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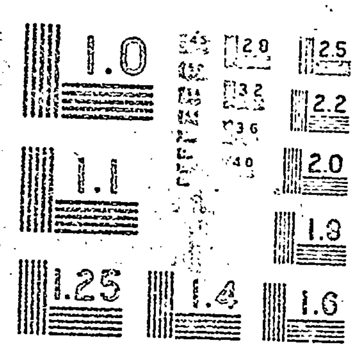

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DESIGN, TESTING, FABRICATION AND LAUNCH SUPPORT OF A LIQUID CHEMICAL BARIUM RELEASE PAYLOAD

(Utilizing the Liquid Fluorine-Barium Salt/Hydrazine System)

By C. S. Stokes, E. W. Smith and W. J. Murphy

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SUMMARY

The program for "Design, Testing, Fabrication, Delivery , and Launch Support of a Barium Chemical Release Payload," (NASA Contract No. NAS 1-7709) was begun in September 1967.

A payload was designed which included a cryogenic oxidizer tank, a fuel tank, and burner section. Release of 30 lb (13.6 kg) of chemicals was planned to occur in 2 seconds at the optimum oxidizer to fuel ratio. The chemicals consisted of 17 lb (7.7 kg) of liquid fluorine oxidizer and 13 lb (5.9 kg) of hydrazine-barium salt fuel mixture. The fuel mixture was 17% barium chloride, 16% barium nitrate, and 67% hydrazine and contained 2.6 lb (1.2 kg) of available barium.

Two significant problem areas were resolved during the program: explosive valve development and burner operation. The use of the extremely reactive oxidizer, fluorine, necessitated the design of special, pyrotechnically actuated, flow release valves. Development of these explosive valves was the pacing item in the program.

The chemical release mechanism consisted of pressurized fuel and oxidizer tanks containing dip tubes which were connected, through the explosive valves, to the burner. The payload was spun-up during second stage rocket motor burning to approximately 6 rps to maintain the liquid chemicals on the tank walls and insure fuel and oxidizer flow by blowdown through the dip tubes.

The average design flow rate of the chemicals was 15 lb/sec (6.8 kg/sec); however, the initial flow was approximately 18 lb/sec (8.2 kg/sec) and final flow about 13 lb/sec (5.9 kg/sec). This characteristic of decreasing mass flow rate led to burner instability in the initial stages of burner development. The problem was solved by installation of control orifices in the fuel and oxidizer lines adjacent to the burner.

A prototype payload was fired in a ground test on April 3, 1970. Data indicated that the test was successful and all systems performed satisfactorily. Combustion of the 30 lb (13.6 kg) of chemicals took place in 2 seconds.

On October 7, 1970, the Research Institute of Temple University (RITU), in conjunction with NASA-Langley Research Center (NASA-LRC), participated in a

liquid chemical barium release payload flight test from Wallops Island, Virginia. The release took place at an altitude of approximately 260 km at 9:51:17 U.T. This marked the first time that cryogenic liquid fluorine was used as an oxidizer in a spacecraft.

The release produced a luminous cloud which expanded very rapidly, disappearing to the human eye in about 20 seconds. Barium ion concentration slowly increased over a wide area of sky until measurements were discontinued at sunrise (about 30 minutes). Although the barium ion yield was less than optimum value, much was learned about the liquid system. A synopsis of flight results is presented in Appendix I.

INTRODUCTION

Barium yield from solid chemical release systems in existence at the time this program began was between one and two percent of total chemical weight (see ref. 1). An improvement in barium yield was needed in order to conduct more ambitious electric and magnetic field experiments using the ionized barium technique at greater distances in the geomagnetosphere. Since theoretical yield from liquid systems appeared to offer significant increases over solid systems, laboratory investigations of promising fuel-oxidizer systems were conducted, in an earlier study, as reported in reference 2. From this work, a liquid system consisting of hydrazine, with dissolved barium salts, as the fuel and liquid fluorine for the oxidizer was selected as the basis for payload hardware development.

The purpose of this program was to develop and test a liquid chemical payload system suitable for a point release of barium in the form of barium atoms and barium ions. To approximate a point release, a release time of 2 seconds was specified. The ionized barium yield of the liquid chemical payload system was evaluated at an altitude of 260 km during a flight test on a Nike-Tomahawk vehicle. The Research Institute of Temple University designed, fabricated, developed, and fully qualified the liquid chemical barium release payload. This report documents the development of the payload and describes the ground support equipment essential for payload preparation and monitoring prior to lift-off. The results of the flight test are summarized in Appendix I.

CHEMICAL SYSTEM CHARACTERISTICS

System Selection

Chemical systems containing dissolved barium salts were evaluated in an earlier study performed by the RITU under NASA Contracts NAS 1-6199 and NAS 1-7070. Some ten different chemical systems were evaluated and compared on the basis of the relative intensities of the spectral lines of barium atoms (Ba° 5535 Å) and barium ions (Ba^{+} 4554 Å). The results of this study, as reported in reference 2, indicated that the system utilizing "B-Mix" fuel and liquid fluorine (LF_2) oxidizer gave the greatest amount of light intensity at the desired spectral lines. This chemical system was selected for development and flight test.

The "B-Mix" fuel consisted of barium salts dissolved in hydrazine with the following formulation:

$$17\%\ BaCl_2 - 16\%\ Ba(NO_3)_2 - 67\%\ N_2H_4$$

The liquid fluorine oxidizer was maintained in a cryogenic state and, when mixed with the fuel in the burner, a hypergolic reaction resulted.

Chemical Properties and Handling Characteristics

All of the chemicals used in the selected chemical system are potentially hazardous materials and were handled either according to government or industry approved procedures such as reference 3 and 4. The properties and handling characteristics of the pertinent materials are summarized here.

Fluorine.- Fluorine is one of the most powerful oxidizing agents known and can react with practically all organic and inorganic substances. Most common metals of construction are compatible for use in a fluorine environment since, in order to burn with fluorine, the reactions must be initiated by a secondary material which can be considered a contaminant or by localized addition of energy such as friction, impact, or heating to ignition temperatures.

The potential hazards to personnel working with fluorine are both chronic and acute. Exposure to jets of liquid or gas causes immediate and deep burning of the skin. This tissue destruction is the result of oxidation, thermal burns and tissue poisoning by formation of hydrofluoric acid.

Excess inhalation of gaseous fluorine results in pulmonary edema. Fortunately, fluorine can be detected by odor in concentration as low as 0.14 ppm. When fluorine can be smelled without irritation to the nose (up to 15 ppm), the individual should leave the exposure area within one-half hour. Concentrations above 15 ppm call for air masks and full safety suits.

There were three main hazards anticipated in handling fluorine in this program. During test operations, there was the hazard of inhalation of fluorine or hydrogen fluoride contaminated air over a long period of time as the result of leakage into the atmosphere. As indicated, the human nose is an excellent fluorine detector and when fluorine was first sensed, it was only necessary for personnel to walk away from the area in an upwind direction, since most operations were conducted outdoors.

The other hazards of concern included accidental exposure to high concentration of the gas or accidental contact or impingement of liquid or gaseous fluorine on the body. The possibilty of such incidents occurring was minimized by proper design, well planned operational and safety procedures, and thoroughly trained personnel. During all operations involving fluorine, a safety suit was worn by personnel and work was done from behind a shield. A breathing air supply was available for emergencies as well as body showers, eye wash fountains, and first aid equipment.

Physical properties of liquid fluorine (LF_2) are summarized as follows:

Density: 1.56 g/cc (97.34 lb/ft^3) @ -196°C (-320°F)
Viscosity: 0.31 cP @ -196°C (-320°F)
Boiling Point: -188°C (-307°F)
Critical temperature: -129°C (-201°F)

Hydrazine.- Hydrazine, N_2H_4, has been known and used as a fuel for many years and its handling peculiarities are well known. Hydrazine is a clear, oily, water-white liquid. It is a strong reducing agent, weakly alkaline and hygroscopic. It has an odor similar to ammonia. Hydrazine is a highly polar electrolytic solvent and is soluble in water, methanol, unsymmetrical dimethylhydrazine, and ethylene diamine but is insoluble in ethers and hydrocarbons.

Hydrazine is very toxic; inhalation of even dilute concentrations should be avoided. Liquid hydrazine, if spilled onto the skin or into the eye, can cause severe local damage or burns. It can also penetrate the skin to cause systemic effects similar to those produced when the compound is swallowed or inhaled. Exposure to hydrazine can also result in dermatitis.

The threshold limit value (TLV) which has been adopted by the American Conference of Governmental Industrial Hygienists is 1 ppm for repeated 8 hour exposures. The minumum for odor detection is about 3 to 5 ppm. Since hydrazine vapors cause olfactory fatigue, the detection of hydrazine by odor can be used only as a first warning.

The toxicity and chemical reactivity of hydrazine dictated that suitable safety equipment be available for the protection of operating personnel and for safeguarding storage areas. Safety equipment used on this program included showers, eye wash fountains, first aid equipment, water spray deluge systems, fire hoses and fire blankets.

Barium Salts.- The soluble barium salts, barium chloride and barium nitrate, are poisonous when taken by mouth. Few cases of industrial systemic poisoning by barium salts have been reported, but one investigator describes a fatal dose of poisoning attributed to barium oxide; the symptoms being severe abdominal pain with vomiting, dyspnea, rapid pulse, paralysis of the arm and leg, and eventually cyanosis and death. The same investigator produced paralysis in animals with barium oxide and carbonate. The usual result of exposure to the sulfide, oxide and carbonate is irritation of the eyes, nose and throat, and of the skin, producing dermatitis. The barium salts mentioned are also somewhat caustic.

Particular precautions were taken to avoid unnecessary exposure or contact with the barium salts during mixing and handling operations.

The physical properties of barium chloride and barium nitrate are summarized in Table I.

Fuel ("B-Mix").- The barium salt solution consisted of a mixture of barium salts dissolved in hydrazine in the following amounts, by weight:

17% $BaCl_2$
16% $Ba(NO_3)_2$
67% N_2H_4

Handling procedures and safety precautions compatible with hydrazine were used. The mixture was found to be relatively stable as shock and impact sensitivity tests gave negative results. Five successive 100 Kg-cm drop tests did not produce any observable decomposition. Care was taken to keep the mixture near room temperature when possible since solids would precipitate out of solution at the freezing point.

Physical properties of the "B-Mix" are as follows:

Density: 1.358 g/cc (84.74 lb/ft^3) @ 25°C (77°F)
See Figure 1: "B-Mix" Density vs. Temperature
Viscosity: 3.535 cS @ 25°C (77°F)
Freezing point: -6°C (21°F)

PAYLOAD CONFIGURATION

The liquid chemical barium release payload consisted of five sections as follows:

- Nose ogive
- Oxidizer tank
- Burner section
- Fuel tank
- Second-stage firing module

The external configuration of the payload is shown in Figure 2. The payload was 9.00 in. (0.299 m) in diameter and 105.94 in. (2.691 m) in length. The length of the payload sections are given in Table II. The total weight of the payload was 175.0 lb (79.4 kg) including the 30 lb (13.6 kg) of chemicals. The payload weight breakdown is tabulated in Table III.

The internal components of the payload and interfaces are shown schematically in Figure 3. Payload components are described in a later section. The payload interfaces with the launcher and ground equipment included three umbilical connectors, a liquid nitrogen (LN_2) supply line to the oxidizer tank jacket, oxidizer fill line, oxidizer dump line, and gaseous nitrogen purge lines to critical areas. The mechanical interface of the payload with the second-stage Tomahawk rocket motor was by means of a simple lap joint.

The liquid chemical barium release payload was launched by a Nike-Tomahawk vehicle. The launch vehicle and payload are shown in figure 4 in position on the launcher during pre-launch operations at Wallops Island. During flight, the Nike first-stage rocket motor was drag separated at burnout. The Tomahawk second-stage rocket motor and the payload remained attached throughout the flight. The Nike-Tomahawk vehicle was furnished by Goddard Space Flight Center.

PAYLOAD HARDWARE AND COMPONENT DESIGN SPECIFICATIONS

Description of Payload Hardware

Nose ogive.- The nose section for the payload furnished by the Government was a standard Nike-Tomahawk ceramic nose ogive. Openings were provided to admit the oxidizer fill tube and an extension handle for opening and closing the oxidizer fill valve, as shown in Figure 3.

Oxidizer tank.- The oxidizer tank was double walled with an inner pressure vessel to hold the cryogenic fluorine surrounded by an outer jacket open to the atmosphere, to hold the LN_2 for cooling. Since the LN_2 has a lower boiling point than the LF_2, the fluorine in the inner tank was kept in a liquid state. During flight, the LN_2 was quickly depleted from the outer jacket but the LF_2 was maintained in a cryogenic state by the heat sink capacity of the heavy oxidizer tank and the LF_2 itself.

During the final coast phase of the flight, the payload was spinning at a rate from 4-6 rps. The inner tank included a diagonal slosh bar which helped to accelerate the LF_2 during spin-up so that the LF_2 would remain on the wall of the tank during the flight. The tank had a dip-tube along the wall through which the oxidizer flowed under the action of helium pressurant at the moment of release.

The material selected for the oxidizer tank was Type 6061-T6 aluminum which is compatible with fluorine and also has excellent welding properties. Oxidizer tank specifications are given in Table IV.

An insulating adaptor section was included at the burner end of the oxidizer tank to reduce heat transfer from the burner and fuel tank sections and possible chilling of the "B-mix" fuel. Insulator material specifications are given in Table V.

Burner section.- The burner section, between the oxidizer and fuel tanks, contained most of the payload components. Structurally, the burner section consisted of two half-sections of rolled 6061-T6 aluminum plate attached to heavy ribs. The cylindrical half-sections comprised the payload skin and either section could be removed to service the internal components, which were mounted on skin attached mounting brackets. The oxidizer and fuel explosive valves were each held in place by a brace integral with the oxidizer and fuel tanks respectively and by top and bottom valve holders attached to the inside of the payload skin.

Fuel tank.- The fuel tank was an integral pressure vessel and also served as a structural section of the payload. The fuel tank contained a diagonal slosh bar to accelerate the fuel mixture during spin-up so that the fuel would remain on the wall of the tank. The tank had a dip-tube along the wall through which the fuel flowed under helium pressure when released by the explosive valve. Fuel tank specifications are given in Table VI.

Second-stage firing module.- The second-stage firing module was furnished by the Government and was basically a Tomahawk firing and despin module with modifications for this payload. The despin mechanism was removed and additional screw holes were added at the payload interface flange, providing a total of 24 screws, to stiffen the lap joint at that location and help reduce vehicle flexibility. There was no electrical interface between the module and the payload. A squib activated battery was used to permit remote battery activation late in the pre-launch countdown. The second-stage ignition system was a 3-wire, redundant pyrotechnic circuit with g-activated mechanical timers. An angle-mounted connector was added to provide umbilical pull-away at first vehicle motion on the launcher.

Payload Fasteners.- Specifications for the screws used to attach the payload skin are listed in Table VII. Joint screw specifications are given in Table VIII. The torque values used on all payload screws are specified in Table IX.

Description of Payload Mechanical Components

Burner and Feed System.- As shown schematically in Figure 3, the burner was centrally located in the burner section between the oxidizer tank and the fuel tank. The chemicals were delivered from the tanks to the burner through feed systems which consisted of 1-inch explosive actuated valves and 1-inch diameter aluminum tubing welded to the burner body and attached to the explosive valves by flared fittings.

The burner is shown schematically in half-cross section in Figure 5. The fuel and oxidizer flowed into their respective feed rings and were mixed in the burner chamber by means of a series of alternate injectors. The burner required no moving parts or mechanisms and the flow was unrestricted except for relatively large flow orifices used in both the fuel and oxidizer tubes to minimize pressure surges. The burner was fabricated from Type 6061-T6 aluminum with material specifications as listed in Table X.

Table XI lists the nominal burner design parameters selected to maintain an oxidizer to fuel ratio of 1.31 over the 2-second run and also to maintain a 75 psi or greater pressure drop in the flow orifice and a 75 psi drop through the burner injector ports.

Oxidizer dump system.- The oxidizer dump system was provided to permit release of fluorine from the oxidizer tank in the event of an abort situation during pre-launch preparations. As shown schematically in Figure 3, a tube connected to the oxidizer tank was manifolded through two ½" normally closed explosive valves, plumbed in parallel, to a ½" stainless steel tube which extended approximately 2" outside of the payload skin at a 45° angle. A slip fitting over this dump line stub connected to a tube which led to the fluorine disposal system on the ground. At launch, the slip fitting and tubing were separated from the payload and retracted.

Oxidizer fill valve.- The oxidizer fill valve was mounted on the forward end of the oxidizer tank and was used during filling and pressurizing of the oxidizer tank. The valve was connected to the tank by means of a 3/8" swage type fitting and was actuated by a removable extension handle through an opening in the nose ogive. The oxidizer fill valve was a commercially available, type 316 stainless steel, bellows seal valve which was suitable for fluorine service.

Fuel fill valve.- The fuel fill valve was mounted on the aft end of the fuel tank and was used during filling and pressurizing of the fuel tank. The fuel fill valve was a type 316 stainless steel forged needle valve and was attached to the tank by means of a standard pipe thread. The valve was not accessible from outside the payload since fueling operations were completed prior to final assembly of the payload. A closing torque of 20-30 in-lb was specified for this valve.

Tubing and fittings.- Payload tubing in contact with fluorine was generally either copper or aluminum, although the payload dump line stub was stainless steel. As previously noted, the feed system tubes were flared aluminum with steel fittings. Standard brass fittings were used with the flared copper tubing and swage type steel fittings were generally used with the stainless steel tubing. Due to the hazardous nature of the chemicals involved, particular care was taken to ensure that all fittings would be leak-free under the expected environmental conditions by setting all fitting torque values at the levels specified in Table XII.

Explosive valves.- The payload included four explosively actuated, normally closed, flow control valves: two ¼" explosive valves in the oxidizer dump system; one 1" explosive valve in the oxidizer feed system; and one 1" explosive valve in the fuel feed system. All of these valves had the requirement to totally contain the chemicals - cryogenic fluorine or "B-Mix" -- until the instant of firing, when full flow was established through the valve. The original development testing was done on the ¼" explosive valve as reported in reference 5. The 1" explosive valve design was a scaled-up version of the ¼" explosive valve, which is shown schematically in Figure 6. The operation of the valve was as follows: a pyrotechnic pressure cartridge was fired causing the ram to translate, severing a nipple on the inlet port. Ram motion continued until the flow passage was cleared and the ram sealed itself by wedging in the body of the valve. The ram included a sliding cup seal and a flash cup to help contain the pyrotechnic particles. However, there was no positive separation of the explosive products from the flow passages during ram translation. Similarly, the ram seals were not designed to seal the ram against downstream pressurization prior to actuation.

The 1" explosive valve, shown schematically in Figure 7, is similar to the smaller valve and employed the same principle of operation. The larger valve had no flash cup arrangement but utilized two seals on the ram. In addition, the ram cavity was closed by a screw-on cover, necessitated by the larger size of the ram.

Both types of valves were compatible with hydrazine and fluorine and were extensively tested during the development phase. Specifications for these valves are given in Table XIII.

Description of Payload Electrical and Instrumentation Components

Payload Electrical Schematic.- The payload electrical system was designed by NASA-LRC and is shown schematically in Figure 8. The electrical system includes the explosive valve firing circuits, contained in the flight programmer, and the payload monitoring systems. The valve firing circuit was a two wire, ungrounded, redundant system remotely armed and safed. Ground monitoring and checkout was done through two umbilical circuits; the payload had no provision for in-flight monitoring.

Flight programmer.- The flight programmer was designed, built, and qualified by NASA-LRC. The programmer included redundant, g-activated mechanical timers, which closed relay contacts to fire the valves. Due to the short release time of the chemicals, it was necessary to ensure that the fuel and oxidizer valves would open simultaneously. To compensate for expected timer variations, the circuits were wired such that closure of either timer, would result in simultaneous actuation of both explosive valves.

Pressure Transducers.- Oxidizer and fuel tank pressures were individually monitored by two Type 17-4PH stainless steel, strain-gage pressure transducers with a range of 0 - 1000 psia and qualified for cryogenic use. Pressure transducers of the same electrical type were used for both the oxidizer and the fuel tanks in order to standardize the electrical characteristics and mechanical requirements. The only difference between the fuel and oxidizer pressure transducers was the use of a teflon coated, stainless steel O-ring for the fuel unit versus a silverplated, stainless steel O-ring body seal for the oxidizer unit.

Temperature Sensors.- Oxidizer and fuel tank temperatures were monitored by two Type 321 stainless steel encased platinum resistance temperature sensors. This sensor met the required temperature range, chemical compatibility, and shock and vibration capability for both fuel and oxidizer use. Again, the advantages of standardization were attained by the use of a single type of sensor. The sensors were attached to each tank with a ¼" swage type stainless steel nut. The 3-wire electrical connection was made through the umbilical cable.

Payload battery.- The payload battery was a flight qualified unit used only to fire the 1" explosive valve cartridges; the ¼" oxidizer dump valves could be fired only through the umbilical by ground power. The battery was squib activated, thermostatically temperature controlled, with two sections, each with 1/8 ampere hour capacity and an open circuit voltage of 15 volts. The battery was activated during the last few minutes of the payload countdown.

Wiring Harness and Connectors.- The payload wiring harness configuration was jointly developed by NASA-LRC and RITU and was fabricated by NASA-LRC. All connectors used were flight qualified items. The umbilical connectors were mounted in a special bracket at a 45° angle to facilitate a fly-away disconnect.

PAYLOAD AND COMPONENT DEVELOPMENT AND QUALIFICATION TESTS

Development and qualification tests were performed on materials, components, subsystems and prototype payload to verify the design adequacy under expected ground handling and flight load conditions. The qualification tests included environmental stress and time duration in excess of that to be encountered by the payload in flight. The payload and component qualification test levels are specified in Table XIV.

Component Development Tests

Tankage Burst Tests.- The payload tankage was designed in accordance with the ASME Boiler and Pressure Vessel Code. The oxidizer tank specifications are given in Table IV and the fuel tank specifications are given in Table VI.

Burst tests were performed on typical fuel and oxidizer tanks. The tanks were fully radiographed over the weld areas before testing. Results of the burst tests are shown graphically in Figures 9 and 10 for the fuel and oxidizer tanks, respectively, and are summarized here:

Fuel Tank	Design	Test
Yield Pressure, psi	2400	2570
Burst Pressure, psi	2700	2850

Oxidizer Tank	Design	Test
Yield Pressure, psi	3710	4300
Burst Pressure, psi	4710	4550

Figure 9 shows a curve of pressure (lb/in^2) versus strain (micro in. elongation/in. length) and a curve of pressure versus permanent strain for the fuel tank. The pressure versus strain curve was a straight line up to about 2000 lb/in^2 pressure. Young's Modulus, as determined by test, was 12.4×10^6 lb/in^2. The fuel tank burst longitudinally in the center of the shell. No cracks, large permanent strains or yield appeared in the dished heads.

The pressure versus strain curve for the oxidizer tank, shown on Figure 10, was a straight line up to about 3000 lb/in^2 pressure and Young's Modulus was calculated to be 11.6×10^6 lb/in^2. The oxidizer tank also burst longitudinally in the center of the shell and no cracks, permanent strains, or yield was apparent in the dished heads.

Tubing Burst Test.- The tubing leading from the tank to the explosive valve was tested separately. An 8" length of 0.065" wall 6061-T6 aluminum tubing was fitted with swage type fittings and subjected to a burst test procedure. The design burst pressure of the tubing was 6750 lb/in^2. The tubing burst at a pressure of 6800 lb/in^2 in a longitudinal direction in the middle of the tube. This test proved the design of the tubing and the integrity of swage type connections for this application.

Tankage Spin-Expulsion Test.- Tests were run on the oxidizer and fuel tankage to determine the effect of rotation on expulsion efficiency. The tankage was mounted with the payload longitudinal axis vertical and with 1" explosive valves to control the release of fluid.

The oxidizer tank was filled with 10.9 pounds of water equivalent to the volume of 17 pounds of LF_2. The oxidizer tank was spun at 22 rps after having been pressurized to 250 psi. The water was released in 1.86 sec, with 0.24 pounds of water remaining in the tank after expulsion; equivalent to 0.37 pounds of fluorine. A second test using LO_2 at a spin rate of 16.5 rps resulted in 0.31 pounds of LO_2 remaining in the tank; equivalent to 0.40 pounds of LF_2 or 2.35% fluid remaining. The test spin rates were higher than the expected payload spin rate to compensate for the effect of gravity.

A test with the fuel tank filled with 9.57 pounds of water, equivalent to the volume of 13 pounds of hydrazine mix, and spun at 22 rps resulted in 0.086 pounds remaining after expulsion; equivalent to 0.17 pounds of hydrazine mix or 1.31% fluid remaining. High speed films and flowmeter recorder traces showed the fuel and oxidizer expulsion to be smooth and continuous. Table XV summarizes the results of the spin tests.

Tankage Slosh-Coning Test.- Tests were conducted at LRC on specially fabricated, transparent plastic fuel and oxidizer tanks to determine the effect of expected vehicle coning motions on the fluids in the spinning tanks. The tanks were set-up on a rotating table so that the simulated vehicle roll axis could undergo coning motions while the tank was being spun at the desired rate about its own axis. The fuel tank test set-up is shown in Figure 11. Note that the tank included the slosh bar to improve acceleration of the fluid.

For the purpose of these tests, the fuel was simulated by 38% sugar-water solution and the oxidizer was simulated by boiling water. The test procedure consisted of spin accelerating the tanks from rest while imposing a coning motion. The time from start of rotation to formation of a stable parabola was recorded. Films showed that, after the acceleration period, fluids were very stable within the tank and were not affected by the coning motion. The data from the tests is summarized in Table XVI.

Mechanical and Electrical Components.- The oxidizer temperature and pressure transducers and fill valve were exposed to liquid fluorine to assure material compatibility. A temperature transducer, pressure transducer and oxidizer fill valve, as received from the vendor, were carefully examined and attached to the bottom of a brass tank. The system was passivated with gaseous fluorine. It was then immersed in a liquid nitrogen bath and one-half pound of fluorine was condensed in the system. Liquid fluorine remained against the components for 5 hours. They were then pressure checked; no leakage was observed. The components were then sent to NASA-LRC for qualification tests. Following qualification tests, they were rechecked for integrity; no leaks or failure of any kind were noted.

Explosive Valves.- An extensive program was undertaken to develop the ¼" and 1" explosive valves for liquid fluorine service. The 1" explosive valves were also qualified for use with the hydrazine fuel mixture; however, the requirement for LF_2 compatibility presented the greatest development problem. As mentioned earlier, the 1" valve was scaled-up from the ¼" valve which had been previously developed. This scaling operation introduced some new dynamic problems which had to be resolved including the external problem of valve mounting and the internal problem of pyrotechnic blow-by around the ram seal into the flow passages. The initial tests were done with the original configuration 1" valves with a single ram seal. Later tests were done with valves refitted with dual ram seals in the final configuration shown in Figures 6 and 7.

The following description summarizes the component testing of the valves and also lists the valves which were tested as part of payload system tests. A total of ten 1" explosive valves were tested: 6 with liquid fluorine; 3 with "B-Mix" fuel; and 1 with liquid oxygen. A total of six ¼" explosive valves were tested: 4 with liquid fluorine and 2 with gaseous fluorine. Table XVII summarizes the test results in tabular form. Figure 12 shows the explosive valve initiator electrical circuit used for ground tests and figures 13 through 18 show various test set-ups.

<u>1" Valve Tests (original configuration valves):</u>

<u>SN 1010-017 - "B-Mix"</u>

This test was to determine fuel compatibility of the valve. Figure 13 shows the piping schematic for the test. Valve SN 1010-017 was installed in the system using 54 ft-lb torque on the valve nuts, as recommended by the manufacturer. Thirteen pounds of "B-Mix" were loaded in a flight-type fuel tank. Both squibs in the pyrotechnic cartridge were used in parallel and had a total resistance of .57 ohms. After pressurizing the tank to 417 psia, the valve was actuated. The flowmeter trace indicated flow was completed after 2.3 seconds and the system held pressure after the test. No pressure spike was indicated by the strain gage type pressure transducer, which was located in the liquid half of the tank, as shown in Figure 13.

On removing the valve from the system, it was noticed that the valve nuts were relatively loose. The "B-Mix" was drained from the receiver system before removing the valve. Some discoloration of the aluminum was noticed in the flow ports but was attributed to discoloration by "B-Mix". Subsequent sectioning of the valve revealed some pyrotechnic blow-by from the cartridge into the valve flow ports.

<u>SN 1010-016 - "B-Mix"</u>

Valve SN 1010-016 was tested using the same set-up. It was installed in the system using 54 ft-lb of torque. Thirteen pounds of "B-Mix" were loaded in the flow tank. It was decided to fire one squib in the pyrotechnic cartridge rather than two. After pressurizing the tank to 617 psia, Squib C-D with a resistance of 1.14 ohms was fired and the valve was actuated. The flowmeter trace indicated flow was completed after 1.5 seconds. The system did not hold pressure after the test and both fitting nuts were loose and leaking. The short welded line from the tank to the inboard valve port was found to be split at the weld. The entire valve displaced itself 1/8" to 5/32" towards the center of the tank due to inadequate mounting. Again, no pressure spike was indicated, but subsequent valve sectioning revealed traces of blow-by.

SN 1010-014 - LF_2

Figure 14 shows the piping scheme for the liquid fluorine tests. Valve SN 1010-014 was installed in the system using 65 ft-lb torque. The squibs were connected in parallel and had a total resistance of 0.56 ohms.

Liquid nitrogen was added to both baths and 16 pounds of fluorine was condensed in the flow tank. The explosive valve was immersed in liquid nitrogen up to and including the flow ports. A thermocouple placed on the top of the valve indicated a temperature of $-297^{o}F$. A strain gage type pressure transducer was mounted in the top of the "boiler plate" type tank. The system was pressurized to 517 psia and the valve actuated. The flowmeter trace indicated flow for 140 ms after firing of the valves, at which time a violent fluorine reaction occurred.

Later inspection of the system showed that the inlet line to the explosive valve was torn off at the 37° AN fitting. The other end of this line, attached to the flowmeter outlet with a swage type connection, was pulled out. The tube connecting the exit port of the valve with the inlet port of the receiver tank was bulged. All of the damage seemed to be external, as the inside of the valve through the flow ports was clean and showed no evidence of blow-by reaction with fluorine. There was indication that some fluorine reacted with ice on the external parts of the valve.

It was concluded that the impact of valve actuation opened some lines slightly or possibly momentarily and a relatively small amount of fluorine reacted with ice on the fittings and blew them out. Most of the fluorine poured out the broken line at the exit of the flowmeter into the liquid nitrogen bath reacting with surrounding ice and blew the bath apart. The bulge in the line leading from the valve to the receiver tank was thought to be due to pressure build-up during the explosion.

The solution to this problem was based strictly on the mechanical failure. A brace was designed and constructed that would hold the valve rigidly in the vertical plane. This brace was built into the split payload shell which, in turn, was secured to the mock-up oxidizer tank. The brace previously used was designed to hold the valve against vibration due to takeoff and flight; these new braces were used in addition to the old braces in the flight configuration.

SN 1010-015 - LO_2

Liquid oxygen (LO_2) was used instead of liquid fluorine in the first explosive valve test using the new brace. If valve actuation were to result in damage to the system, the liquid oxygen would probably cause no more damage than a completely inert material.

Valve SN 1010-015 was installed in the system as shown in Fig. 15, using the flight-type payload tank and 100 ft-lb torque on both fittings. Holes were previously drilled in the tube fitting nuts. After torquing the fittings, lead balls were placed in these holes and a set screw turned down on the balls so that the lead jammed the threads, minimizing the loosening effect of the valve actuation.

Thirteen pounds of oxygen were condensed in the mock-up tank, being equivalent to 17 pounds of fluorine in volume. The system was pressurized to 595 psia and the valve actuated using both squib bridge wires in parallel. Flow to the receiver tank was completed in 2 seconds. No pressure spike was recorded although some blow-by was indicated above the flow ports on subsequent sectioning of the valve.

The system was drained by means of the dump system. The receiver tank was pressurized to 500 psia and the 13 pounds of liquid oxygen were dumped through a conventional solenoid valve and ¼" OD copper line in 7 minutes. The line was orificed close to the tank with a #69 drill hole in a small plate.

