease of ignition and extent of propagation. Tests 234 and 334 were not conducted because the proximity of ignition points to the coaxial cable would have been identical to that in tests 219, 228, 319, and 328.

Test description. - Flame was observed at T + 30 seconds. The fire propagated up the neoprene on the RH outer edge of the saddle clamp. The initial flame went out at T + 53 seconds. Power to the igniter was reapplied at T + 1 minute 45 seconds, and flame reappeared at T + 5 minutes. This flame lasted for an additional 3 minutes 20 seconds. This test was concluded at T + 10 minutes after all related thermocouples indicated no remaining fire.

Visibility. - Visibility was not affected during test 134.

Temperature and pressure. - There was no significant increase in free-air temperature or cabin pressure during test 134.

Gas analysis. - The gas analysis indicated less than 1 ppm carbon tetrafluoride and 2.8 ppm silicon tetrafluoride present in the gas sample.

Post-test inspection. - The post-test inspection indicated that only the outer edge of the neoprene on the clamp burned. There was also some localized damage to wire insulation in the igniter region.

Summary. - The results of this test indicated that the saddle clamps coated with neoprene only on the inside and on the edges did not provide a significant propagation path.

Test 135

Ignition location. - An external igniter was located on the neoprene-coated saddle clamp securing a horizontal wire bundle at the RH side of the RH circuit-interrupter feedthrough plate assembly in the LEB. Coaxial cables are routed through this region. The igniter was located approximately 3/8 inch below the coaxial cable.

Purpose. - The purpose of test 135 was to determine the extent of flame propagation to adjacent wire bundles from the ignition of a neoprene-coated saddle clamp. Because the coaxial cable in this region is flammable, knowledge was required of the ease of ignition and extent of propagation. Tests 235 and 335 were not conducted because the proximity of ignition points to the coaxial cable would have been identical to that in tests 219, 228, 319, and 328.

Test description. - Flame was observed at T + 1 minute 7 seconds. The flame propagated rapidly to the outer neoprene coating on the clamp. At T + 2 minutes, the coaxial cable ignited, and the fire propagated to the left. Initially, the Kynar outer insulation burned; the inner polyolefin did not ignite until approximately T + 5 minutes, at which time the fire attained considerable magnitude. Significant dripping of flaming particles was observed. At T + 12 minutes, the fire self-extinguished. The test was concluded at T + 16 minutes after all related thermocouples indicated no remaining fire.

Visibility. - Very little smoke was produced, and no loss of cabin visibility occurred.

Temperature and pressure. - There was no significant increase in free-air temperature or cabin pressure during test 135.

Gas analysis. - The gas analysis indicated 315 ppm carbonyl fluoride, 43.4 ppm carbon tetrafluoride, and 126.7 ppm silicon tetrafluoride present in the gas sample.

Post-test inspection. - Considerable wire damage caused by flame impingement from the coaxial cable was observed (fig. 23). The coaxial cable was destroyed up to the level of the girth shelf.

Summary. - Burning of the coaxial cable produced such a small amount of smoke that a suited crewmember would not be warned of the existence of fire by the observation of smoke. In this test, the fire on the coaxial cable did not propagate above the girth shelf and eventually self-extinguished. The flame on the coaxial cable self-extinguished at a point where the cable was tightly surrounded by other wire bundles, apparently because of lack of oxygen in the immediate area.

Test 136

Ignition location. - An external igniter was located on the Fluorel-wrapped eyepiece (sextant) in the upper portion of the G&N area (fig. 12).

Purpose. - The purpose of test 136 was to determine the flammability characteristics of Fluorel insulation around the eyepiece and to determine the extent of flame propagation to star charts and procedure manuals used in conjunction with the eyepiece. Tests 236 and 336 were not conducted because the housekeeping configuration associated with these tests was not applicable to test series 200 or 300.

Test description. - Ignition of the Fluorel sponge around the eyepiece occurred at T + 15 seconds; dripping of flaming particles was observed at T + 55 seconds; and the charts below the eyepiece ignited 5 seconds later. A fairly large fire developed rapidly. Because of the rapid propagation, which ignited a procedure manual on the RH couch, the test was terminated at T + 1 minute 20 seconds.

Visibility. - Smoke and soot were observed. However, the test was terminated before significant loss of visibility could occur.

Temperature and pressure. - Free-air temperature rose significantly to 165° F. A pressure rise was indicated by the frequent venting of the cabin-pressure relief valve and the addition of oxygen.

Gas analysis. - The gas analysis indicated 220 ppm carbonyl fluoride, 16.6 ppm carbon tetrafluoride, and 363 ppm silicon tetrafluoride present in the gas sample.

Post-test inspection. - The Fluorel around the eyepiece was severely burned. All of the charts, plastic overlays, and procedure manuals below the eyepiece were burned. Dripping material had also fallen onto one of the stowage boxes on the aft bulkhead and onto a pillow below and to the right of the G&N shelf (fig. 24).

Summary. - The Fluorel material ignited easily and burned vigorously. Dripping particles of the burning Fluorel ignited flammable materials below it.

Tests 137 and 237

Ignition location. - An external igniter was placed on a small Teflon-wrapped wire bundle going to the electrical connector on the RH bulkhead floodlight.

Purpose. - The purpose of tests 137 and 237 was to determine the flammability characteristics of the small Teflon-wrapped wire bundle and to determine if fire would propagate to the Lexan floodlight cover.

Test descriptions. - The following descriptions are for tests 137 and 237.

Test 137: Ignition occurred at T + 16 seconds, and the flame impinged directly on the Teflon-wrapped wire bundle for 50 seconds. No propagation occurred. Some dripping of flaming particles was observed, however.

Test 237: Smoke was observed at T + 13 seconds, and flame was observed at T + 26 seconds. Flame remained visible until T + 2 minutes and self-extinguished at T + 2 minutes 50 seconds. The test was concluded at T + 6 minutes.

Visibility. - Visibility in the cabin was not affected during test 137 or 237.

Temperature and pressure. - There was no significant increase in free-air temperature or cabin pressure during test 137 or 237.

Gas analysis. - The following data are gas-sample-analysis results for tests 137 and 237.

Test 137: The gas analysis indicated 14.2 ppm carbon tetrafluoride present in the gas sample.

Test 237: The gas analysis indicated 179.5 ppm carbonyl fluoride, 30.7 ppm carbon tetrafluoride, and 6.4 ppm silicon tetrafluoride present in the gas sample.

Post-test inspections. - The following data are the results of the post-test inspections for tests 137 and 237.

Test 137: The Teflon overwrap was burned or melted from the wire bundle for a length of 2 inches. The individual wires also lost all or most of the Teflon insulation.

Test 237: Inspection indicated that the Teflon overwrap and the insulation of the small wires in the bundle were burned away. The damage extended to approximately 2 inches on both sides of the ignition point. There was no propagation to the Lexan floodlight cover.

Summary. - The results of these tests indicated that a small, horizontal, Teflon overwrapped bundle may support combustion during direct flame impingement, but that propagation does not occur after the flame source is removed.

Tests 138, 238, and 338

Ignition location. - A 5-foot length of 12-gage SC wire was located in the RH floor tray (fig. 9).

Purpose. - The purpose of tests 138, 238, and 338 was to determine the possibility of simultaneous ignition in several locations occurring from an electrical overload in a long length of SC wire.

Test descriptions. - The following descriptions are for tests 138, 238, and 338.

Test 138: Power was applied in the following manner. The initial current was 62 amps; at T + 30 seconds, the current was raised to 100 amps; at T + 1 minute, to 125 amps; at T + 1 minute 30 seconds, to 150 amps; and at T + 2 minutes, to 230 amps. Burnthrough occurred at T + 2 minutes 30 seconds. No fire or smoke was observed. Only one thermocouple out of the nine spaced along the wire bundle showed a temperature rise. This thermocouple indicated a temperature of 1400° F at T + 2 minutes 5 seconds, but this reading decreased to 120° F at T + 5 minutes 30 seconds. The test was concluded 30 seconds later.

Test 238: Power was applied in the following manner. The initial current was 100 amps; at T + 1 minute, the current was raised to 150 amps; and at T + 2 minutes, to 200 amps. Burnthrough occurred at T + 2 minutes 35 seconds. At T + 3 minutes 40 seconds, flame was observed for approximately 10 seconds in the far RH corner of the floor tray. No significant smoke was observed at the ignition area. All related thermocouple temperatures began to decrease, and the test was concluded at T + 16 minutes.

