ROCKET POWER, INC.

Pyrotechnic Outside Warning System

Final Report - Phase I

(Contract No. OCD-OS-62-76)

Prepared for

OFFICE OF CIVIL DEFENSE
Department of Defense

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FINAL REPORT

PYROTECHNIC OUTSIDE WARNING SYSTEM

(Contract No. OCD-OS-62-76)

Prepared for

OFFICE OF CIVIL DEFENSE
Department of Defense
Washington 25, D.C.

Prepared by

ROCKET POWER, INC.
Falcon Field, Mesa, Arizona

NOTICE OF PUBLICATION

This report has been reviewed by the Office of Civil Defense and approved for publication. This approval does not signify that the contents necessarily reflect views and policies of the Office of Civil Defense or of the various state and local Civil Defense organizations.

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SECTION I

INTRODUCTION AND SUMMARY

This report covers Phase I work on the Pyrotechnic Outside-Warning System (POWS) developed at Rocket Power, Inc., Mesa, Arizona for the Office of Civil Defense, Department of Defense under contract OCD-OS-62-76.

The POWS was conceived as a complement to the National Emergency Alarm Repeater System (NEARS), which will provide indoor warning. The POWS is designed to meet the need for a mass, low-cost outdoor alert system which can provide instant audible and visual warning, day or night.

The POWS is a compact, lightweight package containing two warning rockets and a special control unit. Each rocket is sealed in a metal tube. The control unit is sealed in a separate enclosure between the tubes. These POWS units can be mounted on any poles or buildings having access to ordinary 60-cycle power.

The control unit constantly monitors the power line to detect the presence of a NEAR signal. Upon receiving this signal, the control unit will fire one rocket, sequence to the second and await another signal.

The POWS components are housed within the rocket vehicle casing, and are ejected when the rocket vehicle reaches its terminal altitude. The warning components are an explosive charge, a red smoke cloud, and an intense red flare. The flare and all hardware are lowered by parachute.

The requirements for the POWS are extremely rigorous. The units must withstand temperatures ranging from -65 degrees to +200 degrees F. for a minimum of ten years and remain operable without maintenance. No pyrotechnic device known has been required to meet standards this high.

At the outset of this program, it was felt some of the warning components could be purchased immediately. It was soon discovered that the state of the art of pyrotechnics is considerably behind the space age requirements of POWS. For instance, storage life for fireworks is measured in months and the best of commercial and military flares can offer a maximum shelf life of only two to five years... far below that required for this system.

The only answer lay in development of new components using solid propellant, which fully meets or exceeds all requirements for the POWS. This advanced propellant was used not only for the rocket motor, but also for the delay train, the explosive charge, and the flare.

The electronic control unit, designed and developed shortly after the start of this program, was given a routine test after one year in storage. It functioned perfectly. Timing was precise.

The POWS has been successfully designed and developed and is ready for Phase II, field evaluation. The first part of the Phase II program will be verification of the design changes, effected during the study survey, as outlined in section III herein. The second part of Phase II will include a public test on a scale to be determined by OCD, (see section IV).

SECTION II

PYROTECHNIC OUTSIDE WARNING SYSTEM

Under contract to the Office of Civil Defense, Department of Defense, Rocket Power, Inc., has developed a Pyrotechnic Outside Warning System designed to provide mass, low-cost outdoor warning, day or night in event of imminent nuclear attack.

The system was conceived as a complement to the NEAR indoor warning system, and to cover areas where sirens and other warning devices have not or cannot be effectively used.

SCOPE

The requirements for this program were that Rocket Power, Inc., in consultation and cooperation with the Government, furnish the necessary equipment, personnel, and other facilities as required to develop an inexpensive pyrotechnic rocket of a distinctive nature which could be used as an attack warning signal, visible and audible day and night over a wide area. The specific requirements were as listed in article I of Contract No. OCD-OS-62-76 as amended by modifications and are as follows:

A. As presently envisioned, the operational sequence shall be as follows:
   1. Activation by a decoded National Emergency Alarm Repeater (NEAR) signal.
   2. Rise into the air a few hundred feet.
   3. Produce a loud explosion and a smoke cloud at the top of its path.
   4. Ignite a brilliant-colored flare (visible day or night) which would slowly descend while burning.

B. The device shall be of such a nature that fire hazard will be eliminated, shelf and standby life of ten years attained, performance insured through extreme temperature and humidity ranges, and rocket control designed to insure that the rocket will be released only upon receipt of the NEAR powerline signal. No communication or separate control circuit is to be required.

C. Low cost, simplicity, reliability, and distinctiveness of signal are the principal features required of the device. The device is to comprise a control unit which will fire the rocket, and one or more rockets which provide the visible and audible signals.

D. The project shall include investigations to:
   1. Determine the most effective audio and visual characteristic to be provided for attack warning.
   2. Design the configuration and charge of several rockets.
   3. Design and produce ten (NEAR control unit) activators.
   4. Test fire, compare, and evaluate the several designs of rockets produced under D.2.

E. The various rocket designs determined under D.1 shall lead to selection of optimum characteristics of altitude, flare, smoke, and sound. Unit cost figures for the production of the optimized design shall be developed.

F. Drawings of the basic rocket development and specifications covering the optimum characteristics shall be furnished to the Government on or before March 31, 1963.

SYSTEM DESCRIPTION

The POWS consists of two special-purpose solid propellant-powered miniature rockets coupled to an electronic control unit and hermetically sealed in separate containers. These units may be mounted on poles or any building with access to ordinary 115-volt, 60-cycle power. The two warning rockets are identical. The second rocket can be fired at any time after the first has been launched, to provide a second warning signal.

The warning rockets are boosted by solid propellant motors to an altitude of 1500 to 2,000 feet, where warning devices encased within the rocket vehicle are activated. To avoid hazard to aircraft, the POWS will be located away from airport glide paths. The various components of the POWS, their operation, and the program which led to their selection for POWS are discussed below.

POWS COMPONENTS

Launching Platform (See Figure 1)

The launching platform design consists of two launching tubes and an integral compartment to house the Control Unit. The Launching Platform is equipped with universal brackets for ease of installation in the field. The tubes containing the rocket vehicles are completely separated. Each tube is hermetically sealed. The Control Unit is separated from the tubes and is also sealed against deterioration caused by weather conditions.

An integral shear plane is designed into the cap which seals the top of each launcher tube. When the rocket motor is fired, pressure building up within the tube causes the section of the cap encircled by the shear plane to blow off, releasing the vehicle. If the tube is damaged, (for example, through small arms fire by vandals) the rocket vehicle is designed to remain in the tube even though the rocket motor ignites, avoiding any possibility of an erratic flight.

Within the tubes are guide rails which insure vehicle stability at launch. By the time the vehicle leaves the tube it reaches a velocity sufficient for the fins to become effective, providing stability.

The tubes are joined by panels which enclose the Control Unit. This center section, housing the Control Unit, may be checked in the field through an access door which is provided for this purpose.

Utilizing the assembly shown in Figure I, it is possible to replace rocket vehicle units in the field. However, this is a task requiring a trained technician, and proper sealing of the unit under field conditions is not feasible.

Because of these problems, it is recommended that the unit be returned to the manufacturer for replacement after the rockets have been fired.

If, in the opinion of the Office of Civil Defense, replacement in the field is mandatory, it is recommended that the unit be modified to incorporate the features illustrated in Figure 2. This design houses the Control Unit in a separate tube. This tube incorporates attachments to which one, two, or three autonomous launcher tubes can be attached.

Each of these separate launcher tubes contains a single rocket vehicle. This arrangement offers these advantages:

1. The number of vehicles can be varied from one to three.
2. If one unit is fired, it can be replaced quickly and safely without removal of the control unit or other vehicles from the pole.
3. Where funding is a problem, a single unit can be installed and others added later to bring the system to full effectiveness by stages.