On removal from the flow system, it was noted that the 1" explosive valve had moved downward 1/32" toward the fittings. It was decided to use shims between the valve and lower brace when necessary in subsequent testing.

When removing the explosive valve from the system, it was noticed that the back-off torque on the inlet nuts was 50 ft-lb and on the outlet nut, 60 ft-lb. It was decided to use valve SN 1010-015 in further torque tests. The fitting nut was torqued to 150 ft-lb and the tank pressurized to 500 psia with helium; no leak was noticed. The valve was then lowered into a liquid nitrogen bath and allowed to come to equilibrium. The valve was taken out of the bath and the back-off torque was noted to be 135 ft-lb, while the valve was still very cold. At 150 ft-lb torque, the seal gasket used on 37° AN fittings showed an acceptable deformation indicating that it functions as a seal, and 150 ft-lb torque was chosen as an acceptable minimum torque level. A check with the manufacturer and NASA-LRC verified that torque levels as high as 200 ft-lb could be used, if necessary, without damage to the fitting.

Air Operated 3/4" Globe Valve - LF_2

Prior to further testing of the explosive valves, the transfer system was tested under flow conditions with fluorine but using a valve other than the explosive valve. A pneumatically actuated globe valve was installed in the system shown in Figure 16 using 160 ft-lb torque on the inlet and outlet port fittings. The entire system was pressure checked with helium to 560 psig and then repassivated with 200 psig of fluorine for 25 minutes. The system was again pressure checked with helium to 550 psig.

LN_2 was supplied to the tank jacket and 6.15 pounds of fluorine were condensed in the mock-up tank. The system was pressurized to 515 psig and the valve actuated. Flow was completed in 1 second and the transfer of fluorine was accomplished without incident. This test indicated that the basic system was compatible with LF_2.

Further examination of the previously tested explosive valves showed positive indication of pyrotechnic blow-by around the ram seal. Valve SN 1010-016 that had been tested with "B-Hx", was sectioned in a horizontal plane immediately above the valve flow ports. Burn marks and some material were evident; later analysis of the material indicated the presence of titanium, a constituent of the propellant charge. A small amount of the material was exposed to gaseous fluorine and an immediate and violent reaction occurred. Since fluorine compatibility was a requirement for the explosive valves, it was concluded that the valves would have to be modified to reduce the possibility of pyrotechnic blow-by. Accordingly, the 1-inch valves were refitted by the addition of a second cup seal on the ram to provide seal redundancy. The ½-inch valves had not yet been tested, but they were also modified by the addition of a flash cup seal to help contain particles from the pyrotechnic reaction.

1-inch Valve Tests (refitted valves):

SN 1010-007 - LF_2

A set-up, as shown in Fig. 17, was prepared with a 3000 cc stainless steel cylinder used as the LF_2 supply tank. Pressure transducers were mounted immediately upstream and downstream of the explosive valve. The valve was held in the new brace and the exit line was also clamped. The valve nuts were torqued to 165 ft-lb and locked with lead balls.

The supply tank was filled with 5.54 pounds of LF_2 and pressurized to 520 psia. Squib A-B with a resistance of 1.55 ohms was fired. The valve actuated satisfactorily. Pressure traces indicated an upstream pressure spike of 968 psia and downstream of 837 psia but the system remained pressure tight. Approximately 85 ft-lb were required to loosen the valve nuts at disassembly. Subsequent sectioning of the valve did not reveal any blow-by.

SN 1010-008 - LF_2

Valve SN 1010-008 was placed in the 17-pound system shown in Fig. 15. A strain gage pressure transducer was mounted about 6 inches downstream of the explosive valve outlet port. The valve nuts were torqued to 165 ft-lb and locked with lead balls.

Approximately 17.6 pounds of LF_2 were condensed in the flight-type tank. The tank was pressurized to 510 psia and squib A-B, with resistance of 1.13 ohms, was fired. The valve performed satisfactorily and the system held pressure after 2.5 seconds of flow. The downstream pressure transducer failed, and this was attributed to mechanical shock. The back-off torque on the valve nuts at disassembly was 85 ft-lb.

SN 1010-019 - LF_2

This valve was placed in the 17-pound test set-up, as shown in Fig. 15. A strain gage transducer was mounted 6 inches downstream of the valve, as in the previous test.

The nuts on the valve ports were torqued to 165 ft-lb with lead ball locks. Approximately 18.9 pounds of LF_2 were condensed in the flight-type tank and the system was pressurized to 535 psia. The valve temperature was measured at the time of firing as -110^oF. The valve performed satisfactorily although some blow-by was shown on subsequent examination. The downstream pressure transducer failed again due to mechanical shock and the flowmeter pick-up also failed. The system remained pressure tight and the back-off torque on the valve nuts was 70 ft-lb at disassembly.

SN 1010-009

This valve was placed in the 17-pound test set-up as shown in Fig. 15. The valve nuts were torqued to 165 ft-lb and secured with lead ball locks. The valve was wrapped with a heating tape with a power input of 400 watts. The purpose of the heater was to determine the effect of valve temperature on performance. At the time of valve firing, the top of the valve indicated -20^oF and the side -78^oF.

Approximately 16.5 pounds of LF_2 were condensed in the flight-type tank. A piezoelectric type pressure gage was mounted 6 inches downstream from the valve exit port. The tank was pressurized to 505 psia. The A-B squib was fired and the valve performed satisfactorily. It was concluded that valve temperature did not significantly effect valve operation. A pressure spike of 745 psia was noted about 20 milliseconds after flow started but the system was pressure tight after the run.

SN 1010-006 and SN 1010-013

The above valves were fired in a burner test and their performance is described under the Flight-type Burner Test.

SN 1033-001 and SN 1033-003

The above valves were fired in a prototype burner test and their performance is described under the Prototype Firing Test.

SN 1045-004, SN 1045-006, and SN 1045-007

The above valves were fired during a burner vacuum test and their performance is described under the Burner Vacuum Test.

¼-in Valve Tests:

SN 1010-042 and SN 1010-044

These valves were tested in the LF_2 dump system shown in Fig. 18. The flight-type oxidizer tank was mounted vertically. A strain gage type pressure transducer was mounted upstream of the explosive valves and was exposed to liquid fluorine. A piezoelectric pressure transducer was mounted immediately downstream of the valves. The dump line was attached to a flight-type pull-away fitting equipped with teflon ferrules and tightened to such a torque as to require a force of 300 pounds acting on the fitting to cause separation. The dump line led to the disposal unit, where the fluorine was reacted with charcoal to produce a relatively inert chemical.

The ½-inch AN nuts on the valves were torqued to the specified 146 in-lb. Earlier torque tests showed that aluminum fittings failed in the fitting region between the valve body weld and thread area at 390 in-lb.

The oxidizer tank was loaded with 15.5 pounds of LF_2 and pressured to 490 psia. One squib from each valve was fired by an ac firing system. Firing currents were set off the nominal 5A with 6.1A firing current applied to valve SN 1010-042 and 3.3A applied to valve SN 1010-044. Both valves performed satisfactorily. The average flow during the blowdown operation was estimated to be 0.13 lb/sec. Two minutes were required to empty the tank as determined by the rapid pressure decay on the tank after that time. The disposal unit performed satisfactorily and remained intact through the dump cycle.

SN 1010-040 and 1010-045

These valves were also tested in the dump system shown in Fig. 18 with the flight-type oxidizer tank mounted vertically as in the previous test. This test differed from the previous dump valve test in that the tank was pressurized to 565 psia with 17.0 pounds of LF_2 condensed in the oxidizer tank. The valve AN nuts were again torqued to 146 in-lb.

One squib from each valve was fired using the following firing currents: SN 1010-040 at 8.9A and SN 1010-045 at 4.5A. The valves performed satisfactorily and no pressure spikes were observed. It took 154 sec to discharge the tank, as determined by the pressure trace drop, with average flow of 0.11 lb/sec. The disposal unit functioned satisfactorily.

SN 1010-038 and SN 1010-051

These valves were tested in the dump system shown in Fig. 18, except that the oxidizer tank was in a horizontal position so that gaseous fluorine was released to the dump system. The flight-type oxidizer tank was used for the test and was loaded with 7.0 pounds of LF_2.

The valves were fired at the maximum current of 8.0A using the firing system through the flight programmer. The valves performed satisfactorily. The total dump time was approximately 20 minutes. The longer dump time resulted from the time required for the LF_2 to vaporize and simulated a release from the flight payload in the horizontal position on the launcher.

SN 1010-002 and SN 1010-003

To insure that the dump system would operate successfully if only one of the fluorine dump valves functioned, a test was made in which only one valve was fired. The test set-up consisted of a mock-up oxidizer tank mounted horizontally with the 1-inch line blocked and the dump system, with the valves in position, was oriented to effect a gas phase dump.

The amount of fluorine condensed in the tank was 6.09 pounds and the tank was pressurized to 500 psig. Valve SN 1010-003 was fired. The indicated valve temperature at the time of firing was -98°F: immediately after actuation it was -130°F. The gaseous fluorine was discharged through one explosive valve the dump system with two charcoal burner barrels. No open flame was observed at the barrels during the 45-minute release time and the disposal system performed satisfactorily. After the vapor dump was complete, valve SN 1010-002 was fired; no abnormal operation was observed.

Burner.-

The burner and feed system underwent extensive development during this program. Two types of test burners were designed, fabricated and tested. One type was a single-sided burner; physically one-half the prototype. The other type was a two-sided type, as shown in Fig. 5. Early designs used a straight chamber. The prototype, as shown in Figure 5, incorporated a tapered chamber together with a flow orifice in the fuel and oxidizer lines. The initial burners indicated an instability at a frequency of 7 to 10 cps. This was eliminated by tapering the chamber and installing the flow orifice. The results of tests on the flight-type burner are summarized below.

Flight-type Burner Test:

A test set-up was made with the flight-type tankage mounted horizontally, as shown in Fig. 19. Turbine type flowmeters were installed to measure flow. A piezoelectric pressure gage was mounted on the oxidizer manifold; fuel and oxidizer tanks were instrumented with flight-type pressure and temperature transducers. Explosive valve SN 1010-006 was mounted on the fuel tank; valve SN 1010-013 was mounted on the oxidizer tank. Valve nuts were torqued to 165 ft-lb and lead ball locks were installed.

Heaters were wrapped around the oxidizer valve. At the time of firing, heaters were turned off and the temperature at the valve top was -36°F while at the side it was -82°F. The firing circuit for valve SN 1010-006 was C-D while the A-B circuit was fired for valve SN 1010-013. Both valves actuated and performed satisfactorily.

The recorded data is presented in Figure 20. Plots of oxidizer tank pressure, oxidizer manifold pressure, oxidizer flow and fuel tank pressure are plotted versus time. The fuel meter failed to record due to a faulty pick-up but the fuel pressure trace indicated smooth flow.

The oxidizer and fuel tank pressure traces show that the propellants ran out at essentially the same time - 2600 milliseconds. The oxidizer tank pressure started at 515 psia and decreased to 195 psia. The fuel tank pressure started at 465 psia and decreased to 240 psia. The fuel pressure transducer showed an initial drop to zero after valve actuation; this was attributed to valve shock being transmitted to the shock sensitive pressure transducer. The oxidizer manifold pressure did not show any unexpected pressure spike or undue pressure rise. The maximum oxidizer manifold pressure was 512 psia and then decreased smoothly for 600 milliseconds, at which time the leads from the transducer were burned through.

Following the test, the burner walls showed some erosion. This was attributed to fluorine reacting with the hot burner walls.

Burner Vacuum Test:

This test was performed to determine burner operation under vacuum conditions. A one-sided or one-half burner was placed at the end of a 1500 cu. ft. vacuum chamber with explosive valves and tankage located external to the chamber. On the first attempt to run this test, explosive valve SN 1045-006 was installed on the oxidizer tank and valve SN 1045-004 on the fuel tank. Upon application of the firing current to these 1-inch valves, only the oxidizer tank emptied. Examination of the burner indicated that no combustion occurred so it was concluded that the fuel valve failed to actuate due to insufficient firing current. Resistance checks confirmed that the bridge wires were intact in the fuel valve.

The firing circuit power supply was upgraded and the valve SN 1045-007 was installed on the oxidizer tank and valve SN 1045-004 was reinstalled on the fuel tank. The oxidizer tank was loaded with 3.4 pounds of LF_2 and pressurized to 542 psia and the fuel tank was loaded with 2.6 pounds of "B-Mix" and pressurized to 552 psia.

The valves were fired and a successful burner firing occurred at a chamber vacuum pressure of 400 torr. Valve performance was satisfactory in all respects. Burning took place for 420 ms as evidenced by 42 frames of a 100 frame/sec film. The flame appeared red initially and gradually turned toward bright orange. Scanning spectra showed a relative Ba^o intensity of 2840 mV and a Ba^+ relative intensity greater than 4600 mV. Color film data, pressure recordings, and light intensity measurements of the firing showed smooth ignition followed by rapid plume expansion. The following data shows the relative light intensity of the Ba^o and Ba^+ lines under atmospheric and vacuum conditions.

Test Condition	Relative Light Intensity, mV "B-Mix" Ba^o	Relative Light Intensity, mV "B-Mix" Ba^+
Atmospheric	24,000	9,000
Vacuum	3,840	>4,600
Ratio $\frac{\text{Atmospheric}}{\text{Vacuum}}$	6.2/1	2/1

The successful completion of this test indicated that ignition of the burner in the upper atmosphere should be satisfactory and that combustion could proceed at high flow rates (≈15 lb/sec) as it did in atmospheric tests.

Payload Development Tests

Load-deflection test.- The prototype payload was assembled in the flight configuration including the despin module. All screws and fittings were torqued to values as shown in the specification section. Thirteen pounds of water were placed in the fuel tank and seventeen pounds of water in the oxidizer tank to simulate the payload weight at launch. The payload was mounted with the flight axis horizontal and with the burner axis either vertical or horizontal. Dial gages indicating in thousandths of an inch were placed as shown in the sketch accompanying Table XVIII.

Two types of loading were considered: a 200-pound load applied to the nose ogive to produce a 21,600 in-lb external moment on the despin module to Tomahawk joint; and a distributed load of 133 pounds to simulate a total load of 1.75 g, including the payload weight.

The results of the bend tests are summarized in Table XVIII. The maximum deflection with the 200-pound load applied at the nose was 0.308 in. with the burner axis in the vertical position. In this orientation the final "set", or deflection from the initial position due to repeated application of the load, was 0.002 inches.

The maximum deflection with the distributed load was 0.049 inches. The payload did not show any set with this loading and returned to its original position. These tests showed that the payload would withstand a 21,600 in-lb moment at the despin module to Tomahawk joint without failure or appreciable yield. The tests also showed that the payload would withstand a 1.75 g distributed force and not yield.

Heat transfer tests.- Five heat transfer tests were performed with the payload assembled as in a flight condition with all components in place. The purpose of these tests was to determine if there were any payload or component thermal problems due to heat transfer into the cryogenic oxidizer tank. The oxidizer tank jacket was filled with LN_2 and the oxidizer tank was filled with 12.5 pounds of LO_2 to simulate the volume of 17 pounds of LF_2. The fuel tank was filled with 10.7 pounds of water-alcohol solution to simulate 13 pounds of fuel mix volume.

Copper-constantan thermocouples were attached at the following payload locations:

1. On the bonnet of the oxidizer fill valve
2. On the body of the fuel explosive valve
3. In the burner chamber attached to the rear wall
4. On the battery case side closest to the oxidizer tank
5. On the programmer case side closest to the oxidizer tank
6. On the explosive actuator part of the oxidizer explosive valve
7. On the explosive actuator part of the oxidizer dump valve
8. On the fuel tank skin at the middle
9. On the injector skin at the umbilical connector fitting
10. Attached to an umbilical pin

Temperatures were recorded after the specified "soak times" had permitted the temperatures to stabilize.

Strain gages were mounted on the middle of the 1" line leading from the oxidizer explosive valve to the burner. Strain gages were also mounted on the burner skin at a point opposite to those on the oxidizer line. At each location gages were placed in longitudinal and circumferential direction.

Temperature and pressure transducers were placed in the fuel tank. Oxidizer temperature probe and pressure transducers were placed in the oxidizer tank.

Heat Transfer Test #1:

Test Conditions

Assembled payload mounted in horizontal position on pad.

Ambient conditions:	Soak Time	5 hours
	Air Temperature	50°F
	Wind Velocity	15 to 25
	Relative Humidity	78%

Oxidizer Section	Temperature, °F
Oxidizer fill valve	-236
Oxidizer explosive valve, 1"	-242
Oxidizer explosive valve, ¼"	-242
Oxidizer temperature probe, inside tank	-314
Oxidizer pressure	160 psig
Burner Section	
Battery	-24
Programmer	-2
Burner skin at umbilicals	8
Umbilical pin	8
Stress, burner skin	Nil
Stress tube, circumferential, constant	9600 psi
Stress tube, longitudinal (max. at 30 mm)	6170 psi
Fuel Section	
Fuel explosive valve, 1"	22
Fuel tank skin	38
Fuel temperature probe, inside tank, initial	53
Fuel temperature, final	38
Fuel pressure	157 psig

Results of Heat Transfer Test #1

Oxygen loading time was 20 minutes. Components reached a steady state temperature after 1-3/4 hours. The final temperature of the oxidizer 1" explosive valve and ¼" dump valve was -242°F. The battery reached -24°F. The fuel explosive valve final temperature was 22°F; this is approximately the fuel freezing point. The initial temperature of the fluid in the fuel tank was 53°F and decreased at the rate of 6°F/hr for 1-3/4 hours. After this time, the rate slowed to 1.35°F/hr until a final temperature of 38°F was reached. The warm-up test showed that with an empty LN_2 jacket, the LO_2 temperature increased from -314°F to -293°F in 30 minutes with a corresponding pressure increase from 160 to 200 psig. The oxygen was released after the temperature reached -248°F and the pressure reached 320 psig.

Heat Transfer Test #2:

Test Conditions

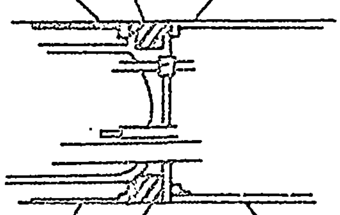
Assembled payload mounted in horizontal position on pad. A fiberglass battery mounting bracket was substituted for the aluminum battery mounting bracket. This was done to lower the heat flow between the battery and surroundings.

Ambient conditions:	Soak Time	4-1/2 hours
	Air Temperature	43°F start, 41°F finish
	Wind Velocity	0 to 15
	Relative Humidity	57%

Oxidizer Section	Temperature, °F
Oxidizer fill valve	-217
Oxidizer explosive valve, 1"	-225
Oxidizer explosive valve, 1/4"	-225
Oxidizer temperature, inside tank	-313.5
Oxidizer pressure	150 psig
Burner Section	
Battery	-50
Programmer	-3
Burner	-7
Burner skin at umbilicals	-7
Umbilical pin	-5
Fuel Section	
Fuel explosive valve, 1"	18
Fuel tank skin	30
Fuel temperature probe, inside tank	28.3
Fuel pressure	150 psig

Results of Heat Transfer Test #2

The battery cooled to -50°F with use of a fiberglass mounting bracket. The previous test showed the battery cooled to -24°F. The insulator apparently prevented the conduction of heat from the fuel and burner sections into the battery. Components did not reach steady state. Ambient temperature continued to drop until end of test. Temperatures between the burner section and oxidizer tankage at the insulator showed a ΔT of about 300°F after 4-½ hr shown in the following sketch.



Heat Transfer Test #3:

Test Conditions

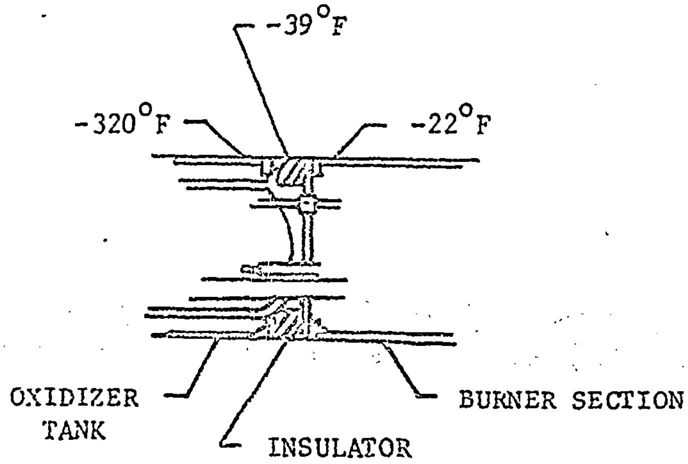
Assembled payload mounted in horizontal position on pad. Aluminum battery mounting bracket installed in place of fiberglass mounting bracket. Glass wool insulation placed around battery and between battery and oxidizer tank.

Ambient conditions:	Soak Time	2-½ hours
	Air Temperature	40°F start, 50°F finish
	Wind Velocity	0 mph
	Relative Humidity	57%

	Temperature, °F
Oxidizer Section	
Oxidizer fill valve	-208
Oxidizer explosive valve, 1"	-264
Oxidizer explosive valve, ¼"	-264
Oxidizer temperature probe, inside tank	-316
Oxidizer pressure	150 psig
Burner Section	
Battery	2
Programmer	25
Burner	15
Burner skin at umbilical	6
Umbilical pin	13
Fuel Section	
Fuel explosive valve, 1"	38
Fuel tank skin	43
Fuel temperature probe	43
Fuel pressure	150 psig

Results of Heat Transfer Test #3

The glass wool provided sufficient insulation to keep the battery at a temperature of 2°F after 2-½ hours. Temperatures between the burner section and the oxidizer section at the insulator joint showed a ΔT of about 300°F after 2-½ hr as shown on the following sketch.



Heat Transfer Test #4:

Test Conditions

Assembled payload mounted in vertical position on pad. Aluminum battery mounting bracket with glass wool insulation.

Ambient conditions:	Soak Time	2-½ hours
	Air Temperature	43°F
	Wind Velocity	10 to 15
	Relative Humidity	55%

Oxidizer Section	Temperature °F
Oxidizer fill valve	-201
Oxidizer explosive valve, 1"	-257
Oxidizer explosive valve, ¼"	-266
Oxidizer temperature probe, inside tank	-316
Oxidizer pressure	150 psig
Burner Section	
Battery	-23
Programmer	37
Burner skin at umbilical	16
Umbilical pin	21

Fuel Section	Temperature °F
Fuel explosive valve, 1"	35
Fuel tank skin	40
Fuel temperature probe	39
Fuel pressure	150 psig

Results of Heat Transfer Test #4

The test showed that in the vertical position the "cold flow" was greater than in the horizontal position. The glass wool placed between battery and oxidizer tank was less effective. The battery (after 2-½ hrs) reached a temperature of -23°F versus 2°F as in the horizontal position.

Heat Transfer Test #5:

Test Conditions

Payload axis horizontal. Payload located inside laboratory. Glass wool installed between battery and end of oxidizer tank.

Ambient conditions:	Soak Time	2-½ hours
	Air Temperature	89.5°F
	Wind Velocity	0 mph
	Relative Humidity	35%

Oxidizer Section	Temperature °F
Oxidizer fill valve	-232
Oxidizer explosive valve, 1"	-246
Oxidizer explosive valve, ¼"	-263
Oxidizer pressure	150 psig
Burner Section	
Battery	20
Programmer	41
Burner skin at umbilical	25
Umbilical pin	31
Fuel Section	
Fuel explosive valve, 1"	57
Fuel tank skin	63
Fuel temperature probe	73
Fuel pressure	150 psig

Results of Heat Transfer Test #5

The battery temperature reached 20°F. This shows that on a warm day (80°F or warmer) the battery would not be expected to get colder than 20°F; however, as a result of these tests, it was decided to incorporate a heater on the battery to insure that the battery would be at the proper operating temperature. It was also concluded that the fuel temperature could be maintained in the correct temperature range with no special provisions for heating the fuel tank.

Prototype firing test.- Subsequent to environmental qualification testing at LRC, which is described later, the prototype payload was test fired at the contractor's facility. The prototype payload, including flight-type tankage, burner, skin, and all flight-type hardware was assembled and mounted on the test pad in a horizontal position approximately 6 feet above the pad. The burner axis was vertical.

Explosive valve SN 1033-001 was mounted on the oxidizer tank and valve SN 1033-003 was mounted on the fuel tank. Both valves were torqued to 165 ft-lb and lead ball locks were installed. Since the prototype payload conformed to flight configuration, there were no flowmeters in the feed system. Dump valves SN 1010-051 and SN 1010-038 were mounted in the payload but were not fired. Pre-test operations were performed as nearly as possible in accordance with procedures intended for use at the launch site. The fuel tank was loaded with 13 pounds of "B-Mix" fuel and pressurized to 551 psia. The oxidizer tank was loaded with 17 pounds of fluorine and pressurized to 620 psia. The payload was then held for approximately 45 minutes to simulate a waiting period on the launcher and to permit thermal cycling of the payload battery heater.

The burner ignited and burned smoothly during the approximately 2-second period of burn followed by a rapid burnout. External examination of the payload following the test showed the hardware to be in good condition with no apparent burner erosion. Umbilical cables, which would normally be withdrawn prior to flight, were slightly burned during burner firing.

The instrumentation used was as follows:

Indicating

Fuel temperature transducer
Oxidizer temperature transducer

Recording

Fuel pressure transducer
Oxidizer pressure transducer
Thermocouples: Side of oxidizer explosive valve
Side of battery
Outside wall of burner
Side of fuel explosive valve
Battery voltage

Optical and Camera

Scanning Spectrograph: 5535Å (Ba^o)
4554Å (Ba^+)
Total Light
Film spectrograph #1

TV camera (non-recording)
Camera #1 - Fastex
Camera #2 - Kodak
Camera #3 - Bell & Howell 200 fps
Camera #4 - Bolex

The oxidizer pressure transducer showed a typical polytropic type pressure versus time expansion. At 1750 milliseconds after ignition, the pressure was 340 psia and an erratic trace developed. The oxidizer valve temperature showed a gradual rise from -270°F at ignition to -158°F at 1600 ms. At this time the temperature rose rapidly to ambient and above.

The fuel pressure transducer did not operate. At ignition the pressure trace went to zero and did not return. The fuel valve temperature gradually increased from near ambient to 85°F at 2000 ms after ignition.

The burner temperature at ignition was 43°F (ambient). The temperature gradually rose with time and at 2000 ms (apparent end of run) was 180°F. At this time the temperature gradient became steeper and at 3000 milliseconds after ignition the temperature was 770°F.

The total light output measured was 41×10^3 candleseconds per pound for the prototype payload. This compares with 46×10^3 candleseconds per pound for the flight-type burner test.

The scanning spectrograph light measurements gave Ba^o (5535Å) and Ba^+ (4554Å) values of 24,000 and 9000 as minimum values. These are within the expected range of relative light output numbers.

Temperatures remained relatively constant during the pre-ignition period and the final tank conditions before burner firing indicated a fuel tank pressure of 561 psia at 58.4°F and an oxidizer tank pressure of 610 psia at -314.7°F.

After activation of the battery squib, the voltage was 15.5 volts. The battery was then load checked at 1 amp for 30 seconds, at which time the battery voltage was 12.5 volts. Following the load check, the battery remained at 15 volts. At ignition the battery voltage dropped to 13 volts then recovered to 14.5 volts.

Based on the test results and on film coverage from the firing, it was concluded that the prototype burner performed satisfactorily during the test. Following post-test examination of the hardware, it was also concluded that the explosive valves had performed satisfactorily on the test. It was concluded from the test results of the prototype firing that the payload design was acceptable for flight.

Component Qualification Tests

Component environmental qualification tests as specified in Table XIV were performed at LRC on the explosive valves, temperature sensors, pressure transducers, fill valves, and programmer. Following environmental exposure, components were either examined or functionally operated to assure that they had suffered no performance degradation during qualification.

In addition, samples from the flight lot of explosive valves were fired in design verification tests and flight units were X-ray inspected. From the flight lot of fourteen 1-inch explosive valves: 3 were fired by the valve subcontractor in design verification tests; 2 were environmentally tested then exposed to LF_2 and successfully fired in component tests at the Lewis Research Center; and 3 were environmentally tested then used in performance of the burner vacuum test. From the flight lot of seventeen ¼-inch explosive valves: 3 were fired by the valve sub-contractor in design verification tests; 2 were exposed to LF_2 and successfully fired in a test of the fluorine dump system; and 2 were exposed to LO_2 and fired during a practice countdown at the launch site.

Payload Qualification Tests

Payload environmental qualification tests were performed at LRC on the completely assembled prototype payload, including the despin module. The qualification test requirements are shown in Table XIV.

To simulate launch conditions, 13 pounds of water were placed in the fuel tank to simulate the weight of the fuel and 17 pounds of LN_2 were used to simulate the weight of the oxidizer. The jacket was filled with LN_2 to maintain cryogenic temperatures and to represent the actual payload temperature condition at launch. The payload setup for vibration testing is shown in Figure 21. Payload structural response was measured at several locations during the vibration test.

The payload satisfactorily met both the vibration and shock qualification requirements prior to successful performance of the prototype firing test previously described.

FLIGHT PAYLOAD PRE-FLIGHT PREPARATION

Design Review

A Critical Design Review of the liquid chemical barium release project was held at LRC on April 28, 1970. The payload design was accepted by the CDR panel and [illegible] was directed to fabricate the flight payload.

Flight Acceptance Test

The Flight Acceptance Test (FAT) of the payload was conducted at LRC on September 1-2, 1970. The payload was environmentally tested to the levels specified in Table XIX and successfully met all requirements.

Electrical functions were monitored during both vibration and shock tests and no anomalies were observed. Post-test visual inspection of the flight payload revealed no structural problems. The structural response of the payload was measured at several key locations during vibration runs and the levels were similar to those which had previously been measured on the prototype payload.

The FAT vibration requirement included both sinusoidal and random excitation in the thrust axis only. The sinusoidal FAT level was 5.0 g from 20-2000 Hz, .02 in. maximum double amplitude, at a sweeprate of 6 oct/min. In addition, a preliminary 1.0 g survey run was made to verify instrumentation. The random level was 5.0 g rms for a 20-second duration. The FAT shock requirement was for two shock pulses along the thrust axis with 75 g peak amplitude and a 6 ms duration.

Payload resonant frequencies occurred at 287 Hz and approximately 860 Hz. Amplification factors were observed over a range from 4.4 to 6.5 at the peak value. A maximum amplification factor of 8.75 was noted at the top of the ozidizer tank and is believed to represent an "oil-can" effect at that particular location which was not considered serious.

The General Environmental Test Specs indicate that the Nike-Tomahawk may exhibit a special vibration characteristic over the frequency range from 80-110 Hz. The payload had no structural or component resonances in this frequency range.

Spin Balance

The flight payload was spin balanced on September 30 and October 1, 1970, at Wallops Island. Following complete payload assembly, weights were added to the fill end of the oxidizer tank and the fill end of the fuel tank. During spin balancing, the tankage was empty. Balancing completed the payload preflight preparations.

Ground Support Equipment

The liquid chemical barium release payload required a unique set of ground support equipment for pre-launch payload operations. This equipment was provided in part by RITU and in part by NASA. The following discussion provides a description of the major ground support components.

Blockhouse Monitoring and Control Equipment

Checkout, Control, and Monitoring Console.- NASA-LRC was responsible for setting up the pre-flight Checkout, Control, and Monitoring Console used at Wallops Island to check squib continuity, to activate the battery, to arm the payload, and to dump the fluorine in case of an emergency. This console shown in Figure 22, was wired to the two umbilical cables and completely checked out by NASA-LRC personnel several weeks before launch.

Pressure Readout.- Pressure readout of the flight payload at Wallops Island was accomplished by the use of a visual readout system shown in Figure 23. The visual systems were mounted in a standard 19" panel and all the necessary interconnecting cables and signal conditioning equipment was provided by RITU. The readout systems had previously been used for the full-scale payload ground firing at the RITU facility.

Temperature Readout.- The temperature in the oxidizer and fuel tanks was monitored by two visual temperature indicators. The oxidizer indicator was calibrated from -320°F to -180°F and the fuel from 0 to 100°F. (See Figure 24.) This temperature readout panel was also used for the full-scale payload ground firing test at RITU.

Both indicators were mounted on a standard 19" panel together with an intercom amplifier which was used to provide continuous communication between the personnel performing pre-launch operations on the pad and personnel monitoring pressures and temperatures in the blockhouse.