Test 338: Power was applied in the following manner. The initial current was 60 amps; at T + 1 minute, the current was raised to 100 amps; at T + 2 minutes, to 150 amps; and at T + 3 minutes, to 200 amps. Burnthrough occurred at T + 3 minutes 25 seconds. No smoke or flame was observed during the test. All related temperatures were at ambient or decreasing when the test was concluded at T + 14 minutes.

Visibility. - Visibility in the cabin was not affected during test 138, 238, or 338.

Temperature and pressure. - There was no significant increase in free-air temperature or cabin pressure during test 138, 238, or 338.

Gas analysis. - The following data are gas-sample-analysis results for tests 138, 238, and 338.

Test 138: The gas analysis indicated 438 ppm carbonyl fluoride, 120 ppm carbon tetrafluoride, and 10 ppm silicon tetrafluoride present in the gas sample.

Test 238: The gas analysis indicated 354.6 ppm carbonyl fluoride, 207.5 ppm carbon tetrafluoride, and 3.2 ppm silicon tetrafluoride present in the gas sample.

Test 338: The gas analysis indicated 161.4 ppm carbonyl fluoride, 33.8 ppm carbon tetrafluoride, and 3.6 ppm silicon tetrafluoride present in the gas sample.

Post-test inspections. - The following notes are the results of the post-test inspections for tests 138, 238, and 338.

Test 138: The insulation of the overloaded wire was completely destroyed. The fire on the insulation burned the insulation off several other wires adjacent to the test wire.

Tests 238 and 338: The insulation of the overloaded wire was completely destroyed. A small amount of damage was done to the insulation on adjacent wires. In the area where the overloaded wire was overwrapped with Teflon, some burning occurred on the Teflon.

Summary. - The results of these tests indicated that simultaneous ignition did not take place in a long wire bundle when a relatively large conductor (12 gage) was overloaded to failure.

Test 339

Ignition location. - An internal igniter was placed under the conformal coating of a switch (SW62) on MDC panel 3 (RH side).

Purpose. - The purpose of test 339 was to determine the flammability characteristics of the nonmetallic materials used in panel 3 and to determine the adequacy of the foam extinguishing agent. Tests 139 and 239 were not conducted because the test configuration was that of a worst-case condition which was covered by test 339.

Test description. - Smoke was observed coming from the face of the panel at T + 1 minute 45 seconds. At T + 3 minutes 15 seconds, smoke was visible throughout the cabin. At T + 3 minutes 50 seconds, the extinguishing-agent valve was opened for 9 seconds, but it did not appear to decrease the burning. At T + 4 minutes 15 seconds, flame was observed. Because of the concentrated smoke in the cabin, the flame was visible for only 5 seconds. Before termination, the extinguishing-agent valve was opened for the second time without apparent effect. The test was terminated at T + 5 minutes 10 seconds.

Visibility. - Visibility in the cabin was lost at approximately T + 4 minutes 20 seconds.

Temperature and pressure. - There was no significant increase in free-air temperature or cabin pressure during test 339.

Gas analysis. - The gas analysis indicated 2258.0 ppm carbonyl fluoride, 837.5 ppm carbon tetrafluoride, and 375.0 ppm silicon tetrafluoride present in the gas sample.

Post-test inspection. - The fire propagated in all directions along the electrical components from the ignition point. All switches, components, and connectors were severely damaged; all wiring leading to these switches and components was destroyed. The connector plate was warped. The silicone-laminate cover was completely destroyed, and only charred pieces of material remained (fig. 49). A weight check of the

foam container indicated that no foam was injected into the panel because of line restrictions in the extinguishing system.

Summary. - The results of this test indicated that a double coating of Ladicote was not adequate protection in an area where several electrical components are located in close proximity to each other. No foam reached the panel because of system failure; thus, no assessment could be made of the foam as an extinguishing agent.

Test 240

Ignition location. - An external igniter was located adjacent to wire bundles in which the individual wires were covered with Teflon shrink tubing. The wire bundle came out of panel 8 and went to a connector plate approximately 14 inches to the right of panel 8 (fig. 8).

Purpose. - The purpose of test 240 was to determine the flammability characteristics of a wire bundle covered with Teflon shrink tubing. It was not considered necessary to conduct test 140 because results were satisfactory in an atmosphere more conducive to combustion. Test 340 was not conducted because the test location had been destroyed by the widespread propagation that occurred in test 312.

Test description. - Smoke was observed at the igniter location at T + 15 seconds, and flame was observed at T + 24 seconds. Smoke was visible for approximately 20 seconds. At T + 2 minutes, with cabin lights out, a faint fire glow was still visible. The test was concluded at T + 7 minutes.

Visibility. - Visibility in the cabin was not affected.

Temperature and pressure. - There was no significant increase in free-air temperature or cabin pressure during test 240.

Gas analysis. - The gas analysis indicated 98.2 ppm carbonyl fluoride, 5.8 ppm carbon tetrafluoride, and 1.1 ppm silicon tetrafluoride present in the gas sample.

Post-test inspection. - Inspection indicated only localized burning of the Teflon shrink tubing and of the wire insulation. No propagation occurred.

Summary. - Only localized damage occurred, and no propagation resulted from this test.

Test 341

Ignition location. - An external igniter was placed on the silicone-rubber insert of the electrical connector on the cabin floodlight. This light was on the RH aft couch strut and faced the G&N control panel.

Purpose. - The purpose of test 341 was to determine the flammability of the silicone-rubber insert and to determine the extent of flame propagation either to the

Lexan lens on the floodlight or to adjacent equipment in the area. Tests 141 and 241 were not conducted because, following test 341, flammable material was replaced with metal.

Test description. - Smoke and then small flames were observed at T + 15 seconds coming from behind the couch support. At T + 45 seconds, the flame propagated to the silicone-laminate cover, and severe burning was observed on the cover at T + 1 minute. Drippings were seen 8 seconds later. At T + 1 minute 15 seconds, fire propagated to the oxygen hoses leading to the suit on the RH couch. The spread of fire along the hoses was rapid to the right but slow to the left. The flames from the hose formed an envelope about 8 to 10 inches high and 1 foot long. At T + 1 minute 30 seconds, the fire propagated to the left heel of the RH suit. The test was terminated at T + 1 minute 35 seconds because of flame impingement upon and possible burning of both the right and center suits.

Post-termination data. - Further flame impingement on the ankle portion of the center suit caused it to rupture at T + 1 minute 50 seconds. The magnitude of the fire increased considerably due to the escape of oxygen through the ruptured bladder in the suit. This fire did not propagate appreciably because of the rapid pumpdown of the BP. All flame appeared to be out at T + 3 minutes 24 seconds.

Visibility. - Visibility in the cabin was moderately reduced.

Temperature and pressure. - There was no significant increase in free-air temperature or cabin pressure during test 341.

Gas analysis. - No gas sample was taken.

Post-test inspection. - The silicone-rubber plug insert, the silicone-laminate guard, and the lower portion of the Lexan lens cover were all severely burned. Both suits on either side of the ignition point received damage from flame impingement in the foot or ankle area (fig. 50).

Summary. - The results of this test indicated that the couch-strut floodlight provides a significant amount of combustible material in close proximity to an ignition source.

Tests 242 and 342

Ignition location. - An external igniter was located in the Teflon-wrapped wire bundle coming from the LH-couch rotational controller. The wire was routed in a Teflon wire tray located between the center and LH couches; wire routing continued parallel to the head of the center couch and looped back into an electrical junction box under the center couch.

Purpose. - The purpose of tests 242 and 342 was to determine the flammability of the Teflon-wrapped wire bundle and to determine the extent of fire propagation to adjacent clothing and equipment. It was not considered necessary to conduct test 142 because results were satisfactory in an atmosphere more conducive to combustion.

Test descriptions. - Following are descriptions of tests 242 and 342.

Test 242: Flame was observed at T + 14 seconds and propagated rapidly to the adjacent Adel clamp. At T + 40 seconds, the Dacron tiedown strap caught fire, and the fire began to propagate upward through the couch toward the suit. The test was terminated at T + 49 seconds.

Test 342: Flame flared up to about 3 inches at T + 17 seconds. Drippings were observed at T + 30 seconds. The flame diminished to low intensity at T + 1 minute 20 seconds. The fire propagated slowly along the wire bundle to the right and left of the ignition point; however, the flame remained very small. The flame self-extinguished at T + 5 minutes 15 seconds. The test was concluded at T + 6 minutes.