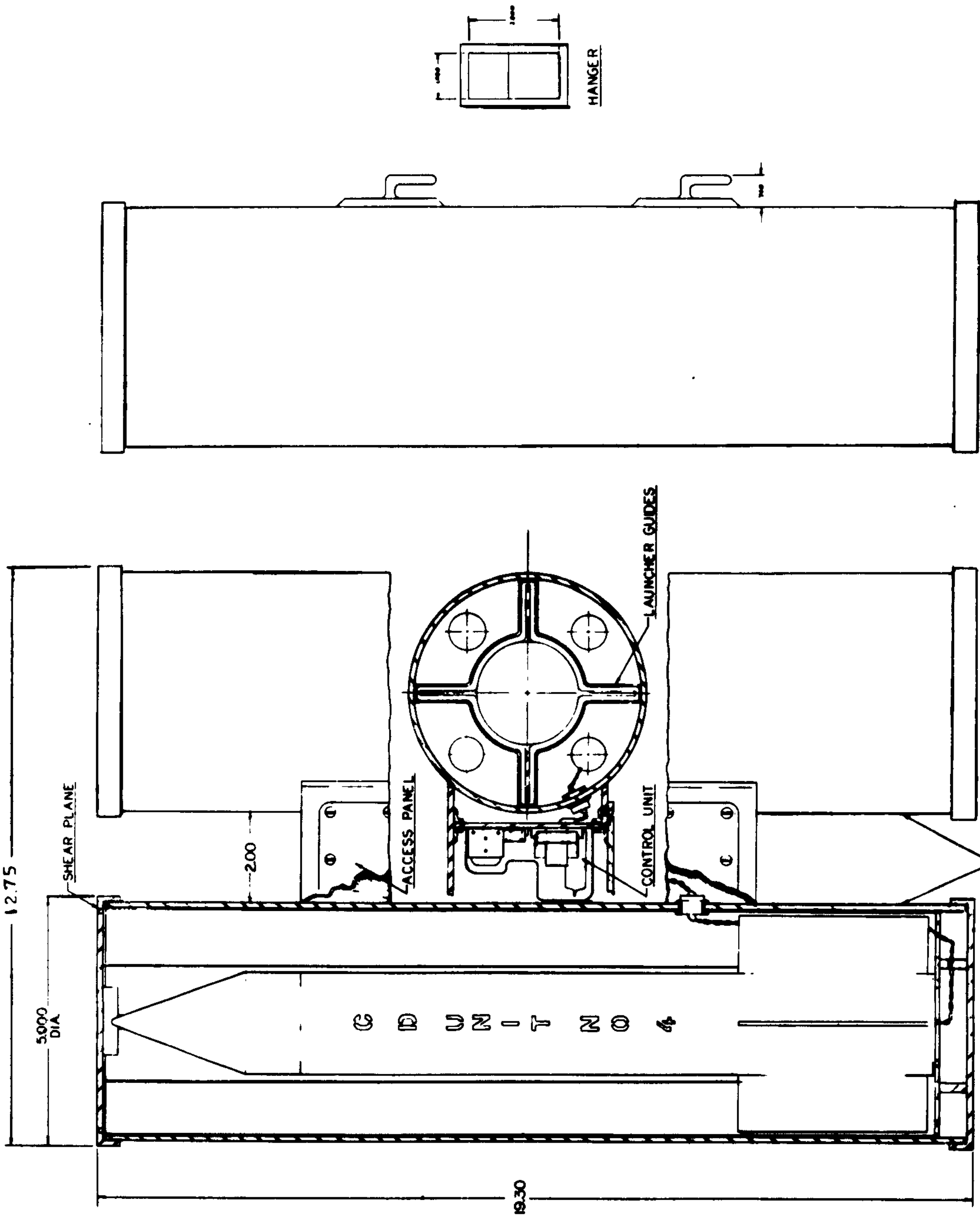


Figure 1 — POWS Launching Platform

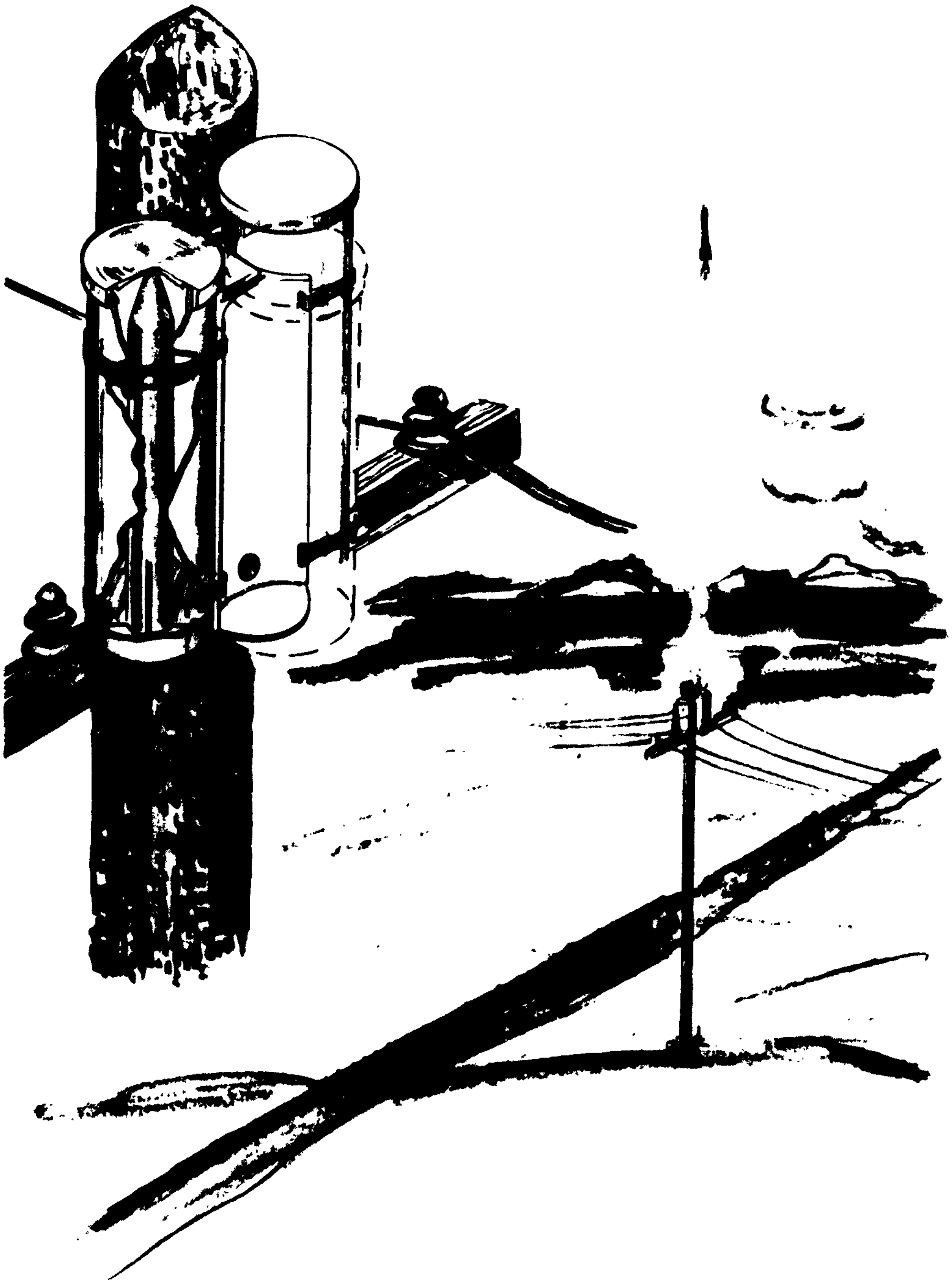


Figure 2 — Proposed Alternate Launcher Assembly

Control Unit (See Figures 3 and 4)

The Control Unit is mounted in a separate sealed section between the launcher tubes. External contact points are provided for field checkout.

The Control Unit meets all requirements established for POWS, including storage life, temperature, and environmental extremes.

This unit is designed to accept a special signal (NEAR). The current design was predicated on a 255-cycle signal being generated. If 270 cycles is required, a minor design change will adjust the unit to accept this signal. If required, the unit may also be activated by conventional control circuits.

The Control Unit continuously monitors a standard 115-volt, 60-cycle power line but will accept only the NEAR signal. When this special signal is received for the length of time required to activate a conventional NEAR receiver, the unit will fire one rocket vehicle and immediately cycle to the second unit to await a second NEAR signal.

a. Functional Description (See Diagram, Figure 3)

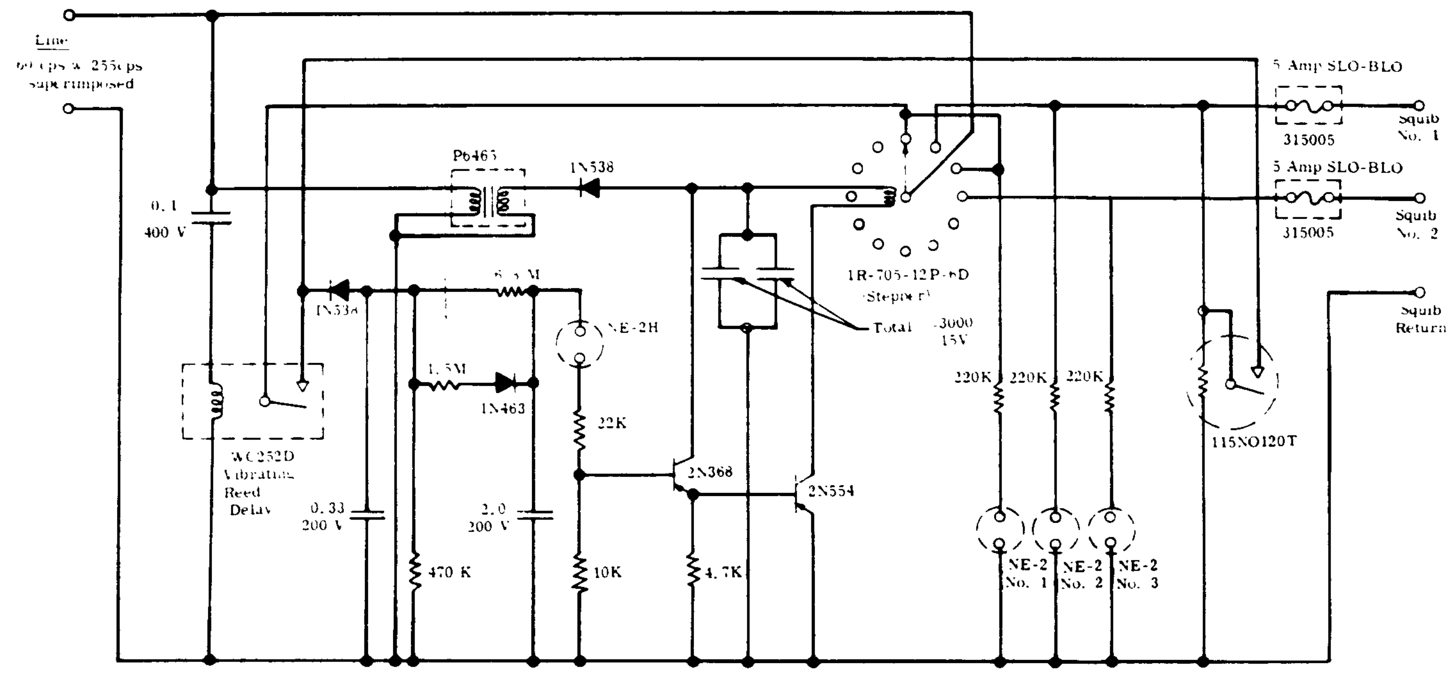
The Control Unit continually monitors the line voltage from which it derives its power. If at any time a NEAR signal is present, it will be detected by the unit's vibrating reed relay which, in turn, energizes a timing circuit.

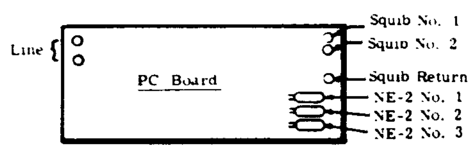
The rectified signal applied to the timing circuit charges the capacitors in the timing circuit at a rate determined by the RC time constant, until the ionization potential of the neon bulb NE-2H is reached.

As soon as the neon bulb ionizes, the 2N368 transistor is triggered, which in turn causes the 2N554 power transistor to conduct and energize the IR-705-12P-6D stepper relay. At this time, 115 volts, 60 cps is applied to squib circuit number 1, firing the first rocket, and to the 115 NO 120T thermal delay relay, beginning a recycling period of approximately 120 seconds.

At termination of the recycling period, the timing circuit mentioned previously begins to cycle, advancing the stepper relay to the next position and readying the Control Unit to repeat the firing sequence for the next rocket. When the last rocket has been launched, the system will no longer respond to a NEAR signal.

Each squib circuit is fused with a five-amp SLO-BLO fuse to protect the Control Unit against the possibility of the squib wires becoming shorted together.





Notes

1. When NE-2 No. 1 is on system is armed and rocket is ready to fire
2. When NE-2 No. 2 is on Rocket No. 1 fired and system is recycling
3. When NE-2 No. 3 is on Rocket No. 2 fired and system is expended

FIGURE 3 - SCHEMATIC DIAGRAM, POWS CONTROL UNIT

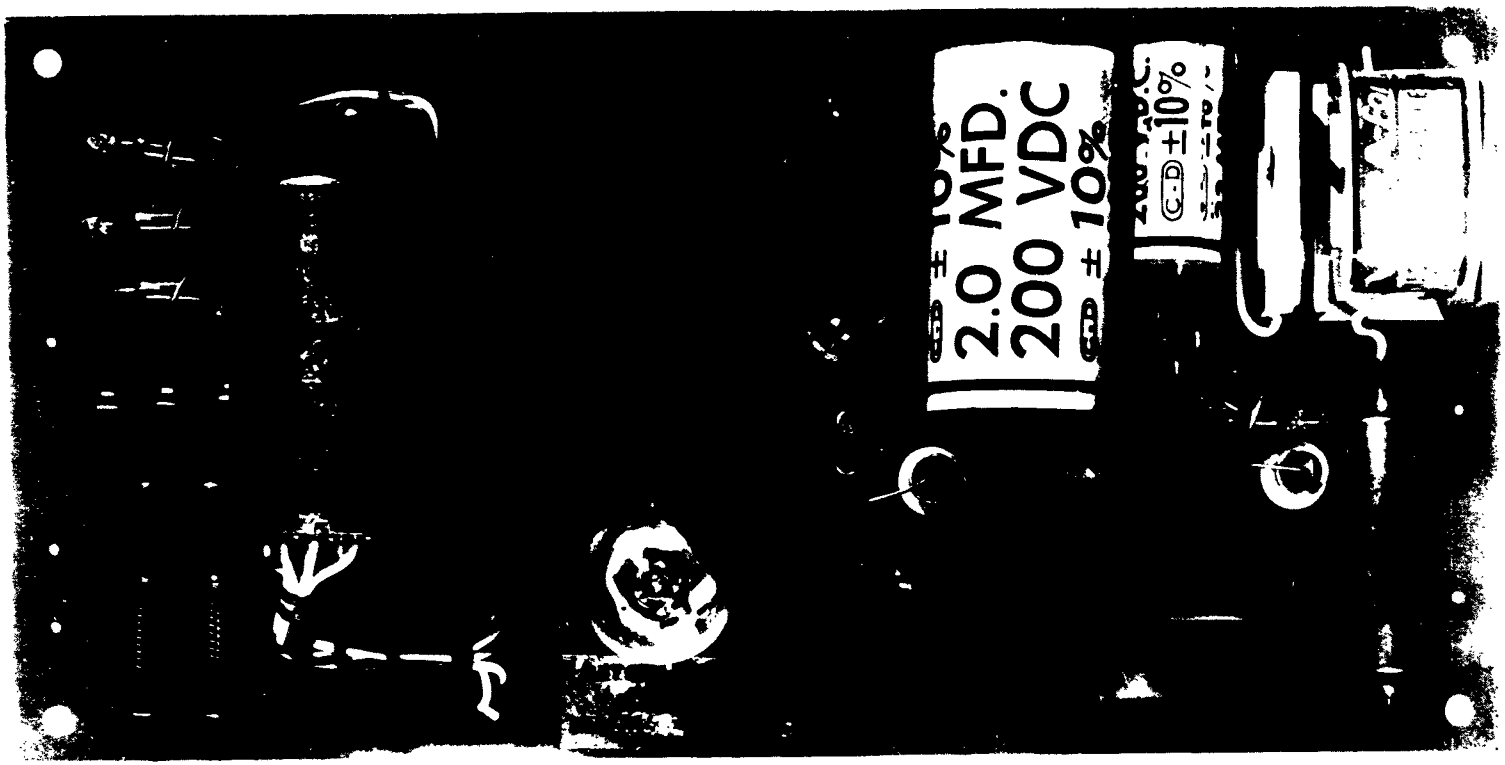


Figure 4 — Top View, POWS Control Unit

The Control Unit circuit contains three neon bulbs (NE-2, No. 1; NE-2, No. 2; and NE-2, No. 3) to provide a simple means of system checkout. The purpose of each bulb is indicated on the schematic diagram, Figure 3.

Presence of the NEAR signal for 15 seconds will cause the Control Unit to fire one of the rockets. The time delay period may be increased or decreased by simply altering the timing circuit resistor and capacitor values. If the NEAR signal is present for less than 15 seconds, the timing circuit is reset to zero time through the action of the 1M 463 diode.

The Control Unit was developed by Betco Electronics, Silver Springs, Maryland, under contract to Rocket Power. Ten prototype control units were manufactured in accordance with the specification included as Appendix A of this report. These units were delivered to Rocket Power. One of the units was delivered to OCD as part of a model of the POWS. The remaining nine units are in storage at Rocket Power.

Rocket Vehicle (See Figure 5)

The rocket vehicle design resulted from a careful study of components to be housed within the vehicle, their space requirements, and other factors including weight, cost, reproducibility, and conformance to requirements of the POWS.

Three methods of stabilization of the Rocket Vehicle were explored: cone, spin, and fin. Fin stabilization was ultimately selected as the logical approach for the POWS vehicle. Each of these methods is discussed below.

a. Cone Stability

Stabilization by this method is accomplished by having the aft end of the vehicle flared or cone shaped. This increases the aerodynamic drag, providing the force to balance the forces on the forward section of the vehicle. Experiments indicated that a 1.5 to 2.0 -inch increase in cone diameter will provide the same stability characteristics as fins of the same nominal diameter. This is partially due to the cone's relative ineffectiveness at low subsonic velocity. Since the velocity range of the POWS vehicle is entirely within the subsonic region, the cone stabilization method was not favorable.

b. Spin Stability

A vehicle stabilized in this manner must be spun at a rate sufficient to produce a gyroscopic action. Since flare burning time is proportional to the length of the flare, initial calculations revealed that the vehicle would have a length to diameter ratio of approximately ten. Gyroscopic stabilization of a vehicle with an L/D of ten would require an excessive spin rate — about 100 revolutions per second. Lowering the spin rate by increasing the diameter was not feasible, since overall weight of the vehicle would become a problem.