In an emergency, as soon as any abnormal situation was recognized, the pad personnel could be notified immediately through the special headset intercom and the standard Wallops public address system.

Flight Umbilical Cables

Two umbilical cables were provided for the launch operations by NASA-LRC. They were wired with the appropriate fly-away connectors for mating to the payload. All the continuity checks of the two umbilical cables and of the blockhouse equipment interconnecting cables were administered by NASA-LRC.

Fluorine Manifold and Shielding

The fluorine manifold consisted of 6 interconnected fluorine storage cylinders in a shielded enclosure (Figure 25). The cylinders were connected to metering valves and redundant pressure gages.

The shielding was ¼" steel plate surrounding the 6 storage bottles on top, sides and front. The open back was never approached while the storage cylinders were open.

The storage cylinders were opened and closed by extension handles through the top of the shield. Metering valves were mounted inside the shielding with handles extending through. Cylinders of fluorine were shipped directly from the manufacturer to the launch site several weeks ahead of launch date. Figure 26 shows the piping diagram for the total fluorine system.

Payload Shielding

The payload shielding consisted of 3/8" steel plate, 9' long and high enough to shield the payload in the horizontal position on the launcher. A 6" x 18" safety glass window was built into the shield in order to view the fill valve extension handle and fill line guillotine cutter, which was actuated after completion of the fluorine loading operation to separate the fill line from the payload.

The fill valve extension handle was connected to the valve in a diagonal plane and came through the shielding in the same plane. The explosively actuated fill line guillotine cutter was mounted on the fill line almost flush to the payload.

Disposal Unit

During the filling operation, no fluorine was released to the atmosphere. All fluorine vent lines were connected to a charcoal reactor disposal system as described in reference 3. One clean 55-gallon drum, lined with refractory cement and 90% filled with charcoal briquettes, was used for the fluorine vent system and two similar drums were used for the payload dump system.

The payload oxidizer dump system consisted of a ¼" copper manifold within the payload attached to the two ¼" explosive dump valves, thence to a swage tee fitting and ending with a 5" piece of ¼" stainless steel tubing extending at a 45° angle from the skin of the payload burner section.

To this tubing extension, a 3/8" swage type heat exchanger tee, together with a nitrogen purge line, was attached by use of teflon ferrules. The piece of 3/8" copper tubing attached to the other end of the tee went to the charcoal disposal system.

Interconnecting Tubing

The tubing connecting the fluorine manifold, payload, and disposal system is ½" soft annealed copper, 0.035" wall, and prepassivated for fluorine service. All tubing crossing the launch area was hung from stanchions 7' off the ground. The launch area layout of tubing, shielding and disposal system is shown in Figure 27.

Liquid Nitrogen Cooling System

Liquid nitrogen was supplied to the integral jacket surrounding the oxidizer tank from the start of countdown to launch. A liquid nitrogen storage container of 500 gallon capacity was used for the launch operation.

Umbilical Retractor

Due to the critical nature of the payload, it was necessary to maintain continuous hard-line contact until the moment of launch. A continuous flow of LN_2 was provided to cool the oxidizer jacket as described above and it was also necessary to maintain the continuity of the oxidizer dump system to provide for fluorine disposal in the event of a launch abort. Dry GN_2 purge flow was also required to prevent possible frost build-up in critical payload areas. Umbilical attachment was also required up to actual launch of the payload.

However, at the moment of launch, it was necessary to positively retract all of these hardlines and cables to assure that there would be no interference with the vehicle fin hardware.

An umbilical retraction system was designed and developed by NASA-Wallops Station to positively retract and hold all of the necessary payload attachments. This system provided a positive preloaded force to withdraw all lines by means of a cable system. However, the mechanism could be triggered only by first motion of the vehicle on the launcher. This system was thoroughly tested by means of a simulated vehicle on the launcher and performed satisfactorily during the launch.

Launcher and Launch Area

The Nike-Tomahawk vehicle with the liquid chemical barium release payload was launched from the H.A.D. Launcher in Launch Area No. 3 at Wallops Island. During pre-launch preparations, this launcher was completely checked-out and calibrated by Wallops Station personnel to assure satisfactory performance during launch. Necessary modifications were made to outfit the launcher with the Umbilical Retractor. Equipment in the Launch Area was positioned in accordance with the layout of Figure 28. Special lighting was provided in the launch area to permit work operations and closed-circuit TV coverage of the payload during pre-launch preparations.

Practice Countdown

A practice countdown at Wallops Station was conducted the week of August 24, 1970. The purpose of this practice was to assure systems performance and procedures for flight.

The week of August 17 was devoted to practice preparation. Lines were laid out and checked for length. A charcoal disposal unit site was selected. RITU communication lines were set-up. The RITU panel in the blockhouse was readied. The fluorine mainfold was set-up with oxygen cylinders filled to 400 psia in place of fluorine cylinders. A nitrogen manifold was set-up. A 500-gallon liquid nitrogen dewar was placed behind the blast shield. Placement of equipment at the launch pad was made in accordance with the procedure outlined in the Critical Design Review.

A mock-up center section of the payload was assembled on the launcher for umbilical and tubing pull-away tests. The umbilicals, fly-away dump line, burner and nose cone purge lines, and liquid nitrogen lines were installed. Release tests were performed to determine effects on rocket launch.

The flight despin module was mated to the flight payload to check for satisfactory fit. No difficulty was experienced in the trial fitting.

A simulated prelaunch procedure was followed using prototype hardware. The oxidizer system was made up with ¼" explosive valves in the dump section. Blocked oxidizer and fuel explosive valves were installed. Part I of the Payload Check List (PCL) was performed at the contractor's facility. Part II of the PCL was performed at Wallops Island.

During the simulated fuel loading operation, the fuel tank was loaded with 9.57 pounds of water to simulate the fuel volume and the tank was pressurized to 500 psig. The payload was next attached to the Tomahawk on the launcher. Prefill instrumentation checks were made. The oxidizer tank jacket was supplied with liquid nitrogen. Six bottles of oxygen attached to the fill line manifold provided 13.1 pounds of oxidizer to simulate the volume of liquid fluorine. Following oxidizer fill, the oxidizer tank was pressurized to 500 psig and the fill valve closed. The fill tube cutter was then activated, severing the fill line.

The temperature of the fuel remained constant at 82°F during the test. The oxidizer temperature remained at -315°F for 60 minutes, at which time the safety disc on the liquid nitrogen dewar released. Since it was not possible to flow liquid nitrogen to the oxidizer jacket, the pressure in the oxidizer tank built up. When pressure went to 530 psig, due to loss of coolant, the dump system was activated. The steps followed were as in the Abort Procedure given in PCL. Several seconds after firing the explosive valves, the oxidizer tank pressure leveled off and began dropping. Pressure relief was not immediate due to the fact that the valves were dumping liquid and this was vaporizing.

tending to create some back pressure in the dump line. The payload was removed from the launcher after the vehicle was lowered.

The practice countdown generally validated the procedures specified in the PCL. Some of the safety procedures used are presented in the following paragraphs.

Personnel Safety Procedures

Fluorine.- All personnel working near the fluorine manifold or payload during any fluorine operation wore safety suits. This is secondary protection - the main protection was afforded by shields or barricades. Water deluge facilities were available in the immediate pad area. Also, a doctor was available.

Hydrazine.- The filling of the hydrazine fuel tank took place in the holding area. A water deluge system in the form of a safety shower and fire fighting equipment was available. Adequate personnel protection was provided by ordinary work clothes, face shield and rubber gloves.

Pressurization of the fuel tank was not done until after the payload had been transported to the launch pad. During the operations of tank pressurization and mating the payload to the rocket, personnel wore protective clothing and face shields.

Criteria for Aborting Mission

Ground Support Equipment.-

(1) Malfunction of fluorine systems, including fill system, dump system or liquid nitrogen cooling system.

(2) Malfunction of ground monitoring equipment, including payload temperature and pressure indication, electrical systems, and blockhouse monitoring equipment.

Payload Failure.-

(1) Oxidizer system

(a) No squib continuity on any one valve
(b) Temperature and/or pressure readout failure
(c) Hardware failure of any kind during fluorine fill due to chemical reaction
(d) Liquid nitrogen supply failure
(e) Temperature in oxidizer tank above -290°F
(f) Pressure exceeding 680 psig
(g) Inability to disconnect fluorine fill system due to frosting on exterior of hardware.

(2) Fuel System

(a) No squib continuity on fuel valve
(b) Temperature and/or pressure readout failure
(c) Chemical reaction in tank
(d) Fill valve failure. This will be determined before payload is attached to vehicle.
(e) Temperature in fuel bank below 32°F or exceeding 120°F
(f) Pressure exceeding 640 psig

(3) Umbilical
Loss of umbilical cable continuity

(4) Electrical
Programmer and/or battery malfunction

RELIABILITY AND QUALITY ASSURANCE

RITU employed reliability and quality assurance functions to satisfy the contract requirements. In accordance with NASA requirements, RITU personnel attended the following reviews:

Payload Design Review	March 1, 1968
Preliminary Design Review	October 3, 1968
Critical Design Review	April 21, 1970
Systems Readiness Review	September 16, 1970
Pre-Launch Review	September 18, 1970

An immediate inspection of equipment, parts, and stock was made on receipt of the items. Written logs were kept at the RITU Test Site facility and at the RITU machine shop. These logs included seller, date of purchase, date of delivery, condition of item on delivery, appropriate lot identification number, chemical analysis if metal stock used and when and for what purpose. In the case of equipment, the date used or the date of incorporation into a system was recorded. The details of all outside testing or fabrication were recorded.

The RITU constantly reviewed its techniques. Internal reviews of techniques took place during the weekly progress meeting.

Objective evidence was available to cognizant NASA personnel. This evidence consisted of inspection records, receipt records, and test records.

Gross Hazards Analysis

A Gross Hazards Analysis of the payload is presented in Appendix II. The classification of all identified potential hazards is based on the following definition of hazard categories:

- Category I - Personnel loss or system loss and mission abort
- Category II - Personnel injury or system damage and mission abort
- Category III - Mission abort without personnel injury or system damage

A simplified diagram is presented in Appendix II depicting identified gross hazards. The diagram identifies each item by number and is used as a guide for the analysis presented in the GHA sheets.

The GHA sheets present discussion of hazards and causes. The recommended corrective actions shown involve operating procedures.

The terms used to describe action status are defined as follows:

Closed: The corrective action is considered to be part of the standard operating procedure.

Open: The item requires further investigation or review.

The comments provided in the Remarks Column of the GHA tables relate to existing design characteristics or operational conditions which act as preventive measures.

Failure Modes and Effects Analysis

The Failure Mode and Effects Analysis is included in Appendix III. A logic block diagram is shown first. The diagram shows the functional interdependencies of the system rather than a descriptive diagram showing the physical interconnection of components.

On the logic diagram the payload is divided into six systems:

1. Power Supply
2. Programmer
3. Ground Support
4. Fuel Systems
5. Oxidizer System
6. Burner

Following the logic diagram is the analysis itself. All headings are self-explanatory with the possible exception of "criticality category" they are as follows:

I. Personnel loss or injury
II. System loss
III. Subsystem loss
IV. All others

The payload was cleaned and assembled at RITU Test Site facility. The oxidizer tank was passivated, as well as the burner tubing and dump system. All applicable checks such as tank leakage and electrical continuity were made at this time. The programmer was installed and checked by NASA-LRC personnel at Wallops Island. The fuel mixture was made up by RITU personnel at Wallops Island.

The following is a condensation of the major items in the payload countdown:

T-44 hours - Check out ground support systems including liquid nitrogen, fluorine fill, fluorine disposal, purge gases, blockhouse readouts, and pyrotechnic actuation systems.

T-20-3/4 hours - Bring empty payload to launch pad, install umbilicals and check all circuits through umbilicals. Remove payload to holding area.

T-7 hours - Fill the fuel tank in the holding area.

T-5-½ hours - Bring payload to launch area. Plug in umbilicals. Pressurize fuel tank. Mate payload to vehicle.

T-4-3/4 hours - Mount oxidizer fill line cutter, oxidizer fill line, dump line, all purge lines, LN_2 line and fill valve handle. Check and safe fill line cutter.

T-4 hours - Start all dry nitrogen purges.

T-3 hours - Start LN_2 cool down of oxidizer tank. Fill and condense in oxidizer tank 17 lbs. of fluorine. Pressurize oxidizer tank with He and close fill valve. Remove extension handle from fill valve. All personnel retired to blockhouse. The next item was the firing of the fill line cutter. There was no deviation from the countdown until the fill line cutter was actuated and failed to sever the line and separate from the payload. At this time, the launch vehicle and payload were ready for launch, ground stations were prepared to monitor the chemical release, and weather conditions were favorable. Prior to failure of the fill line cutter, the entire operation was very smooth and the pressure in the oxidizer tank was constant. After discussion with safety personnel, it was decided to approach the payload and cut the fill line by hand The Failure Mode Analyses were most conservative in regards to corrective action for this incident (see Failure Mode No. 7-Appendix III). The same personnel that write the Failure Mode Analyses were involved in this corrective action, as well as one man from NASA-LRC and one man from NASA-Wallops Island.

T-40 minutes - Actuation and cycling of battery heater.

T-30 minutes - Start elevation of launcher. Check explosive valve squibs.

T-10 minutes - Activate battery. Continue to monitor all systems until launch.

The vehicle was launched on schedule with chemical release being initiated at 5:51:17 AM EDT on October 7, 1970. The release observed was one of a bright initial burst with a very rapidly expanding luminous cloud which disappeared to the naked eye within 20 seconds. The ground instrumentation detected barium ions distributed relatively uniformly over a very large area of the sky for about 30 minutes when measurements were discontinued due to sunrise. Further results of the flight test are given in Appendix 1.

CONCLUDING REMARKS

The flight test of the Liquid Chemical Barium Release Payload has demonstrated that the use of liquid fluorine as an oxidizer on small payloads is practical. All fluorine transfer operations during the launch preparation proceeded without incident. The success of the pre-launch operation was made possible since all personnel working with the fluorine fill operation had several years experience in handling hazardous materials. Wallops Island launch and safety personnel were also well educated in the problem areas.

The payload appeared to operate satisfactorily. However, since there was no telemetry on-board, the actual payload performance cannot be determined. In retrospect, some means of determining the critical O/F ratio during the release would have been very helpful in analyzing the flight results. The chemical release occurred at the proper time and a definite reaction was observed. However, the experimental results were less than optimum. A bright dot appeared which very quickly expanded in a spherical direction with loss of light intensity. Within 20 seconds, the phenomenon had disappeared to the unaided eye.

The poor performance could have resulted from the basic chemistry of the system. A low barium yield would result if the O/F ratio obtained in the payload was too high. There are several failure mechanisms in the payload by which this could occur, however there was no pre-launch indication of any payload anomalies and no flight indication to suggest a particular type of failure.

A contributing factor to the loss of intensity of the cloud was its rapid expansion. This was probably because of a high exhaust gas velocity resulting from a relatively high chamber pressure and a slightly diverging nozzle exit. Lower chamber pressures would not have expanded the cloud as rapidly.

RECOMMENDATIONS

The following are recommendations for improvement in the pre-launch operations associated with the fluorine-hydrazine-barium payload.

Fluorine System

Fluorine tanks should be stored in a separate, well-ventilated shelter with a roof to prevent exposure to direct sunlight and rain. The vent from the gaseous fluorine manifold should not go into a charcoal disposal unit but should simply be vented to the atmosphere at a distance of approximately 200 feet. A small amount of fluorine is normally released at the beginning of the fill operation. When vented to the disposal barrel, the charcoal in the barrel was ignited and continued to burn in the air. This melted and closed the tube inside the disposal unit so that later in the fill operation when it was necessary to vent helium or fluorine down this line, the line was clogged and could not be vented. This would not occur if the fluorine was simply vented to the atmosphere. The small amounts of fluorine dumped from this manifold vent line would not represent a safety hazard. Of course, disposal barrels would still be provided for the possible disposal of LF_2 during an abort situation.

Liquid Nitrogen System

The LN_2 storage cylinder should have provision not only for constant pressure but also a remotely activated pressurizing mechanism to regulate the flow rate. This could be accomplished by a remotely actuated vent valve and a remotely operated regulator for control of the He pressurant. The flowmeter on the LN_2 line should be closer to the payload so that a more accurate indication of flow is obtained. On a long line, it is possible that much of the LN_2 could be vaporized before it reaches the payload.

Gaseous Nitrogen Purge Lines

Reliable flowmeters should be provided on the dump line purge and the burner purge system to assure that dry gaseous nitrogen is supplied to these areas.

Umbilical Cables

The umbilical cable should have separate shielded conductors for instrumentation to preclude interference during power switching.

Fill Line Cutter

Separation of the fill line before elevation should be done with a reliable, remotely actuated mechanism. This device should be protected from impingement of LN_2 which can cause icing of the mechanism.

Payload Modifications

Consideration should be given to welding the LN_2 jacket at both ends. This was not done because of possible differential thermal expansion. However, the resulting crack at the forward end of the jacket could not be sealed and resulted in the leakage of LN_2 into the nose ogive area while the payload was in the horizontal position.

Considerable trouble was experienced in assembly of the oxidizer fill valve to the payload with swage-type fittings. An improved method of attaching fittings to the tanks is needed.

The fuel fill valve should be above the center line of the tank to simplify the pressurization procedure and eliminate the need to tilt the payload in order to pressurize the fuel tank.

A heater should be built into the fuel tank to control fuel temperature during the pre-launch period. The wrap-around thermal blanket used was not entirely satisfactory.

FIGURES

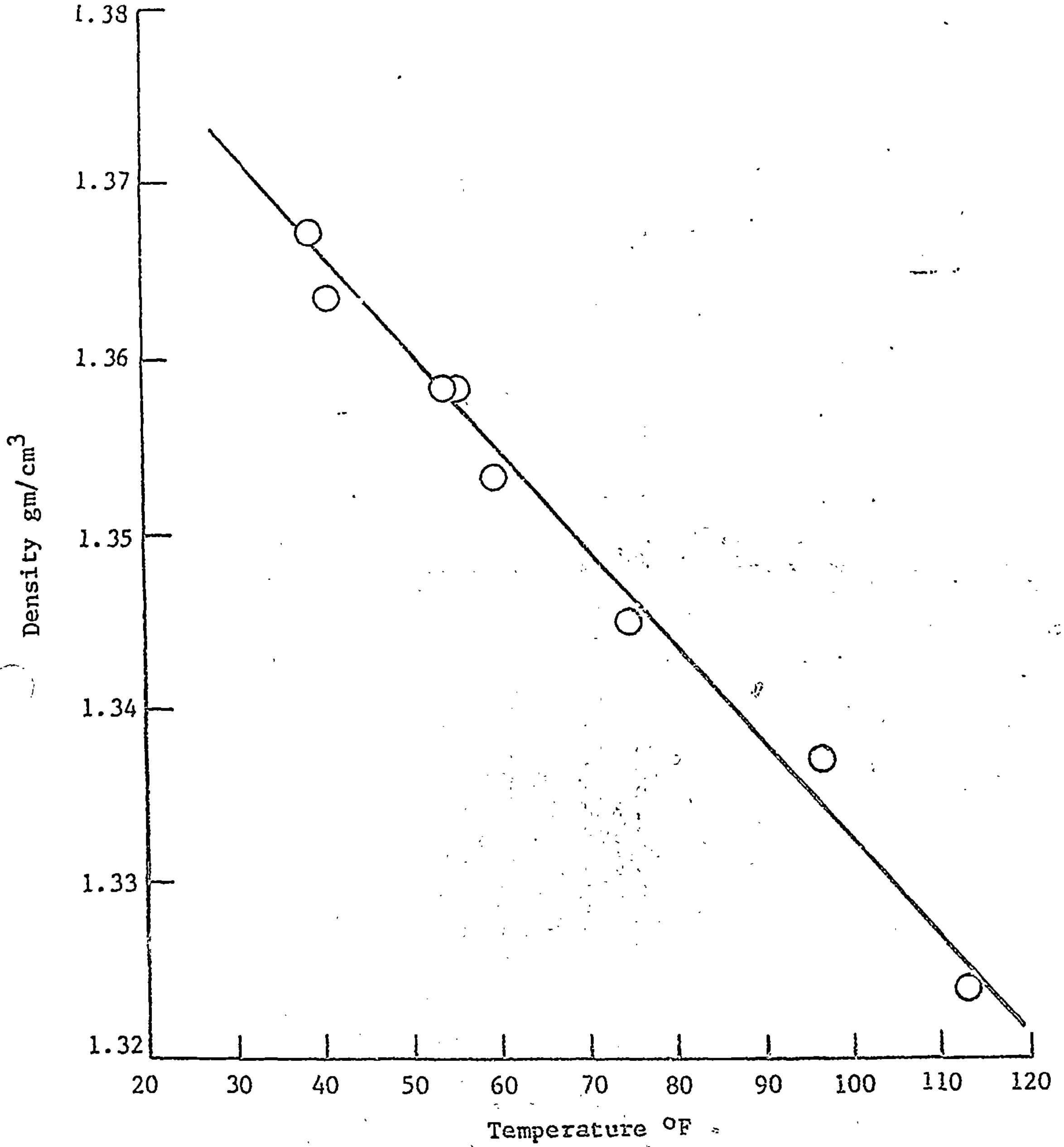


Figure 1.- "B-Mix" density vs. temperature.

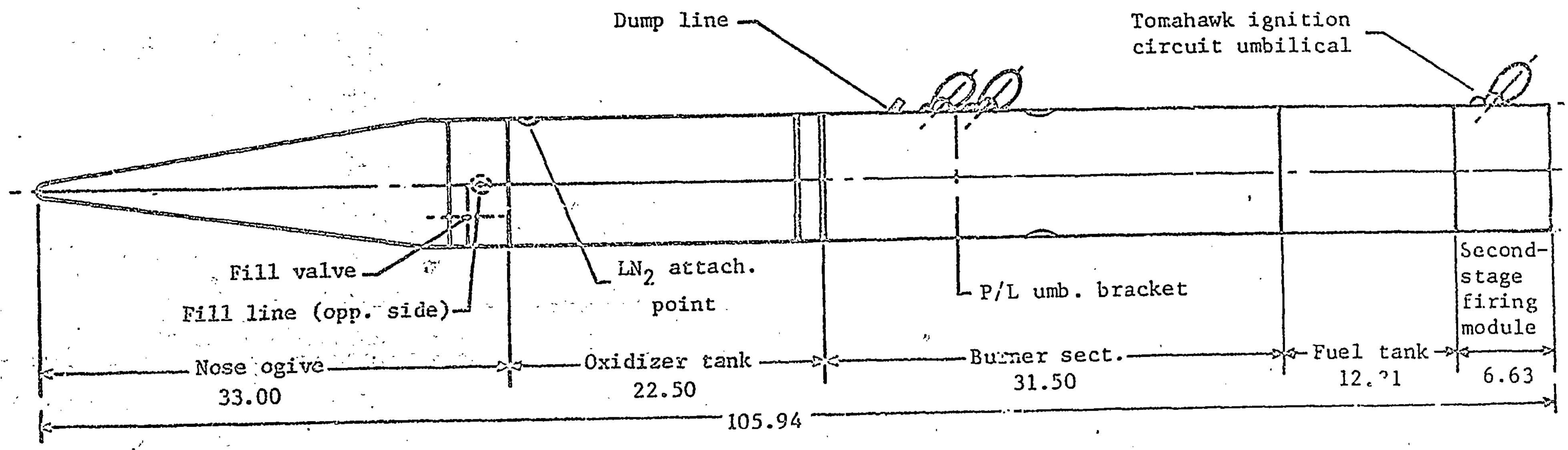


Figure 2.- Payload (all dimensions are in inches).

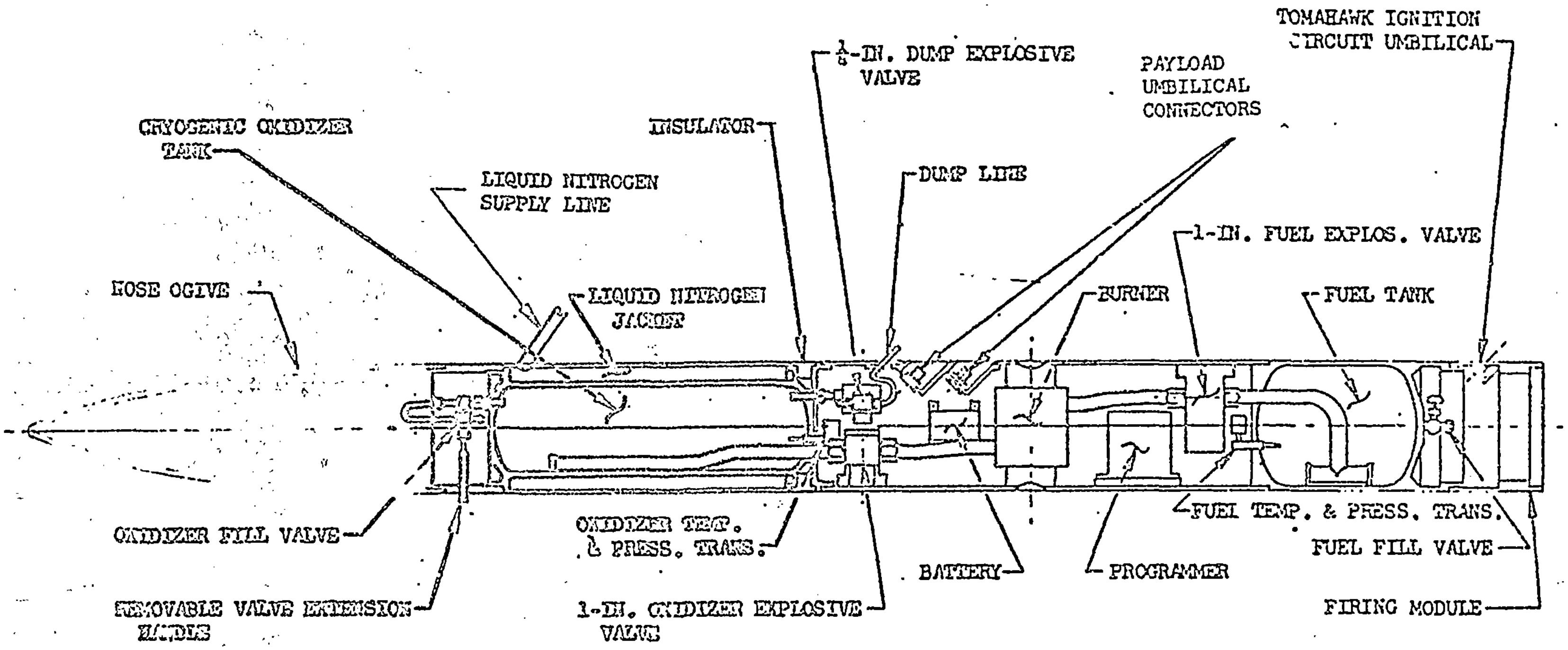


Figure 3.- Payload schematic.

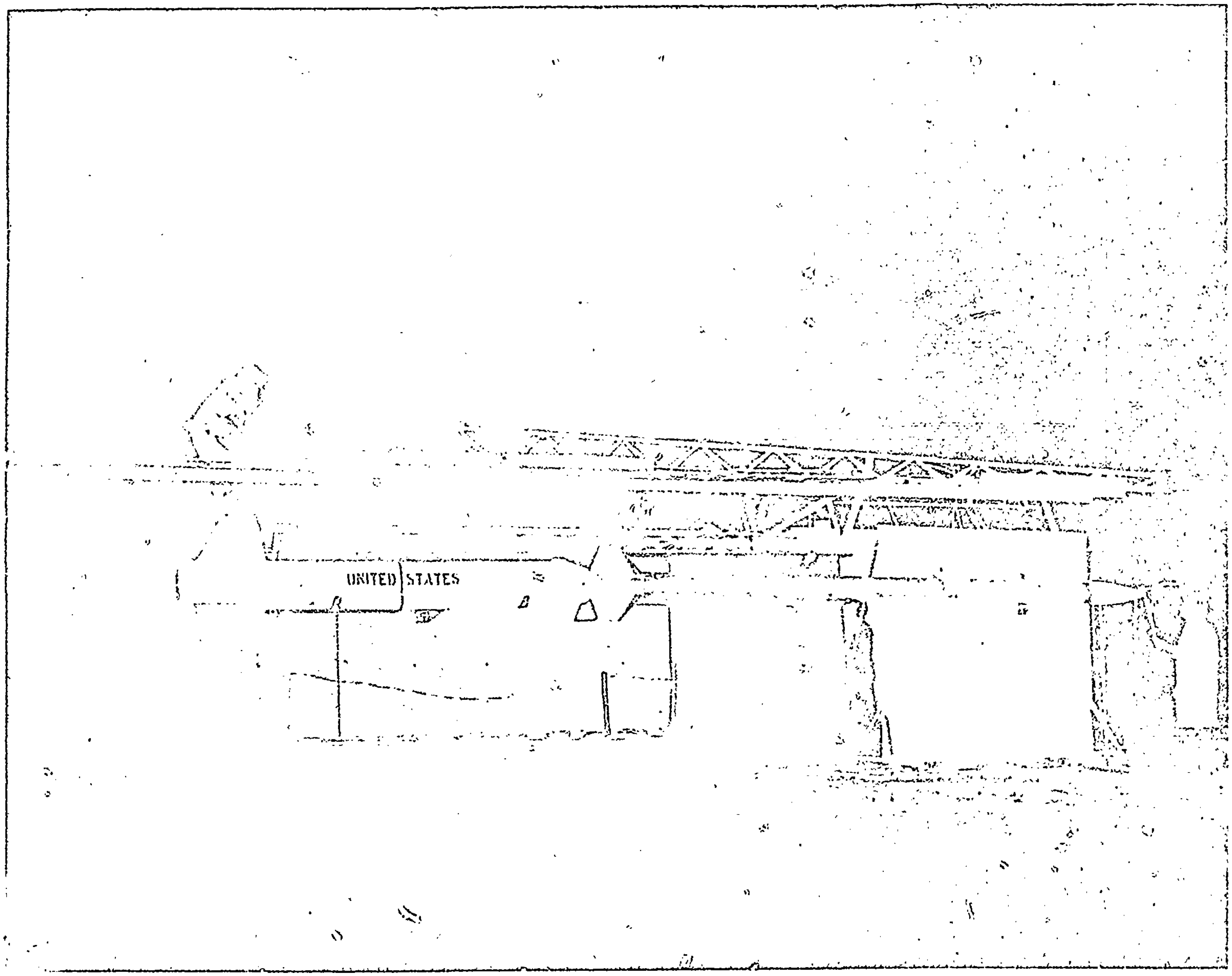
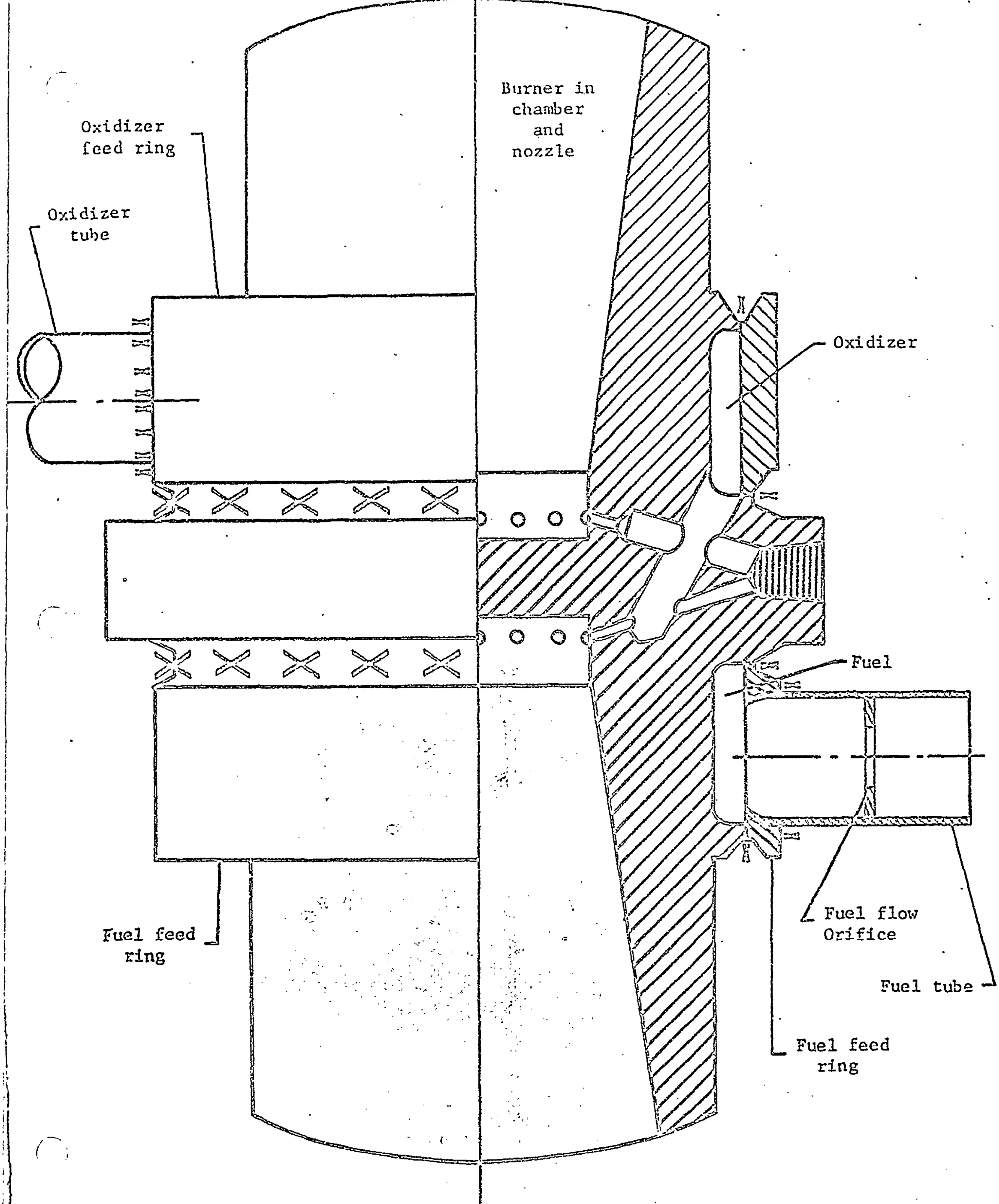


Figure 4.- Vehicle and payload on launcher at Wallops Island.