Visibility. - Visibility in the cabin was not affected during test 242 or 342.

Temperature and pressure. - There was no significant increase in free-air temperature or cabin pressure during test 242 or 342.

Gas analysis. - Following are gas-sample analysis results for tests 242 and 342.

Test 242: The gas analysis indicated 4.5 ppm carbon tetrafluoride and 5.6 ppm silicon tetrafluoride present in the gas sample.

Test 342: The gas analysis indicated 701.9 ppm carbonyl fluoride, 200.0 ppm carbon tetrafluoride, and 9.6 ppm silicon tetrafluoride present in the gas sample.

Post-test inspections. - Following are the results of the post-test inspections for tests 242 and 342.

Test 242: The fire propagated from the igniter to the silicone-cushioned Adel clamp and then to the Dacron restraint harness. The fire then propagated along the harness toward the center-couch suit. No damage was done to the suit because of the forced termination of the test. Only localized burning of the Teflon-wrapped wire bundle occurred.

Test 342: The fire propagated 8 inches along the controller cable. The Teflon wrap and some of the insulation on the individual wires were burned.

Summaries. - Following are summaries of tests 242 and 342.

Test 242: The results of this test indicated that the silicone-cushioned Adel clamps and the Dacron restraint harness provide a rapid fire-propagation path.

Test 342: The results of this test indicated that some propagation did take place along the Teflon wrap but that the fire was not severe enough to propagate to suits, to helmets, or to other equipment in this region.

APPENDIX B

TEST ARTICLE

GENERAL

The test article consisted of BP 1224 with the interior configuration and equipment of the CM representing a composite of the SC 101 and 2TV-1 configurations. The interior of the steel BP was finished with sheet aluminum to simulate the inner mold line of a Block II CM. The resulting total internal volume was slightly larger than that of the flight SC. The secondary structure installed above the girth shelf used SC 102 hardware to facilitate the installation of flight-type components and to maintain a high degree of structural fidelity in the primary test areas. The secondary structure below the girth shelf consisted of simulated hardware fabricated from aluminum sheets. The electrical wiring system consisted of the SC 102 wire harness reworked to the SC 101 and 2TV-1 configurations. The SC instrumentation overlay harnesses were not installed. However, the main section of the SC 008 instrumentation harness was reworked to the 2TV-1 configuration and was installed to simulate the 2TV-1 configuration. The MDC and a number of other key electrical panels were obtained from SC 102 and installed in the BP. The remaining panels were simulated by closeout covers and by EL overlays where applicable; however, components and wiring were not installed. A partial water-glycol loop was installed without the coldplates. Oxygen-system components were limited to the components listed in the subsequent description. The SC storage boxes were simulated in size, configuration, and heat capacity by containers that were fabricated from aluminum stock. The Government-furnished equipment (GFE) and contractor-furnished equipment (CFE) that would contribute to flame propagation were included in the SC. In addition, the special crew equipment required for 2TV-1 tests was provided. From the standpoint of possible flame propagation, BP 1224 included the worst-case conditions represented both by 2TV-1 and by SC 101. The guidance equipment and test instrumentation were installed. Configuration control and material control were maintained throughout fabrication to ensure that the specified degree of simulation was achieved. A general view of the BP interior is shown in figure B-1. Comparisons of various areas of BP 1224 and of 2TV-1 are shown in figures B-2 to B-7.

Boilerplate Structure

Primary structure. - The primary structural shell of the BP was fabricated of approximately 0.30-inch-thick structural steel plate welded to form a pressure shell. The forward, side, and aft bulkheads were stiffened with beams. Also, the crew wall below the girth ring was fabricated of structural steel. The internal diameter at the girth ring was approximately three-fourths of an inch less than the similar dimension on SC 101. The forward bulkhead was moved up approximately 5 inches to simulate the SC vertical dimensions. The total internal volume of the BP structure was somewhat larger than that of the SC; however, exact duplication of the SC volume was not of overriding importance, because any fire sufficiently large to cause significant oxygen depletion would be too large to be acceptable in the BP and would be extinguished

before it reached this stage. An inner skin of 0.062-inch-thick aluminum sheet was installed, as required, in the areas of the forward bulkhead, the girth ring, and the aft bulkhead to form the inner mold line of the CM, to provide a smooth interior surface, and to provide a surface for mounting secondary structures. The pressure shell formed by the inner CM mold line was proof tested to 36 ± 2 psia and vacuum tested to 5 ± 3 torr. The pressure decay did not exceed 0.4 psia/hr.

Secondary structure. - The interior configuration of the BP was representative of the SC storage areas and equipment. The secondary structure installed above the girth shelf was obtained from SC 102. This structure was reworked in certain areas to represent the latest SC 101 configuration. The production secondary hardware installed included the following.

1. RH intermediate bay
2. LH intermediate bay
3. LEB, forward
4. MDC
5. RH and LH side consoles
6. LH forward equipment bay
7. RH forward equipment bay

High-fidelity simulation of the compartments and storage areas above the girth shelf was necessary to evaluate the exposure of the stored crew equipment to fire in adjacent areas or compartments. The secondary structure installed below the girth shelf was simulated with aluminum sheets and plates of the same thickness as SC installations, thus providing heat-sink characteristics equal to or less than that of the SC. This hardware included the following.

1. RH LEB
2. LH LEB
3. Aft LEB

This structure simulated the SC installation and provided the necessary mounting provisions for installing the ECU, ECU controller, lithium hydroxide canisters, oxygen and water panels, guidance equipment, and storage items. Except in the areas of this equipment, the high-fidelity secondary structure below the girth shelf was not required because the other subsystem equipment was not installed.

Spacecraft-configuration couches were refurbished and were provided with pads and straps according to the 2TV-1 installation.

Electrical System

Wire harness. - The wire harness from SC 102 was modified to the 2TV-1 and CM 101 configuration. This rework included the protective wraps, spot ties, clamps, spacers, and conformal coating. There were certain differences in the wire-harness clamp installations of 2TV-1 and SC 101. For example, the wire harness and the routing were like that in SC 101; and the clamp-filler material was like that in 2TV-1.

The overlay harness for the 2TV-1 and SC 101 instrumentation was not installed. For simulation of a composite 2TV-1/SC 101, this omission represented only a small percentage of the total harness. The smaller harness offered lower heat-sink characteristics to induced fires; therefore, it was considered a worst-case simulation. To provide for the simulation of 2TV-1, a portion of the SC 008 instrumentation harness assembly was modified to the 2TV-1 configuration and was installed. The instrumentation feedthrough assembly plate was mounted in the RH viewing window; and the harness was routed to the aft bulkhead, extending a minimum of 2 feet into the main aft-bulkhead floor-harness wire trays.

Standoffs and insulation were provided where the wire harness was routed adjacent to the BP structure to prevent heat conduction into the structure. The simulated subsystem equipment boxes behind the closeout panels were not installed; however, provisions were made to support connectors in the installed position. The floor-harness trays and covers were production hardware.

Panels. - The following electrical panels were installed.

1. Panel 1 — MDC, commander station
2. Panel 2 — MDC, CM pilot station
3. Panel 3 — MDC, LM pilot station
4. Panel 8 — LH center side display console
5. Panel 225 — RHEB auxiliary CB panel A
6. Panel 226 — RHEB auxiliary CB panel B
7. Panel 250 — Power CB panel
8. Panel 275 — Power CB panel
9. Panel 276 — Instrumentation power control panel
10. Panel 300 — Suit-connector panel
11. Panel 301 — Suit-connector panel
12. Panel 302 — Suit-connector panel

All of the panels, with the exception of panel 3, were removed from SC 102. Panel 3 was available from another test and was treated with an overlay prior to installation in the BP. All other electrical panels were simulated by sheet-metal closeouts which had EL overlays, as applicable, but which did not have components, wiring, or conformal coating.