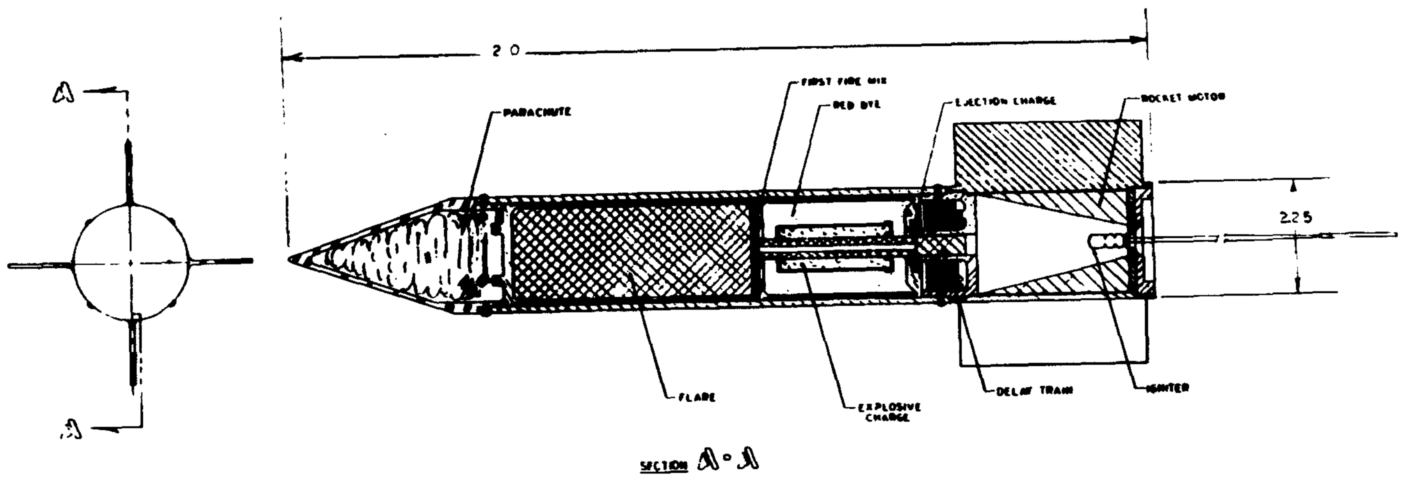


Figure 5 — POWS Rocket Vehicle P/N 2589-13 (Final Design)

c. Fin Stability

A prime requirement for fin stabilization is that initial velocity be sufficient for aerodynamic forces to be effective. This initial boost phase can be accomplished simply by changing the initial burning surface of the propellant grain. Therefore, stability problems can be overcome by either a slight modification of the propulsion unit, or by increasing the effective fin area. These changes can be made quickly and at nominal cost.

For the reasons listed above and to assure low cost and ease of fabrication Rocket Power elected to use fins for stability. Each fin on the present vehicle configuration is approximately four square inches in size. These fins are economically stamped out of aluminum stock, and spot welded to the case prior to assembly.

Propulsion Systems

Prior to selection of a conventional rocket motor as the optimum propulsion unit for the POWS, several other methods were investigated. These propulsion methods are discussed below.

a. Cold Propulsion

Several companies are currently manufacturing cold propulsion units capable of attaining the altitude necessary for the POWS. Although such units are often advertised at a cost of $100 in quantity, this price does not include the launcher — a fairly complex and expensive device.

Another disadvantage to cold propulsion is the size of the launcher tube needed for the boost phase and for stability. The tube is ten feet long. This cumbersome arrangement with its attendant costliness makes cold propulsion appear impractical for the POWS application.

b. Frangible Motor Case

After careful consideration, use of a frangible motor case, one which is exploded at altitude, was considered inadvisable for the POWS. The frangible case method would require an additional delay train system, adding to the cost of the overall system and lowering its reliability.

Also, use of the frangible casing would mean pieces of motor casing would be permitted to free fall from high altitude. Having any piece of hardware falling was considered unacceptable from a safety standpoint and led to use of a parachute for lowering the hardware. The parachute technique has proven highly successful and entirely safe.

c. <u>Nozzleless Rocket Motors</u>

During the POWS program, Rocket Power has fired and evaluated a number of nozzleless rocket motors. This type motor was ultimately rejected. Evaluation revealed several reasons why the motor is unacceptable for use in the POWS.

Nozzleless motors have an inherent problem of thrust misalignment which becomes progressively worse as the propellant forming the nozzle is eroded away.

Altitude is partially dependent upon the erosion rate of the propellant. Since erosion rate may vary, this introduces an altitude variable.

d. <u>Gun Projectile Concept</u>

Although this system has many advantages, one major problem precluded its use in the POWS. This technique required that the vehicle accelerate to such high velocity before leaving the launching tube that it will coast to the required altitude.

This extreme acceleration exerts tremendous G forces on components of the vehicle, far in excess of allowable loads. For example, assume a launch tube length of two feet, and a desired altitude of 2,000 feet:

$$\text{Altitude} = \frac{\text{Velocity}^2}{2\,g}$$

$$\text{Velocity}^2 = 2 \times \text{acceleration} \times \text{tube length}$$

$$\text{Altitude} = \frac{2 \times \text{acceleration} \times \text{tube length}}{2\,g}$$

$$2000 \text{ feet} = \frac{2 \times \text{acceleration} \times 2 \text{ feet}}{2\,(32.2)}$$

$$= 32{,}200 \text{ ft/sec}^2$$

$$= \frac{32{,}200}{32.2} = 1000 \text{ g's}$$

e. <u>Conventional Fireworks</u>

Rocket Power discussed possible use of conventional fireworks with several fireworks companies. It was learned that such pyrotechnic products will not withstand storage for more than one year, and are produced only a short time before actual use.

Since the POWS has storage requirements under severe climatic conditions for at least a decade, existing fireworks obviously could not be adapted to this Civil Defense warning device.

f. Progressive Thrust Unit

A progressive thrust (pressure) unit, one whose pressure increases until the rocket motor explodes, was investigated and rejected by RPI as a possible propulsion device for POWS. A progressive thrust unit provides no guarantee that all propellant will have been consumed by the time the case ruptures. It is therefore possible that burning propellant fragments would be showered onto a populated area. This situation was absolutely intolerable under the strict safety considerations mandatory for the operational POWS. An additional reason for rejection is the intimated marginal reliability of this type of unit.

g. Catapult

A catapult system has the same inherent disadvantage of the gun projectile method. The G loading would be far in excess of the design limits of the components housed within the flight vehicle.

h. Conventional Rocket Motor

This type propulsion was chosen as the ideal means for boosting the POWS rocket. This type motor meets or exceeds all specifications established for the POWS. The propellant will withstand temperatures from -65 to +200 degrees for prolonged periods, and suffers little or no degradation under severe environmental conditions.

These solid propellant motors have a reliability factor of 99-plus percent and are the equal of motors qualified for use on manned spacecraft projects. This propellant has been used on Project Mercury, and is to be used for the rocket catapult escape system for the Gemini spacecraft. It has proven extremely reliable in use on rocket catapult ejection seats for military aircraft.

Rocket Power currently is manufacturing a family of miniature solid propellant rocket motors with grains* produced from standard size propellant rods. These rods have diameters ranging from 3/8-inch to two inches.

* Grain, as used in this report refers to the cast solid propellant charge used in the rocket motor.

Use of these propellant rods in the manufacture of propellant grains during the development and verification phases results in a considerable saving of time and tooling costs. Still another advantage of this type of propulsion system is its versatility. By simply varying the internal configuration, the thrust time curve and total impulse can be changed as desired with no loss in time. This permits a variation of altitude with no change of hardware.

Rocket Motor

To meet requirements for the POWS, a polysulfide ammonium perchlorate propellant was selected by Rocket Power. This propellant has proved extremely reliable and stable. It is used extensively in rocket catapult escape systems for manned aircraft.

Several grain configurations were tested during development of the POWS to provide the smallest motor capable of meeting system requirements. The first rocket motor tested had a grain with a cylindrical internal configuration. This design proved unsatisfactory because the sudden pressure drop when the rocket motor burned out caused the delay train to extinguish also. To correct this, the internal configuration of the grain was changed from cylindrical to conical, thus producing a gradually decreasing burning area and consequently a gradual pressure decay.

After the first few flights, it was evident that the vehicle was attaining an altitude in excess of that required for this system. In an effort to decrease the overall system size, a shorter rocket motor with a grain coned from each end was tested. This "hour glass" configuration (See Figure 6, Appendix IV) proved satisfactory during static testing, but during development flights the time delay malfunctioned, "chuffing" when a severe pressure drop occured inside the motor. It is believed that the pressure drop was caused by the venturi effect of the air flow passing over the aft end of the rocket motor.

A second attempt was made to reduce the rocket motor size by simply decreasing the length of the grain with the conical internal configuration. This configuration also caused the delay train to extinguish. It was determined from these tests that a particular internal free volume of the rocket motor at burnout was required to insure a gradual pressure decrease. Consequently, the rocket motor length was not decreased and the original conical internal grain configuration was maintained.

The propellant weight of this rocket motor grain can be varied to meet any altitude requirements without affecting the rate of change of the rocket motor pressure.

Ignition of the motor is accomplished by a standard electrical squib initiating a mixture of copper oxide and aluminum powder. This is a hot particle igniter and is essentially pressureless, eliminating the possibility of pressure from the igniter releasing the vehicle prior to the time the motor has attained maximum thrust. This is important, since stability of the vehicle is assured only when the motor reaches peak thrust prior to leaving the launcher tube.

During the initial flights of the development phase, the forward end of the rocket motor, which houses the attachment for the delay train, was made from 6061-T6 aluminum. In order to keep the cost of the production hardware to a minimum, it was desirable to go to a less expensive aluminum such as 2024-T4. The first few tests failed due to the lower bearing strength of this material. To overcome this problem, the number of pins holding the motor case to the forward end of the rocket motor were increased to twenty. Subsequent tests have proven the integrity of this hardware.

Time Delay Train

Since the audible and visual warning components of the POWS are activated in sequence at peak altitude, it was necessary to provide a means of sequencing ignition of these components. Use of standard pyrotechnic time delays was ruled out for reasons of economy and because these delays fail to meet the storage life requirements of this system.

To meet the needs of the POWS, a unique delay train utilizing the same type solid propellant as the motor was developed. This delay is simple, inexpensive, and highly reliable. It is made from a tube filled with propellant. This type of propellant rod is in use on several pilot and astronaut escape systems and has passed environmental tests more severe than those required for the POWS.

Small holes were drilled in the outside of this rod and lengthwise through the center. The delay train and rocket motor are ignited simultaneously. The delay end burns to the hole exposed to the ejection charge. The flame flashes through this hole, igniting the charge. At this point the delay is ignited all along the small hole down the center of the tube, and the components are ejected. The flame in the center hole causes the flare to ignite, and the propellant in the tube continues to burn outward radially. Seconds later, the flame reaches the tube O.D. and flashes through small holes, igniting the explosive charge. This delay assures that the explosive charge is a sufficient distance from the flare to prevent damage from the detonation.

Early in the POWS development program, Rocket Power reported periodic malfunction of the delay train. A board of inquiry was established to study recovered vehicles. It was discovered that all suffered a common failure. The graphite nozzle slug was either cracked or broken. Evaluation revealed that the igniter was being placed too near the nozzle.

To combat this problem, a device was incorporated to hold the igniter in a fixed position away from the nozzle. No further delay train problems were encountered.

Explosive Charge and Smoke Cloud

Investigation during this program (See Section III) indicated that a smoke trail is not completely acceptable as a warning device. The smoke is quickly dissipated by wind. By the time the explosive charge has detonated at altitude, the smoke trail barely exists.

A large red smoke cloud is more favorable. At the altitude the smoke cloud is formed, it is less affected by wind than is the smoke trail. It is formed at the instant the explosive charge is detonated, providing simultaneous audio and visual warning.

The explosive charge and smoke are combined in one component. The charge, which is surrounded by red dye, is sufficient to burst the outer chamber. The heat from the detonation volatizes the red dye, producing a dense cloud in the same manner as military marking shells.

To attain maximum warning capability with minimum size, it is desirable to use a high energy explosive. To produce the necessary sound pressure level with a lower energy explosive material may require an increase in size of the rocket vehicle.

Ejection Charge

The ejection charge which expels the flare, parachute, and explosive charge, consists of a boron/potassium nitrate granulation. This is a pressure-producing mix, is very stable, and has worked very well in both the POWS and in other rocket motor applications for several years. It is capable of long storage life and has an extremely high auto ignition temperature.

Flare

The original flare designed by RPI for use in the POWS provided a bright violet light. The data survey indicated that a red flare is more effective as a warning signal. Accordingly, the flare has been modified to produce a red light. A special flare utilizing solid propellant was necessary for the POWS since no standard high performance flare being marketed today can guarantee ten years of storage life. The RPI propellant flare is a castable mixture and will withstand the rigorous environmental requirements of the POWS for at least one decade.

Some difficulty was encountered during development in attaining reliability of flare ignition. Several methods were tried without success. The problem was resolved by use of a "first fire mix" compound which ignites easily and produces reliable ignition of the flare.