⅄ - Denotes weld

Material: 6061 T6 Aluminum

Figure 5.- Burner schematic.

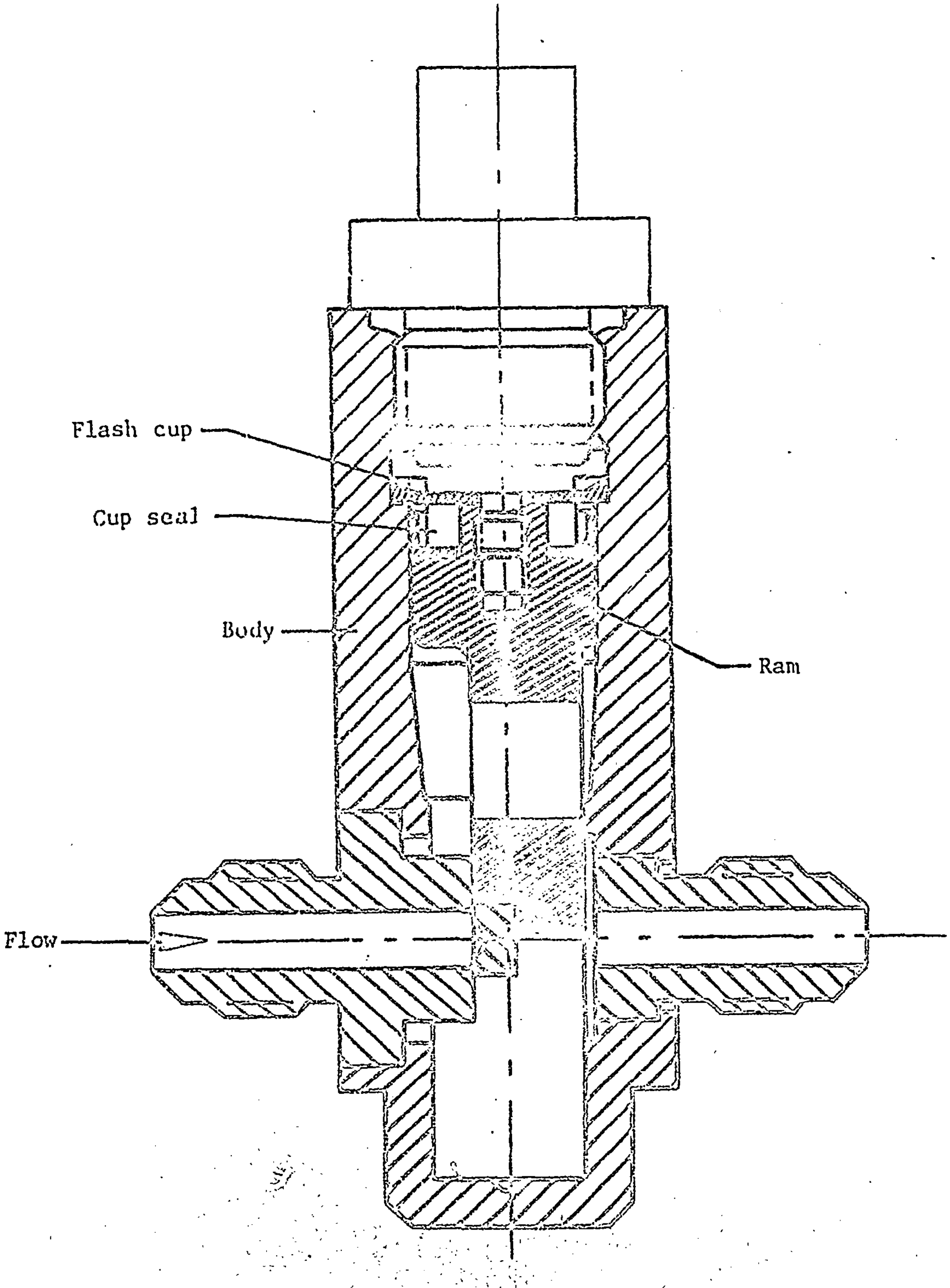


Figure 6.- ¼ inch explosive valve.

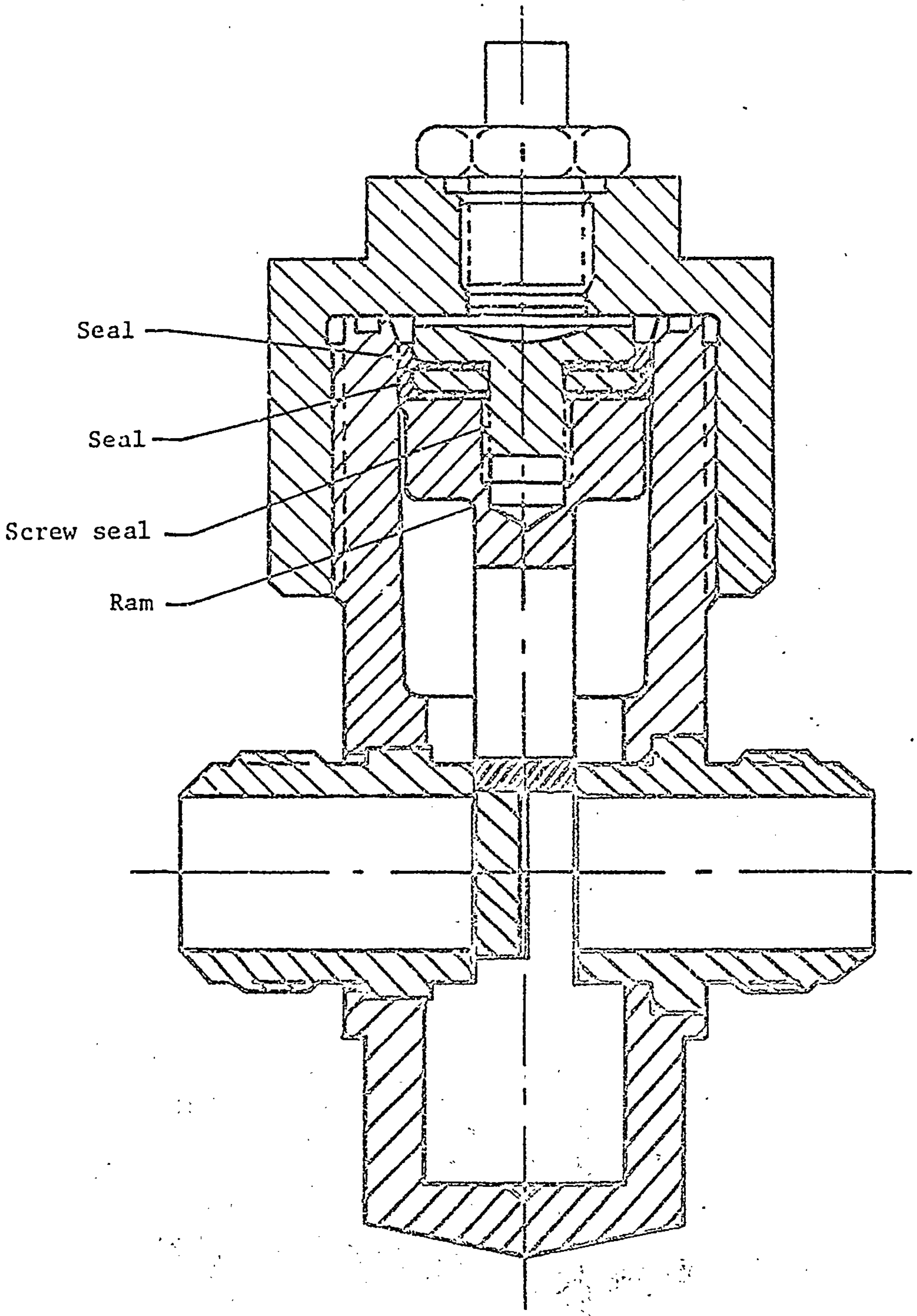


Figure 7.- One inch explosive valve.

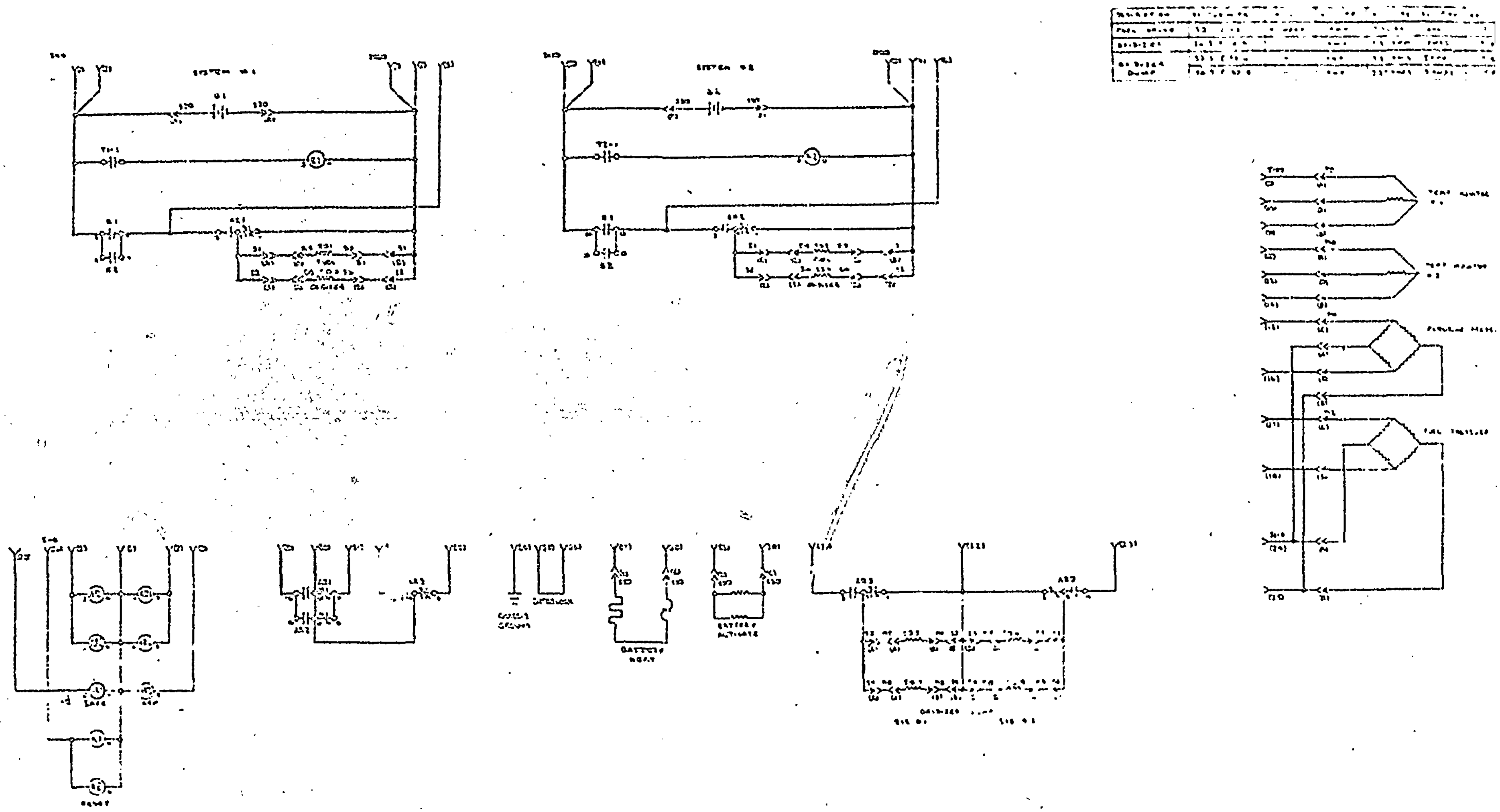


Figure 8.- Payload electrical schematic.

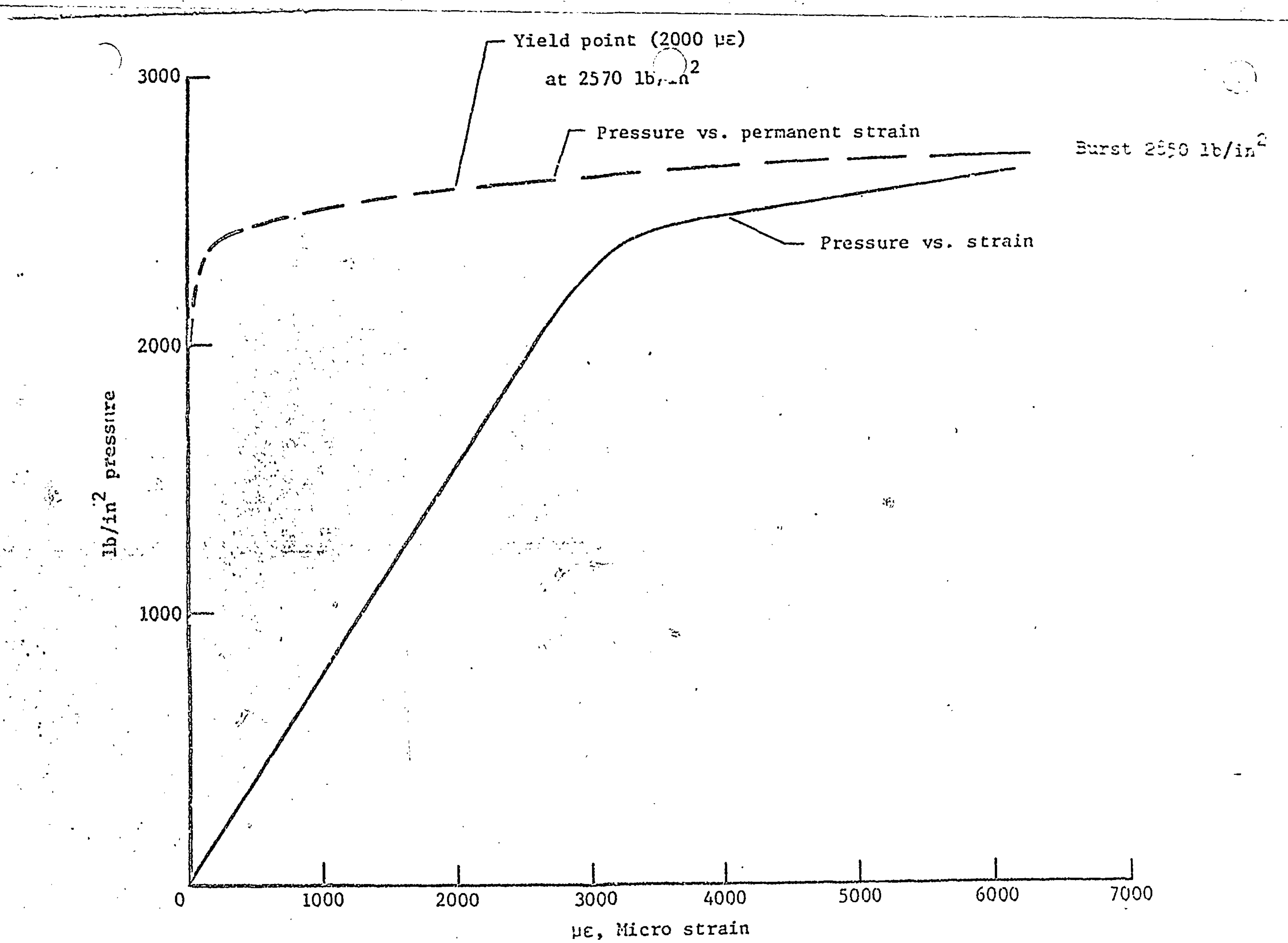


Figure 9.- Fuel tank burst test results.

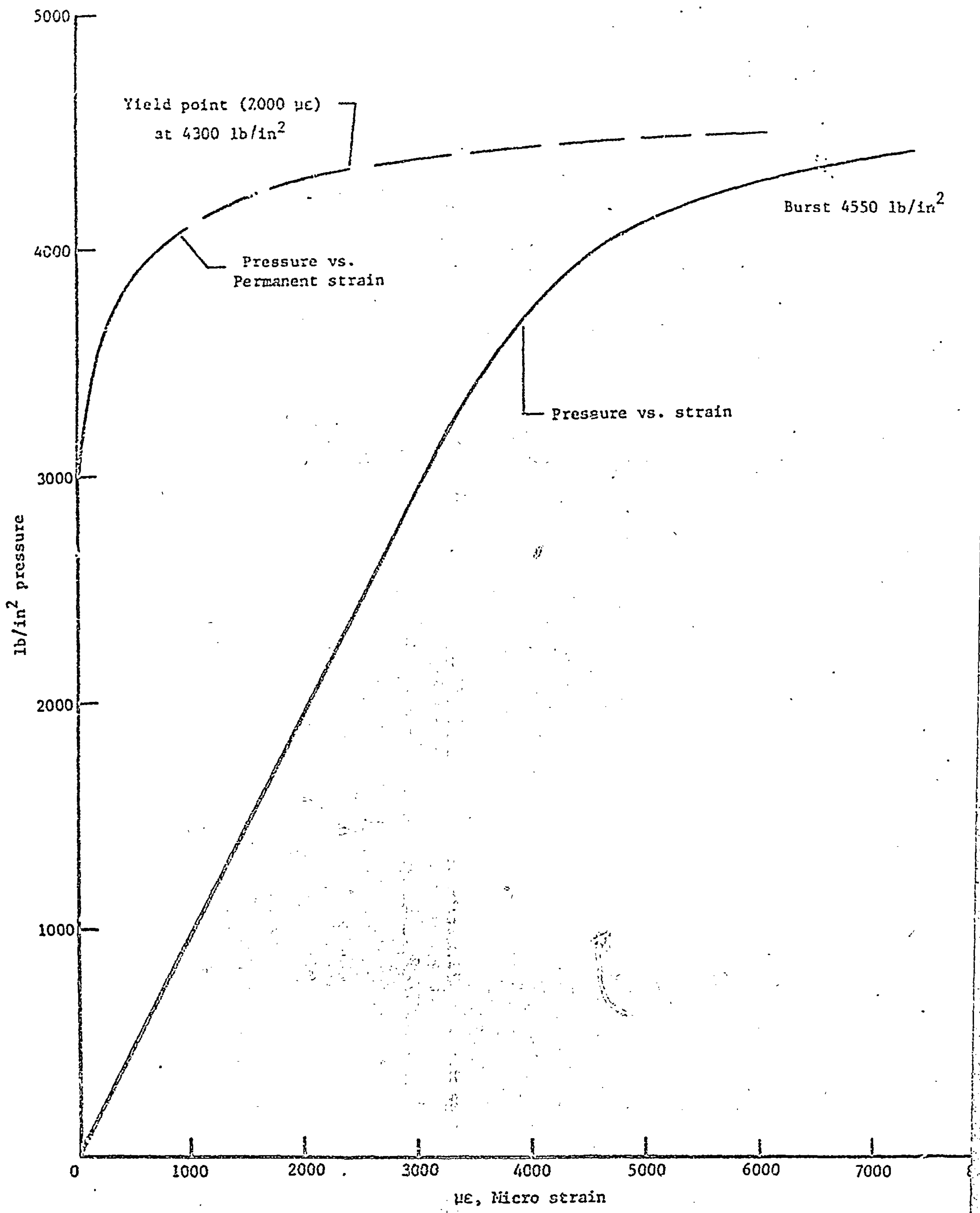


Figure 10.- Oxidizer tank burst test results.

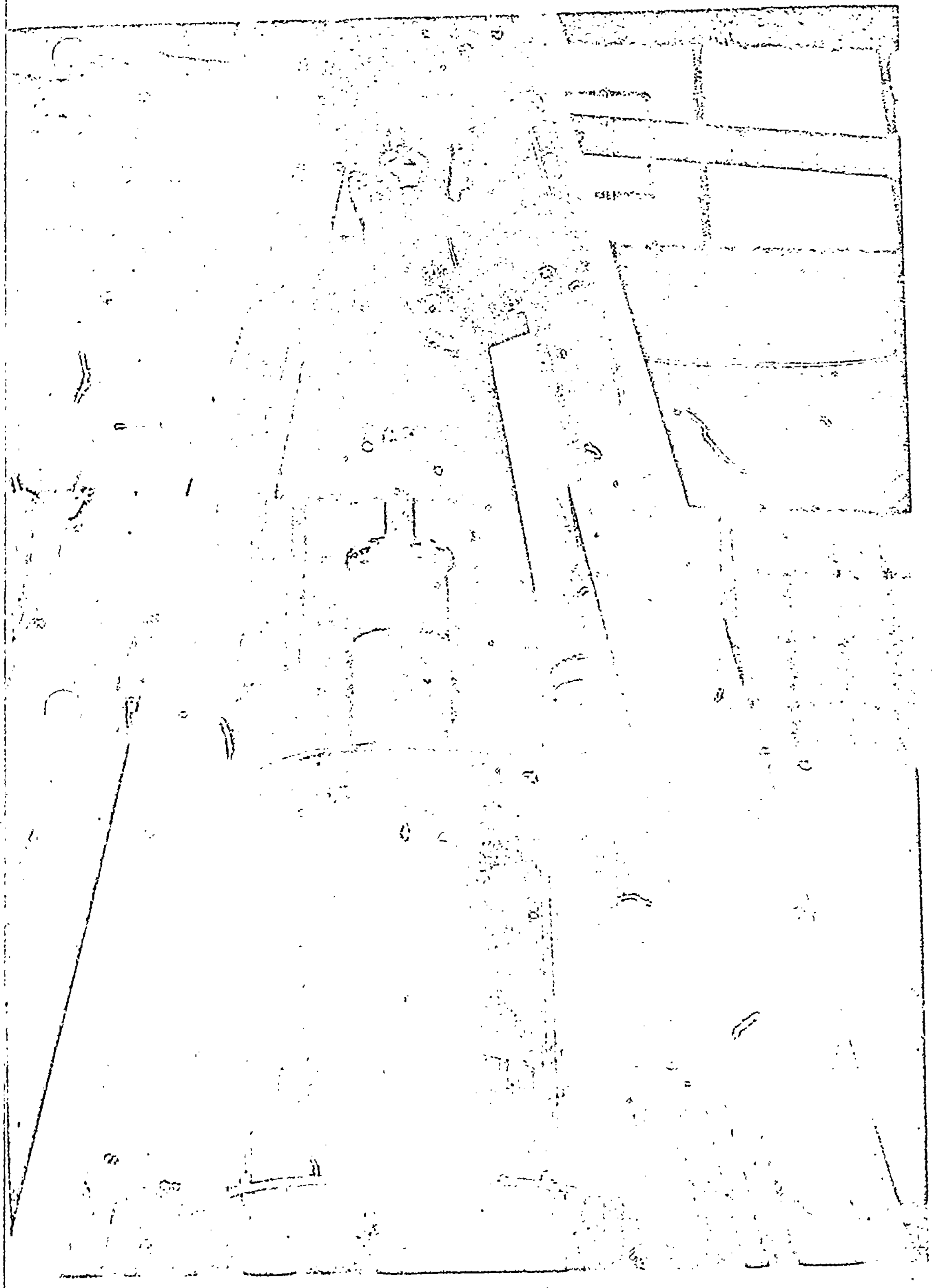


Figure 11.- Fuel tank mockup setup for Slosh coning test.

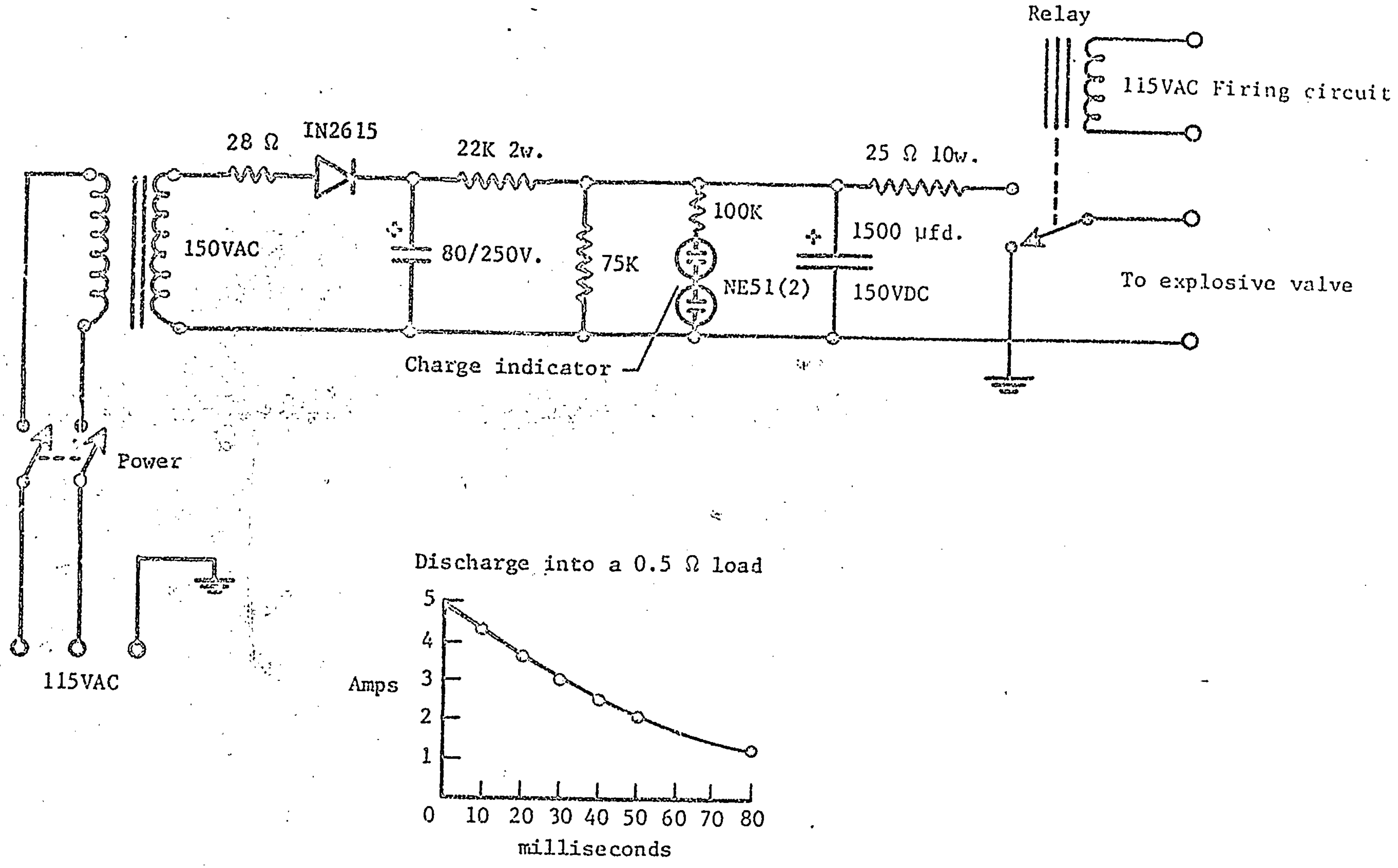


Figure 12.- Explosive valve initiator electrical circuit.

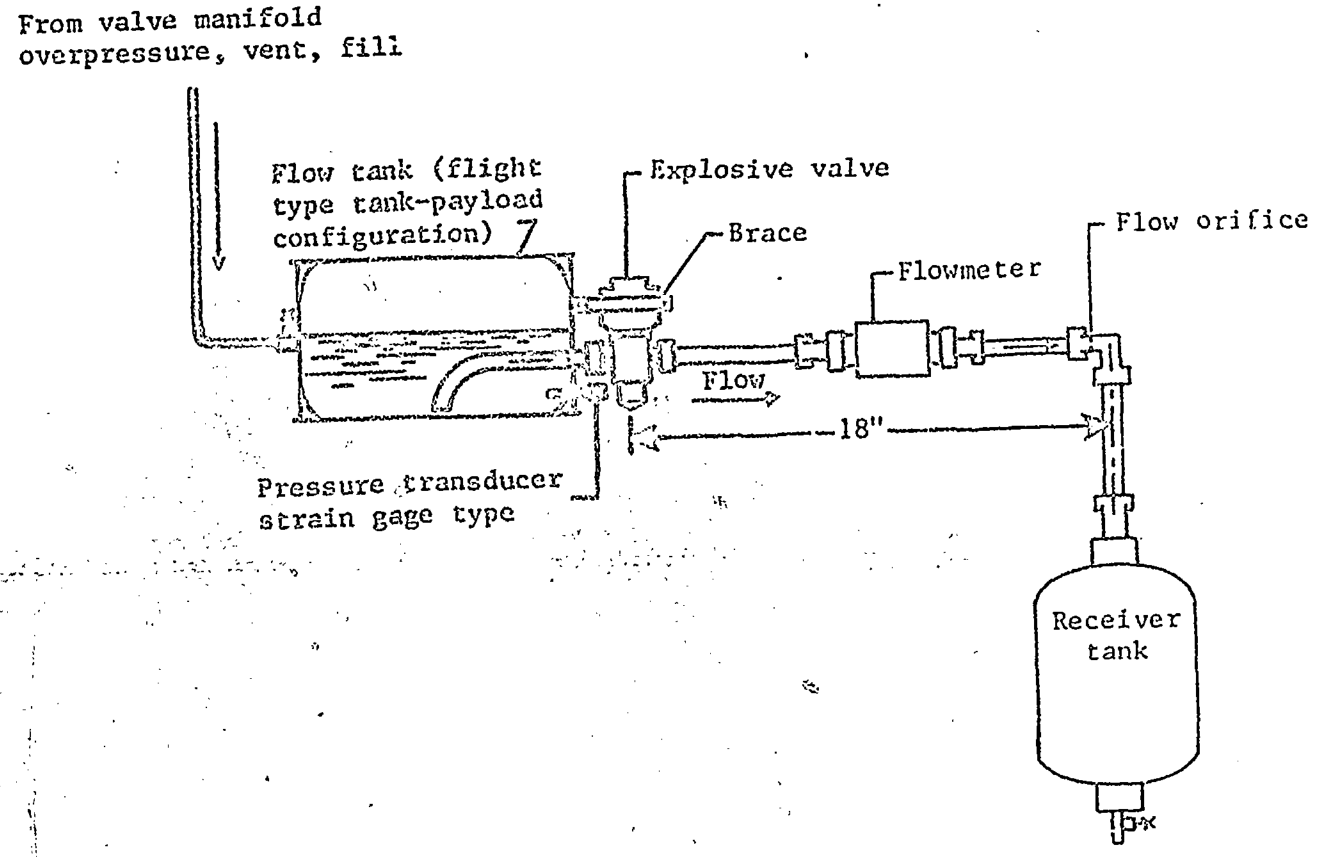


Figure 13.- "B-Mix" flow system for explosive valve tests.