Environmental Control System

Coolant system. - A portion of the ECS coolant system was simulated by a primary glycol loop which included a 2.40 controller, a pump, and an accumulator. Coldplates were not installed. The coolant lines were bridged at the coldplate interfaces to provide continuous coolant flow. The lines were routed to the specific locations of the IMU, FDAI, and ECU. A representative number of the various types of joints were provided in the LHEB area and behind the MDC. Two properly insulated water-glycol evaporator mockups were installed in their normal positions in the LHEB. An operable cabin heat exchanger was installed and connected to the primary glycol loop. The water-glycol inlet and outlet lines were terminated externally for connection to a pump and control unit. The glycol flows and pressure profile existing in the SC could not be simulated because the coldplates were not in the loop. However, a given flow rate and pressure condition could be maintained at one specific location in the loop. The test requirement for the simulated coolant loop was that it would provide typical water-glycol flow conditions at specific test areas.

Oxygen system. - Although the ECU was not installed, a portion of the oxygen system was included in the installation. This portion consisted of the oxygen control panel, a simulated suit heat exchanger, lithium hydroxide canisters, a suit supply duct, a cabin-air-recirculation pressurization system, and three suit-connector valves. Three oxygen supply hoses with cobra cables were connected to the flow-control faceplates located on the inboard face of the LH forward equipment bay. Insulation on the suit supply duct was postcured TG-15000. The ECU amplifier package was mounted in its normal position beneath the lithium hydroxide canisters and was connected to the SC wire harness. An operable cabin fan and a pressure-relief valve were installed.

Each nonmetallic material in the oxygen subsystem or attached to it was reviewed against NASA and NR criteria for flammability. The review resulted in the replacement (on 2TV-1 and subsequent models) of the external polyurethane tube on the demand pressure regulator and of the polyolefin sleeving used over the wiring on the cabin-depressurization shutoff valve. The depressurization valve was not electrically connected on 2TV-1 and SC 101 and was deleted from subsequent SC. To verify the acceptability of nonmetallic seats, poppet inserts, seals, gaskets, and diaphragms, oxygen-pressure cycling tests were conducted on suspect materials at 200° F and at 2000 psi or greater. Tubing support clamps made of silicone were replaced by Teflon clamps in selected instances to decrease the possibility of flame propagation. All tubing for the oxygen subsystem in the cabin, except for the tubing in the ECU and in the oxygen-valve panel, was changed to steel on SC 101 and subsequent models. For 2TV-1, the aluminum-tubing solder joints were armored except in the ECU and oxygen panels.

For additional assurance, the oxygen main-pressure regulator which contains polyurethane valve seats, was replaced by a different regulator on 2TV-1 and subsequent models. This action was taken even though the seat material successfully withstood several pressure-cycling tests.

Electrical wiring in proximity to oxygen lines was rigidly secured to maintain a minimum clearance of one-half inch. In addition, wire bundles closer to the oxygen lines than 6 inches were covered with Teflon wrap.

As previously stated, the oxygen subsystem has undergone extensive evaluation, testing, and changes, as required. Therefore, it is considered that no further meaningful information would be forthcoming from installing and testing this subsystem in BP 1224.

Crew Equipment

Storage boxes. - The GFE and CFE stowage facilities included in BP 1224 are listed in table B-I.

The locations of the storage boxes are shown in figure B-1. All stowage provisions were included to be representative of 2TV-1 installations. Stowage boxes A1 and A2 were unique to SC 101 installations and were replaced by stowage box A9 (2TV-1 only) which represented worst-case nonmetallic material stowage.

The simulated storage boxes were representative of 2TV-1/SC 101 and, where practical, were constructed from aluminum material of the same thickness as flight hardware. An exception in the assembly of these storage boxes was the deletion of metal stiffeners integral to the boxes. These deletions were not considered significant to the tests because the heat sink afforded by the assemblies was somewhat less than that of the SC-type boxes and, thus, compensated for the absence of stiffness. The remaining storage boxes were for SC hardware.

Spacecraft GFE and CFE. - Items from the SC GFE and CFE equipment lists which would contribute to flammability or flame propagation were provided in BP 1224. These items, along with their respective storage locations, are listed in tables B-II and B-III.

The following are additional BP 1224 equipment items not carried on the loose-equipment list.

1. Water dispenser and hose (installed item)
2. G&N equipment (installed items)
    a. Two eyepieces
    b. Two handholds
    c. Two displays and keyboards

d. CM power and sequencing assembly

e. G&N indicator-control-panel overlay

f. G&N harness

g. Eyepieces and heaters

h. CM simulation control area

3. Aft-bulkhead protective device (GSE item)

4. Hand controllers

a. Two rotation

b. Two translation

Special 2TV-1 equipment. - The requirements of manned thermal-vacuum testing necessitated a number of deviations in crew equipment and stowage arrangement. Among the more significant items were extra padding applied to the aft bulkhead and crew couches, blankets, pillows, special tools, debris bags, and drinking water. Items of this type were provided, as required, to be representative of the 2TV-1 configuration.

Other Equipment

Guidance, navigation, and control equipment. - The G&N equipment was provided and installed. The rotation and translation hand controllers and associated electrical cables were installed but were not operable.

Other subsystem equipment. - Generally, SC subsystem-equipment items (other than those noted in the preceding paragraphs, i.e., sequencers, communications equipment, inverter, etc.) were not installed in BP 1224. The flammability characteristics of representative equipment were demonstrated by the component tests, and further testing in the BP environment was not required.

TABLE B-I. - GOVERNMENT-FURNISHED EQUIPMENT AND CONTRACTOR-FURNISHED EQUIPMENT STOWAGE FACILITIES

Storage box	SC configuration	Simulated	Remarks
R1		X	
R2		X	
R3		X	
R4	X		
R5			
R6	X		
R8	X		
R9		X	
R10	X		
R11		X	
R12		X	
R13		X	
A1		X	SC 101 only; replaced by A9 for 2TV-1
A2		X	
A3		X	
A4		X	Largest of the two
A5		X	
A6		X	
A7		X	
A8		X	
A9		X	2TV-1 only
U1		X	
U2		X	
U3		X	
B1	X		
B2		X	
B3		X	
B4		X	
B5		X	
B6		X	
B7		X	
B8		X	
L1		X	
L2	X		
L3	X		

TABLE B-II. - GOVERNMENT-FURNISHED EQUIPMENT

Nomenclature	Part no.	Quantity
16-mm film magazine	SEB33100022-207	4
Power cable	SEB33100026-203	1
Pilot's preference kit	SEB12100018-201	2
Commander's checklist	SKB32100027-201	1
CM pilot's checklist	SKB32100028-201	1
LM pilot's checklist	SKB32100029-201	1
Detailed test procedures 5059, volume I	SKB32100065-201	1
Detailed test procedures 5059, volume II	SKB32100066-201	1
Landmark maps, volume I	SKB32100032-201	1
Landmark maps, volume II	SKB32100033-201	1
Landmark photographs	SKB32100035-201	1
Lunar landmark maps	SKB32100034-201	1
Systems data	SKB32100036-201	1
Malfunction procedures	SKB32100037-201	1
Charts and graphs	SKB32100038-201	1
CSM rendezvous book	SKB32100039-201	1
Crew log	SKB32100040-201	2
Procedures	SKB32100041-201	1
Updates	SKB32100042-201	1
Photo log	SKB32100043-201	1
Mercator star chart	SKB32100054-201	1
Polar star chart	SKB32100056-201	1
Orbital map	SKB32100058-201	1
Tape	SEB33100050-201	1
Inflight exerciser	SEB33100086-201	1
Medical accessories kit	SEB42100082-201	1
Survival kit assembly	SEB40100077-201	1
Survival rucksack kit 1	SEB40100071-201	1
Survival rucksack kit 2	SEB40100073-201	1

TABLE B-II. - GOVERNMENT-FURNISHED EQUIPMENT - Concluded

Nomenclature	Part no.	Quantity
Tissue dispenser	SEB42100086-202	6
CM utility towel assembly	SEB42100079	
Red	SEB42100079-201	1
White	SEB42100079-202	1
Blue	SEB42100079-203	1
CM helmet stowage bag	To be determined	3
EMU maintenance kit	To be determined	1
Constant-wear garment (CWG)	SEB13100061-201	6
Oxygen mask and hose	651-400	1
Inflight overalls	SEB13100062	3
Food package	14-0122	1
Food package	14-0123	1
Toothbrush	To be determined	3
Toothpaste	To be determined	1
Pressure garment assembly (PGA)	To be determined	1
Dual lifevest	SEB40100095-201	3
Penlight	ACR-FA-4	1