The first flare ignition mix tried was of the hot particle type. However, this booster charge burned too fast and failed to ignite the flare. Next, a polysulfide propellant booster charge was tried. Use of this booster charge resulted in random failures due to the booster charge failing to ignite. As shown in Section III of this report, investigation revealed that a barium chromate and boron ("first fire mix") mixture had been successfully developed and is now incorporated in the POWS.

An increase in flare intensity can be attained from a pressed flare of the same dimensions; however, the storage life of pressed flares varies from two to five years. Use of a pressed flare would mean lowering the system shelf life by at least 50 percent.

All flares have a gradual degradation of output intensity over a given time period. The selected flare, therefore, is designed to deliver an output 20 percent above the minimum requirements for the POWS. The flare is designed to give a burning time of 60 seconds, minimum.

<u>Parachute</u>

During the data survey portion of this program, RPI and OCD personnel witnessed flare recoveries by parachute. It was noted that the "international orange" color of the parachutes being used made the flare easy to spot and simpler to track after burnout. This color was selected for the POWS hardware and flare parachute.

The 900 square inch parachute utilized for the POWS provides a fall rate of approximately nine feet per second. This slow rate of descent assures flare burnout several hundred feet above terrain, eliminating any fire hazard. Since all metal hardware from the vehicle is attached to the parachute, no falling pieces can cause injury or damage.

Early in the development program, some parachutes failed to open. Rocket Power conducted several wind and load tests. The wind test results indicated that the parachute configuration being used would open only at low velocities. To insure reliability this was remedied by doubling the number of shroud lines. Load tests revealed the parachute area was inadequate for the weight of the vehicle. Two solutions were available; use a larger parachute, or a lighter vehicle. Since a larger parachute required more packing area, the optimum approach was to decrease vehicle weight. This was accomplished by replacing the solid nose cone with a lighter weight, hollow plastic shell and replacing the smoke generator with a red smoke device. The parachute then performed satisfactorily.

<u>Recovery of Metal Parts</u>

The method of fastening the hardware to the parachute was affected by several conditions. The first method, a wire fastened to the exterior of the case, quickly proved impractical because of a sealing problem. Next, a coil of wire was incorporated inside the unit. Although this eliminated the problem of sealing, the single strand wire separated under stress. Consequently, the wire was replaced by .032-inch steel cable.

SECTION III

DEVELOPMENT OF TECHNICAL PARAMETERS

The Phase I program encompassed development of a Pyrotechnic Outside Warning System as a complement to the NEAR System and to cover areas where other warning devices did not exist. However, it was decided that a survey should be conducted to gather available data from existing industrial and government documents concerning optimum requirements for warning devices.

This survey of data was accomplished by RPI in cooperation with representatives of the Office of Civil Defense, Department of Defense.

POWS UNIT SIZE

The size and weight of the POWS units are dictated by several factors. The U.S. Department of Labor, (special bulletin no. 11, Bureau of Labor Standards) states that 50 pounds is the safe limit that one man can lift. If the weight of the POWS exceeds 50 pounds, it will require special handling equipment and additional personnel. It is believed that this added expense would more than offset the gain in area coverage realized by increasing the unit size. The existing rocket vehicles have been designed as large as possible, within weight limitations, to house the largest warning devices feasible with corresponding maximum area coverage. The current unit design weight is in excess of 40 pounds.

FLARE

Of critical importance in the POWS is the flare, which provides visual warning day or night. Since all warning flares, warning lights and warning signs are traditionally red, it is quite evident that if the public is to take this flare as a warning device, it too must be red. Another advantage of the red flare is that it is more visible during the day.

In order to incorporate all of the required components into the size of the vehicle as previously established, the allowable length of the flare is approximately 5 inches long. To fit inside the flight vehicle, the flare O.D. cannot exceed 1.89 inches. This allowable volume is:

$$\text{Volume} = \frac{\pi \, (\text{diameter})^2}{4} \times \text{length} = \frac{\pi \, (1.89)^2}{4} \times 5 = 14 \text{ in}^3$$

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FLARE

Of critical importance in the POWS is the flare, which provides visual warning day or night. Since all warning flares, warning lights and warning signs are traditionally red, it is quite evident that if the public is to take this flare as a warning device, it too must be red. Another advantage of the red flare is that it is more visible during the day.

In order to incorporate all of the required components into the size of the vehicle as previously established, the allowable length of the flare is approximately 5 inches long. To fit inside the flight vehicle, the flare O.D. cannot exceed 1.89 inches. This allowable volume is:

$$\text{Volume} = \frac{\pi\,(\text{diameter})^2}{4} \times \text{length} = \frac{\pi\,(1.89)^2}{4} \times 5 = 14 \text{ in}^3$$

To determine flare output capability, standard proven government flares were investigated and their output correlated in intensity x time, divided by the required volume. Intensity is expressed in candle-power, time in seconds, and volume in cubic inches. The MK 25 flare, developed as a tracking flare for the TALOS guided missile, has an output of 150,000 candle-power for 250 seconds, is 15.96 inches long and 2.5 inches in diameter. This gives an output per volume factor (K) of:

$$K = \frac{150{,}000 \text{ C.P. } x \text{ (250 sec)}}{(15.9 \times \frac{\pi (2.5)^2}{4}} = 4.8 \times 10^5 \text{ C.P.-sec per in}^3$$

The XM-145 Warning Flare developed by Picatinny Arsenal has an output of 45,000 candle-power for 52 seconds, is 3.5 inches long and has a diameter of 1.33 inches. This gives an output per volume factor (K) of:

$$K = \frac{45{,}000 \text{ C.P. } x \text{ 52 sec}}{3.5 \times \frac{\pi (1.33)^2}{4}} = 5.0 \times 10^5 \text{ C.P.-sec per in}^3$$

Based on these results, assuming we can obtain an output of 5.0×10^5 C.P.-sec per cubic inch for the C.D. flare, and since the available volume is 14 in^3, the output will be:

$$14 \text{ in}^3 \; (5.0 \times 10^5) \text{ C.P.-sec per in}^3 = 7{,}000{,}000 \text{ C.P.-sec}$$

Investigation into the problem of poor flare ignition characteristics has shown that this is a common problem, especially at low temperatures; ref. Document No. AD250-720.

All commercial flares have incorporated a "First Fire Mix" to guarantee reliable ignition over the temperature range. The "First Fire Mix" is an ignition booster charge of Barium Chromate and Boron, or equivalent, pressed onto the end of the flare. This charge is readily ignited and burns long enough to insure stable flare burning.

SMOKE TRAIL

The original POWS design incorporated a smoke generating unit which produced a white smoke trail during ascent. After a careful study under varying conditions it was determined that this smoke trail was not entirely acceptable for two reasons:

1. Because of the velocity of the rocket vehicle, the smoke trail was relatively thin and was rapidly dispersed during windy conditions.
2. The explosive charge contained in the vehicle as a warning sound was timed to detonate after the vehicle had begun its descent and the smoke trail was already beginning to disperse at this point.

Because it is desirable to have audio and visual warning components of the POWS activated almost simultaneously, and due to the disadvantage of the smoke trail as mentioned above, it was determined that a smoke cloud produced at terminal altitude is superior to the smoke trail as a warning device.

The current POWS design reflects this decision. The smoke generating unit was eliminated and the smoke cloud was incorporated with the explosive charge in a design similar to that of military marking shells. Specific requirements for the smoke cloud are listed in the specifications for POWS included as an addendum to this report.

EXPLOSIVE CHARGE AND SMOKE CLOUD

Maricopa County, Arizona Civil Defense Department sirens have an output of 126 decibels at 100 feet and have a warning range of two miles. By utilizing the method of "Outdoor Propagation" by Francis M. Wiener, prepared for a special summer program at M.I.T., the minimum warning sound pressure level at 2 miles can be calculated as follows:

$$SPL_1 = SPL_0 - 20 \log \frac{r_1}{r_0} - Ae$$

Where:

SPL_1 = sound pressure level at 2 miles

SPL_0 = sound pressure level at 100 ft

r_1 = 2 miles = 10,560 ft

r_0 = 100 ft

Ae = loss in air = 8 db per referenced article

Therefore:

$$SPL_1 = 126 \text{ db} - 20 \log \frac{10,560 \text{ ft}}{100 \text{ ft}} - 8 \text{ db}$$

$$SPL_1 = 77.5 \text{ db}$$

However, with an explosive charge, the duration is quite short and the required minimum sound pressure level throughout the covered area should be 100 db, based upon an engineering estimate.

As evidenced by the test conducted at RPI, a very small amount of explosive material is required to produce the required sound pressure level. Also, since a small increase in the explosive charge will produce a considerable increase in the sound pressure level, it is not believed that the explosive charge will limit either altitude or area coverage.

Explosive tests conducted under Phase I show that the volume for the explosive charge as shown in Figure 5, is sufficient to house the new explosive charge-smoke puff combination.

WHISTLE

The original concept for POWS included a warning whistle. Considerable time has been expended in study of the various approaches to this device. The simplest method appeared to be the use of the air flow as the rocket vehicle ascended. However, investigation proved that at the speed the rocket is moving, the ram pressure air flow is insufficient to produce a loud, sustained whistle or siren effect. There is a possibility that the exhaust gases from the rocket motor can be utilized to provide a whistling effect. However:

1. The high-energy, solid propellant motor required for POWS burns for only three seconds, then coasts for another seven seconds before reaching terminal altitude. This would only produce a whistle for three seconds.
2. The rocket fuel burns at a 5,000-degree Fahrenheit temperature. It would undoubtedly be costly and complicated to design a whistle component to cope with this problem.
3. A whistle utilizing the hot gases would disrupt the rocket exhaust flow and would probably create stability problems due to the resulting thrust misalignment.

Information obtained during the data survey indicates that a whistling propellant may be the most favorable approach. This device would be separate from the rocket motor and probably would be attached to the outside of the rocket vehicle at the aft end. However, this propellant is a pressed mixture and cannot meet the present storage life requirements for POWS.

The only method that presently appears feasible for producing a whistle is through the use of an independent gas generator. However, due to the added unit cost, the additional development time, and the complicating of the overall system, it is not recommended that this method be pursued at this time.

ALTITUDE

One of the main unknowns for the POWS during the development phase was the altitude. However, investigation has shown:

1. Based upon classified Ordnance Report No. ORDP 20-245, which deals with military marking shells, the minimum altitude at which the explosive charge should be initiated is 1500 feet. This is due to the lower velocity winds which are prevalent at that altitude, which result in the smoke cloud remaining in a distinct, dense form for a maximum period of time.
2. Since illumination varies as the square of the distance to the source, the maximum area coverage of the flare will be attained at a minimum altitude.
3. In order to meet F.A.A. requirements on a falling flare, (ref. TSO-C-24 Para. 4.1.3) the maximum average fall rate is 550 feet/minute or approximately 9 ft/sec. To insure that the flare attachment to the chute is cooled sufficiently to eliminate the possibility of fire, it is estimated that the flare should be burned out approximately 90 seconds prior to contact with the ground. At a fall rate of 9 ft/sec the burn out altitude is 810 feet. If the maximum altitude is 1500 feet and the fall rate is 9 ft/sec, the maximum flare burning time should be:

$$\frac{1500 \text{ ft} - 810 \text{ ft}}{9 \text{ ft/sec}} = 76 \text{ seconds}$$

Information attained from flare manufacturers shows that an increase in burning time, due to aging effect, of 20% can be expected. This gives a design burning time of 76 sec - 20% (76 sec) = 60.8 sec. Since the output for this flare is 7,000,000 C.P. sec, The intensity should be:

$$\frac{7,000,000 \text{ C.P. sec}}{60.8 \text{ sec.}} = 115,100 \text{ candlepower}$$

MATERIALS

Large quantity, low-cost production is one of the major requirements for the POWS. Since the cost of each individual part must be kept to a minimum, it is believed that injection molding is one of the most desirable means of manufacture. Upon investigation, it was found that, although most injection molding compounds would not meet the temperature and storage life of the POWS, there was one compound, polycarbonate, which exhibits the required properties. Polycarbonates are manufactured by a number of companies under various trade names but most of them have the following properties:

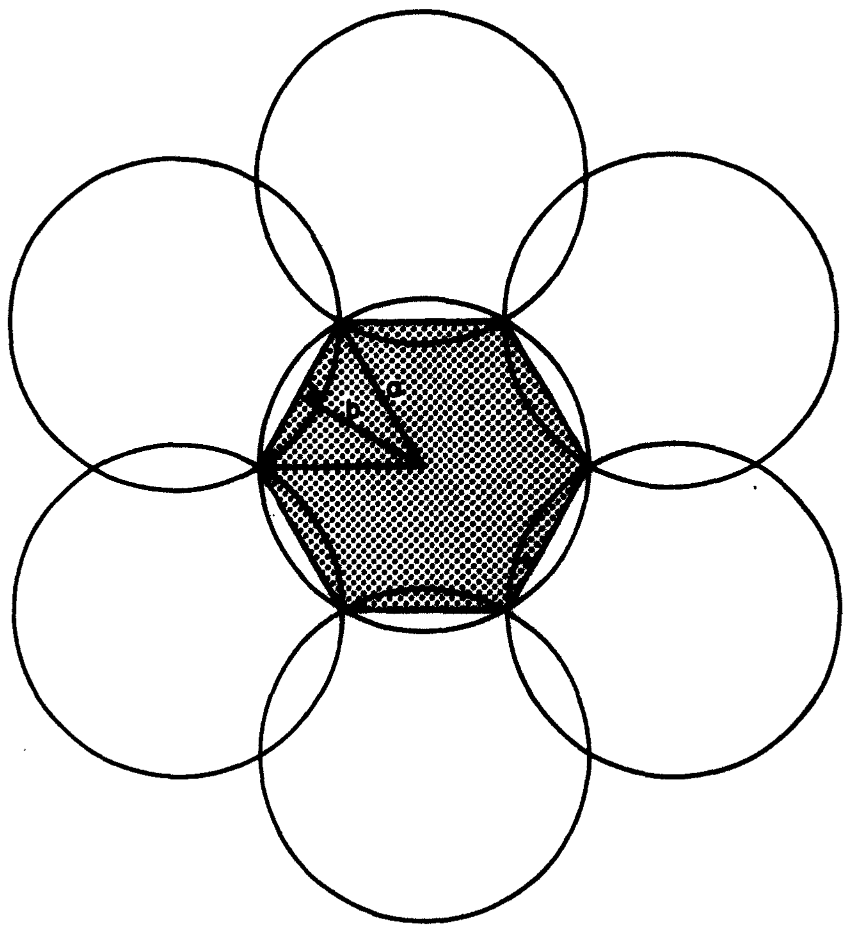
Specific Gravity	1.2
Melting Point	514°F
Coefficient of Expansion	7×10^{-5} in/in per °F
Compression Modulus	240,000 psi
Storage Life	Unlimited
Tensile Strength Ult.	10,500 psi
Compressive Strength	11,000 psi
Shear Strength (yield)	6,400 psi
Heat Distortion Point @ 160 psi	290°F
Brittle Point	-275°F

In order to insure reliability, it is believed that the rocket motor components and the outer tube should be made of aluminum. This eliminates the possibility of problems due to new materials in critical areas.