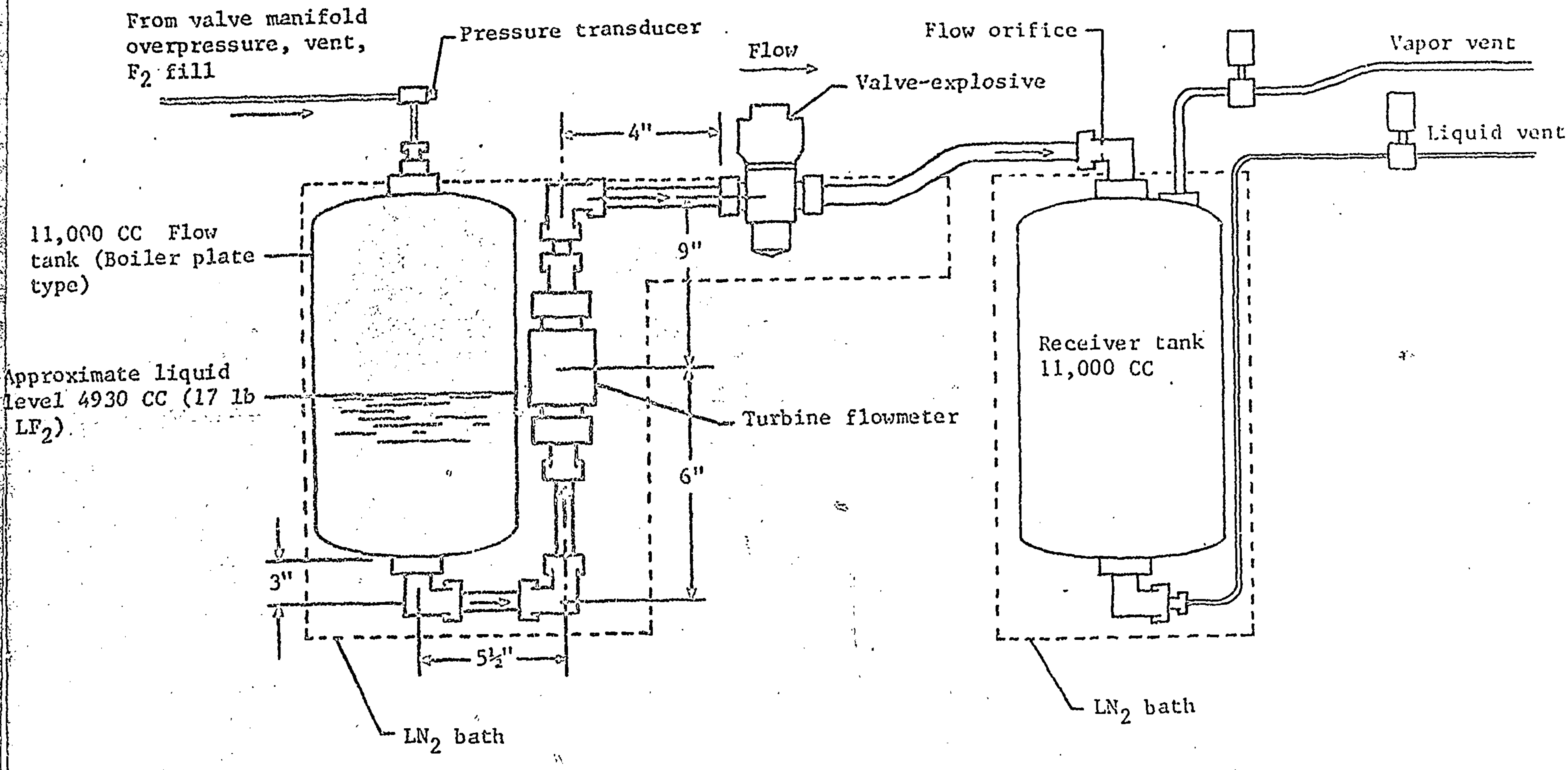


Figure 14.- Liquid fluorine transfer system for explosive valve tests.

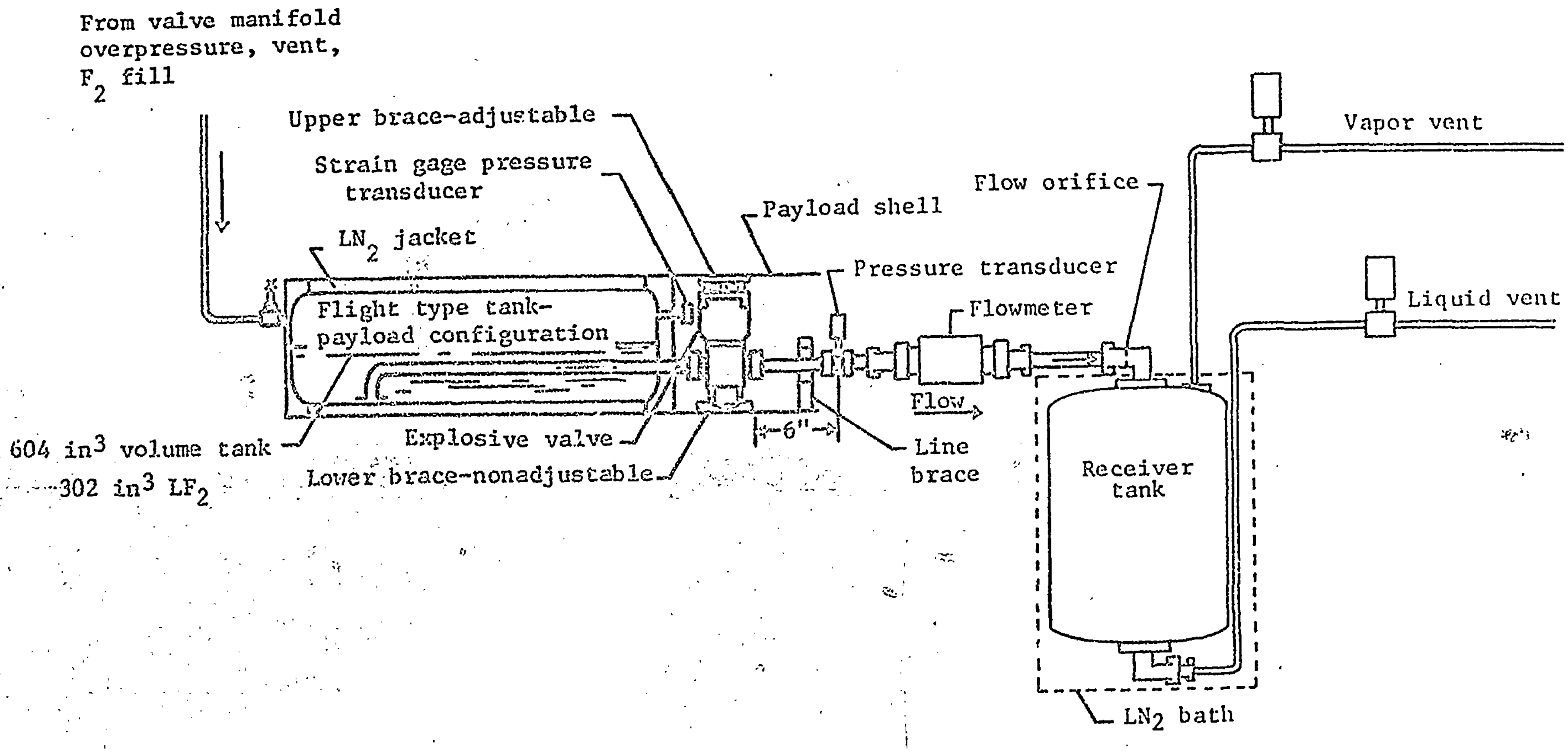


Figure 15.- 17-Pound flight-type liquid fluorine transfer system.

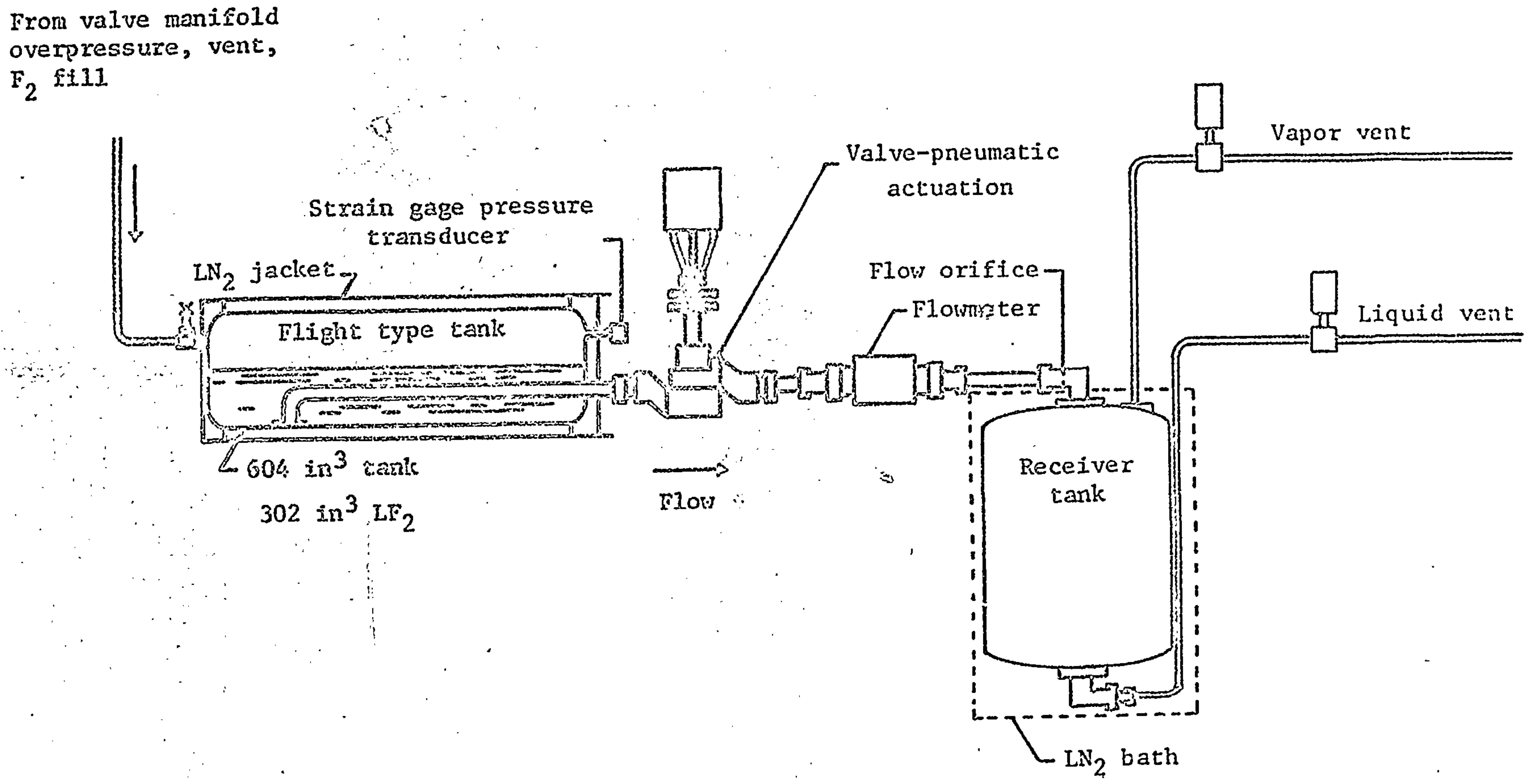


Figure 16.- Liquid fluorine transfer system check-out test.

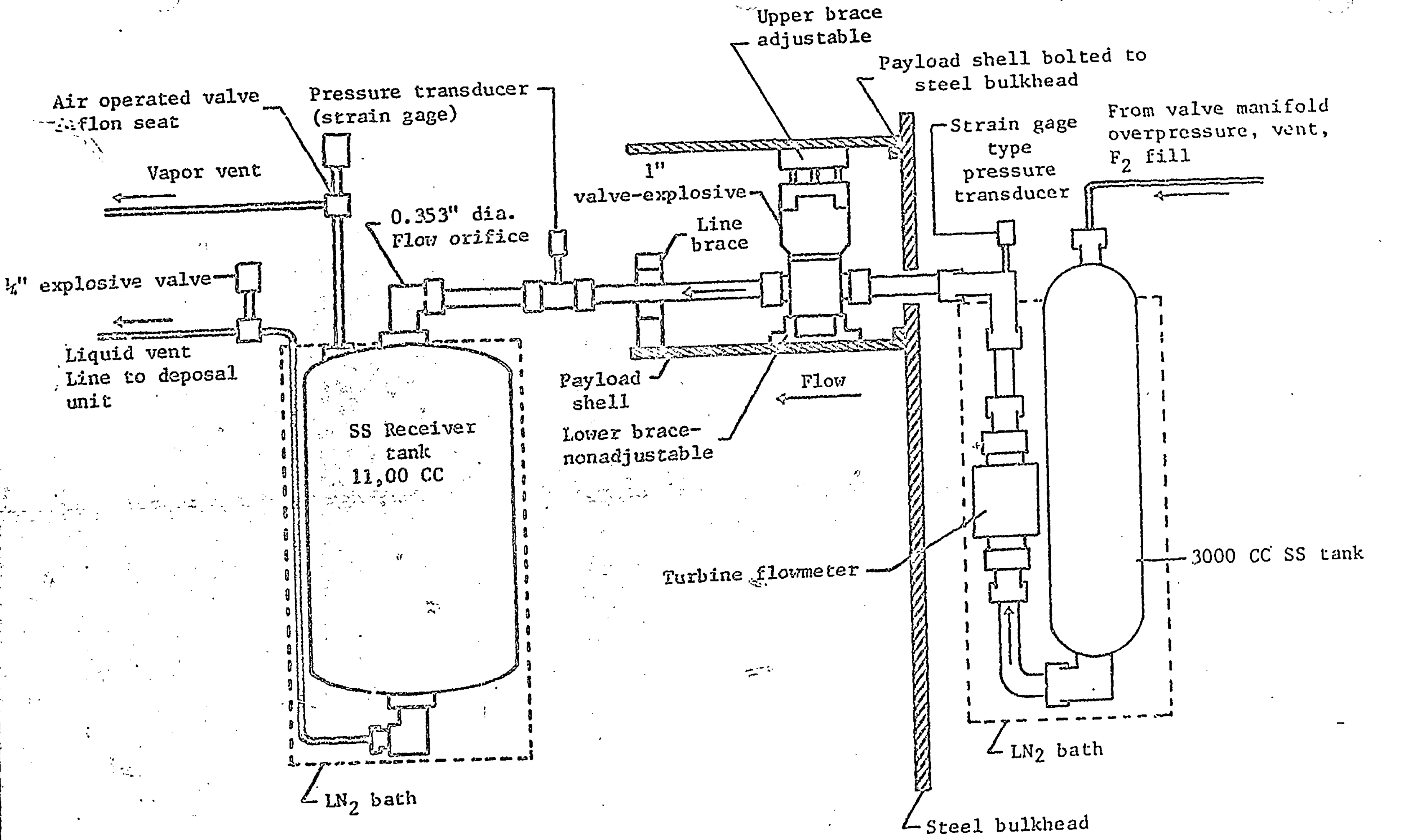


Figure 17.- 6-Pound liquid fluorine transfer system for explosive valve tests.

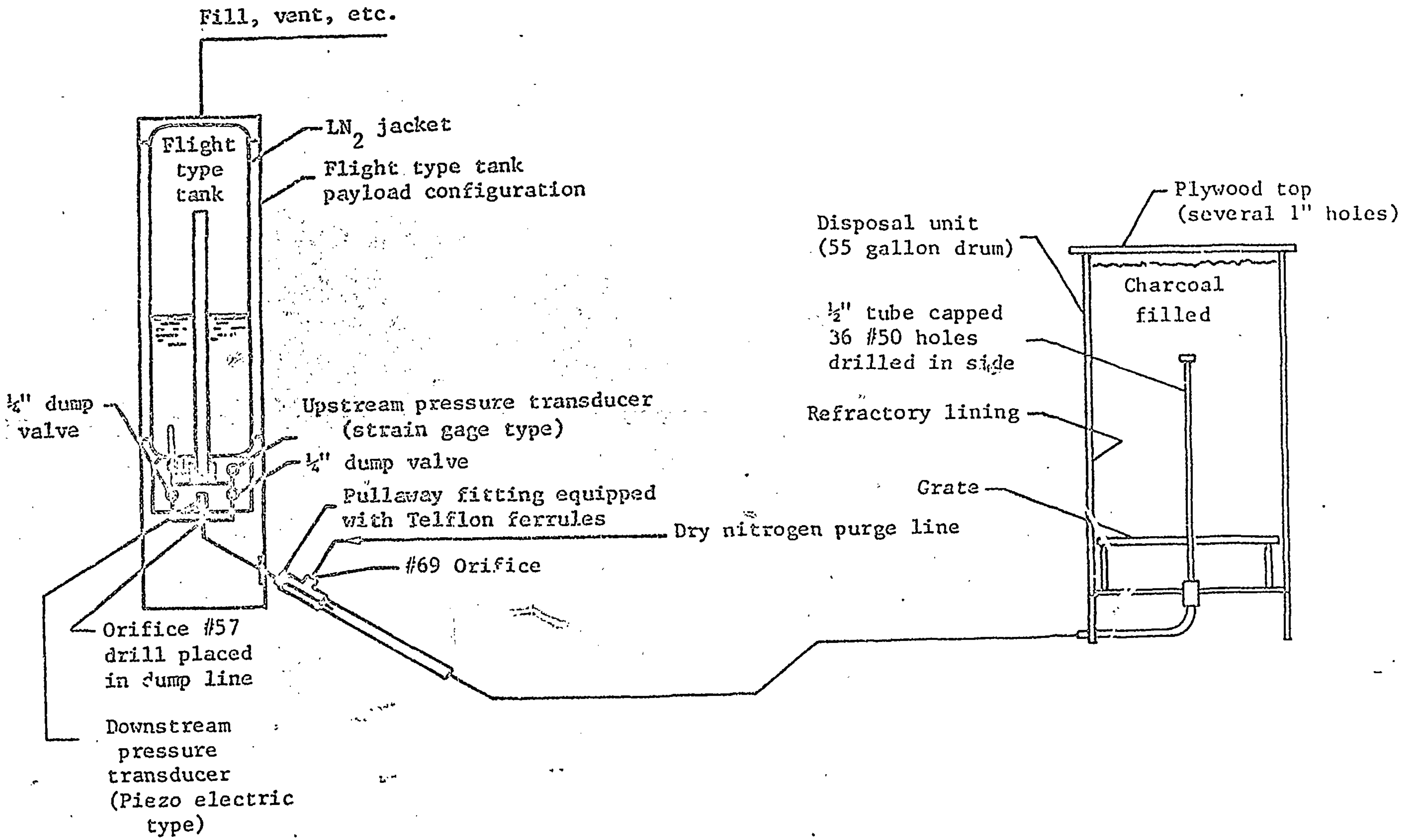


Figure 18.- 17-Pound flight-type tank setup for dump test.

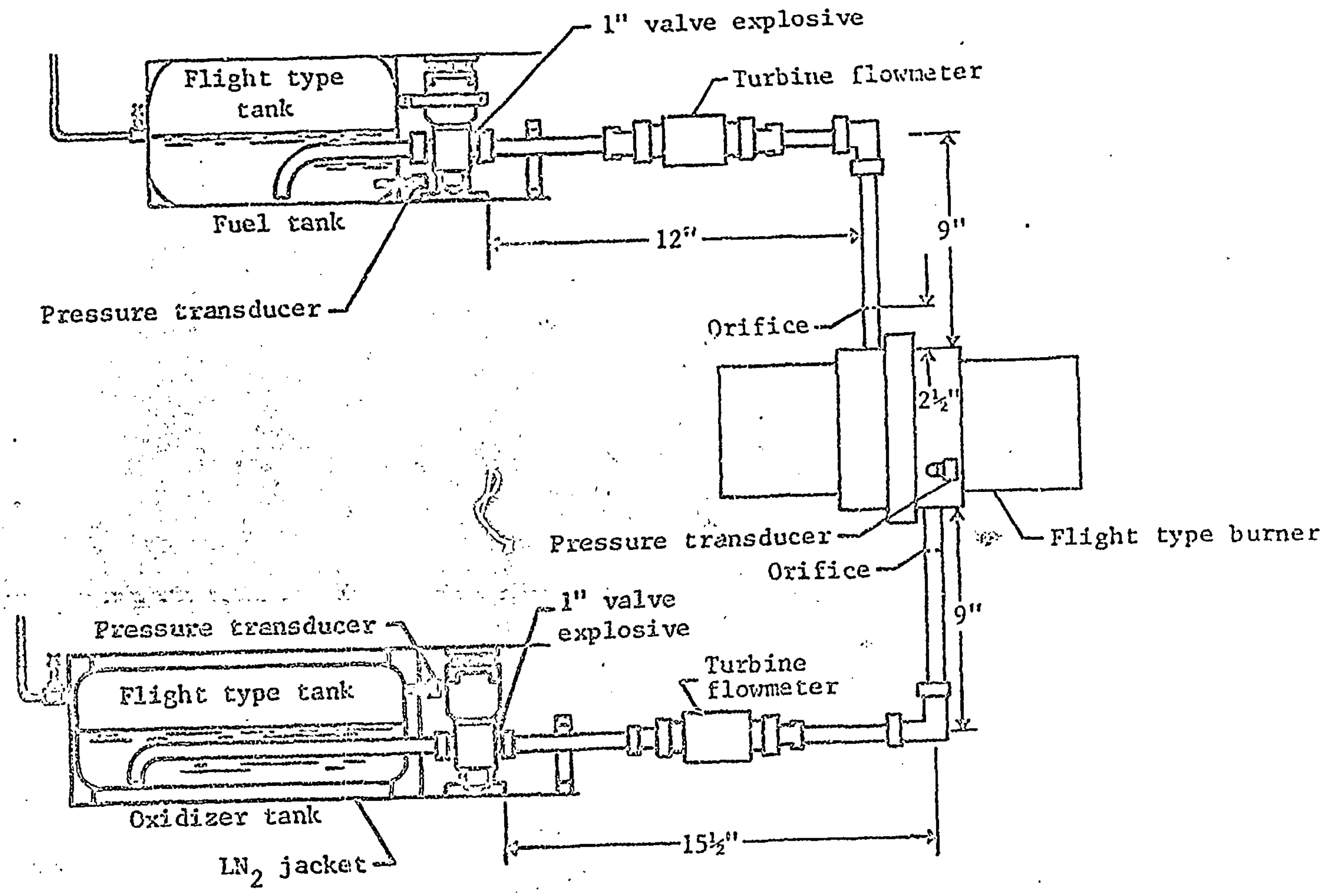
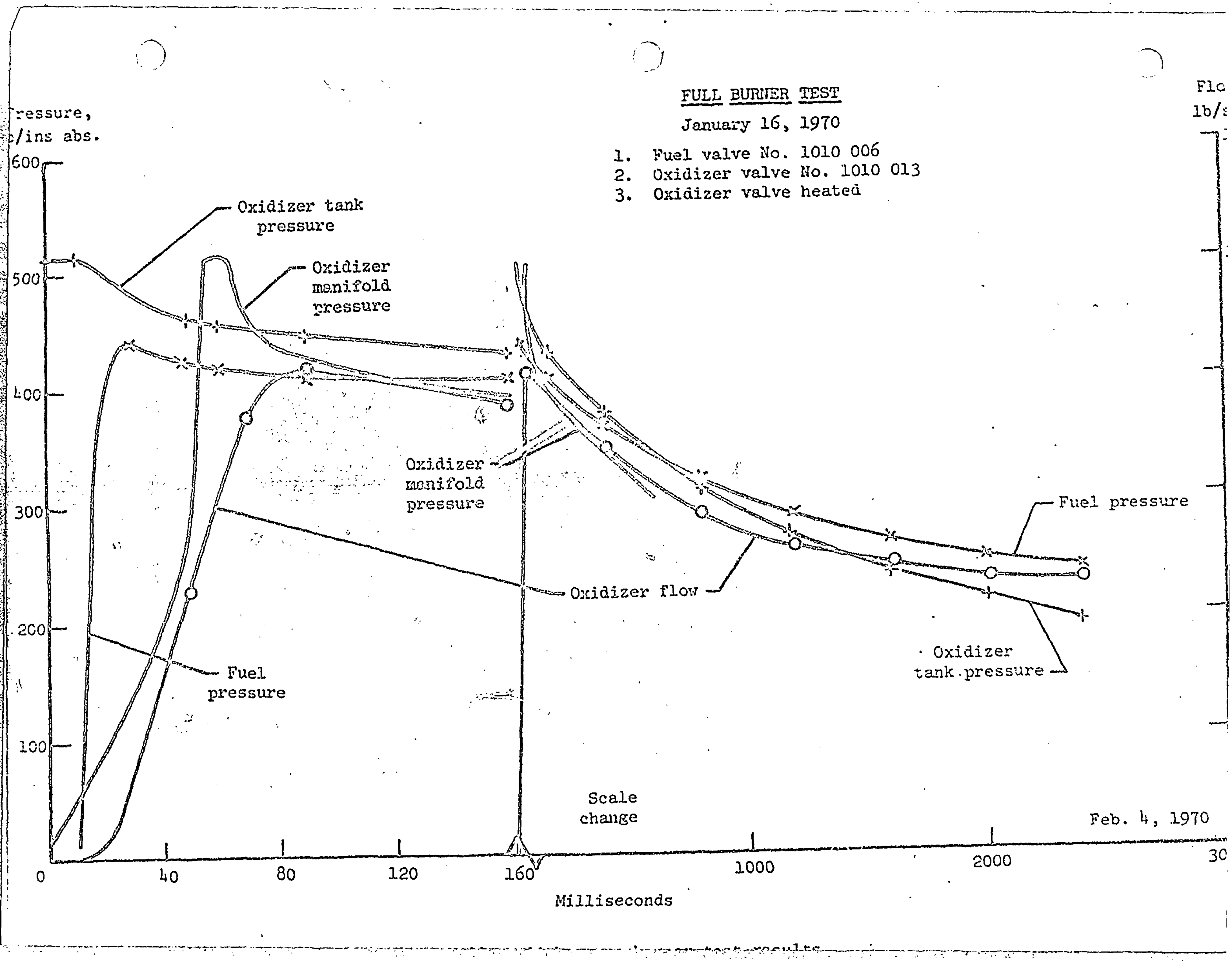


Figure 19.- Flight type burner test setup.



FULL BURNER TEST
January 16, 1970
1. Fuel valve No. 1010 006
2. Oxidizer valve No. 1010 013
3. Oxidizer valve heated
ressure,
/ins abs.
600
500
400
300
200
100
0
40
80
120
160
1000
2000
Milliseconds
Scale change
Oxidizer tank pressure
Oxidizer manifold pressure
Oxidizer manifold pressure
Fuel pressure
Oxidizer flow
Fuel pressure
Oxidizer tank pressure
Feb. 4, 1970

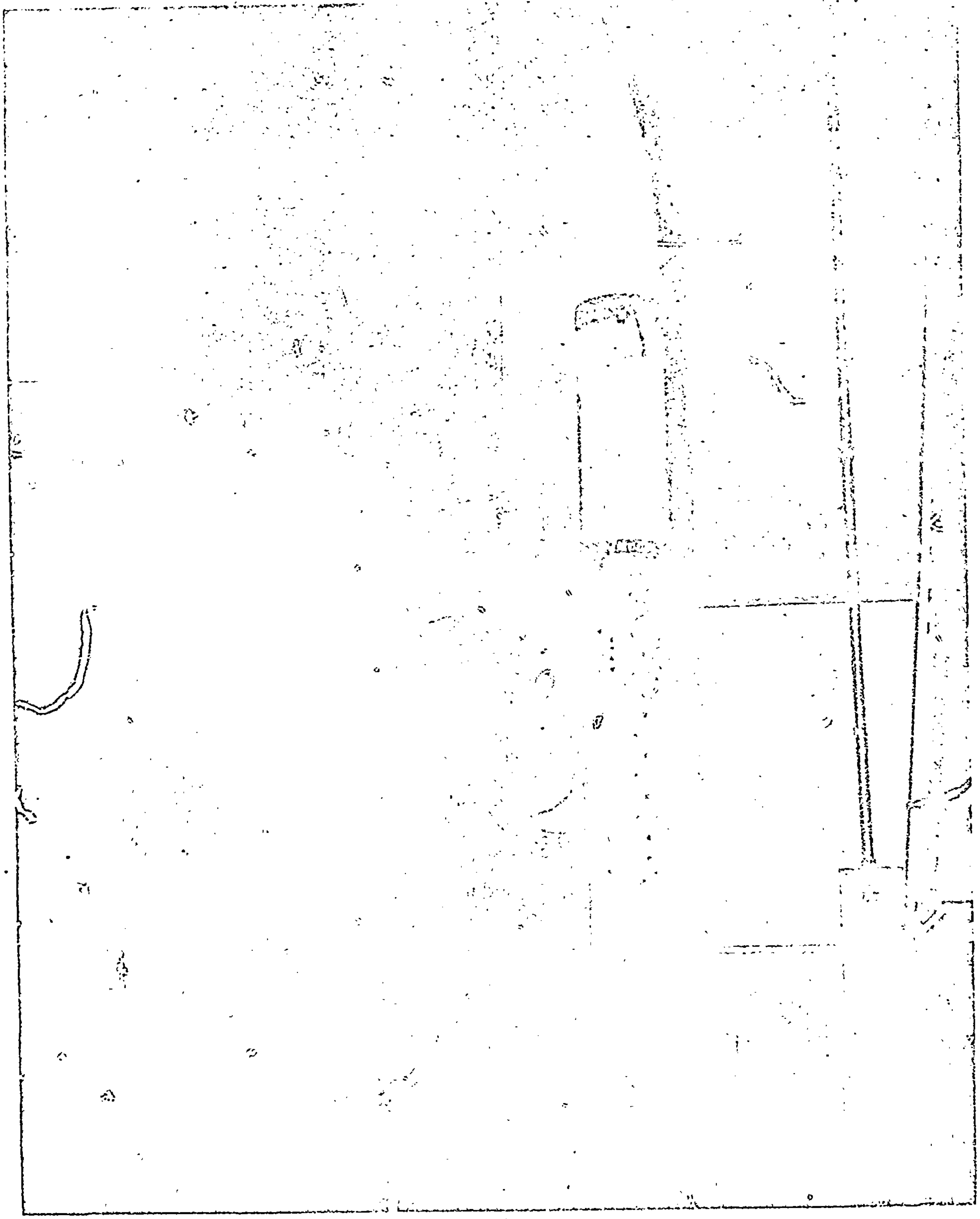


Figure 21.- Prototype payload qualification test.