TABLE B-III. - CONTRACTOR-FURNISHED EQUIPMENT

Nomenclature	Part no.	Quantity
PGA container	V36-601013	3
Temporary stowage container	V36-601444	3
Side shade	V36-770030	2
Hatch shade	V36-775026	1
Rendezvous shade	V36-77028	2
Tool set assembly	V36-601135-41	1
Aft sanitation supply stowage box	V36-601219	1
Sanitation supplies	V36-601419	30
Portable floodlight	V36-771102	1
Crewman communication control head	V36-715110	3
Rotational mount	V36-334560	1
Vacuum cleaner	V36-612546-11	1
Vacuum-cleaner debris bag	V16-611241-21	10
Vacuum-cleaner nozzle assembly	V16-611241-21	1
Flight-data-file container assembly	V36-331092-101	2
Crewman sleeping-assembly restraint	V36-601012	
Left	V36-601012-101	1
Right	V36-601012-201	1
Fecal canister	V16-601418-421	1
Relief tube assembly receptacle	V16-601421-501	1
Fecal canister pad	V36-601310	1
Couch pad (lg)	V36-601300	1
Couch headrest pad (lg)	V36-601301	1
Glycol temperature-measuring unit	ME280-0008-0002	1
CWG communications-control-unit (CCU) adapter cable	To be determined (or V36-715102)	4
Sleep station pad (lg)	V36-601304	1
Pillow (lg)	V36-601303	2
Blanket (lg)	V36-601302	2

TABLE B-III. - CONTRACTOR-FURNISHED EQUIPMENT - Continued

Nomenclature	Part no.	Quantity
Couch back assembly pad	V36-601325	
Left	V36-601325-1	1
Right	V36-601325-2	1
Center	V36-601325-2	1
Seat pan assembly pad	V36-601327	
	-11, -21	1
	-22, -31	1
	-41, -42	1
Inboard and outboard lower armrest pad	V36-601331	4
Headrest support pad	V36-601328	3
Outboard armrest pad	V36-601329	2
Inboard upper armrest pad	V36-601332	2
Power cable, glycol-temperature measuring unit	V36-421141	1
Injector assembly chlorination	V36-610309	1
Chlorination ampule	V36-610295	14
CO_2 absorbers	ME901-0218-0031	7
CO_2 absorber shims	V16-613205-3	4
Crewman communication umbilical cable	V36-715101	
Left	V36-715101-11	1
Center	V36-715101-21	1
Right	V36-715101-31	1
Oxygen umbilical	V36-601201	
Left	V36-601201-81	1
Center	V36-601201-91	1
Right	V36-601201-101	1
PGA oxygen umbilical interconnect coupling assembly	ME273-0076-0001	3

TABLE B-III. - CONTRACTOR-FURNISHED EQUIPMENT - Continued

Nomenclature	Part no.	Quantity
Gas- and liquid-waste-management-system quick disconnect filter assembly	V36-612547	2
Container A1	V36-758865	1
Container A2	V16-331090-101	1
Container A3	V36-331003-391	1
Container A6	V36-331003-361	1
Container A7	V36-331065	1
Container A8	V36-331064	1
Container A9	To be determined	1
Container B3	V36-334064	1
Container B4	V36-334068	1
Container B5	V36-331091-31	1
Container B6	V36-331091-31	1
Container B7	V36- (to be determined)	1
Container U1	V36-331074	1
Container U2	V36-331075	1
Container U3	To be determined	1
Cushion, volume A7	V36-758854	1
Cushion, volume A7	V36-758855	1
Cushion, volume B3	V36-758875 (2TV-1)	1
	V36-759951 (SC 101)	1
Cushion, volume B8	V36-758877 (2TV-1)	1
	V36-758853 (SC 101)	1
Cushion, volume A9	V36-758881	1

TABLE B-III. - CONTRACTOR-FURNISHED EQUIPMENT - Concluded

Nomenclature	Part no.	Quantity
Cushion, volume R13	V36-758857	1
Chlorination equipment container (B4 pouch)	V36-758860	1
Window container	V36-768866	1
Wire-run cover	V16-601494	1
Wire-run cover	V16-601495	2
Wire-run cover	V16-601496 -1, -2	1
Panel-assembly work optics covers	V36-601041-21	1
Container straps installation	V36-758882	1
	V36-758883	1
	V36-758884	1
	V36-758885	1
Inflight retainer straps	V36-758870	3
Glycol-temperature strap	V36-601016	1
Glycol-temperature water	ME280-0008-0002	1
Measuring unit and card (LM pilot)		
CWG CCU adapter cable	V36-715102	3

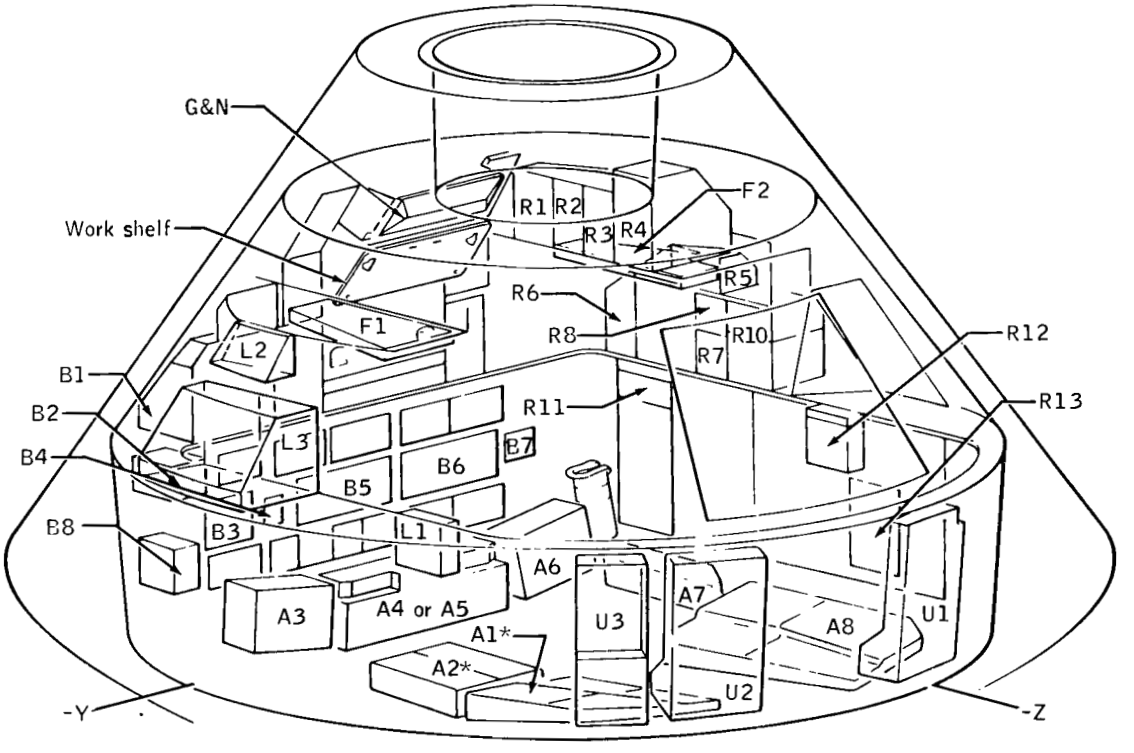


Figure B-1. - Arrangement of BP interior components.