AREA COVERAGE

The most effective spacing and consequently area coverage will be established in Phase II. Based on the anticipated candlepower and decibel output of this unit, we can expect an effective slant range of 5000 feet. If the slant range is 5000 feet, the area coverage is in the shape of a circle with a 4580 foot radius.

As shown in Figure 7, in order to obtain complete coverage of the area, the warned areas will necessarily overlap. The average coverage per unit is the area of a hexagon. The effective area coverage is calculated as follows:



Shaded Area Indicates Effective Coverage Of One POWS Unit For Planning Purposes

Figure 6 — Diagram, POWS Unit Area Coverage

area = 1/2 a b n (area of a regular polygon)

n = number of sides = 6 (See Figure 6)

b = a sin 60° = .867 a

Area = .5(.867 a) (a) (6)

$= 2.601\ a^2$

Area/Unit = $2.601\ (4580)^2 = 5.46 \times 10^7\ ft^2$

$= (5.46 \times 10^7\ ft^2)\ 3.587 \times 10^{-8}$ sq. mi./sq. ft.

$= 1.955\ mi^2$/unit

COSTS

The estimated cost of the POWS units is as follows: (with two vehicles each)

Unit	Quantity	Cost
P/N 2617-10	100	$ 460
(See Figure 1)	1,000	300
	10,000	200
	100,000	148 *
P/N 2617-11	100	$ 495
(See Figure 2)	1,000	322
	10,000	218
	100,000	160

The above costs are budgetary and do not include amortization or tooling.

A POWS of twice the size would cost approximetely 60 percent more. One of four times the size would cost approximately twice as much.

* The cost per square mile of coverage is $\$148/1.955\ mi^2 = \$75.70$ dollars/mi^2. A further breakdown of costs is on the following page.

The price of the launcher assembly P/N 2617-10 is as follows:

Item	Cost With One Vehicle	Cost With Two Vehicles
Igniter	$ 1.89	$ 3.78
Delay Train	1.88	3.76
Explosive Charge	5.37	10.74
Flare	2.90	5.40
Propellant Grain	8.25	16.50
Hardware & Assy.	13.79	27.58
Parachute	4.00	8.00
Inspection	1.65	3.30
Acceptance Tests	2.37	4.74
Launcher Assy.	40.00	40.00
Control Unit	10.00	10.00
subtotal	$ 92.10	$ 134.20
Fee @ 10%	9.21	13.42
Total	$ 101.31	$ 147.62

SECTION IV

PROPOSED PHASE II PROGRAM

Rocket Power, Inc., under contract to the Office of Civil Defense, Department of Defense, has successfully completed the development of a prototype Pyrotechnic Outside Warning System.

Rocket Power, Inc., recommends that this program enter a second phase for verifying the prototype design, determining public reaction, and incorporating the modifications recommended after the completion of Phase I. The recommended Phase II Program is divided into four parts as follows:

CATEGORY A — SUBSYSTEM VERIFICATION

A quantity of each subsystem, sufficient to demonstrate the capability of each component, shall be tested prior to performing any tests of the complete POWS.

CATEGORY B — INDIVIDUAL SYSTEM VERIFICATION

Testing will consist of 50 consecutive successful firings, part of which shall be multiple firings to determine the unit spacing for Category C testing.

CATEGORY C — MULTIPLE SYSTEM VERIFICATION

Testing will consist of 25 simultaneous day firings and 25 simultaneous night firings to determine the effect of mass firings, verify the unit spacing selected in Category B, and establish reliability prior to Category D testing.

CATEGORY D — PUBLIC TEST

Testing will consist of both day and night firings to obtain public reaction, prove the feasibility of the POWS and its capability to accomplish the tasks envisioned for it at the onset of the program.

Since the future of the POWS depends largely on public reaction to Category D testing, the proposed Phase II program is considered to be an absolute minimum. It is believed that the 100 consecutive successful firings of Categories B and C will be necessary to decrease the possibility of failure during public testing.

APPROACH

Since the POWS will be installed on an operational status in public areas, prime consideration will be given to safety of installation, and reliability of operation. All POWS manufactured must meet the same rigorous standards as those of manned escape systems where failure is virtually non-existant. RPI has 4,000 such products in service and no failure has been experienced to date. Each POWS subsystem will be tested to verify its integrity prior to integration into the POWS.

CATEGORY A — SUBSYSTEM VERIFICATION

Flare
Various chemical formulations will be tested until the color and illumination requirements determined from Phase I are met. In conjunction with these tests, verification of flare burning time and reliability of ignition will be accomplished.

Explosive Charge and Smoke Cloud
The data obtained during Phase I indicates that a smoke cloud would be more effective than a smoke trail as a warning device. The smoke trail is easily dispersed by wind, and virtually disappears by the time the explosive charge is detonated at altitude to attract attention; whereas, a smoke-producing material can be packaged in the area surrounding the explosive charge to produce simultaneous audio and visual warning. Verification of the smoke cloud method will be accomplished during this phase of the program and will consist of sufficient tests to determine the proper charge and dye load for optimum audio and visual warning.

Propellant Delay Train
The various problems associated with perfecting the unique propellant delay train for the POWS were resolved in the latter part of the Phase I Program. The capability of this device to perform its functions (ignite the ejection and explosive charges, ignite the flare, and provide sequencing) will be further verified during this phase of the program.

Ejection Charge

Adequate verification tests will be conducted to assure the reliability of the ejection charge in performance of its task.

Propulsion System

The propulsion system will undergo tests to verify its capability to reliably deliver a thrust level sufficient to achieve the required altitude as determined during Phase I.

Flight Vehicle

Problems of flight stability encountered early in Phase I have been eliminated. Further verification of the vehicle's stability will be accomplished in Phase II.

Control Unit

The Control Unit has functioned perfectly in all tests conducted since its development in the early part of Phase I. Verification tests will be run in Phase II to prove the unit's capability to accept only the intended NEAR signals and to precisely time and control launch of the rocket warning vehicles.

Launching Platform Verification Test

A minimum of three units (six vehicles) will be tested to verify integrity of the launching platform and control unit.

One test of the launching assembly will be conducted wherein a flight vehicle will be deliberately restrained in the launcher tube after motor ignition. This test will determine the effect on the control unit and on the number two vehicle when the number one vehicle explodes in the tube.

In another test of the launching platform, three rounds from a .22 caliber rifle will be fired into tube one and three rounds from a 30-30 caliber rifle will be fired into tube two. These tests will determine the susceptibility of the POWS to damage (for example, small arms fire by vandals).

CATEGORY B — INDIVIDUAL SYSTEM VERIFICATION

The feasibility, integrity, and operational reliability of the individual POWS will be determined during testing under this category as follows:

After each subsystem is tested and verified separately (Category A), the components will be integrated and tested as a complete system. A quantity of complete systems, sufficient to conduct 50 consecutive successful firings, will be manufactured and tested. Included as part of these 50 firings will be a small number of multiple systems firings to determine the spacing for Category C testing.

CATEGORY C — MULTIPLE SYSTEM VERIFICATION

The integrity and operational reliability of multiple POW systems will be established during testing under this category. Twenty-five simultaneous day firings and 25 simultaneous night firings will be performed to establish the effect of mass firings, verify the system spacing selected in Category B, and determine the system reliability prior to the Public Test of Category D. TheCategory C tests will be conducted at a fovernment facility, such as Fort Huachuca.

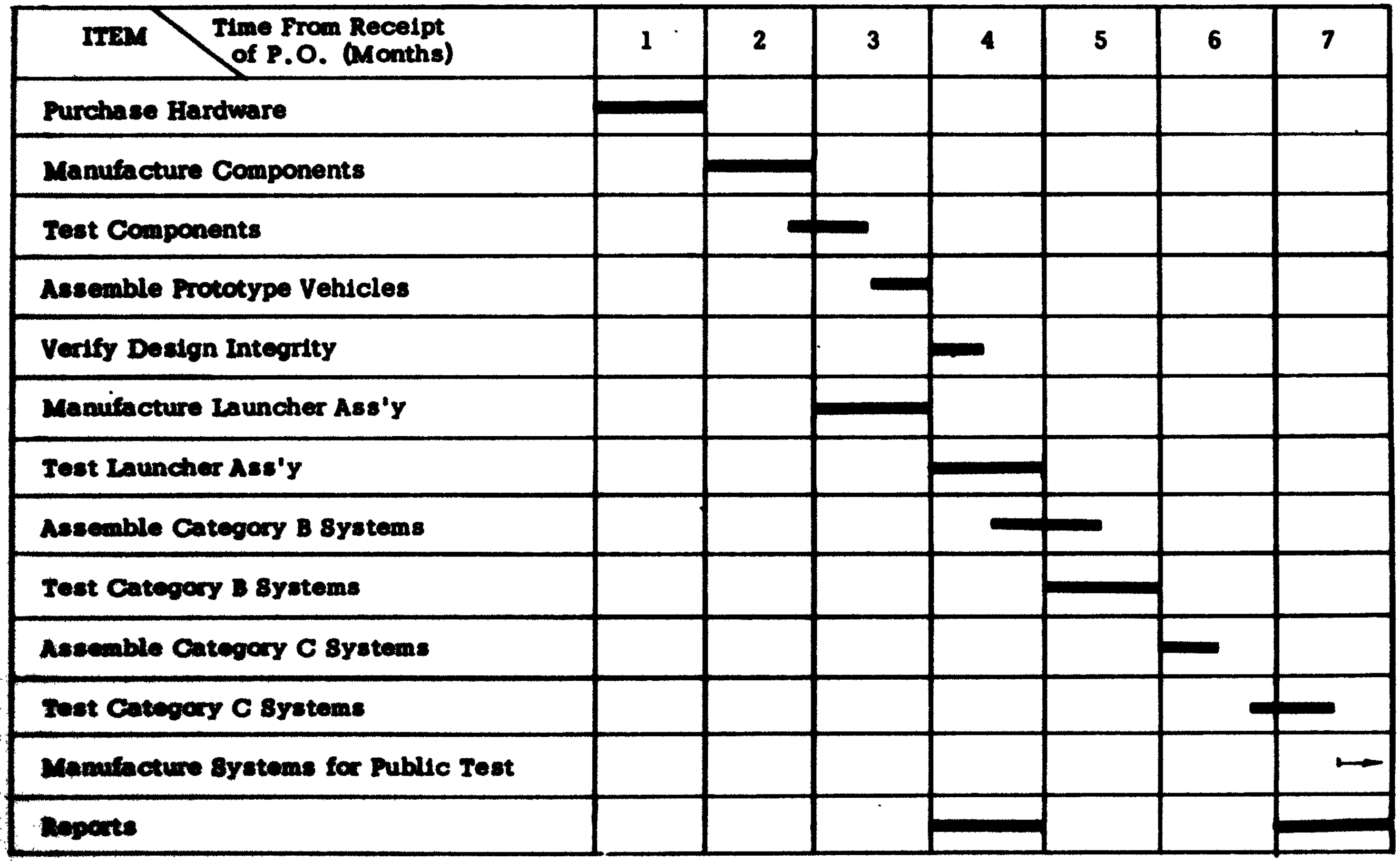
CATEGORY D — PUBLIC TEST

After completion of the verification testing of Categories A, B, and C, a Public Test to be conducted by an organization independent of RPI, is proposed. This testing will obtain the public's reaction to the POWS, determine the feasibility of the system and exhibit its ability to accomplish the tasks envisioned for it at the onset of the program. The test will provide the first opportunity for the public to witness and judge the effectiveness of the system in operation. It will also provide a source of information for representatives of the Office of Civil Defense in judging the operating effectiveness of the system. In addition to its obvious value as a guage of public reaction, the test will supply data pertinent to proper placement of units, the precise area of coverage per unit in actual use, and will serve as a guide to future installations.