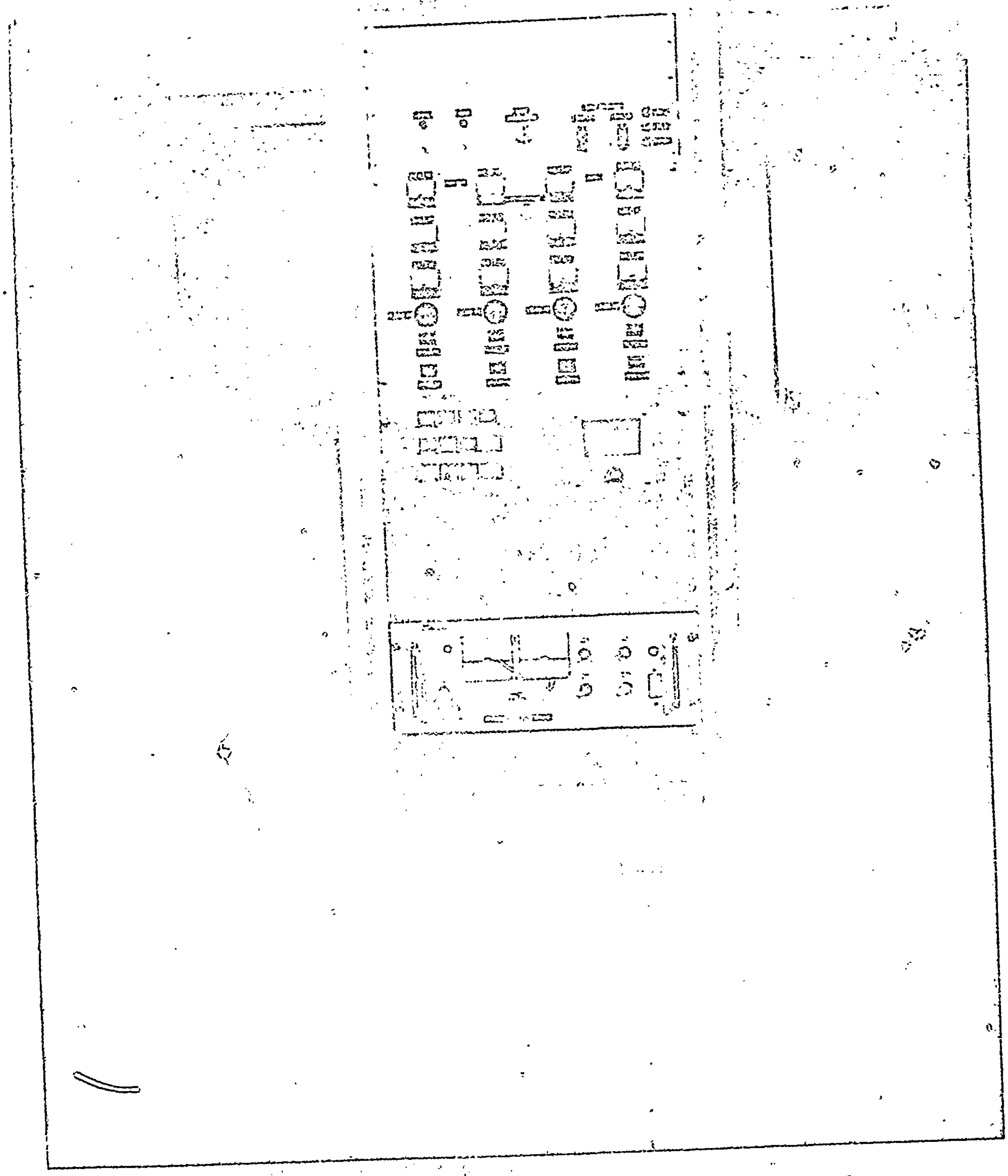
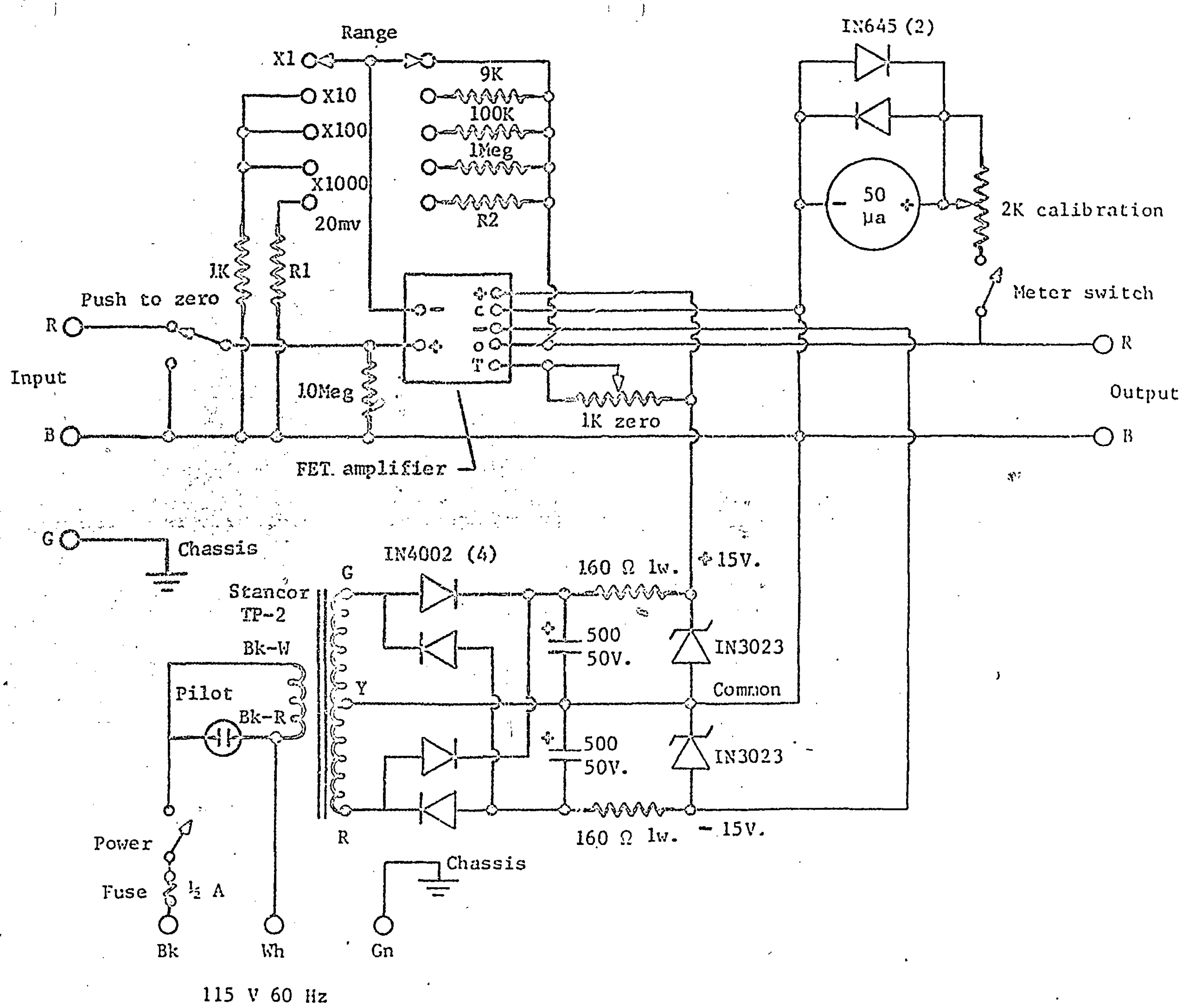
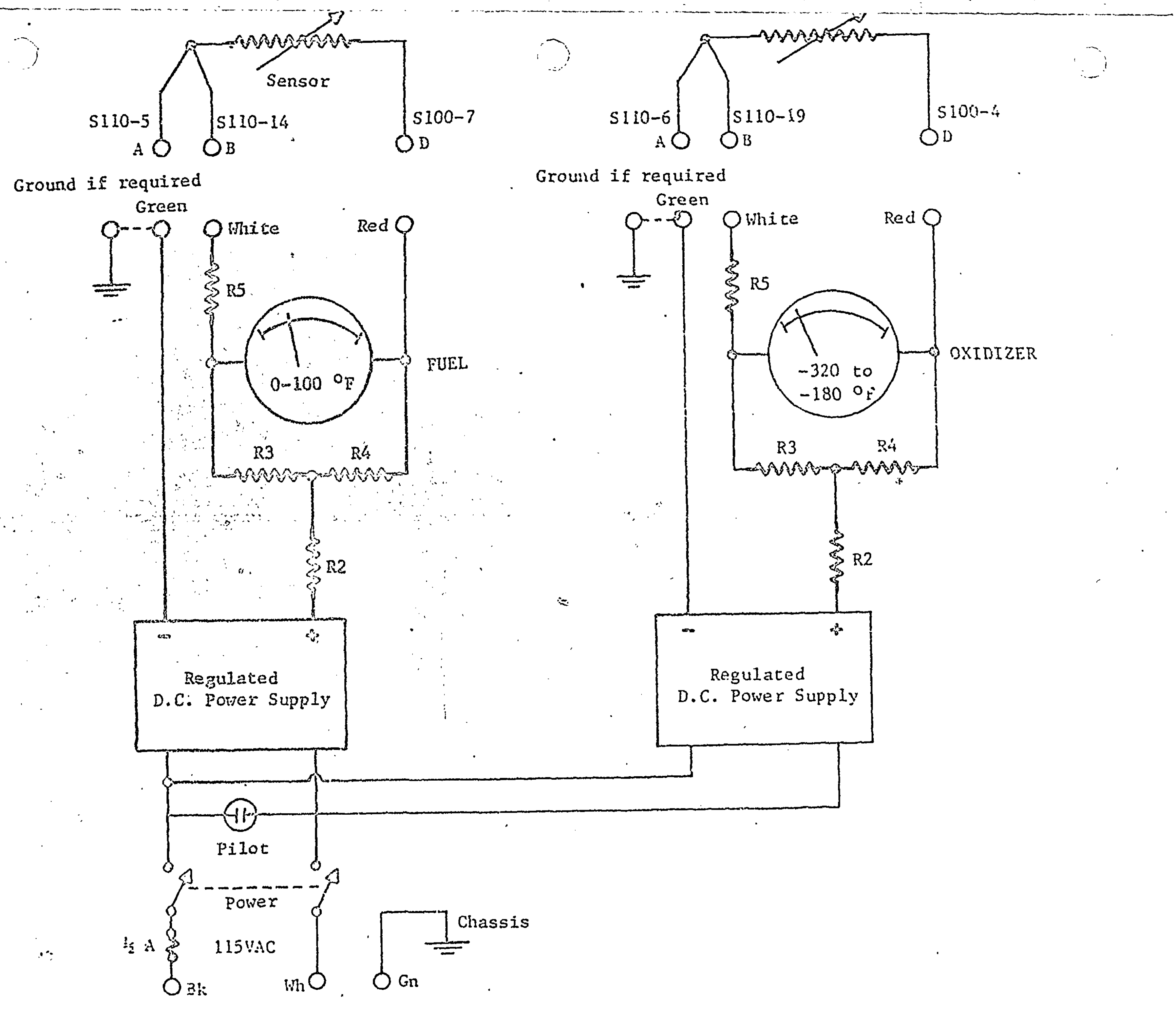


Figure 22.- Checkout, control, and monitoring console.


Range
X1
X10
X100
X1000
20mv
9K
100K
1Meg
R2
1K
R1
Push to zero
R
Input
B
10Meg
FET amplifier
1K zero
IN645 (2)
50 µa
2K calibration
Meter switch
Output
R
B
G
Chassis
IN4002 (4)
Stancor TP-2
G
Y
R
Bk-W
Pilot
Bk-R
Power
Fuse ½ A
Bk
Wh
Gn
Chassis
160 Ω 1w.
500 50V.
500 50V.
160 Ω 1w.
+15V.
IN3023
Common
IN3023
-15V.
115 V 60 Hz


Sensor
S110-5
A
S110-14
B
S100-7
D
S110-6
A
S110-19
B
S100-4
D
Ground if required
Green
White
Red
R5
0-100 °F
FUEL
R3
R4
R2
Ground if required
Green
White
Red
R5
-320 to -180 °F
OXIDIZER
R3
R4
R2
Regulated D.C. Power Supply
Regulated D.C. Power Supply
Pilot
Power
½ A
115VAC
Bk
Wh
Gn
Chassis

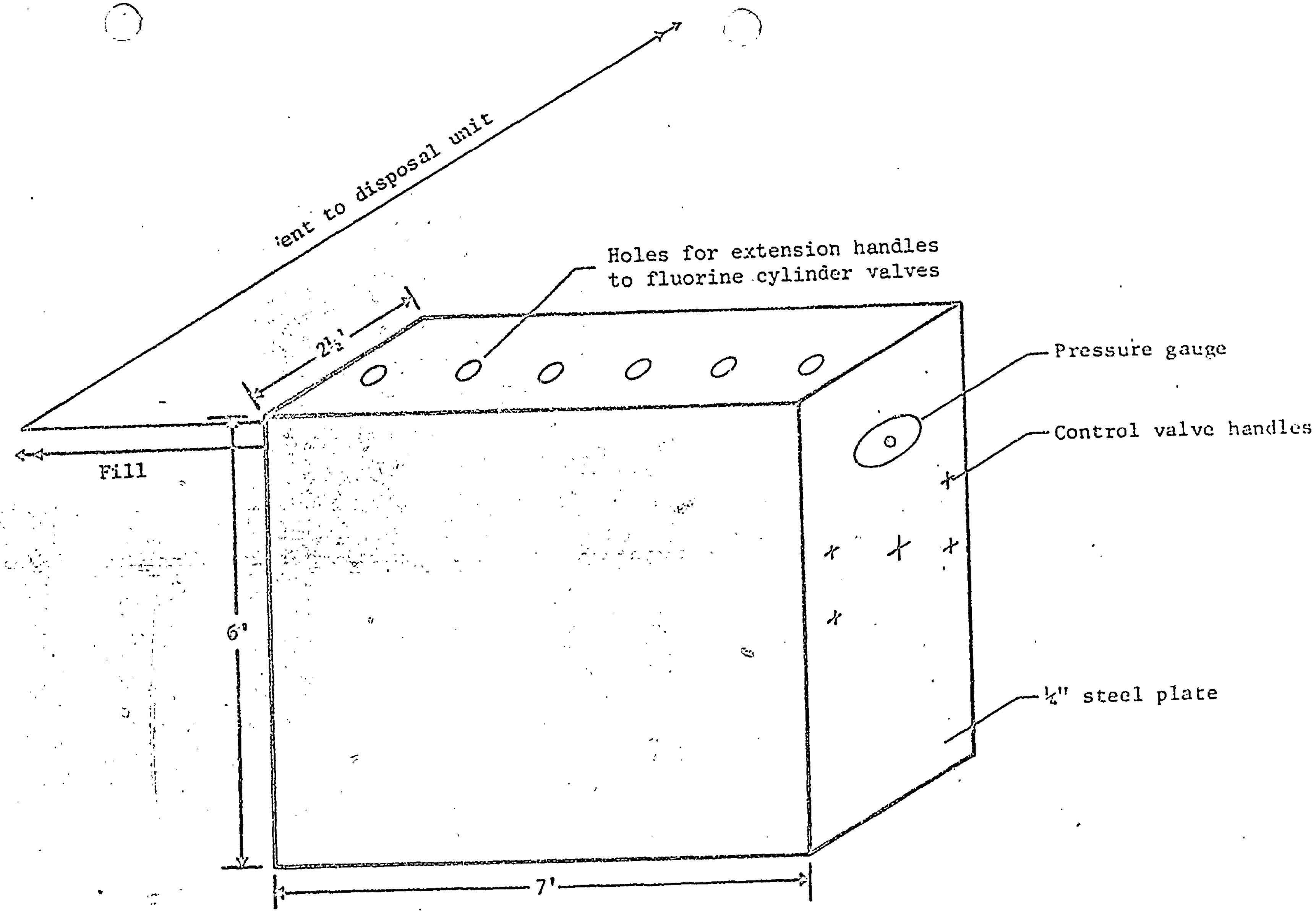


Figure 25.- Fluorine manifold shield.

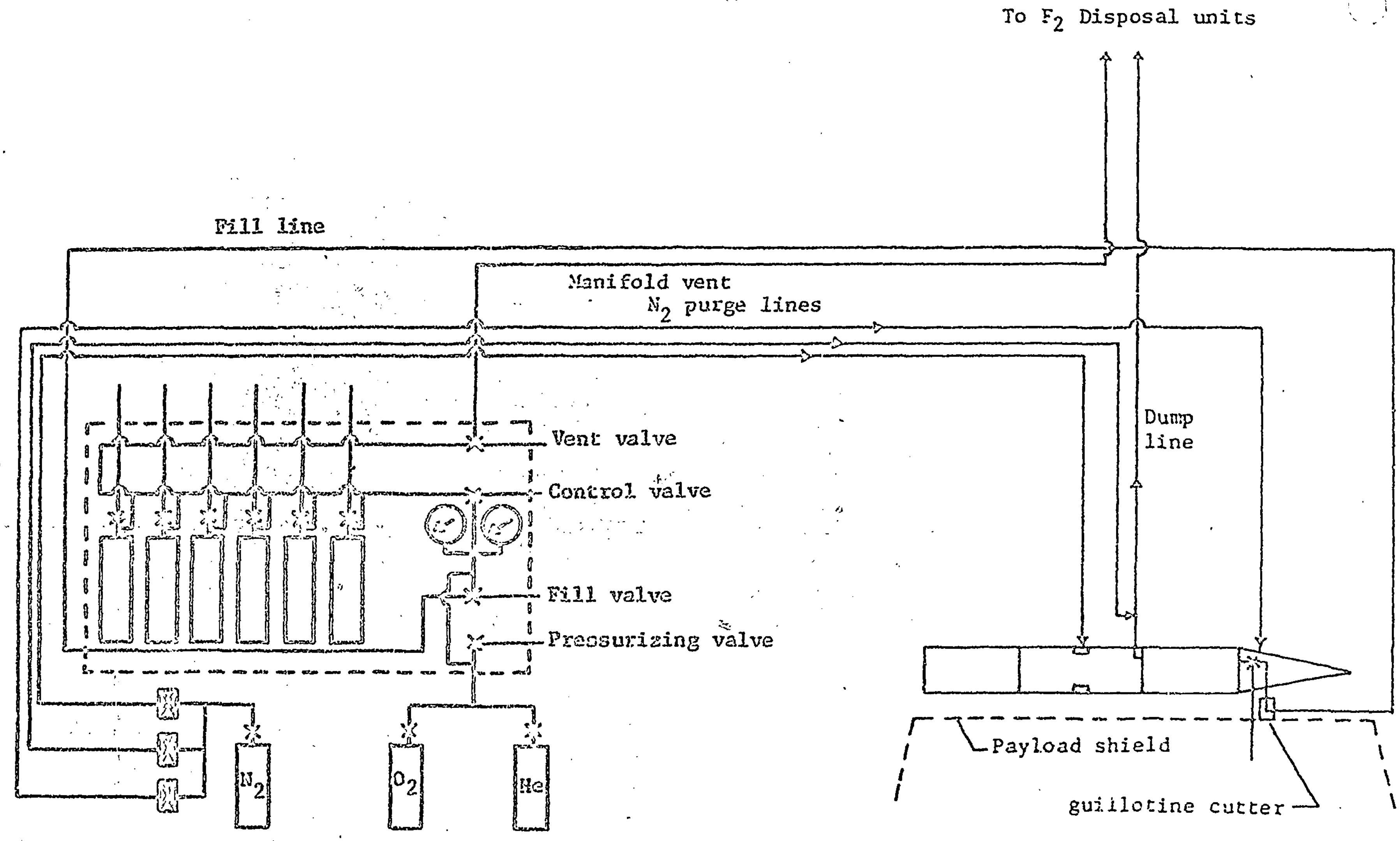


Figure 26.- Fluorine system piping diagram.

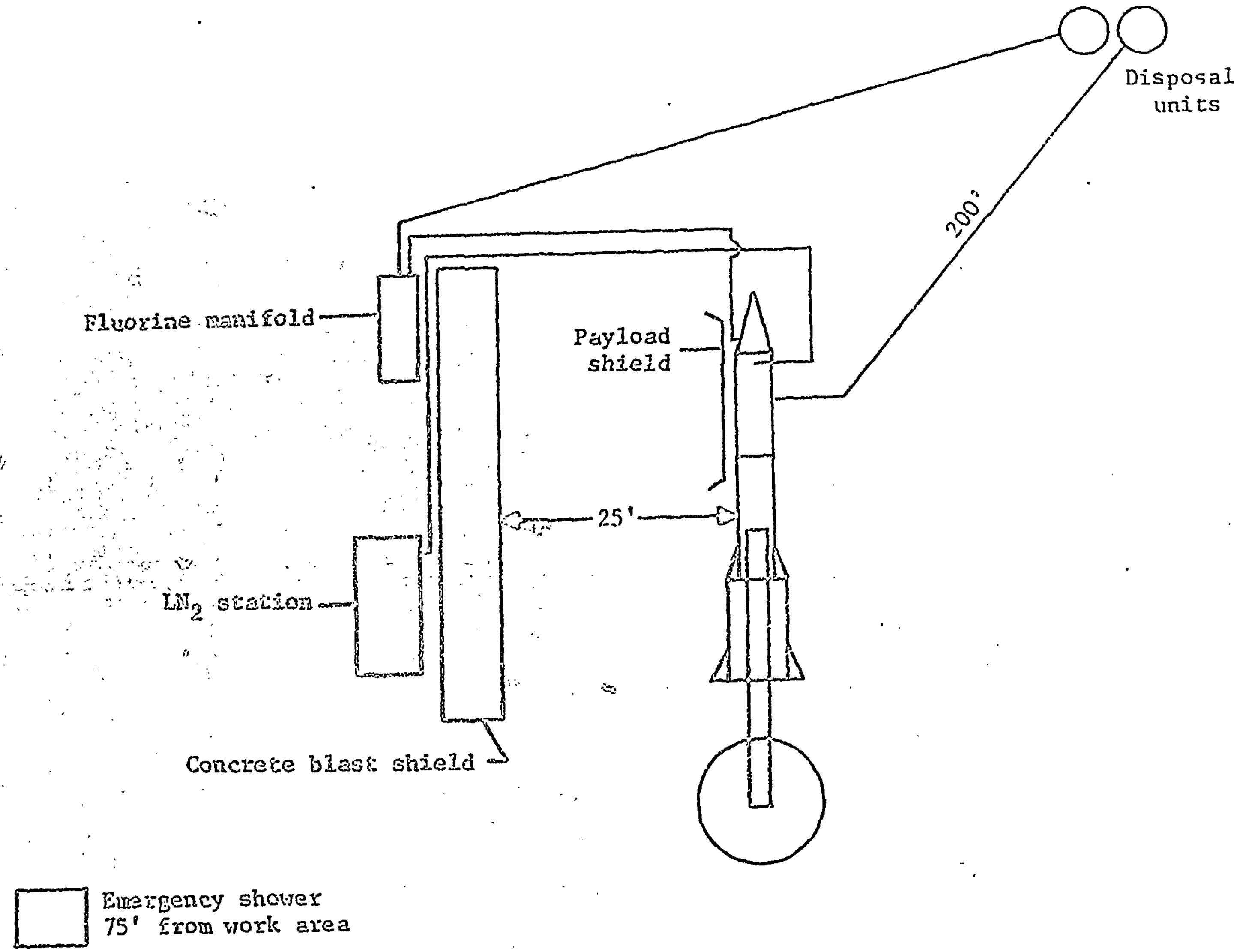


Figure 27.- Launch area layout.

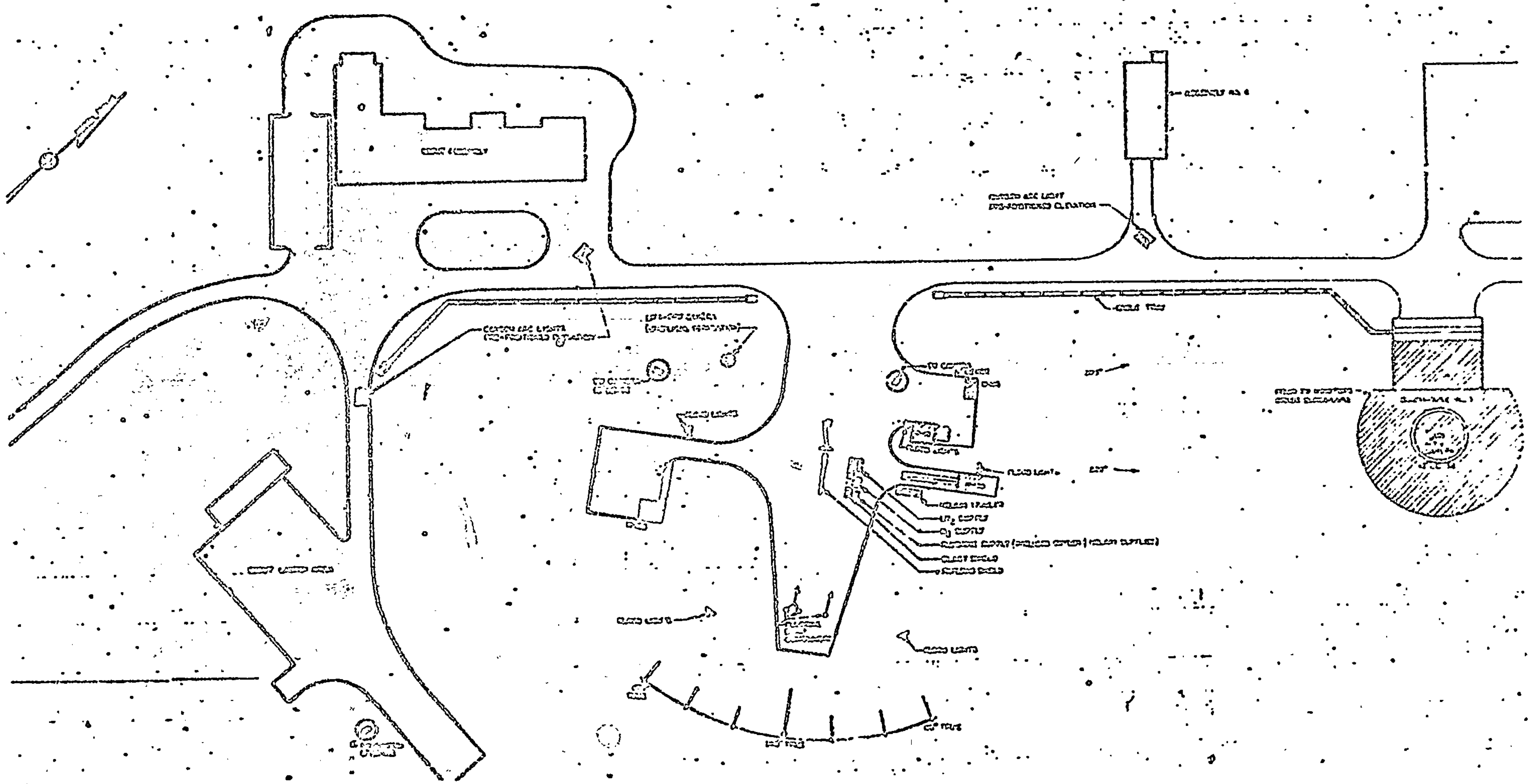


Figure 28.- Launch area layout.

TABLES

TABLE I

PHYSICAL PROPERTIES OF BARIUM SALTS

Formula	Chloride $BaCl_2$	Nitrate $Ba(NO_3)_2$
Color & Crystalline Structure	Colorless flat	White
Molecular Weight	208.27	261.38
Melting Point, °C	962	592
Boiling Point, °C	1560	Decomposes
Density, g/cc	3.856 (24°C)	3.24 (23°C)

TABLE II - PAYLOAD LENGTH, In.

Nose Ogive	33.00
Oxidizer Tank	22.50
Burner Section	31.50
Fuel Tank	12.31
Second-stage Firing Module	6.63
Total Payload Length	105.94

TABLE III - PAYLOAD WEIGHT, lb

Fuel Tank - Pressure transducer, temperature transducer, fill valve and cap and 1" explosive valve	24.25
Nose Ogive	16.87
Burner	11.00
Oxidizer Tank - 2-½" explosive valves, 1-1" explosive valve, temperature transducer, pressure transducer, fill valve and fittings, insulator, adaptor	36.39
Burner Skin and Umbilical Brace	25.75
Programmer and Connectors	7.37
Battery	1.87
Plate Separator	0.94
Valve Holders	4.33
Dump Tubes	0.62
Cables	0.63
Screws and Fittings	2.10
Firing Module	12.88
	145.00
Chemicals	30.00
Total Payload Weight	175.00

TABLE IV - OXIDIZER TANK SPECIFICATIONS

Material - Type 6061-T6 Aluminum with machined, dished heads

Ultimate Strength - 45,000 psi

Yield Strength - 40,000 psi

Joint Efficiency - 100% - Welds fully radiographed

Working Pressure (max.) - 1,000 psi; safety factor 4.7:1

Burst Pressure - 4,710 psi (5,510 psi @ -320°F)

Yield Pressure - 3,710 psi (4,410 psi @ -320°F)

Tank Volume - 604 in^3 with 50% ullage for 17 lbs LF_2

Tank Dimensions - 22.50" length; 9" O.D.; 1-1/16" annular space for LN_2 jacket

TABLE V - INSULATOR MATERIAL SPECIFICATIONS

Material - Grade G-3 phenolic base, continuous filament, glass fabric

Tensile Strength -	Lengthwise	23,000 psi
	Crosswise	20,000 psi
Compressive Strength -	Flatwise	50,000 psi
	Edgewise	17,000 psi
Modulus of Elasticity -	Lengthwise	1.5×10^6 psi
	Crosswise	1.2×10^6 psi
Shear Strength -		18,000 psi
Specific Gravity -		1.65
Coeff. of Thermal Expansion -		1.0×10^{-5} in/in/°F
Thermal Conductivity -		0.17 BTU/hr/ft^2/°F/ft

TABLE VI - FUEL TANK SPECIFICATIONS

Material - Type 6061-T6 aluminum

Ultimate Strength - 45,000 psi

Yield Strength - 40,000 psi

Shear Strength - 30,000 psi

Modulus of elasticity - 10×10^6 psi

Modulus of rigidity - 3.8×10^6 psi

Poisson's ratio - 0.33

Thermal conductivity - 96 Btu/hr/ft^2/^{o}F/ft

Coefficient of thermal expansion - 13.0×10^{-6} in/in/^{o}F

Joint Efficiency - 100% - Welds fully radiographed

Working Pressure (max.) - 1,000 psi; safety factor 2.7:1

Burst Pressure - 2,700 psi

Yield Pressure - 2,400 psi

Tank Volume - 530 in^3 with 50% ullage for 13 lbs. of "B-Mix"

Tank Dimensions - 12-5/16" length; 9" O.D.

TABLE VII - SKIN SCREW SPECIFICATIONS

Description - Screw - Machine, Flat Head, 100° Countersink

Standard - AN 509; P/N 416R10

Head - Cross Recess, Type I or II Drive

Material - Steel, Cadmium plated

Tensile Strength - 4,520 lb min

Stress - 125,000 psi

Thread - ¼ - 28 UNF - 3A

TABLE VIII - JOINT SCREW SPECIFICATIONS

Description - Screw, Cap, Socket Head

Standards - MS 16995 thru MS 16998
MS 24673 thru MS 24678
NAS 1351, NAS 1352

Head - Hexagon socket

Material - Heat treated alloy steel

Tensile Strength - 6,910 lb min

Stress - 190,000 psi

Thread - ¼ - 28 UNF - 3A

TABLE IX - SCREW TORQUE SETTINGS

Screw Type	Failure Torque, in-lb	Torque Used, in-lb
10-32 Socket Head	--	70
¼ - 28 UNF Socket Head	--	120
¼ - 28 UNF Flat Head	153	75
Valve Holder Screws	--	50
Valve Holder Locking Screws	--	75

TABLE X - BURNER MATERIAL SPECIFICATIONS

Material - Type 6061-T6 aluminum

Ultimate Strength - 45,000 psi

Yield Strength - 40,000 psi

Shear Strength - 30,000 psi

Modulus of elasticity - 10×10^6 psi

Modulus of rigidity - 3.8×10^6 psi

Poisson's ratio - 0.33

Specific gravity - 2.70

Thermal Conductivity - 96 BTU/hr/ft^2/$^\circ$F/ft

Coefficient of thermal expansion - 3.0×10^{-6} in/in/$^\circ$F

TABLE XI

BURNER DESIGN PARAMETERS

Fuel Side	
Flow	
Start, lb/sec	8.0
End, lb/sec	5.0
Average, lb/sec	6.5
Tank Pressure	
Start, psi	500
End, psi	165
Oxidizer Side	
Flow	
Start, lb/sec	10.2
End, lb/sec	6.5
Average, lb/sec	8.5
Tank Pressure	
Start, psi	600
End, psi	203
Chamber Pressure	
Start, psi	150
End, psi	75
Flow Orifice Pressure Drop	
Start, psi	150 - 180
End, psi	60 - 70

TABLE XII - FITTING TORQUE SETTINGS, IN-LB

Fitting Type		
37° Flare		
1" Aluminum M to Steel F	--	1980
¼" Steel M to Aluminum F	--	146
¼" Steel M to Steel F	--	146
¼" Steel M to Brass F	--	146
¼" Aluminum M to Brass F	--	146
¼" Aluminum M to Steel F	--	146
¼" Brass M to Brass F	--	146
Swage Type		
3/8" Steel M to Steel F	--	110
3/8" Aluminum M to Steel F	--	240
¼" Steel M to Steel F	550	146
¼" Aluminum M to Steel F	--	146
¼" Brass M to Brass F	280	146
¼" Steel M to Brass F	290	146
Steel M to Brass F (ferrules)	--	65
Pipe		
¼" NPT Steel M to Aluminum F	--	360

M = Male fitting

F = Female fitting

TABLE XIII - EXPLOSIVE VALVE SPECIFICATIONS

Cartridge

Bridge: 1 amp, 1 watt, 1.1 ± 0.1 ohm (using no external resistors or internal wire wound configurations) Dual bridge wires (A-B, C-D)

Initiator: No-fire static charge of 8KV from pin to case

Cartridge: Fire between $-320^{\circ}F$ and $+125^{\circ}F$ at 1×10^{-5} torr pressure

Body Assembly

Material: Type 2219-T6 aluminum body

Fitting ends: 37° flared tube fittings

Working pressure: 1000 psi

Proof pressure: 2000 psi

Burst pressure, closed port shear fitting: 5000 psi

Leak rate through closed port: 1×10^{-6} scc/sec He at 1000 psi

Actuation time: 75 ms maximum

Cleaning procedure: All valve parts, excluding cartridge, cleaned for oxygen service and bagged.