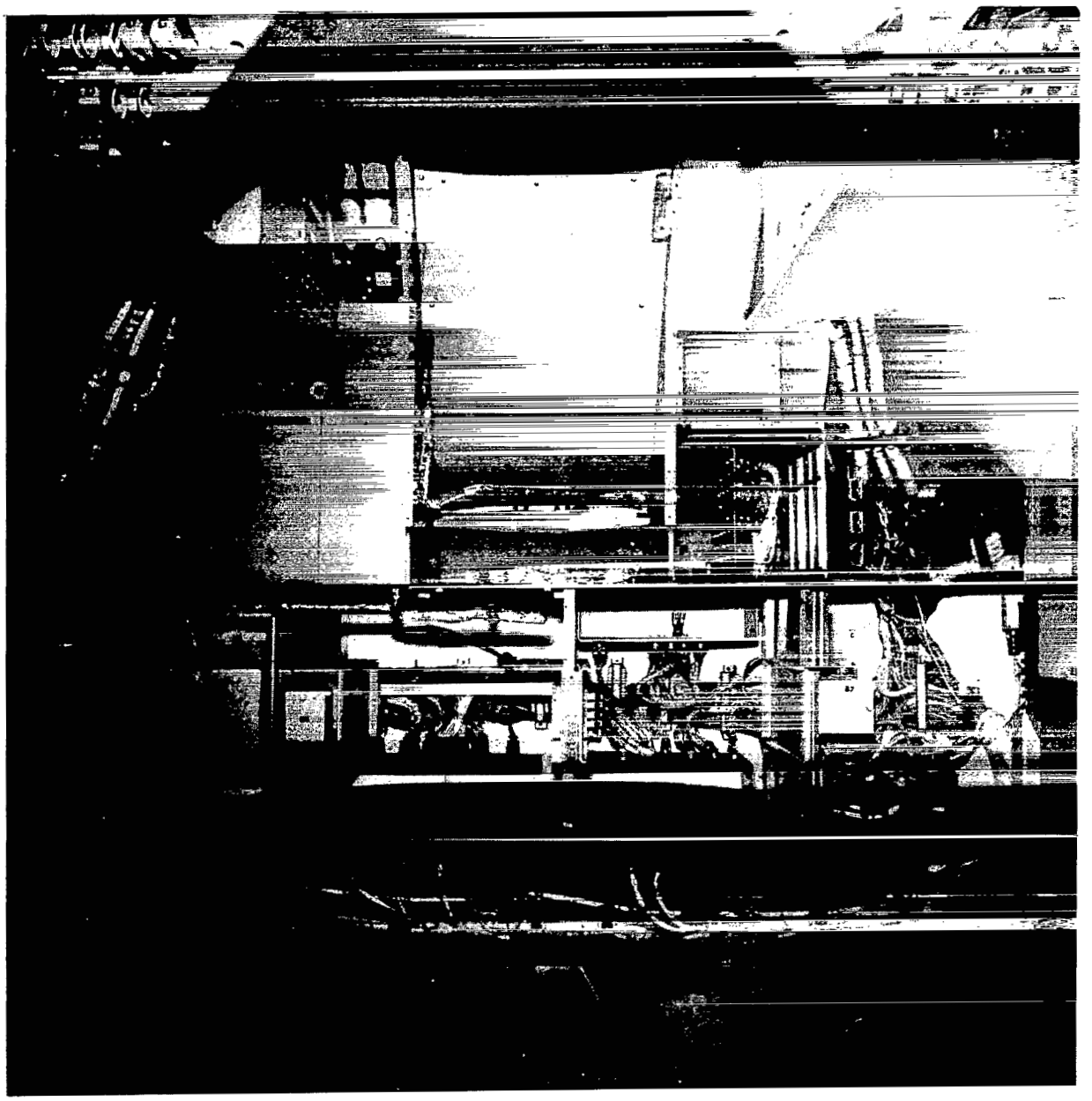


Figure B-2. - Lower equipment bay (BP 1224).

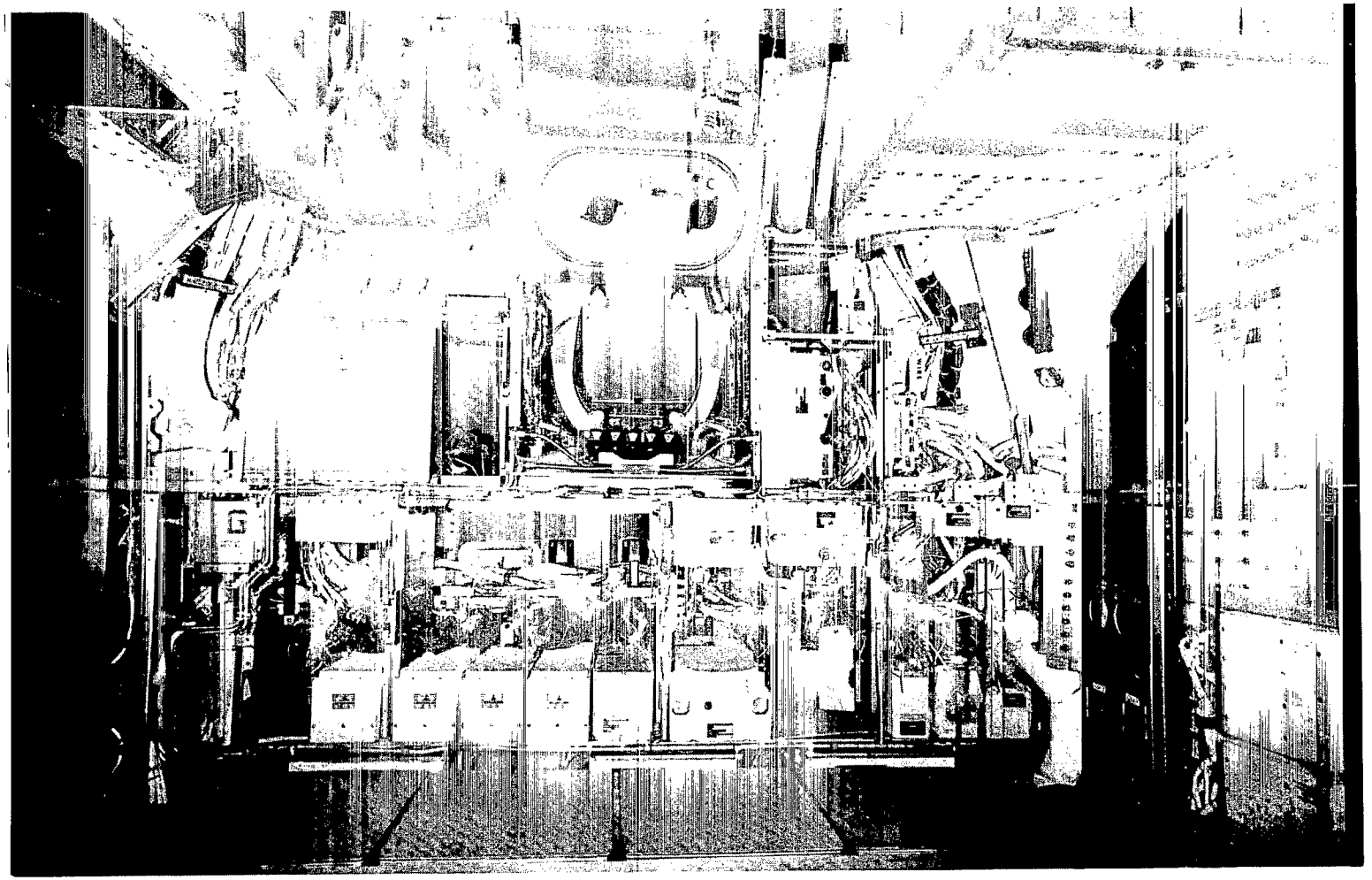


Figure B-3. - Lower equipment bay (2TV-1).