The test will consist of both day and night operations. The number of units to be used will depend on the area of coverage desired by OCD. A complete survey of the area of installation will be made in coordination with OCD officials. Techniques of this survey, as well as method of installation will be documented in detail.

Extensive visual and photographic observations will be made from the ground and air. Sound intensity will be determined by audiometer, with decibel readings taken from varied locations. Photographic and instrumentation coverage will become a part of a thorough final report which will be provided to OCD. This report will serve as a guide to installation of the system in other areas. Information gained from this test will be useful in preparation of documentary films, instruction material, and for public information programs. Since the NEAR system will not become operational in time for this special test, a means of activating the POWS from a local source must be provided for this program.

PHASE II
PROPOSED SCHEDULE



SECTION V

PROPOSED PHASE III PROGRAM

After completion of the Phase II Program, Rocket Power, Inc., recommends the POWS enter a third phase (qualification) prior to being mass produced.

The Phase III Program shall consist of environmental testing of fifteen units to prove their transportation, storage, and operating capabilities. A unit shall consist of vehicles, control unit, and launching platform. Units of final design established by Phase II shall be tested as outlined below.

Accelerated Aging

Three units shall be subjected to accelerated aging. The units shall be maintained at $200^{\circ} \pm 5^{\circ}F$ for 500 hours, 750 hours, and 1000 hours respectively. After removal, the units shall be inspected and test fired.

Temperature Shock

Twelve units shall be subjected to Temperature Shock as outlined in Procedure I of MIL-E-5272* except the temperatures shall be $+200^{\circ}F$ and $-65^{\circ}F$ in lieu of $185^{\circ}F$ and $-40^{\circ}F$ as follows:

The units shall be exposed to $+200^{\circ}F$ for a period of four hours, at the conclusion of which, and within five minutes, the units shall be transferred to a chamber having an internal temperature of $-65^{\circ}F$. The units shall be subjected to $-65^{\circ}F$ for a period of four hours. This constitutes 1 cycle. The number of complete cycles shall be three. Two units shall be test fired within a period of one hour after removal from the test temperature. The remaining ten units shall be subjected to Sand and Dust.

Sand and Dust

The ten units from Temperature Shock shall be subjected to Sand and Dust as outlined in Procedure I of MIL-E-5272, except that $+200^{\circ}F$ shall be used in lieu of $160^{\circ}F$ as follows:

* Military Specification — General specification for environmental testing of aeronautical and associated equipment. (Approved for Air Force and Navy Bureau of Aeronautics).

The units shall be placed in a test chamber equal to MIL-C-9436. The internal temperature of the test chamber shall be maintained at +77°F for a period of six hours with sand and dust velocity through the test chamber between 100 and 500 feet per minute. After six hours at the above conditions, the temperature shall be raised to and maintained at +200°F. These conditions shall be maintained for six hours. At the end of this exposure period, the units shall be removed and allowed to stabilize at room temperature. Two units shall be test fired, and the remaining eight units shall be subjected to Rain.

<u>Rain</u>

The eight units from Sand and Dust shall be subjected to Rain, as outlined in Procedure II of MIL-E-5272 as follows:

A test chamber equal to MIL-C-8811 shall be used and the units mounted therein to simulate installed conditions. The rain test chamber temperature shall be uncontrolled except as regulated by water introduced as rain, throughout the test period. A simulated rainfall of 4 ± 1 inch per hour as measured at the surface of the equipment by a U.S. Weather Bureau type guage shall be produced by means of water spray nozzles. The direction of rainfall shall be capable of variation up to 45° from the vertical. The rainfall shall be dispersed uniformly over the test area within the limits as specified above. Each of the four sides of the equipment shall be exposed to the simulated rainfall for a period of 30 minutes, for a total test duration of 2 hours. After completion of this test, the eight units shall be transferred immediately to Humidity.

<u>Humidity</u>

The eight units from Rain shall be subjected to Humidity as outlined in Procedure I of MIL-E-5272 as follows:

The units shall be placed in the test chamber and set up to simulate installed conditions. The test chamber shall be vented to the atmosphere to prevent thebuildup of pressure. Prior to starting the test period, the chamber temperature shall be between 68 and 100°F with uncontrolled humidity. During the first two hour period, the temperature shall be gradually raised to 200°F. This temperature shall be maintained during the next six hour period. The velocity of the air throughout the test area shall not exceed 150 feet per minute. During the next sixteen hour period, the temperature in the chamber shall be gradually reduced to 60 to 100°F which constitutes one cycle. The relative humidity throughout the cycle shall be 95 percent. The cycle shall be repeated a sufficient number of times to extend the total time of the test to 240 hours (10 cycles). At the conclusion of the 240 hour period, the equipment shall be returned to standard conditions. Two units shall be test fired within one hour from the time they are removed from conditioning. The six remaining units shall be subjected to Salt Spray.

Salt Spray

The six units from Humidity shall be subjected to Salt Spray as outlined in Procedure II of MIL-E-5272 as follows:

The units shall be subjected to the salt atmosphere in accordance with Federal Test Method Standard No. 151, Method 811 for a period of 50 hours. Two units shall be test fired within one hour after removal from testing. The remaining four units shall be rinsed with tapwater and allowed to air dry before being subjected to Shipping Vibration.

Shipping Vibration

The four units from Salt Spray shall be crated and subjected to Shipping Vibration as outlined in Method 514-6 of MIL-STD-810 (USAF) as follows:

The units shall be subjected to sinusoidal vibration for a period of two hours in each of three mutually perpendicular axes. After this test, two units shall be test fired. The remaining two units shall be subjected to Drop.

Drop

The two units from Shipping Vibration shall be subjected to the following drop tests:

One unit, still crated, shall be dropped from a height of six feet onto a reinforced concrete slab to simulate rough handling during shipping. The unit shall not fire from impact. After the drop test the unit shall be uncrated, disassembled, inspected, reassembled, and test fired.

The other unit, still crated, shall be dropped from a height of 40 feet on to a reinforced concrete slab. After drop test, the unit shall be uncrated, disassembled and inspected. This unit shall not be required to function after being subjected to the 40 foot drop test.

Test Criteria

After each phase of the qualification program, an inspection and test firing will be conducted to determine the effect of that particular conditioning on the unit. If the unit shows any effects which could cause a malfunction, necessary changes will be made to the units and all tests will be repeated.

Test Records
Sufficient records, recordings, and pictures will be maintained during the tests to permit a complete and documented report to be prepared at completion of the qualification program.

Lot Acceptance Tests
RPI is presently manufacturing a large number of items for manned escape systems. In these systems where human life is at stake, a straight ten percent of all production quantities is tested.

Based on the use of this unit in populated areas where human life could be endangered if a unit were to malfunction, it is recommended that a straight ten percent lot acceptance test is required.

APPENDIX I

SPECIFICATION FOR

PYROTECHNIC OUTSIDE WARNING SYSTEM

SPECIFICATION
FOR
PYROTECHNIC OUTSIDE WARNING SYSTEM
P/N 2617-10

1. SCOPE

1.1 General. This specification covers the requirements for the POWS (Pyrotechnic Outside Warning System).

1.2 Function. The POWS shall consist of special purpose miniature rocket vehicles within a launcher assembly, equipped with various audio and visual warning devices, coupled to electronic control units which will accept the NEAR signal for activation.

2. GENERAL PERFORMANCE REQUIREMENTS

The performance characteristics of the POWS are based on the use of the components specified on Dwg. No. 2617-10 and discussed below.

2.1 Launcher Assembly- Figure 1 (Alternate Figure 2)

2.1.1 The launcher assembly shall consist of sealed launcher tubes, connected by a separate section which shall house the control unit and shall be capable of maintaining a seal for a minimum of 10 years.

2.1.2 Each launcher tube is to be equipped with stationary guides which will guide the vehicle until it has left the tube. These guides must be sufficient to insure initial flight stability.

2.1.3 Between the launcher tubes, there will be a control section to house the control unit. This section will have attachment brackets for fastening the control unit in place.

2.1.4 An access panel will be incorporated into the control section to allow the field inspection of the control unit.

2.1.5 Hermetically sealed connectors will be provided between the control unit and each launcher tube to accommodate the igniter lead wires.

2.1.6 The maximum envelope for the launcher assembly is 21 inches in height, 5.5 inches deep and 14 inches wide. (Alternate, 21 x 11 x 14 inches)

2.1.7 The maximum weight of the total assembly, including two vehicles and control unit, shall not exceed 50 pounds.

2.1.8 Each launcher assembly shall incorporate integral hooks for easy installation in the field. These hooks must be designed to withstand a minimum of twice the load produced by the firing of one vehicle, to insure that the assembly will not be released from the pole when the rocket motor fires.

2.1.9 Each launcher tube shall have a shear area or diaphragm which will fail at a maximum pressure of 120 psi internal pressure. However, this diaphragm or shear area shall not fail when exposed to an internal pressure of 20 psi.

2.2 Flight Vehicle. A flight vehicle consists of one complete warning rocket, incorporating a rocket motor, delay train, flare, explosive charge, smoke charge and parachute.

2.2.1 The vehicle shall be a completely sealed unit to further insure its storage life capability.

2.2.2 The flight vehicle shall have a maximum assembled weight of 5.5 pounds, including igniter.

2.2.3 The maximum envelope for the vehicle shall be 20 inches long and 2.3 inches in diameter excluding the fins, which may have a maximum outside diameter of 5.4 inches. The fin area must be sufficient to insure stable flight.

2.3 Rocket Motor

2.3.1 The rocket motor shall be capable of propelling the flight vehicle to an altitude of 2000 feet after conditioning to -65°F. The rocket motor shall have a burning time of three ± 1/2 seconds.

The propellant grain shall be of a polysulfide binder, ammonium perchlorate oxidizer system capable of withstanding uncontrolled storage conditions for a minimum of ten years between -65°F and +200°F.

2.3.2 Propellant - The propellant shall be RPI-PAP-11H, or equivalent, RPI-PAP-11H propellant shall conform to the following formulation:

Ingredients	Function	% by Weight
Ammonium Perchlorate	Oxidizer	73.9
Aluminum	Resonance Suppressor	1.6
Polysulfide Polymer	Fuel	19.1
Curatives		5.4
		100%

2.3.2.1 Propellant Properties - The nominal properties of the propellant shall be as follows:

a) Temperature Sensitivity Coefficient = 0.17%/°F from -65°F to +200°F.

b) Characteristic Exhaust Velocity (C*) = 4750 ft/sec

c) Burning Rate @ 1000 psi = .5 in/sec

d) Pressure Exponent of Burning Rate = 0.5

e) Density = 0.0617 lbs/in^3

2.3.2.2 Auto Ignition Temperature - The propellant shall not spontaneously ignite when held at a temperature of 275°F for one hour or at 225°F for eight hours. Auto ignition occurs at approximately 365°F.

2.3.3 Restrictor & Bonding Agent - A Minnesota Mining and Mfg. Co. product - EC 801, or equivalent, shall be used to bond the propellant grain to the nozzle slug and the nozzle slug to the aft closure. It shall also be used to restrict burning on the ends of the propellant and to seal all threads.

2.3.3.1 The internal grain configuration shall be designed to give a gradually decreasing burning area to insure stable burning of the delay train. No excess bonding agent is allowed on the surface of the grain beyond 3/8-inch from each end of the grain.

2.3.3.2 To insure maximum stability, the rocket motor must produce a regressive thrust-time curve with maximum thrust occuring within the first .040 second.

2.3.3.3 Each rocket motor must be X-rayed in two planes prior to assembly to insure against any defects which could effect the reliability of the POW System.

2.3.4 Igniter. The rocket motor igniter shall be an electrically actuated metallic particle type igniter and shall perform with a minimum of shock. It shall consist of RPI-CAI-1 ignition material, or equivalent, and an electrically actuated squib.

The RPI-CAI-1 ignition material shall conform to the following formulation and material specifications:

Material	Function	Spec. No.	Nom. Parts by Wt.
Cupric Oxide	Oxidizer	RPI-MS-4190	81.6
Aluminum Powder	Fuel	RPI-MS-4050	18.4

2.3.4.1 Auto Ignition Temperature. The ignition material will not auto-ignite when exposed to 420°F for 8 hours or to 1000°F for 30 minutes.

2.3.5 Liner - The motor case liner shall be RPI-PSL-2, or equivalent. RPI-PSL-2 shall conform to the following material specifications:

Ingredient	Specification No.
LP-3 (Liquid Polymer)	RPI MS 4671
Thermax (Carbon Black)	RPI MS 4162

MGO(Para-Quinonedioxime)	RPI MS 4810
MgO(Magnesium Oxide)	RPI MS 4610
DPG (Diphenylguanidine)	RPI MS 4240

2.3.6 Delay Train. The delay train will be RPI PAP 8 propellant cast directly into a 3/8 I.D. inhibitor tube.

2.3.6.1 Ballistic Properties. The nominal ballistic properties of the propellant are as follows:

a) The burning rate at 500 psi = .45 in/sec

b) Temperature sensitivity coefficient (K) = 0.13%/°F

c) Pressure exponent of burning rate (n) = 0.61

d) Characteristic exhaust velocity (C*) = 4680 ft/sec

2.3.6.2 Auto Ignition Temperature - The auto ignition temperature of the propellant is approximately 360°F.

2.3.6.3 The delay train must reliably and reproducibly:

a) Be ignited by the rocket motor

b) Initiate the ejection charge at maximum altitude

c) Ignite the flare

d) Delay 1 to 2 seconds prior to igniting the explosive charge

2.3.7 Ejection Charge - The ejection charge shall consist of a boron/potassium nitrate formulation capable of meeting the storage life and temperature requirements.