TABLE XIV

PART I - PAYLOAD QUALIFICATION TESTS

(a) Shock

Two shock pulses along thrust axis, 100 g (±10 g) peak amplitude, ramped sawtooth or ½ sine wave pulse shape, 6 (±.6) ms duration.

(b) Vibration

Sinusoidal:

Axis	Frequency Range, cps	Amplitude, g	Sweeprate,
Thrust	20 - 70	0.03 in. D.A.	2 oct/min
	70 - 2000	±7.5	2 oct/min

Random:

Axis	Frequency Range, cps	PSD Level, g^2/cps	Accel., g-rms.	Duration, Sec
Thrust	20 - 2000	.028	7.5	40

PART II - COMPONENT QUALIFICATION TESTS

(a) Shock

One shock pulse, ramped sawtooth or ½ sine wave pulse of 6 (±.6) ms duration, 100 g (±10 g) peak amplitude. (MIL STD-810)

(b) Vibration

Sinusoidal:

Axis	Frequency Range, cps	Amplitude, g	Sweeprate,
Thrust,	20 - 100	0.04 in. D.A.	2 oct/min
Normal, and	100 - 200	±20	2 oct/min
Transverse	200 - 2000	±20	2 oct/min

Random:

Axis	Frequency Range, cps	PSD Level, g^2/cps	Accel., g-rms.	Duration, Sec
Thrust, Normal, and Transverse	20 - 2000	0.028	7.5	40

TABLE XV - SPIN TEST SUMMARY

Tank	Initial Set Pressure lb/in^2	rev/sec	Medium and Charge wt, lb	Release Time, sec	Equivalent of Propellant Remaining lb	%
Oxidizer	250	22	H_2O-10.9	1.86	0.37	2.18
	320	16.5	LOX-13.1	2.00	0.40	2.35
Fuel	612	22	H_2O- 9.57	1.16	0.17	1.31

TABLE XVI - SLOSH - CONING TEST SUMMARY

FUEL TANK

Test No.	Spin Rate, cps	Coning Angle, deg	Coning Period, sec	Pounds of Fuel or % Ullage	Time from start to formation of parabola
1	6	6	25	13 lb	(not recorded)
2	6	6	25	50%	
3	7	6	25	50%	
4	5	6	25	50%	
5	5	6	12½	50%	
6	5	4	25	50%	
7	6	4	25	50%	
8	6	4	25	66%	
9	6	4	25	75%	

Note: (1) 38% sugar-water solution used to simulate hydrazine/barium salts solution

OXIDIZER TANK

Test No.	Spin Rate, cps	Coning Angle, deg	Coning Period, sec	Pounds of Fuel or % Ullage	Time from start to formation of parabola
1	6	6	25	17 lb	23 sec
2	6	6	25	11½ lb; 50%	21 sec
3	5	6	25	50%	20 sec
4	7	6	12½	50%	19 sec
5	6	4	25	50%	13 sec
6	5	4	25	50%	15 sec
7	6	4	25	66%	16 sec
8	6	4	25	75%	17 sec

Note: (1) Boiling H_2O used to simulate fluorine oxidizer

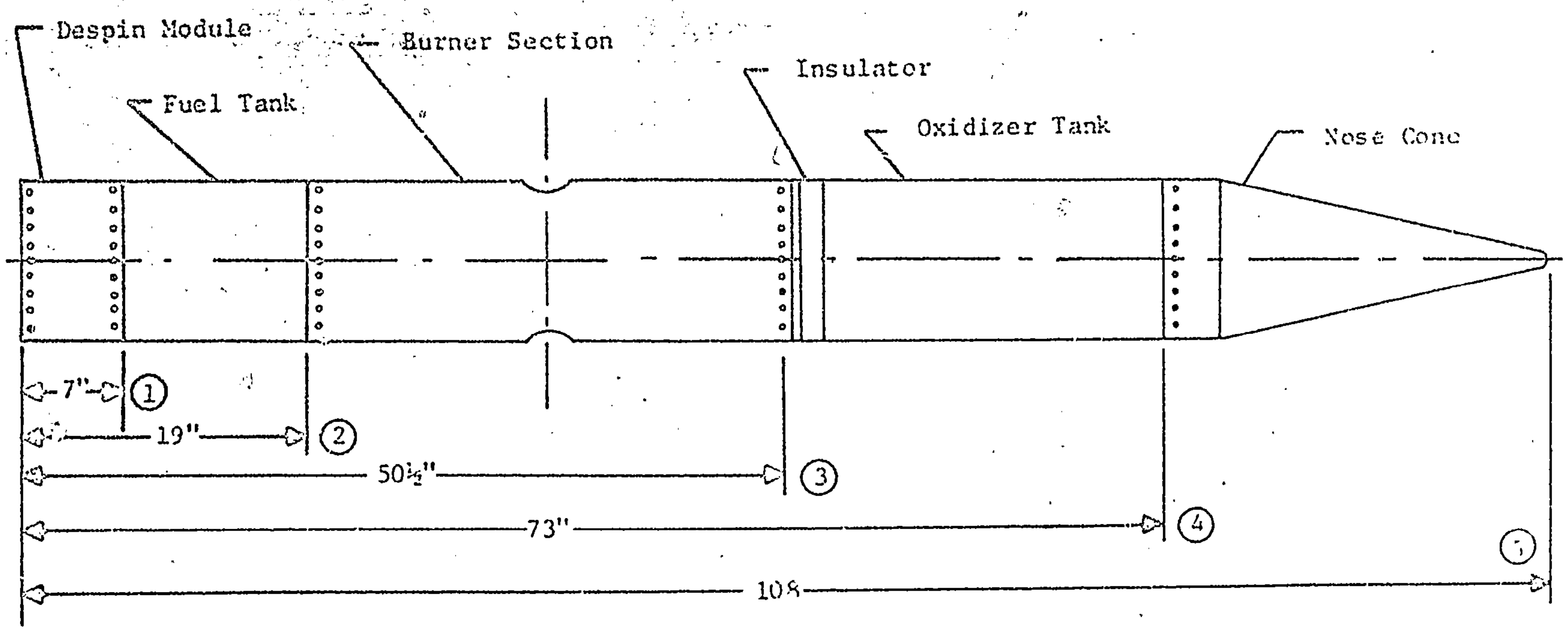
TABLE XVII - EXPLOSIVE VALVE TESTS

Valve S/N	Valve Size	Test Material	Charge	Firing Circuit	Tank Type	Tank Press. psia	Ave. Flow Rate, lb/sec (Time)	Press. Spike, psia	Valve Temp.	Torque, Valve Fittings, ft-lb	Valve Holder Used	Remarks
Original Configuration Valves (Single Ram Seal)												
1010-017	1"	"B mix"	13 lb	A-B and C-D	Flight	417	4.5	N.R.	Ambient	54	No	1" B-Nuts loose after run; valve movement; blow-by above flow ports.
1010-016	1"	"B mix"	13 lb	C-D	Flight	618	5.4	N.R.	Ambient	54	No	1" tank exit tube deformed; 1" B-Nut loose after run; blow-by
1010-014	1"	LF_2	16 lb	A-B and C-D	Boiler Plate Tank	417	6.9 (14.0 ms)	N.R.	-297°F (top)	65	No	Explosion at 140 ms after actuation; slight blow-by at ports.
1010-015	1"	LO_2	13 lb	A-B and C-D	Flight	595	5.4	N.R.	-275°F	100	Yes	Slight leak at inlet fitting; 1" B-Nuts loose after run; blow-by above port.
Air Operated Globe	3/4"	LF_2	6.15 lb	---	Flight	515	3.4	N.R.	N.R.	160	---	System check
Refitted Valves (Dual Ram Seal)												
1010-007	1"	LF_2	5.54 lb	A-B	3000 cc SST	520	5.8 (500 ms)	968 up 837 down	Ambient (-32°F)	165	Yes	Valve actuated satisfactorily.
1010-008	1"	LF_2	17.6 lb	A-B	Flight	510	5.4	Trans. failed	N.R.	165	Yes	Valve actuated satisfactorily.
1010-019	1"	LF_2	18.9 lb	A-B	Flight	535	Appr. 5.8 (Flow meter failed)	Trans. failed	-110°F (top)	165	Yes	Valve actuated satisfactorily.
1010-009	1"	LF_2	16.5 lb	A-B	Flight	505	5.7	745 down (piezo)	-20°F Top -75°F Side	165	Yes	Heater used ([illegible] watts [illegible]); glass wool around valve; valve actuated satisfactorily.
1010-013	1"	LF_2	19 lb	A-B	Flight	515	5.4	None	-36°F Top -52°F Side	165	Yes	Flight type heater tested satisfactorily; valve heater used on ex. valve [illegible] ([illegible]); glass wool used; valves actuated satisfactorily.
1010-006 (Not refitted)	1"	"B mix"	13 lb	C-D	Flight	462	Appr. 4.7 (Flow meter failed)	N.R.	Ambient	165	Yes	

TABLE XVIII

SUMMARY OF BEND TESTS

Test No.	Burner Axis Orientation	Type of Load	Deflection Due to Load mil, Station 1	2	3	4	5	"Set" Due to Repeated Application of Load mil, Station 1	2	3	4	5
1	Vertical	200 lb	16	39	127	200	308	0	0	0	2	2
2	Horizontal	200 lb	16	39	117	184	284	0	0	2	3	[illegible]
3	Vertical	1.75 g	5	10	26	35	49	0	0	0	0	0
4	Horizontal	1.75 g	4	10	24	34	47	[illegible]	0	0	0	0



LOCATION OF DIAL GAGE STATIONS

TABLE XVII - EXPLOSIVE VALVE TESTS (continued)

Valve S/N	Valve Size	Test Material	Charge	Firing Circuit	Tank Type	Tank Press. psia	Ave. Flow Rate, lb/sec (Time)	Press. Spike, psia	Valve Temp.	Torque, Valve Fittings, ft-lb	Valve Holder Used	Remarks
1033-001	1"	LF_2	17 lb	A-B and C-D (Flt. Programmer)	Prototype	605	8.5	N.R.	-270°F	165	Yes	Prototype firing; all e[illegible] operated satisfact[illegible]; [illegible] blow-b[illegible] in both valves; [illegible] wool used; [illegible] of payload; [illegible]
1033-003	1"	"B mix"	13 lb	A-B and C-D (Flt. Programmer)	Prototype	537	6.5	N.R.	58°F	165	Yes	
1045-004	1"	"B mix"	2.6 lb	A-B and C-D	Prototype	552	N.R.	N.R.	75°F	165	Yes	Vacuum test; did not fire [illegible] to low power in firing circuit.
1045-005	1"	LF_2	3.4 lb	A-B and C-D	Prototype	542	8.5 (400 ms)	N.R.	-270°F	165	Yes	Vacuum test; valve fired at low power; released LF_2 into vacuum tank.
1045-004	1"	"B mix"	2.6 lb	A-B and C-D	Prototype	552	6.5 (400 ms)	N.R.	75°F	165	Yes	Successful vacuum firing.
1045-007	1"	LF_2	3.4 lb	A-B and C-D	Prototype	542	8.5 (400 ms)	N.R.	-270°F	165	Yes	Successful vacuum firing.
Dump Valves										in-lb		
1020-042 1010-044	½" ¼"	LF_2	15.5 lb	C-D 6.9 A. A-B 3.6 A.	Flight	490	(2 min)	None	-145°F -160°F	146	No	Valves actuated satisfactorily; disposal unit intact.
1010-030 1010-035	½" ¼"	LF_2	17.0 lb	A-B 8.4 A. C-D 4.3 A.	Flight	565	(2 min-34 sec)	None	-155°F -140°F	146	No	Valves actuated satisfactorily; disposal unit intact; plywood lid used.
1010-051 1010-038	½" ¼"	LF_2	7.0 lb	Flt. Programmer 5.2 Amp.	Flight	500	(3½ min)	N.R.	N.R. N.R.	146 145	No	Gas dump; valves actuated satisfactorily.
1010-003 1010-002	½" ¼"	LF_2	6.0 lb	AB-CD None	Flight	515	(45 min)	N.R.	-95°F	146	No	Gas dump; 1010-003 only fired; 1010-002 fired after tank [illegible] clean; valves actuated satisfactorily.
1044-021 1044-022	½" ¼"	LOX	13.1 lb	AB-CD AB-CD	Prototype	590	(10 min)	N.R.	N.R.	146	No	Practice count down at Wallops Island; system [illegible]; valves actuated satisfactorily.

N.R. = Not recorded

TABLE XIX

PART I - PAYLOAD FLIGHT ASSURANCE TESTS

(a) Shock

Two shock pulses along the thrust axis, 75 g (±7.5 g) peak amplitude, ramped sawtooth or ½ sine wave pulse shape, 6 (±.6) ms duration.

(b) Vibration (thrust axis only)

Sinusoidal:

Axis	Frequency Range, cps	Amplitude	Sweeprate
Thrust	20 - 70	.02 in. D.A.	6 oct/min
	70 - 2000	±5.0 g	6 oct/min

Random (Gaussian):

Axis	Frequency Range, cps	PSD Level, g^2/cps	Accel., g-rms.	Duration
Thrust	20 - 2000	0.013	5	20 sec

PART II - COMPONENT FLIGHT ASSURANCE TESTS

(a) Shock

One sawtooth or ½ sine wave pulse, 6(±.6) ms duration, at 75 g (±7.5 g) amplitude, along thrust axis. (MIL STD-810)

(b) Vibration

Axis	Frequency Range, cps	Amplitude	Sweeprate
Thrust	20 - 100	0.04 in D.A.	6 oct/min
Normal	100 - 200	± 10 g	6 oct/min
Transverse	200 - 2000	± 10 g	6 oct/min

Axis	Frequency Range, cps	PSD Level, g^2/cps	Accel. g-rms.	Duration
Thrust Normal Transverse	20 - 2000	0.013	5	20 sec

REFERENCES

1. Baber, H. F., Jr.; Crumbly, K. H.; and Adamson, D.; compilers: Barium Releases at Altitudes Between 200 and 1000 Kilometers, A Joint Max-Planck-Institute-NASA Experiment. NASA SP-264, 1971.

2. Stokes, C. S.; Smith, E. W.; and Murphy, W. J.: Development of a Barium Chemical Release System. NASA Contractor Report CR-1415, August 1969.

3. Schmidt, Harold W.: Handling and Use of Fluorine and Fluorine-Oxygen Mixtures in Rocket Systems. NASA SP-3037, 1967.

4. Chemical Propulsion Information Agency: Liquid Propellant Manual. December, 1966.

5. Endicott, D. L. and Donahue, L. H.: Development and Demonstration of Criteria for Liquid Fluorine Feed System Components. NASA Contractor Report CR-72543, June 1969.

APPENDIX

APPENDIX I

This appendix is a synopsis of the results obtained from the flight test of the liquid chemical barium release payload and analyses performed subsequent to the flight test.

Vehicle Performance

Table A1 summarizes the Nike-Tomahawk rocket performance in terms of flight parameters at the time of release. From the table it can be seen that vehicle performance was quite close to pre-flight prediction with release occurring within 0.10° longitude, 0.12° latitude and 2 km altitude of the expected location. Accuracy of release time was well within the quoted accuracy of ±6 sec for the mechanical timer.

Payload Results

Although the release was seen with the unaided eye at Baltimore, MD and Coquina Beach, NC as well as at Wallops Station, VA the intensity and persistence of the subsequent cloud were much lower than expected. Figure A1 is a view of the release obtained by a K-37 camera (exposure from T + 227 sec. to T + 233 sec.) at Coquina Beach, NC.

Cloud growth as a function of time was measured from enlargements of 35mm motion pictures of image orthicon video tape data. These results are shown on Figure A2. The initial expansion rate was about 1.8 km/sec. Estimated root mean square velocity (1.92 km/sec) using average molecular weight of expected combustion products agrees well with the observed expansion.

Figure A3 presents data in terms of photon flux measured with a photometer located at Coquina and operated by Dr. E. R. Manring of the Physics Dept. of North Carolina State University. Dr. Manring reported that the cloud expanded to 2 - 3 times the photometer field of view of 10°. This raw data was translated, by LRC personnel, into terms of ionized barium (Ba II) yield using the method of ref. 1, section VII. The yield from the liquid chemical barium release system is presented in Table A2, along with the Max-Planck-Institute solid system yields from a release at comparable altitude in 1966 and at much higher altitude (approx. 910 km) in 1970. An efficiency of 90 - 95% (based on available Ba) was expected from the liquid system.

Theoretical and actual ionization time histories are shown in Figure A4.

The low yield of Ba II, the slow rate of production, and the rapid, wide dispersion of the ion cloud were not what had been expected from ground-based tests of the liquid system and past flight experience with another type of Ba release system.

Heavier atoms such as Ba (m=137.34) and particles or droplets would achieve the same velocity as the main body of lighter molecules ($m_{avg} \simeq 21$), but they would travel greater distances before coming to equilibrium with the environment. This has previously been observed in the flow of metallized propellants. It is believed that particulate matter was formed in the release and traveled much greater distances than the lighter molecules. Assumption of formation of Ba containing particles (or droplets) and the greater dispersion thereof would explain why Ba ions were found over such a large region. The reason the total Ba ion density continued to increase over a long period of time rather than reaching a maximum very rapidly and slowly decaying is believed to be due to slow release of Ba+ from particles or droplets at ambient temperature. This low rate of production of Ba ions and rapid dispersion would account for the low yield observed. After due consideration of possible burner operating conditions (see Fig. A5), the case of O/F > 1.31 seems to be the condition which best fits the observed results. On the basis of payload conditions (pressure and temperature) at release, extrapolated from conditions at launch, it is believed that essentially all of the oxidizer and fuel were expelled, but for some reason which cannot be determined from this experiment, the O/F ratio was higher than required to obtain near optimum yield. Additional flight experiments with telemetered oxidizer and fuel flow measurements would be required to give a definite explanation for the observed results.

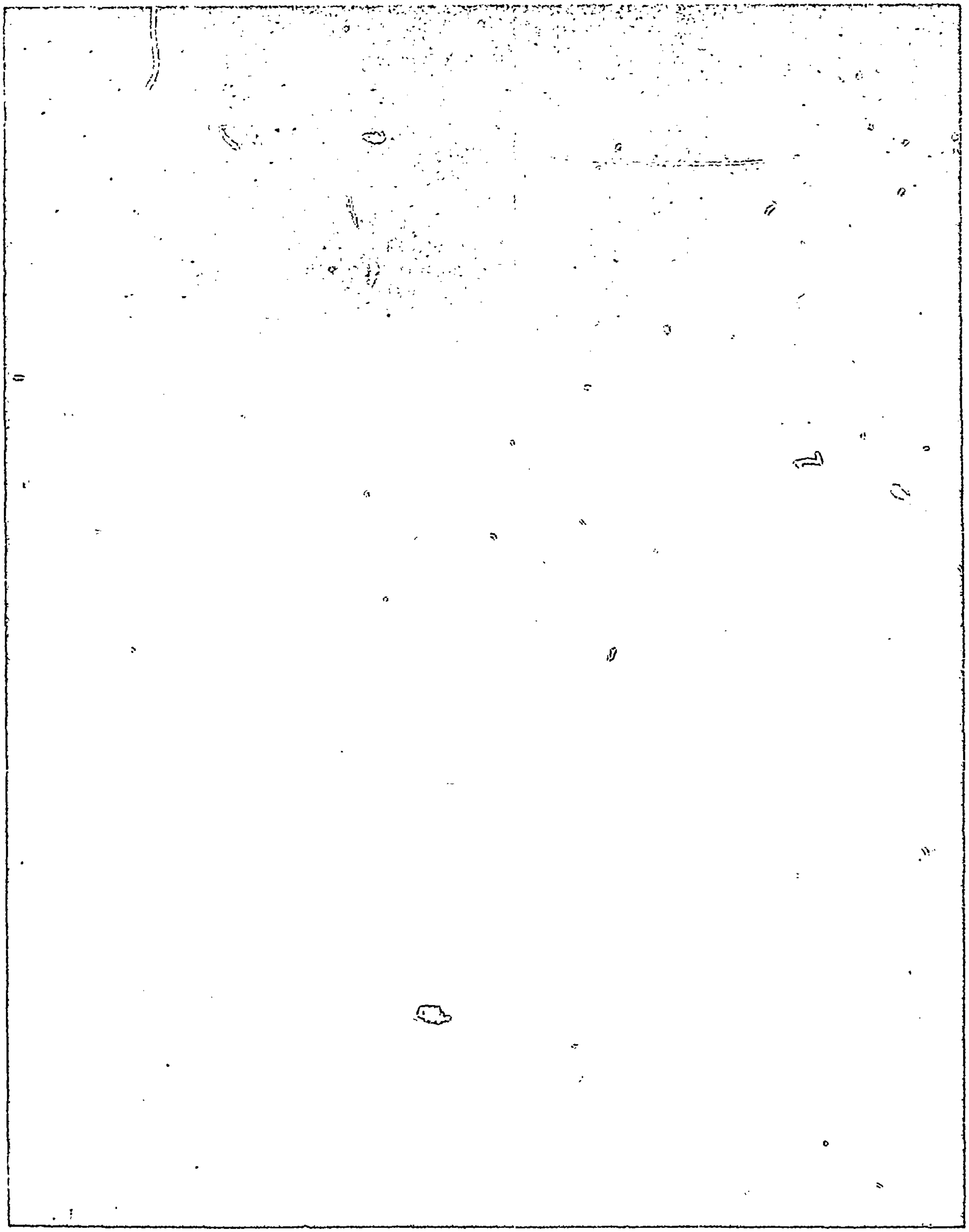


Figure A-1.- Barium ion cloud viewed from Coquina Beach, North Carolina.

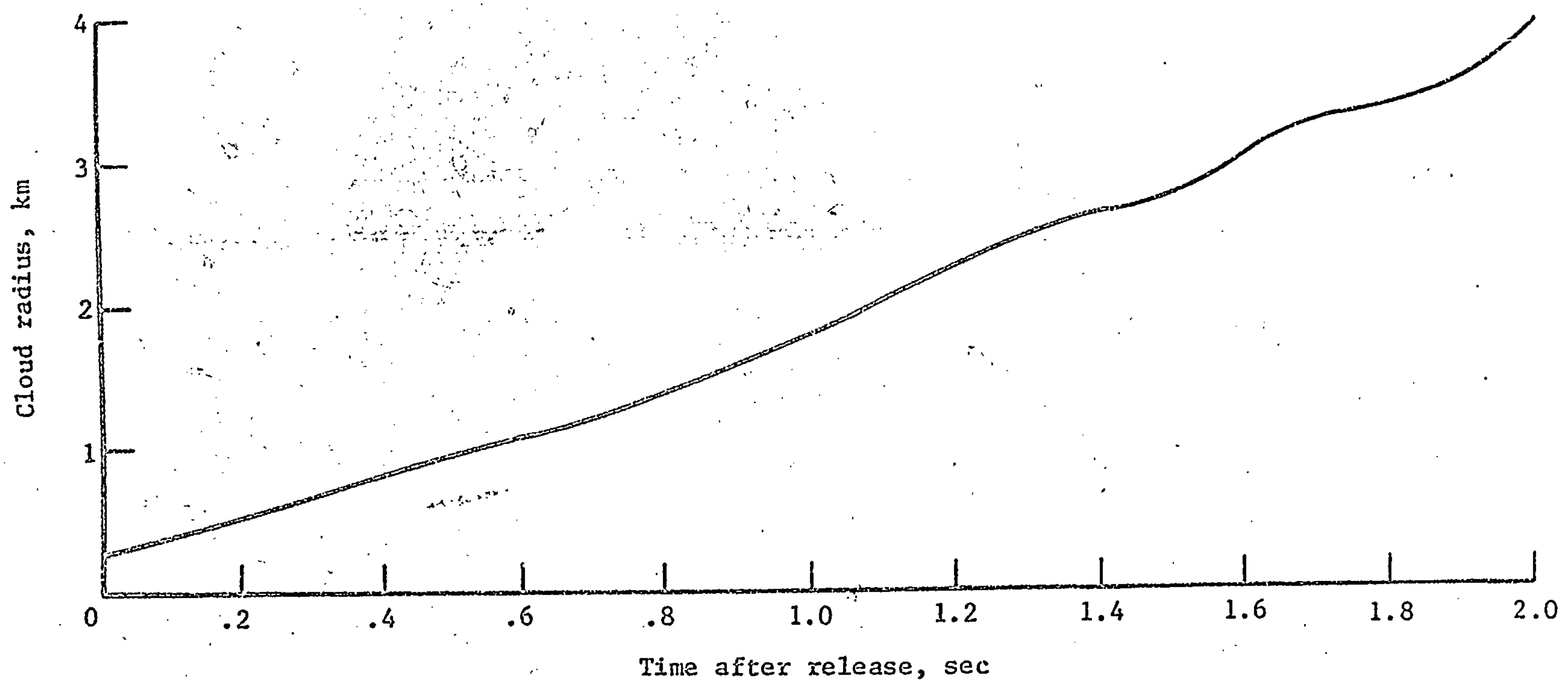


Figure A-2.- Barium ion cloud growth vs. time.

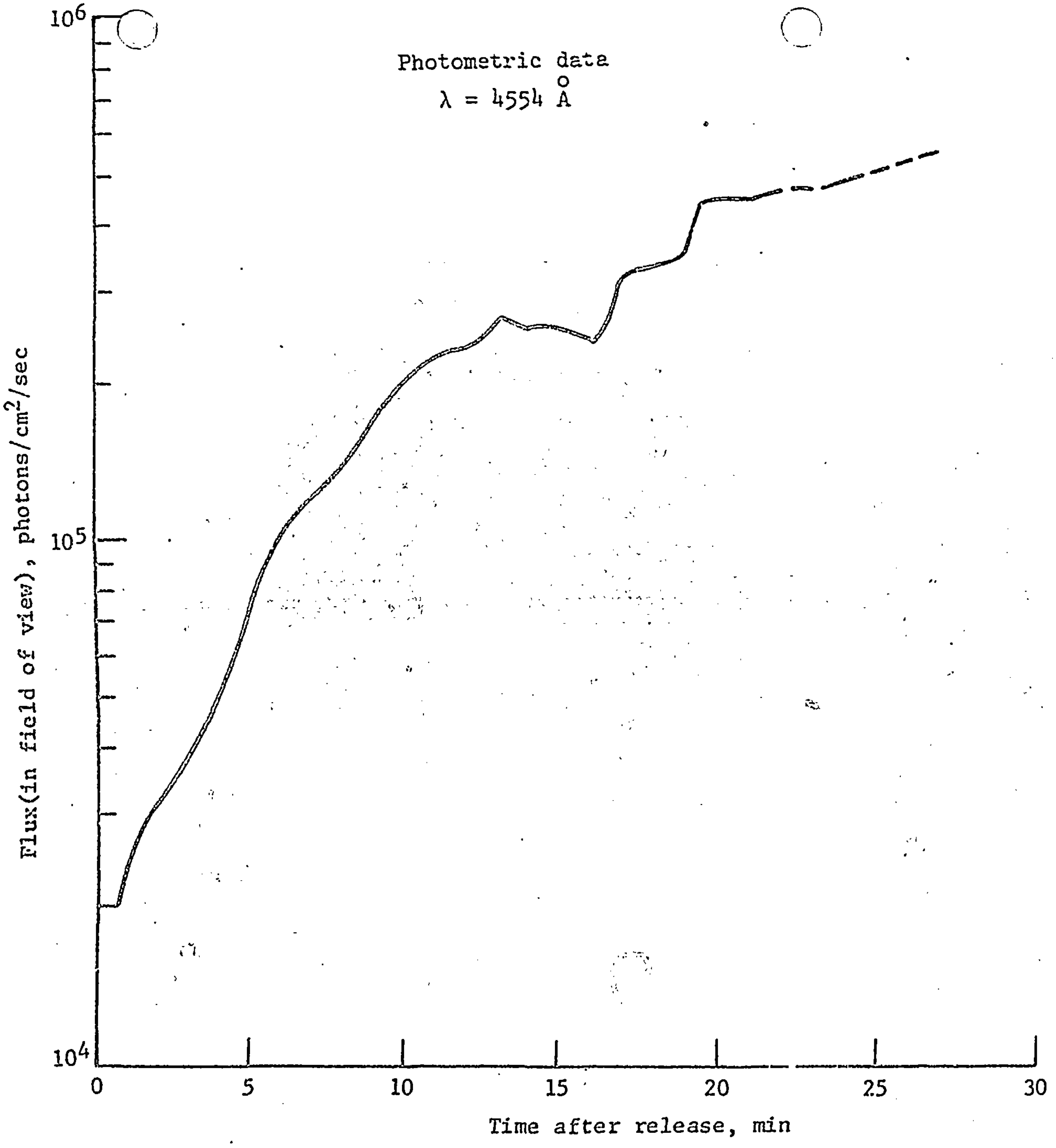


Figure A-3.- Photon flux measured vs. time.

Photon flux from Ba^+, 4554 Å in photons/cm^2/sec
against time after release in minutes

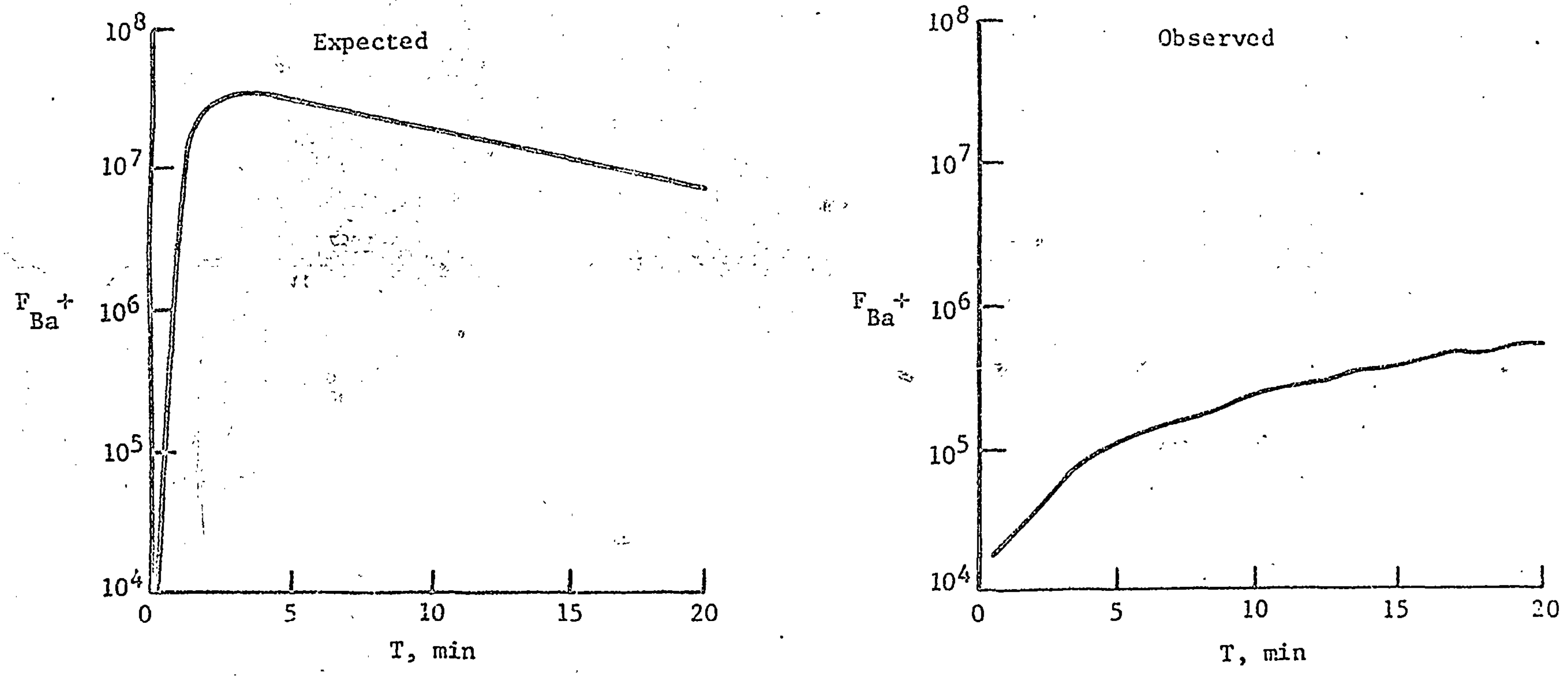


Figure A-4.- Theoretical and actual ionization time histories for liquid system.