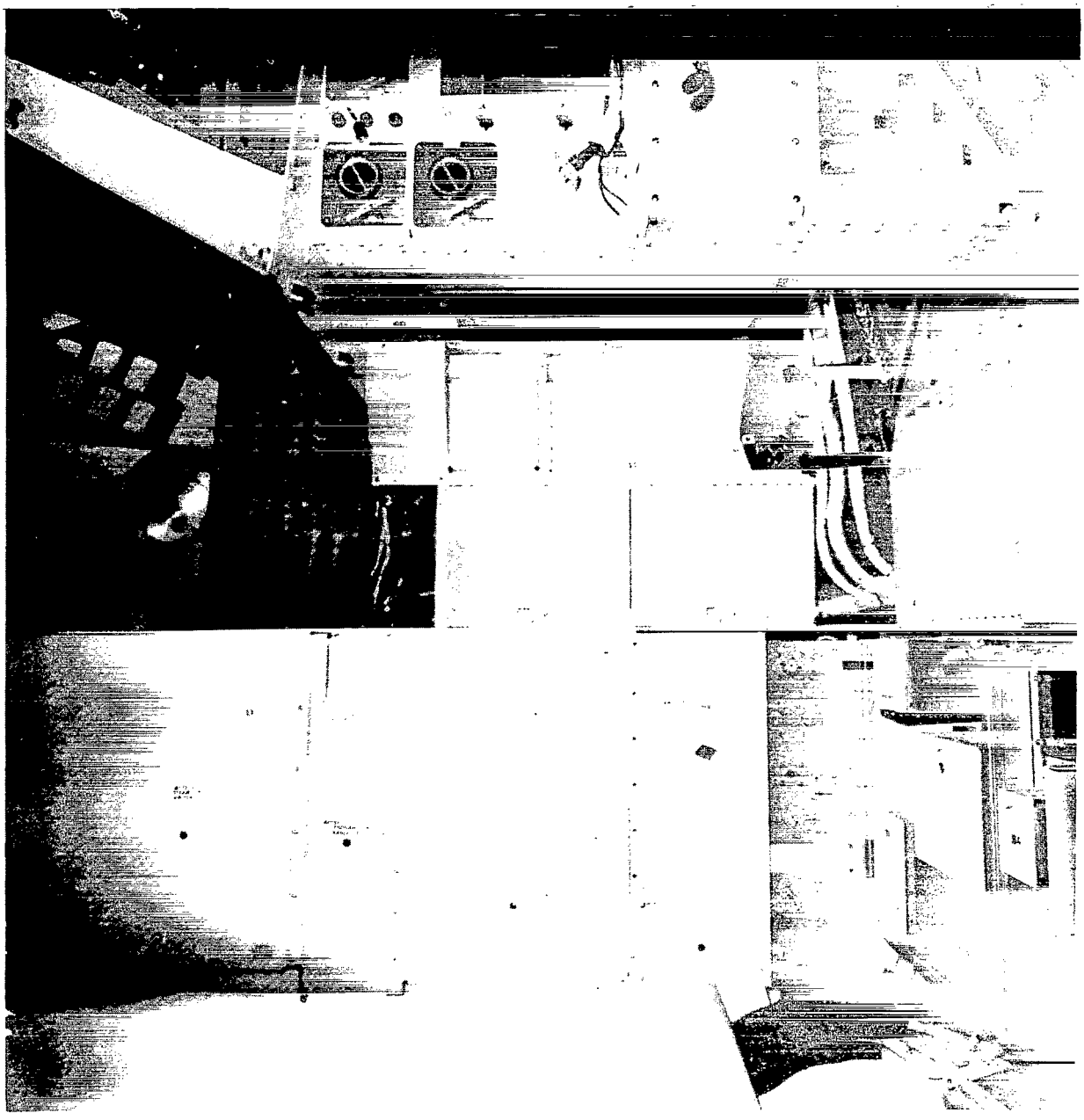


Figure B-4. - Left-hand equipment bay (BP 1224).

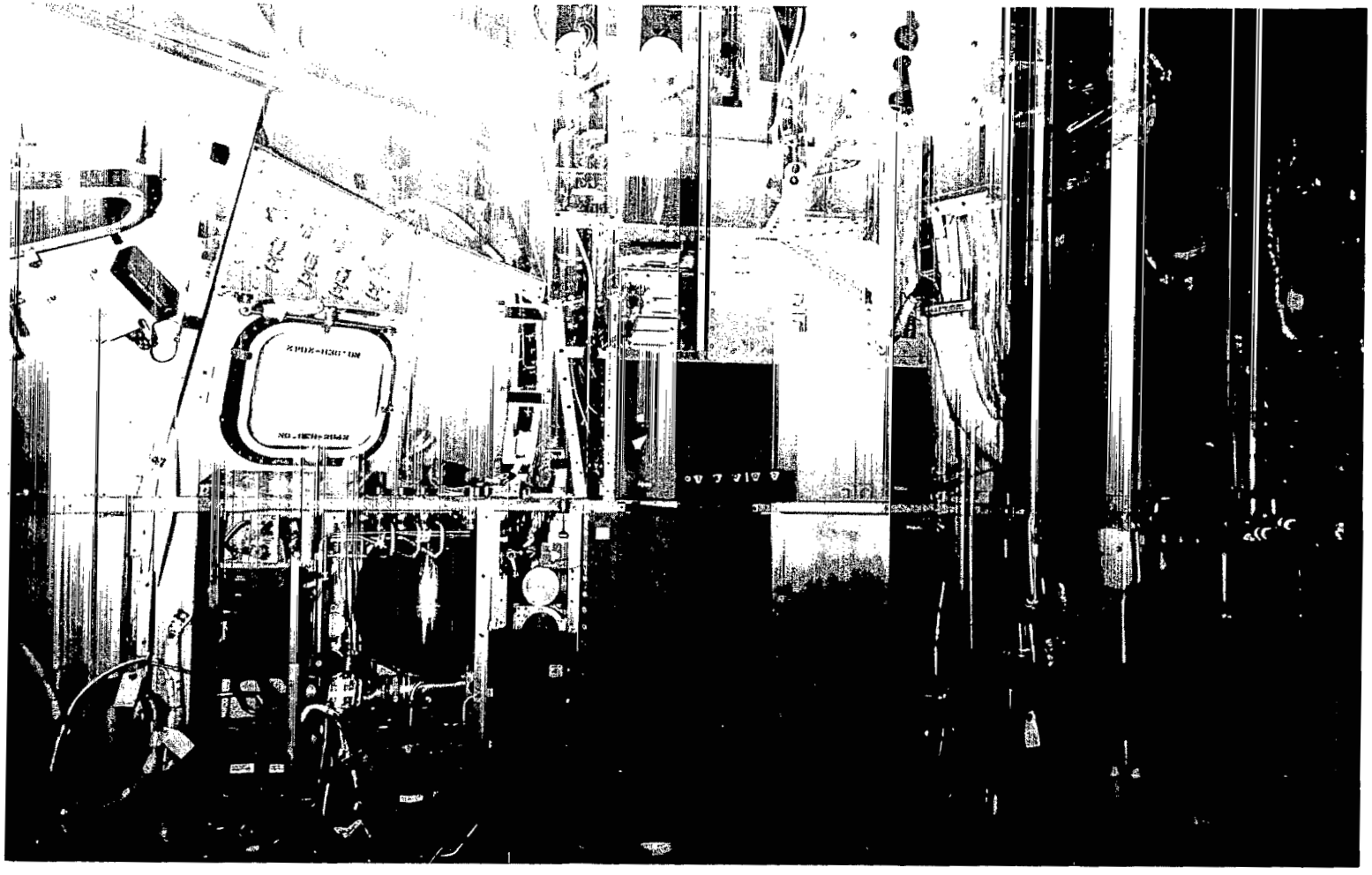


Figure B-5. - Left-hand equipment bay (2TV-1).