2.3.7.1 The gases produced by the ejection charge must be sufficient to shear the two aluminum shear pins in the nose cone and eject the flare and the explosive charge without causing damage to the rest of the vehicle.

2.3.8 Flare - In order to meet the storage life, the flare must be of a cast propellant type formulation which will produce a red flame while burning. The flare is cast to minimize deterioration due to storage time.

2.3.8.1 The flare must produce a bright red flame of 100,000 candle power intensity for a minimum of 60 seconds.

2.3.8.2 The maximum outside diameter of the flare shall not exceed 2.00 inches.

2.3.8.3 The flare case shall be of a material which will not sustain burning after the flare is burned out and shall accommodate attachment fittings for the chute and hardware.

2.3.9 Explosive Charge - The explosive charge must be very stable and insensitive to shock.

2.3.9.1 The explosive charge must be capable of producing a minimum sound pressure level of 100 decibels throughout the covered area (obstructions excluded), as measured by a sound intensity meter conforming to ASA requirements.

2.3.9.2 The explosive charge must detonate within two seconds after ejection.

2.3.9.3 The enclosure for the explosive charge shall contain no metal parts which could be dangerous to persons or property.

2.3.10 Smoke Cloud - The smoke cloud is to be dense and compact and is to persist in recognizable form for a minimum of 40 seconds in still air.

2.3.10.1 The smoke cloud is to form immediately upon burst without any build up period.

2.3.10.2 The cloud must be red in color and must be unmistakably recognizable in hue.

2.3.10.3 To increase the duration of the smoke cloud, it must be detonated above 1500 feet.

2.3.10.4 The dye used to produce the smoke cloud should belong to one of the following groups: Azine, Azo, Quinaline, or Xanthene.

2.3.10.5 The following groups may be present:

NH_2	CHLORO
RNH	BROMO
R_2N	ALKOXY
ARYL	HYDROXY
ALKYL	

2.3.10.6 The following groups must be absent:

SULFONIC	NITROSO
HYDROCHLORIDE	QUATERNARY AMMONIUM
NITRO	OXONIUM

2.3.10.7 The dye should be volatile, should sublime readily, should have good thermal stability, and a high flash point, should have a high color saturation, should have a molecular weight less than 450 and should not undergo auto-oxidation.

2.3.11 Parachute - The parachute must be orange or red in color (preferably international orange) and must be capable of functioning properly after uncontrolled storage for the life of the POWS.

2.3.11.1 The parachute must be capable of retaining the hardware and the flare and still not exceed an average fall rate of 550 feet per minute.

2.3.12 Control Unit - The control unit must be sealed and capable of performing satisfactorily after exposure to uncontrolled storage for 10 years. During phase II, a secondary initiation system will be used.

2.3.12.1 The control unit must be capable of monitering a power-line at all times. Upon receipt of a warning signal for a minimum of 15 seconds, it will fire the first vehicle, switch the firing circuit to the second vehicle and remain on standby until the second signal is received.

2.3.12.2 The control unit will incorporate a method of checking the circuit and step location so that periodic checks can be made in the field.

2.4 Fabrication

2.4.1 Materials and Processes - Materials and processes shall be of high quality suitable for the purpose to which applied and shall conform to the specifications and drawings herein.

2.4.1.1 Reuse of Parts - All parts of the rocket motor are expendable.

2.4.1.2 Dissimilar Metals - Dissimilar metals are not used in contact with each other in the assembly defined herein.

2.4.2 Workmanship - The workmanship shall be of the best commercial practice to insure satisfactory operation, reliability and durability consistent with the service life and application of the system.

2.4.3 Interchangeability - All parts and vehicles shall be completely and readily interchangeable at any time prior to final assembly.

2.4.4 Protective Treatment and Finish - All metal parts used in the construction of the POWS shall be protected against deterioration during service usage. The protective treatment will in no way prevent compliance with the performance requirements of this specification. The protective coating and finish is specified on the applicable Rocket Power drawings.

2.4.5 Identification of Product - The rocket vehicle and launcher assembly shall be identified and marked as specified on the applicable Rocket Power drawings and as specified by contract. Each vehicle shall exhibit a serial number marked on the identification label.

3. QUALITY ASSURANCE PROVISIONS

3.1 Inspection Procedures - The requirements for sampling inspection and tests shall be as specified in MIL E 25532.

3.1.1 Radiographic Inspection - Each vehicle shall be X-rayed in a minimum of two planes after final assembly to insure that the vehicle is properly assembled and all components are in their proper location.

3.2 Acceptance Tests - Acceptance test units shall consist of 10% of the production run from a single lot provided that no change has occured in any manufacturing process procedure during the production run. In the event that a change has occurred in one of the catagories listed above, 10% from the new group of motors in the same run shall be test fired. Test units will be fired after the units have been conditioned to -65°F, +70°F and +200°F alternately throughout all production lot samples.

4. PREPARATION FOR DELIVERY

4.1 Shipment - Preparation for delivery shall be contingent upon contractual requirements. The launcher assembly, control units, and the flight vehicles shall be packaged in accordance with the conditions specified on applicable RPI drawings.

4.1.1 Packaging - The launcher assemblies and control units shall be identified in accordance with RPI drawings and shall bear evidence of acceptance.

5. NOTES -

5.1 Illustrated installation and safety handling manuals will be furnished as required.

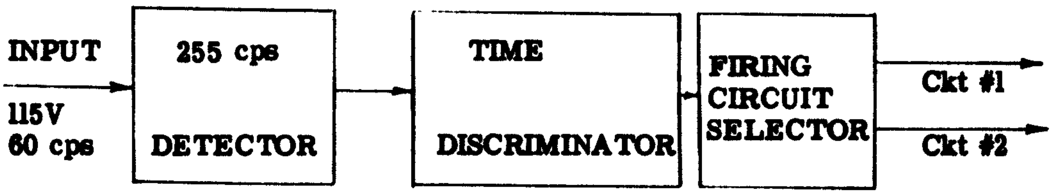
APPENDIX II

SPECIFICATION FOR A WARNING ROCKET CONTROL UNIT

SPECIFICATION
FOR
A WARNING ROCKET CONTROL UNIT

1. INTRODUCTION

This specification describes the requirements for a control unit which shall monitor a standard 115 V rms 60 cps power line upon which is superimposed a coded 255 cps sine wave ranging in amplitude from 0.8 through 6 V rms. The unit shall be actuated only by a 255 cps signal with a specific time interval. All other signals shall be rejected by the unit. When actuated, the unit shall fire one of two rockets. When the actuating signal is removed, the Control Unit shall automatically ready itself to fire the next rocket when the command is received.



BLOCK DIAGRAM

WARNING ROCKET CONTROL UNIT

2. INPUT

The control unit shall monitor a standard 115 volt, 60 cps power line. A 255 cps sinusoidal signal ranging in amplitude from 0.8 through 6 V rms shall be superimposed on the 60 cps power line. Time duration of the 255 cps signal may vary from zero to sixty seconds. Quiescent power consumption shall be 2 watts or less with a leading power factor.

3. DETECTOR

A detector, capable of continuously monitoring a standard 115 V

60 cps power line, shall be sensitive to the 255 cps signal only. It shall produce an output signal which operates a Time Discriminator. The Detector output signal shall be present as long as the 255 cps signal is present.

4. TIME DISCRIMINATOR

A discriminator circuit shall monitor the detector signal and actuate the Firing Circuit Selector if the signal is present for a period greater than 30 seconds. If the signal is interupted at any time under 30 seconds, the timing device shall automatically reset itself to zero and standby to start count.

5. FIRING CIRCUIT SELECTOR

Upon receipt of the signal from the Time Discriminator, the Firing Circuit Selector shall apply 6 V rms, at 10 amperes to an igniter load in Circuit #1. This voltage shall be present as long as the Time Discriminator signal is present. If the input signal is removed for any period of time, the voltage shall be removed from Circuit #1 and the selector shall automatically ready itself to apply 6 V rms at 10 amperes to Circuit #2 upon reapplication of the Time Discriminator signal.

6. ENVIRONMENTAL REQUIREMENTS

The unit shall be capable of withstanding the following Environmental test program.

6.1 Temperature Cycling - The unit shall function satisfactorily during and after cycling between -65°F and +200°F for a total of 50 cycles. Each cycle shall consist of exposing the unit to -65°F for one hour, then to +200°F for one hour.

6.2 Humidity - Unit operation shall not be affected by exposure to relative humidity greater than 95% at temperatures between 95°F and 100°F for a period of ninety-six hours.

6.3 Vibration - Shipping vibration described in MIL STD 300 shall not affect operation of the unit.

6.4 Dust - The units shall be capable of withstanding a simulated dust storm for a period of twelve (12) hours.

6.5 Salt Spray - Operation of the unit shall not be affected by a twelve (12) hour exposure to a 95°F finely divided, wet, dense, fog generated with a salt solution prescribed in Federal Test Method Standard No. 151, Method 811, Paragraphs 2.1.4, 2.1.4.1, and 2.1.4.2.

6.6 Simulated Snow - The units operation shall not be affected by a twelve (12) hour direct exposure to snow while at a temperature of 32°F.

6.7 Drop Test - The units, while packaged in a shipping container, shall be capable of withstanding a twelve (12) foot drop onto solid reinforced concrete.

6.8 Aging - The unit shall be capable of satisfactory operation over a period of ten (10) years.

6.9 Life Cycle - The 255 cps Detector and Time Discriminator must have an expected life of 5000 cycles. A cycle to be defined as the actuation of the Time Discriminator and return to standby condition.

APPENDIX III

FLIGHT TESTS

FLIGHT NUMBER 1

FLIGHT VEHICLE DATA

Propellant Grain: Burning Time 1.16 seconds - Impulse 50 pound-seconds

Smoke Generator: None

Initiator: S-90 Squib

Igniter: 2 grams CAI-1

Delay: None

Explosive Charge: None

Flare: None

Fin Area: 1.25 square inches (bonded on at a 2° incidence angle)

Nose Cone: Flat (with ballast)

Length: 17.50 inches

FLIGHT DESCRIPTION

Launch was made from an open, circular tube 24 inches long. The object of this first flight was to determine altitude and flight stability. The actual altitude obtained was approximately 3000 feet (4000 feet was predicted). The vehicle showed a tendency to curve into the wind which was a result of a margin of aerodynamic stability. This accounted for the "lower than expected" altitude. The flight was considered successful.

FLIGHT NUMBER 2

FLIGHT VEHICLE DATA

Propellant Grain: Burning Time 1.16 seconds - Impulse 40 pound-seconds

Smoke Generator: None

Initiator: S-90 Squib

Igniter: 2 grams CAI-1

Delay: None

Noisemaker: None

Flare: None

Fin Area: 1.25 square inches (bonded on at a 2° incidence angle)

Nose Cone: Flat (with ballast)

Length: 17.50 inches

FLIGHT DESCRIPTION

Launch was made from an open, circular tube 24 inches long. This second flight was identical to the first with exception of the motor impulse (40 pound-seconds). The lower impulse was predicted to produce an altitude of 2,500 feet. The vehicle impacted approximately 500 yards from the launcher after attaining an altitude of approximately 2,500 feet. The flight was considered successful.

FLIGHT NUMBER 3

FLIGHT VEHICLE DATA

Propellant Grain: Burning time 1.16 seconds - Impulse 30 pound seconds

Smoke Generator: Yellow

Initiator: S-90 Squib

Igniter: 2 grams CAI-1

Delay: None

Noisemaker: None

Flare: None

Fin Area: 1.25 square inches (bonded on at a 2° incidence angle)

Nose Cone: Flat

Length: 17.50 inches

FLIGHT DESCRIPTION

Launch was made from an open, circular tube at an angle of 85° Q.E. The vehicle path was normal and the 1,500 foot altitude predicted for 30 pound-second impulse was attained. A very thin smoke trail was observed but it was quickly dispersed by the wind (5 mph). The hardware was recovered.

FLIGHT NUMBER 4

FLIGHT VEHICLE DATA

Propellant Grain: Burning time 2.0 seconds - Impulse 50 pound-seconds

Smoke Generator: 1.5 inch O.D. x 15 inches long (Mfg. by S.D.)

Initiator: S-90 Squib

Igniter: 2 grams CAI-1

Delay: None

Noisemaker: None

Flare: None

Fin Area: 2.5 square inches (bonded)

Nose Cone: Flat (no cone)

Length: 21.00 inches

FLIGHT DESCRIPTION

Launch was made from a square tube. The smoke generator and rocket motor were ignited at the same time. The vehicle emerged from the launcher at a very slow acceleration and veered sharply to the left during motor burning. After motor burnout, the vehicle stabilized and flew normal. A good smoke trail was observed throughout the flight. The vehicle could not be found after the flight. Thrust misalignment and aerodynamic instability were felt to be the cause of the vehicle veering off the intended flight path. This flight proved that a visible smoke trail can be obtained if sufficient volume is available for the smoke generator. Approximate altitude obtained was 2,000 feet.