Possible release modes and predicted flux-time

curve types for Ba^+, 4554 Å photons

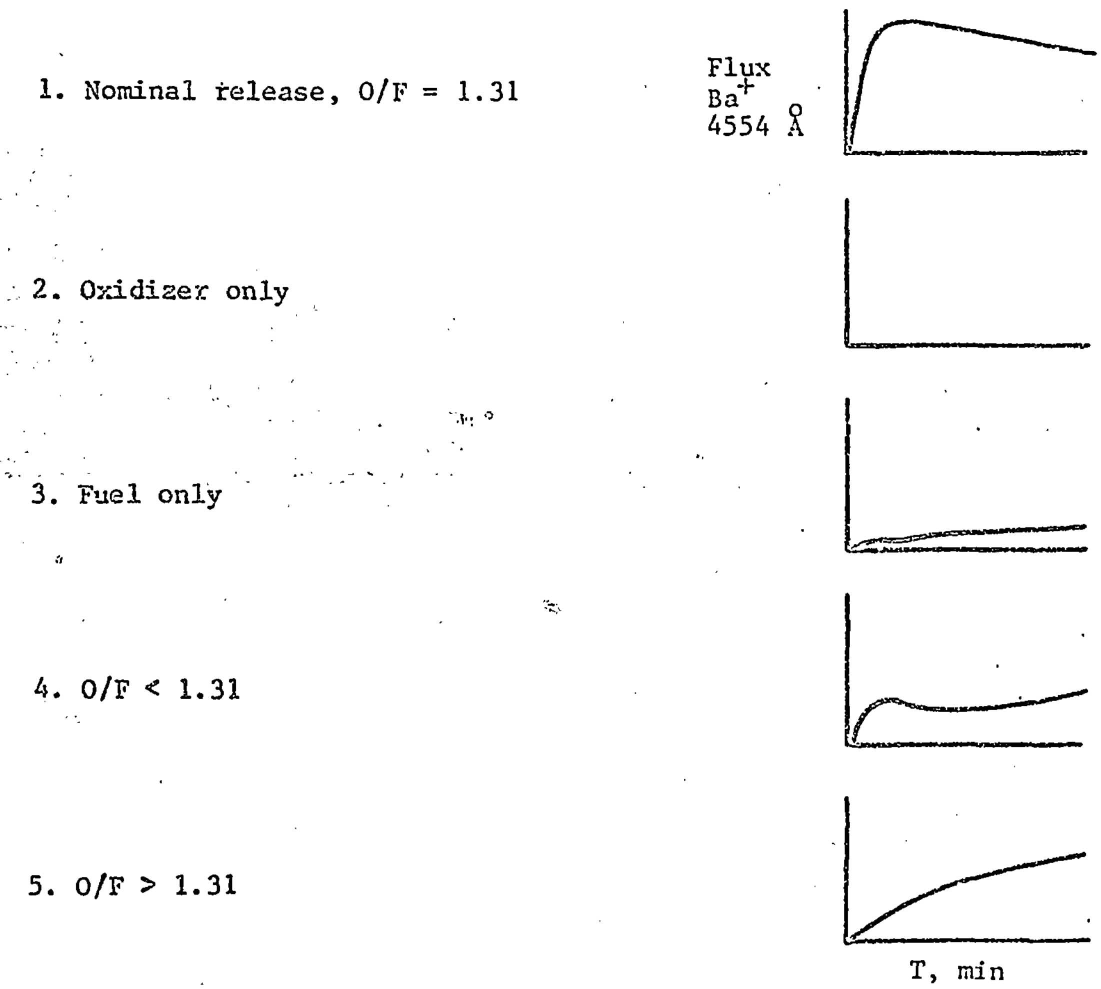


Figure A-5.- Possible release modes and predicted ionization time histories.

TABLE A1

VEHICLE PERFORMANCE IN TERMS OF
BARIUM RELEASE PARAMETERS

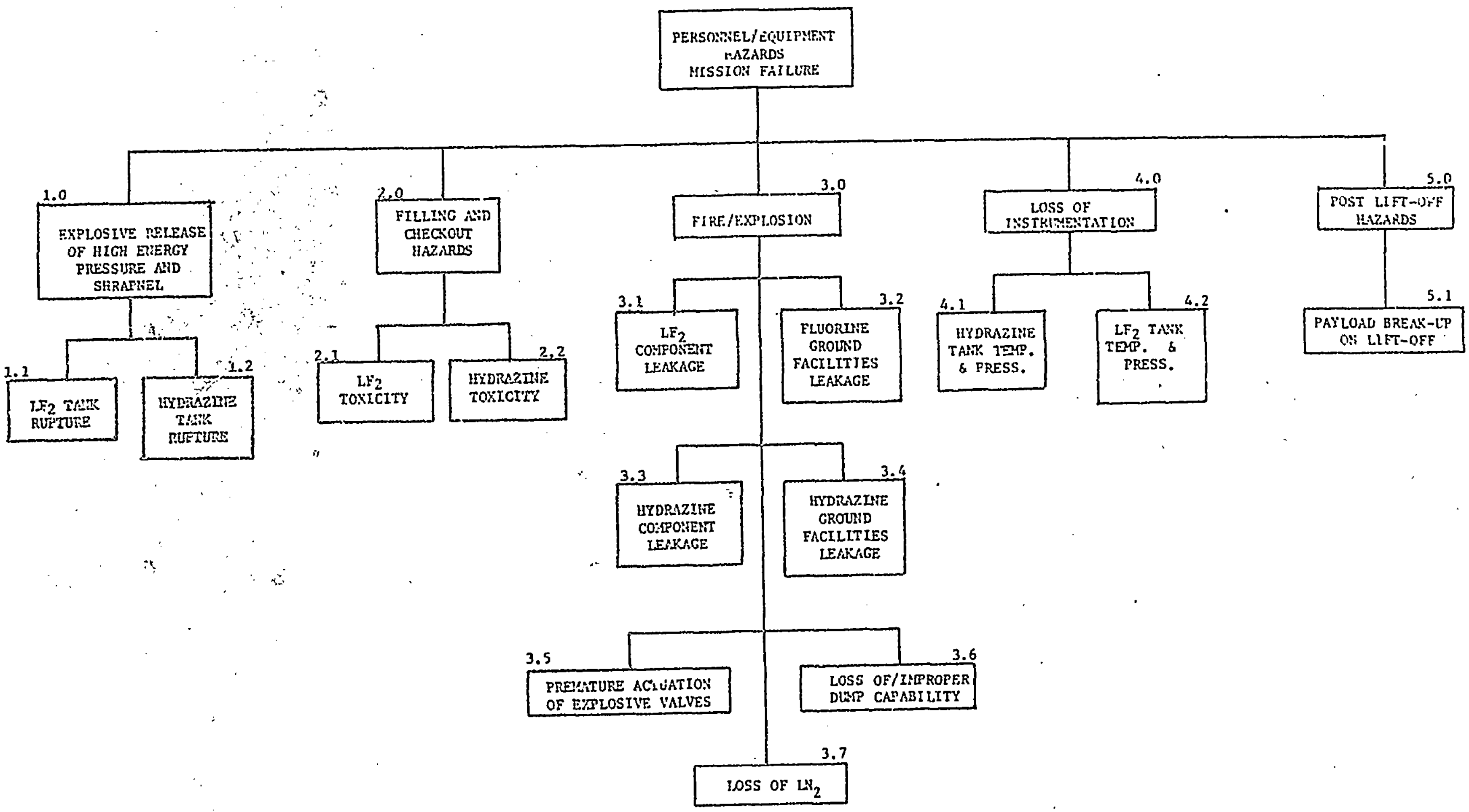
PARAMETER	EXPECTED	ACTUAL
TIME	T + 229 SEC	T + 227.5 SEC
ALTITUDE	853,200 FT. (260 Km)	859,468 FT. (262 Km)
COORDINATES:		
LATITUDE	37.375°	37.261°
LONGITUDE	-74.940°	-74.853°

TABLE A2

BARIUM RELEASE YIELDS

SYSTEM	CHEMICAL WT. Kg	YIELD WT. OF Ba IONS / CHEMICAL WT.	AVAILABLE Ba, % CHEMICAL WT.	EFFICIENCY
LIQUID CHEMICAL	13.63	.083 to .187%	8.52%	.97 to 2.20%
MPI '66 SOLID	10.02	.58%	28%	2.10%
MPI '70 SOLID (JAVELIN RELEASE)	16.50	7.27%	48%	15.0%

GROSS HAZARDS ANALYSIS



GROSS HAZARDS ANALYSIS

HAZARD	HAZARD POTENTIAL	HAZARD CLASS	CORRECTIVE ACTION RECOMMENDED	ACTION STATUS	REMARKS
1.0 Explosive release of high energy, pressure and shrapnel	1.1 Liquid fluorine tank rupture due to excessive pressure due to human error or reaction	II	None	Closed	The burst value of the tank is 4700 psig. Pressuring gases are available at 2200 psig. One tank was burst tested to 4700 psig. Tanks are proof tested to 1000 psig. Tanks are leak tested before and after installation. The flight tank will be fully passivated before delivery. The tank will be shipped with approximately 20 psig clean, dry helium pressure. Operating pressure is expected to be 500 psig.
	1.2 Hydrazine tank rupture due to excessive pressure due to human error or decomposition	II	None	Closed	The burst value of the tank is 2800 psig. Pressurizing gases are available at 2200 psig. One tank was burst tested to 2800 psi. Tanks are proof tested to 1000 psig. Tanks are leak tested before and after installation. Excessive pressure due to decomposition is unlikely since a relatively high temperature is necessary.

GROSS HAZARDS ANALYSIS

HAZARD	HAZARD POTENTIAL	HAZARD CLASS	CORRECTIVE ACTION RECOMMENDED	ACTION STATUS	REMARKS
2.0 Filling hazards	2.1 LF_2 toxicity/chemical hazards due to leakage or spillage	II	Retire from area	Closed	All fluorine fill operations are conducted with a shield between personnel and fluorine. A ½" thick steel closet encloses the gaseous fluorine manifold. A 3/8" steel shield shall separate personnel from the payload for the fill valve closing operation. The shielding will make direct fluorine impingement impossible. All personnel will wear protective clothing and face shields. Emergency showers will be close by. Wind direction during fill and launch will be considered.
	2.2 Hydrazine toxicity/chemical hazards due to leakage or spillage	II	Retire from area	Closed	Personnel will wear protective clothing and face shields. Emergency showers will be close by.

GROSS HAZARDS ANALYSIS

HAZARD	HAZARD POTENTIAL	HAZARD CLASS	CORRECTIVE ACTION RECOMMENDED	ACTION STATUS	REMARKS
3.0 Fire/ Explosion	3.1 LF_2 component leakage	II	After personnel have cleared the area, actuate ½" dump valves allowing fluorine to flow to disposal unit. Water fog nozzles used at discretion of Fire Dept.	Closed	Components are leak tested before and after installation. Components have been passivated before delivery to Wallops Island.
	3.2 Fluorine	II	Shut off fluorine supply if possible. Retire from area. Water fog nozzles used at discretion of Fire Dept.	Closed	Fluorine ground facilities plumbing is always pressure checked before opening fluorine cylinders.
	3.3 Hydrazine component leakage	II	Retire from area. Stop fluorine fill if started. Dump any fluorine in tank through ½" valves to disposal unit.	Closed	Payload must be removed from vehicle before pressure can be relieved in hydrazine tank.
	3.4 Hydrazine ground facilities spill	II	Retire from area. Decontaminate with water.	Closed	Relatively non-critical point in countdown. It is possible that fueling with hydrazine could continue with no holdup after decontamination.

GROSS HAZARDS ANALYSIS

HAZARD	HAZARD POTENTIAL	HAZARD CLASS	CORRECTIVE ACTION RECOMMENDED	ACTION STATUS	REMARKS
3.0 Fire/ Explosion	3.5 Premature actuation of explosive valves				
	3.5.1 ¼" Dump Valves actuate	II	Water fog nozzles used at discretion of Fire Dept.	Closed	Fluorine flows into disposal unit. Safe/arm mechanism makes the failure improbable.
	3.5.2 Both hydrazine and fluorine 1" Valves actuate	II	Water fog nozzles used at discretion of Fire Dept.	Closed	30 lbs. hot gas will exit the burner in 2 seconds in the vertical plane. Any personnel near payload will be protected by: (1) Steel payload shield (2) Protective clothing Safe arm mechanism makes this failure improbable.
	3.5.3 Hydrazine Valve only actuates	II	Water fog nozzles used at discretion of Fire Dept.	Closed	13 lbs. of Hydrazine will exit the burner in 2 seconds in the vertical plane. A fire is possible if an ignition source is available. Any personnel near payload will be protected by: (1) Steel payload shield (2) Protective clothing Safe arm mechanism makes this failure improbable.
	3.5.4 LF_2 valve only actuates	II	Water fog nozzles used at discretion of Fire Dept.	Closed	17 lbs. of fluorine will exit the burner in 2 seconds in the vertical plane. A reaction is probable because of water ice on payload and practically any other material the fluorine comes in contact with. Any personnel near payload will be protected by: (1) Steel payload shield (2) Protective clothing Safe arm mechanism makes this failure improbable.

GROSS HAZARDS ANALYSIS

HAZARD	HAZARD POTENTIAL	HAZARD CLASS	CORRECTIVE ACTION RECOMMENDED	ACTION STATUS	REMARKS
3.0 Fire/ Explosion	3.6.1 Loss of dump capability before fill valve is closed	II	Pressure may be relieved through fluorine ground facilities and fluorine vented to disposal unit.	Closed	
	3.6.2 Loss of dump capability after fill valve is closed	III	If close to launch window and no other systems indicate abnormality, hold launch until proper time; otherwise launch, if possible.	Closed	
	3.6.3 Burn through or loss of plumbing integrity at vehicle-pullaway interface	III	Water fog nozzles used at discretion of Fire Dept.	Closed	
	3.6.4 Loss of disposal unit resulting in raw fluorine dumped into sand or concrete pad	III	Water fog nozzles used at discretion of Fire Dept.	Closed	
	3.7 Loss of LN_2 and subsequent warm up of LF_2 tank	III	Observe temperature and pressure read-out of oxidizer tank. A pressure increase of approximately 10% will be enough to abort the mission due to increased oxidizer flow. Actuate the dump valves at this time or earlier depending on how	Closed	

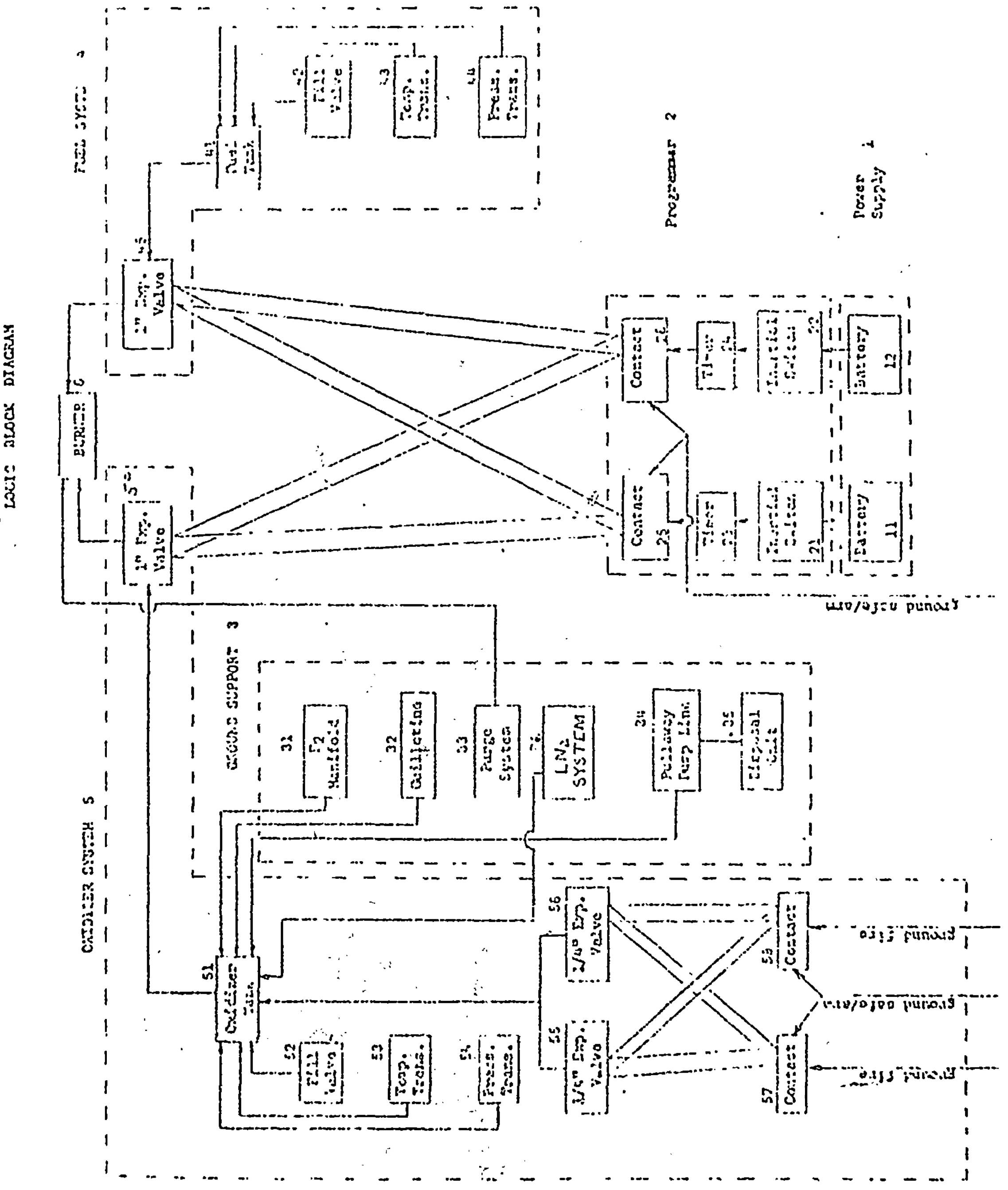
GROSS HAZARDS ANALYSIS

HAZARD	HAZARD POTENTIAL	HAZARD CLASS	CORRECTIVE ACTION RECOMMENDED	ACTION STATUS	REMARKS
4.0 Loss of Instrumentation	4.1 Malfunction of temperature and/or pressure transducer in hydrazine tank	III	Off load payload and repair or ignore and launch - depends upon what stage count down is in and whether one or both instruments fail.	Closed	
	4.2 Malfunction of temperature and/or pressure transducer in LF_2 tank	III	Off load payload and repair or ignore and launch - depends upon what stage count down is in and whether one or both instruments fail.	Closed	

GROSS HAZARDS ANALYSIS

HAZARD	HAZARD POTENTIAL	HAZARD CLASS	CORRECTIVE ACTION RECOMMENDED	ACTION STATUS	REMARKS
5.0 Post Lift-Off Hazards	5.1 Payload break-up on or shortly after lift off	III	None	Closed	Payload was subjected to vibration and shock tests as per specifications.

APPENDIX III



FAILURE MODE AND EFFECTS ANALYSIS

F.D. NO.	COMPONENT (DWG. NO.)	LOGIC DIAG. NO.	FUNCTION	FAILURE MODE	INDICATION	CAUSE	CORRECTIVE ACTION	FAILURE EFFECT ON: [illegible]	FAILURE EFFECT ON: SYSTEM	FAILURE EFFECT ON: MISSION	CRIT. CAT.	DISPOSITION AND JUSTIFICATION	REMARKS
1	Battery	11 or 12	Power supply for programmer	Fails to function or fails during operation	Blockhouse monitoring	Battery dead or not fully charged	Redundant component available	None	None	None	IV	Components previously qualified	
2	Inertial Switch	21 or 22	Start timer at lift off	Fails to function or fails during operation	None	Faulty switch	Redundant component available	None	None	None	IV	Components previously qualified	
3	Timer	22 or 23	Actuate relay to fire 1" explosive valves	Fails at any time	None	Faulty timer	Redundant component available	None	None	Possible loss of mission if timer operates early	IV	Components previously qualified	
4	Contact	25 or 26	Close circuit to explosive valves	Fails to actuate at proper time	None	Faulty unit	Redundant component available	None	None	None	IV	Components previously qualified	
5	F_2 Manifold	31	Loading and metering of F_2 gas into oxidizer tank	Leaks during operation	Odor of F_2 gas during fill	Loose fittings or loose valve packing	Stop operation-flush F_2 from line-tighten part	None	None	None	IV II & III	Manifold always leak checked immediately before any F_2 operation	
6	Guillotine	32	To cleave 1/4" copper fill line	Premature operation	Loss of He pressure if it operates before fill valve is closed	Human error or premature current to bridgewire	None	None	Loss of He Pressure	Abort mission	IV	Open	
7	Guillotine	32	To cleave 1/4" copper fill line	Failure during operation	Fails to cleave line completely on application of current	Internal malfunction	None	None	Vehicle cannot be raised to launch position	Abort mission	IV	Open	
8	Guillotine	32	To cleave 1/4" copper fill line	Fails to operate at prescribed time	Fails to cleave line	Human error or internal malfunction	None	None	Vehicle cannot be raised to launch position	Abort mission	IV	Open	
9	Pull away Dump Line	34	Interface between flight system and ground support	Leaks during operation	Reaction of F_2 at point of leak	Loose fitting	None	Possible loss	Possible loss	------	IV II & III	Components tested during development phase	
10	Pull away Dump Line	34	Interface between flight system and ground support	Sustains [illegible] on take off	Examination of ground support section after take off or if oxidizer tank sustains damage, no flame at altitude	Excessive torque on pull-away fitting causing excess pull-away forces	None	Possible loss	Possible loss	Possible mission loss	II, III & IV	Component tested during development phase	
11	Disposal Unit	34	To react fluorine with charcoal to form CF_4	Fails during operation allowing raw F_2 into atmosphere	Odor of F_2	Complete disintegration of barrel	None	Loss of barrel	None	------	II	Component tested during development phase	Tests show F_2 reacts completely if barrel is new [illegible]
12	Purge System	33	To provide dry N_2 purge to burner from cool down to lift off	Fail to operate at prescribed time	No indication on flow meter	Blocked line or closed valve	Replace line or open valve	Possible loss of burner and valve	Possible loss	Loss of mission abort	IV	System was tested during development phase	A [illegible] but critical before [illegible] as correction can be easily made

FAILURE MODE AND EFFECTS ANALYSIS

F.M. No.	Component (Dwg. No.)	Logic Diag. No.	Function	Failure Mode	Indication	Cause	Corrective Action	Failure Effect on Subsystem	Failure Effect on System	Failure Effect on Mission	Crit. Cat.	Disposition and Justification	Remarks
13	Purge System	33	To provide dry N_2 purge to burner from cool-down to lift off	Failure during operation	No indication on flow meter	Blocked line or closed valve	None	Possible loss of burner and valve	Possible loss	Mission abort	IV	System tested during development phase	
14	Purge System	33	To provide dry N_2 purge to burner from cool-down to lift off	Failure during operation (line slips out of burner)	Visual	Human error in taping line on	None	Possible loss of burner and valve	Possible loss	Mission abort	IV	System tested during development phase	
15	Hydrazine Tank	41	To contain hydrazine "B" Mix	Failure during operation	Burst tank	Excessive over-pressure or reaction in tank	None	Loss	Loss	Abort	IV	"B" Mix has never shown reaction in tank. Available pressurizing gases are well below burst value of tank	
16	Manually operated fuel fill valve	42	To effectively seal fuel tank	Leaks after tank pressurization	Pressure loss on blockhouse readout	Deformed valve seat	Time is not critical at this point-tank emptied valve replaced	None	None	None	IV	Component tested during development phase	
17	Pressure Transducer	43	To indicate pressure in fuel tank	Failure during operation previous to launch	Readout suddenly shifts	Any internal malfunction	None	None	None	None	IV	Component tested during development phase	If both components should fail, the mission would be aborted and the contents of the tank dumped immediately
18	Temperature Transducer	43	To indicate temperature in fuel tank	Failure during operation previous to launch	Readout suddenly shifts	Any internal malfunction	None	None	None	None	IV	Component tested during development phase	
19	1" Explosive Valve	45	To allow "B" Mix (hydrazine) to flow from tank	Failure to operate at pressurized time	Absence of flame at altitude	Broken bridgewire or any other internal malfunction	None	None	None	None	IV	Component tested during development phase	
20	1" Explosive Valve	45	To allow "B" Mix (hydrazine) to flow from tank	Failure during operation	Absence of flame at altitude	Reaction of "B" Mix with excessive blow by or failure of valve broken	None	Loss of valve	Possible loss of fuel system	Loss of mission	IV	Component tested during development phase	
21	1" Explosive Valve	45	To allow "B" Mix (hydrazine) to flow from tank	Premature operation	If loss of "B" Mix [illegible] burner in 2 sec.	Human error or premature current to [illegible] causing to fire valve	None	Loss of valve	None	Loss of mission	IV	Component tested during development phase	
22	LF_2 Tank	52	To contain liquid fluorine	Failure during operation	Burst tank, leakage or fire	Excessive overpressure or reaction in tank	None	Loss	Loss	Abort	IV	Available pressurizing gases are well below burst value of tank	
23	Manually Operated Oxidizer Fill Valve	52	To admit gaseous fluorine and gaseous He to oxidizer tank	Leak during gas flow	Chemical reaction at point of leak	Fitting not torqued properly	None	Possible loss of oxidizer tank if reaction is violent	None	Abort launch	III	[illegible] valves are [illegible] flow [illegible] tested during development phase	
24	Manually Operated Oxidizer Fill Valve	52	To effectively seal oxidizer tank	Leak after tank pressurization	Pressure buildup [illegible]	Deformed valve seat	None	None	Loss of He pressure in oxidizer tank	Abort launch	I[illegible]	Component tested during development phase	

FAILURE MODE AND EFFECTS ANALYSIS

F.M. NO.	COMPONENT (DWG. NO.)	LOGIC DIAG. NO.	FUNCTION	FAILURE MODE	INDICATION	CAUSE	CORRECTIVE ACTION	FAILURE EFFECT ON SUBSYSTEM	FAILURE EFFECT ON SYSTEM	FAILURE EFFECT ON MISSION	CRIT. CAT.	ELIMINATION AND JUSTIFICATION	REMARKS
25	Temperature Transducer	53	To indicate temperature of liquid in oxidizer tank	Failure during operation previous to launch	Readout suddenly shifts	Any internal malfunction	None	None	None	None	IV	Component tested during development phase	If both transducers [illegible] the mission must be aborted and contents of the tank dumped immediately
26	Pressure Transducer	54	To indicate pressure in oxidizer tank	Failure during operation previous to launch	Readout suddenly shifts	Any internal malfunction	None	None	None	None	IV	Component tested during development phase	
27	1" Explosive Valve	53	To allow fluorine to flow from tank to burner	Failure to operate at prescribed time	Absence of flame at altitude	Broken bridgewire or any other internal malfunction	None	None	None	Loss of mission	IV	Component tested during development phase	
28	1" Explosive Valve	53	To allow fluorine to flow from tank to burner	Failure during operation	Absence of flame at altitude	Reaction of F_2 with excessive blowby or failure of valve bronze	None	Loss of valve	Loss of oxidizer system	Loss of mission	IV	Component tested during development phase	
29	1" Explosive Valve	55	To allow fluorine to flow from tank to burner	Premature operation	If lbs. of fluorine will exit from burner in 2 sec.	Any premature current to bridgewire exceeding no fire value	None	Loss of valve	Possible loss of oxidizer system	Loss of mission	I & IV	Component was tested during development phase	
30	1/4" Dump Explosive Valve	55 or 55	To offload fluorine in case of abort	Failure during operation	If lbs. of fluorine will dump into burner section of payload	Reaction of F_2 with excessive blowby causing line rupture	None	Loss of valve	Loss of oxidizer system	------	II & III	Component tested during development phase	
31	1/4" Dump Explosive Valve	55 or 56	To offload fluorine in case of abort	Premature operation	Increase in tank pressure reaction at disposal unit	Human error or premature current to bridgewire exceeding no fire value	None	None	Loss of oxidizer	Loss of mission	III & IV	Component tested during development phase	
32	1/4" Dump Explosive Valve	55 or 56	To offload fluorine in case of abort	Failure to function at proper time	No decrease in tank pressure-no visible reaction at disposal unit	Broken bridgewire or any other internal malfunction	Redundant system available	None	None	------	IV	Component tested during development phase	
33	Burner	6	Mixing chamber and flame holder for F_2-"B" mix flame	Failure to operate at prescribed time	Visual-no flame at altitude	No ignition in vacuum	None	None	None	Mission loss	IV	System tested during development phase-never failed to ignite	
34	Burner	6	Mixing chamber and flame holder for F_2-"B" mix flame	Failure during operation	Visual explosion at altitude	Expulsion of "B" gas in feed ring or violent reaction of F_2 in feed ring	None	Loss of burner	Loss of burner system	Mission loss	IV	System tested during development phase	
35	LN_2 System	24	Supply LN_2 to oxidizer tank jacket	Failure to operate at prescribed time	Visual	Lack of pressure in LN_2 storage container or valve failure	Pressurize container or repair valve	None	None	None	IV	LN_2 system was tested during development	[illegible]
35	LN_2 System	56	Supply LN_2 to oxidizer tank jacket	Failure during operation	Visual and temperature and pressure increase in oxidizer tank	Valve failure or line break	If failure is [illegible] storage cylinder repair is possible; if repair impossible LF_2 tank must be dumped	None	None	Abort	IV	LN_2 system was tested during development	

LIBRARY CARD ABSTRACT

Title and Subtitle

DESIGN, TESTING, FABRICATION AND LAUNCH SUPPORT OF A LIQUID CHEMICAL BARIUM RELEASE PAYLOAD

(Utilizing the Liquid Fluorine-Barium Salt/Hydrazine System)

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ABSTRACT

Barium yield from solid chemical release systems in existence at the time this program began was between one and two percent of total chemical weight. An improvement in barium yield was needed in order to conduct more ambitious electric and magnetic field experiments using the ionized barium technique at greater distances into the geomagnetosphere. An earlier study indicated that theoretical yield from liquid systems appeared to offer significant increases over solid systems. From this work, a liquid system consisting of hydrazine, with dissolved barium salts, as the fuel and liquid fluorine for the oxidizer was selected as the basis for payload hardware development. The purpose of this program was to develop and test a liquid chemical payload system suitable for a point release of barium in the form of barium atoms and barium ions. The ionized barium yield of the liquid chemical payload system was evaluated at an altitude of 260 km during a flight test on a Nike-Tomahawk vehicle on October 7, 1970. The release produced a luminous barium ion cloud which expanded very rapidly, disappearing to the human eye in about 20 seconds.

The barium yield was much less than expected, however, the test demonstrated that the use of liquid fluorine as an oxidizer on small payloads is practical. This report documents the development of the payload, describes the ground support equipment essential for payload preparation and monitoring prior to lift-off, and summarizes the results of the flight test.

Key Words

Liquid chemical barium release
Fluorine
Barium ion cloud