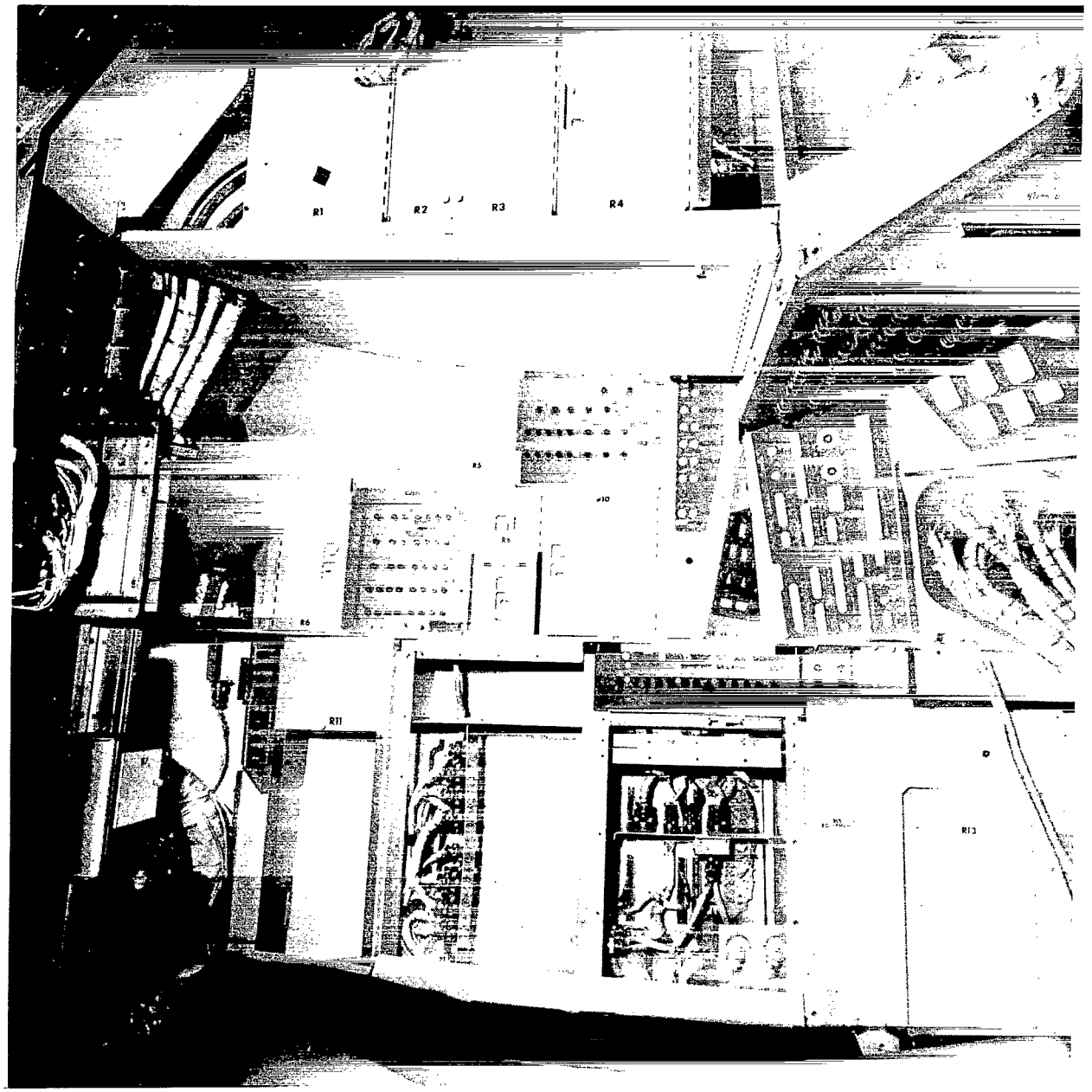


Figure B-6. - Right-hand equipment bay (BP 1224).

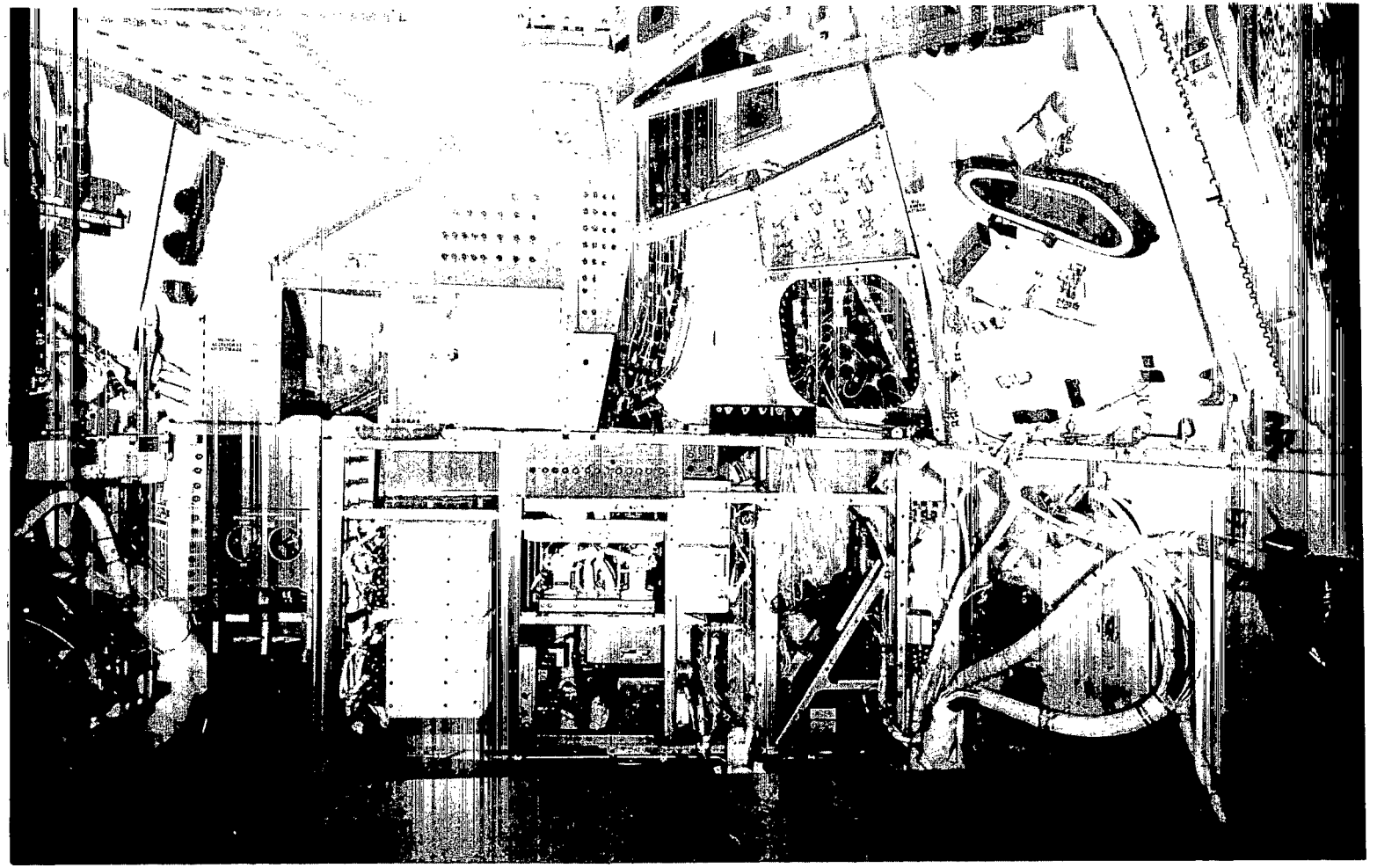


Figure B-7. - Right-hand equipment bay (2TV-1).

APPENDIX C

QUALITY ASSURANCE PROVISIONS

TEST READINESS REVIEW BOARD

To assure the technical quality of the Flammability Test Program, the MSC Assistant Director for Engineering and Development established a Test Readiness Review Board composed of the following persons.

Jerry W. Craig, Apollo Spacecraft Program Office
Vance D. Brand, Astronaut Office
Edward L. Hays, Crew Systems Division
Albert L. Branscomb, Jr., Structures and Mechanics Division
Robert L. Johnston, Structures and Mechanics Division
Milton W. Steinthal, Apollo Spacecraft Program Office
Anthony W. Wardell, Flight Safety Office

The following detailed functions were assigned to this board.

1. To review the refurbishment and assembly of the test article to ensure an adequate degree of fidelity in simulating 2TV-1 and SC 101

2. To review project planning and provide technical direction concerning the test plan, test procedures, and utilization of the test facility and instrumentation

3. To review the selected ignition points and recommend to the CM manager any additional testing necessary

4. To monitor the conduct of the tests for technical accuracy and adequacy

5. To review the final results and recommendations

Test Quality Control

The responsibilities of the NASA quality control representatives during the BP 1224 flammability tests were to provide continuous monitoring of the test operation and to assure compliance with the in-house test procedures for CM mockup testing.

These test procedures provide verification of control and calibration of the test equipment before the start of the test. Verification is obtained by the following steps.

1. Check the mechanical systems setup and operation.

2. Check the instrumentation and control systems.

3. Check the installation and verification of photographic and television-camera coverage.

4. Check all special test setup and test-preparation-sheet procedures.

5. Check certification and acceptance by the Flammability Test Review Board of all materials that are part of the BP 1224 mockup.

6. Check that the setup, countdown, and testing of each ignition point are performed correctly.

7. Check that all deviations from established test procedures are recorded on test summary sheets.

All of these procedural checks were carefully performed and verified by the quality-control monitor.

Configuration and Material Control

Configuration. - Configuration control was enforced throughout the fabrication of BP 1224. An installation log was maintained which noted structures and equipment installed by name, by part, by serial number, by date of installation, and by acceptance by NR. Photographs were taken of all areas before installation, after structure and equipment installation, and before closeout.

Material. - The use of acceptable nonmetallic materials was verified by the materials-control representative. Where the use of NR process specifications was required, the specification was identified and the use of proper materials and methods was verified. Clamp locations and harness routing were verified as closely as practicable by comparison with SC 101 and 2TV-1 drawings and photographs.

"The aeronautical and space activities of the United States shall be conducted so as to contribute . . . to the expansion of human knowledge of phenomena in the atmosphere and space. The Administration shall provide for the widest practicable and appropriate dissemination of information concerning its activities and the results thereof."

—NATIONAL AERONAUTICS AND SPACE ACT OF 1958

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