FLIGHT NUMBER 5

FLIGHT VEHICLE DATA

Propellant Grain: Burning time 1.16 seconds - Impulse 50 pound-seconds

Smoke Generator: 1.50 inch I.D. x 8 inches long

Initiator: S-90 Squib

Igniter: 2 grams CAI-1

Delay: None

Noisemaker: None

Flare: None

Fin Area: 2.50 square inches (bonded)

Nose Cone: Flat

Length: 21.0 inches

FLIGHT DESCRIPTION

Launch was made from a split, rectangular tube at an angle of 85° Q. E. The vehicle was fired and the trajectory veered sharply to the right and impacted approximately 300 yards from the launch point. No visible smoke trail was produced. The expended hardware was recovered and showed that the aluminum retainer in the aft end of the motor had been severely eroded by the hot gases from the motor which would cause a significant thrust misalignment. Maximum altitude obtained was approximately 500 feet.

FLIGHT NUMBER 6

FLIGHT VEHICLE DATA

Propellant Grain: Burning time 1.16 seconds - Impulse 50 pound-seconds

Smoke Generator: Smoke puff

Initiator: S-90 Squib

Igniter: 2 grams CAI-1

Delay: Propellant rod

Noisemaker: None

Flare: Kilgore (red)

Fin Area: 2.5 square inches (bonded)

Nose Cone: Flat (no cone)

Length: 21.0 inches

FLIGHT DESCRIPTION

Launch was made from a split, circular tube at an angle of 85° Q.E. A chamfer was machined in the aft retainer ring to eliminate the erosion problem and thrust misalignment. The rocket motor characteristics were the same as those in the two previous flights. The launching was made from an open-end circular tube and the flight trajectory followed the planned launch angle. It appeared that the rework of the aft retainer had eliminated the thrust misalignment problem. It was determined from examining the hardware after the flight that the time delay to ignite the gas generator, which in turn fires the flare, had malfunctioned. The flight was considered successful so far as the flight path was concerned but unsuccessful when testing the flare.

FLIGHT NUMBER 7

FLIGHT VEHICLE DATA

Propellant Grain: Burning time 1.16 seconds - Impulse 50 pound-seconds

Smoke Generator: Smoke puff

Initiator: S-90 Squib

Igniter: 2 grams CAI-1

Delay: Propellant rod

Noisemaker: None

Flare: Aluminized

Fin Area: 2.50 square inches (bonded)

Nose Cone: Flat (no cone)

Length: 21 inches

FLIGHT DESCRIPTION

The rocket motor for this flight was identical to Flight No. 6. The flare was the highly aluminized propellant being manufactured by RPI and a smoke puff charge. Launch was conducted from a circular open tube. The vehicle became unstable as soon as it cleared the launcher tube and impacted approximately 100 feet away. The time delay on the smoke puff charge functioned shortly after impact and ignited the smoke puff. However, the time delay to ignite the flare, which was the same type delay as malfunctioned on Flight 6, again failed to operate satisfactorily. The stability margin on this vehicle was less than on previous flights. It was concluded that the low acceleration and low stability margin had allowed the vehicle to get into a high angle of attack as it left the launcher and caused the flow to separate over the blunt nose of the rocket. This in turn caused the fins to lose effectiveness and the vehicle to go aerodynamically unstable.

FLIGHT NUMBER 8

FLIGHT VEHICLE DATA

Propellant Grain: Burning time 1.0 seconds - Impulse 50 pound-seconds

Smoke Generator: 50 gram smoke puff

Initiator: S-90 Squib

Igniter: 2 grams CAI-1

Delay: Propellant rod

Explosive Charge: CAI-1 and AP

Flare: RPI PPAL-X17-06

Fin Area:1.25 square inches (bonded)

Nose Cone: Flat (no cone)

Length: 21. inches

FLIGHT DESCRIPTION

In an effort to correct the problems felt to have caused the instability in Flight No. 7, the burning time of the motor was reduced to one second to increase the acceleration. The motor's total impulse was the same as previous flights. The vehicle was launched from the square tube launcher with one end closed. The vehicle flight path was normal except the vehicle showed a tendency to curve into the wind which, as mentioned before, is a result of the vehicle having a large amount of aerodynamic stability. The time delay functioned as planned. The smoke puff charge ignited and produced a smoke puff of approximately 10-15 feet in diameter, and a noise which was heard two miles away. The flare did not ignite but visual observation of the flare on the parachute showed that the parachute was giving the desired fall rate. It was decided that additional ignition material was required on the end of the flare to assist in the ignition of the flare. The maximum altitude obtained on the flare was approximately 3,500 feet. All aspects of the flight were satisfactory except for the ignition of the flare.

FLIGHT NUMBER 9

FLIGHT VEHICLE DATA

Propellant Grain: Burning time 1.0 seconds - Impulse 50 pound-seconds

Smoke Generator: 50 gram smoke puff

Initiator: S-90 Squib

Igniter: 2 grams CAI-1

Delay: Propellant rod

Explosive Charge: CAI-1 and AP

Flare: RPI PPAL-X17-06

Fin Area: 1.25 square inches

Nose Cone: Flat (no cone)

Length: 21.0 inches

FLIGHT DESCRIPTION

Launch was made from a square tube closed at one end. The stability margin in this vehicle was slightly below that on Flight No. 8. Immediately after the vehicle left the launcher the same stability problem was encountered as in Flight No. 7. The cause of the instability apparently was the lower stability margin on the successful flights and the flat nose on the vehicle causing the flow to be disturbed over the fins.

FLIGHT NUMBER 10

FLIGHT VEHICLE DATA

Propellant Grain: Burning time 1.0 seconds - Impulse 50 pound-seconds

Smoke Generator: None

Initiator: S-90 Squib

Igniter: 2 grams CAI-1

Delay: Propellant rod

Explosive Charge: CAI-1 and AP

Flare: Special Devices magnesium flare

Fin Area: 1.25 square inches

Nose Cone: Hollow with RPI Siren

Length: 21.0 inches

FLIGHT DESCRIPTION

It was decided that one more test should be conducted using the blunt nose configuration with the higher stability margin to definitely determine if the vehicle configuration should be changed to include a nose cone and eliminate the problem of flow separation at the nose of the rocket. A rocket motor identical to that used for the two previous flights was used to check the feasibility of obtaining a loud noise on the ascending phase of the flight path. Launch was conducted from a square tube closed at one end. Immediately after launch the time delay malfunctioned causing the expulsion charge to ignite and as a result the flare and siren were ejected prematurely. Impact was approximately 200 feet from the launcher.

FLIGHT NUMBER 11

FLIGHT VEHICLE DATA

Propellant Grain: Burning time 1.16 seconds - Impulse 50 pound-seconds

Smoke Generator: Red dye cloud

Initiator: S-90 Squib

Igniter: 2 grams CAI-1

Delay: Single Delay Train

Explosive Charge: CAI-1 and AP

Flare: Kilgore (green)

Fin Area: 4 square inches (bonded on at a 2° incidence angle)

Nose Cone: Solid (wood)

Length: 21 inches

CG: 8.75 inches from the aft end

Weight: 3.1 pounds

FLIGHT DESCRIPTION

Launch was made from a split, circular tube at an angle of 75 ° Q.E. Flight looked good and vehicle gained altitude rapidly. No flare or dye ejection was observed. The hardware could not be located.

FLIGHT NUMBER 12

FLIGHT VEHICLE DATA

Propellant Grain: Burning time 1.16 seconds - Impulse 50 pound-seconds

Smoke Generator: Red dye cloud

Initiator: S-90 Squib

Igniter: 2 grams CAI-1

Delay: Single Delay Train

Explosive Charge: CAI-1 and AP

Flare: Kilgore (orange)

Fin Area: 4 square inches (bonded on at a 2° incidence angle)

Nose Cone: Solid (wood)

Length: 21 inches

CG: 8.63 inches from the aft end

Weight: 3.10 pounds

FLIGHT DESCRIPTION

Launch was made from a split, circular tube at an angle of 75 ° Q.E. The vehicle flight was unstable and impacted approximately 300 feet from the launcher. Instability was attributed to insufficient aerodynamic design margin. It was decided to move the C.G. forward for the next attempt.

FLIGHT NUMBER 13

FLIGHT VEHICLE DATA

Propellant Grain: Burning time 1.16 seconds - Impulse 50-pound-seconds

Smoke Generator: Iron Oxide Cloud

Initiator: S-90 Squib

Igniter: 2 grams CAI-1

Delay: Single Delay Train (bonded)

Explosive Charge: None

Flare: None

Fin Area: 4 square inches

Nose Cone: Solid

Length: 21 inches

CG: 9.75 inches from the aft end

Weight: 3.65 pounds

FLIGHT DESCRIPTION

The center of gravity was moved forward. Except for the propellant rod time delay, no components were included in the payload. Flight 13 was planned as a stability test. Launch was conducted from a split, circular tube set at 75° Q.E. Acceleration was estimated at 8 g's. Immediately after launch, the nose cone separated from the flight vehicle which became unstable. Hardware was recovered one-fourth mile from the launch site. Investigation of recovered hardware revealed that bonding material holding the propellant rod time delay had failed, causing motor pressure to escape into the forward portion of the flight vehicle. This pressure caused separation of the nose cone. Two fins broke away from the vehicle upon impact. The test was considered unsuccessful.

FLIGHT NUMBER 14

FLIGHT VEHICLE DATA

Propellant Grain: Burning time 1.16 seconds - Impulse 50 pound-seconds

Smoke Generator: Iron Oxide Cloud

Initiator: S-90 Squib

Igniter: 2 grams CAI-1

Delay: Fuse with Olin-Matheson flame squib

Explosive Charge: CAI-1 and AP

Flare: Kilgore (yellow)

Fin Area: 4 square inches

Nose Cone: Solid

Length: 21 inches

CG: 9.50 inches from the aft end

Weight: 4.27 pounds

FLIGHT DESCRIPTION

Launch was made from a split, circular tube at an angle of 75° Q.E. Initial acceleration was calculated at 6.5 g's. The fuse delay was set for 7.5 seconds. The vehicle remained stable throughout the flight, although exhibiting a tendency to weather-cock to the left. The time delay failed to function during flight. Impact point was not detected. Hardware was not recovered. The flight was considered a partial success.

FLIGHT NUMBER 15

FLIGHT VEHICLE DATA

Propellant Grain: Stepped configuration*

Smoke Generator: Iron Oxide Cloud

Initiator: S-90 Squib

Igniter: 5 grams CAI-1

Delay: Double Delay Train

Explosive Charge: CAI-1 and AP

Flare: RPI PPAL-X17-06 with CAI-1 igniter

Fin Area: 4 square inches

Nose Cone: Solid (30°)

Length: 21 inches

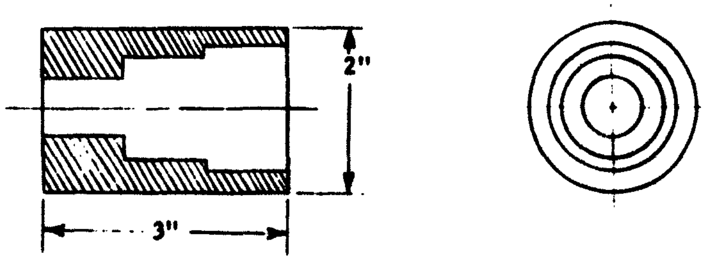
CG: 11.31 inches from the aft end

Weight: 4.94 pounds

FLIGHT DESCRIPTION

Launch was made from a split, circular tube at an angle of 75° Q.E. Ignition and flight were good, but the delay train malfunctioned. The hardware was not recovered.

*



FLIGHT NUMBER 16

FLIGHT VEHICLE DATA

Propellant Grain: Stepped Configuration

Smoke Generator: Iron Oxide Cloud

Initiator: S-90 Squib

Igniter: 5 grams CAI-1

Delay: Double Delay Train

Explosive Charge: CAI-1, Fe_2O_3, and AP

Flare: RPI PPAL-X17-06 with CAI-1 Igniter

Fin Area: 4 square inches

Nose Cone: Solid (30°)

Length: 21 inches

CG: 11.25 inches from the aft end

Weight: 4.74 pounds

FLIGHT DESCRIPTION

Launch was made from a split, circular tube at an angle of 85 ° Q.E. Ignition was good but the delay train malfunctioned and the hardware was not recovered.

FLIGHT NUMBER 17

FLIGHT VEHICLE DATA

Propellant Grain: Stepped Configuration

Smoke Generator: Iron Oxide Cloud

Initiator: S-90 Squib

Igniter: 5 grams CAI-1

Delay: Single Delay Train

Explosive Charge: CAI-1 and AP

Flare: Kilgore (red)

Fin Area: 4 square inches

Nose Cone: Solid (30° wood)

Length: 21 inches

CG: 8.75 inches from the aft end

Weight: 3.09 pounds

FLIGHT DESCRIPTION

Launch was made from a split, circular tube at an angle of 75° Q.E. Ignition was good but flight was unstable. All components functioned properly after impact. The hardware was recovered.

FLIGHT NUMBER 18

FLIGHT VEHICLE DATA

Propellant Grain: Tapered, Stepped Configuration *

Smoke Generator: Red dye cloud

Initiator: S-90 Squib

Igniter: 5 grams CAI-1

Delay: Single Delay Train

Explosive Charge: CAI-1 and AP

Flare: Kilgore

Fin Area: 4 square inches

Nose Cone: Solid (30° wood)

Length: 21 inches

CG: 8.75 inches from the aft end

Weight: 3.16 pounds

FLIGHT DESCRIPTION

Launch was made from a split, circular tube at an angle of 85° Q.E. Ignition and flight were good and all other components functioned properly including the red dye cloud. The hardware was not recovered.

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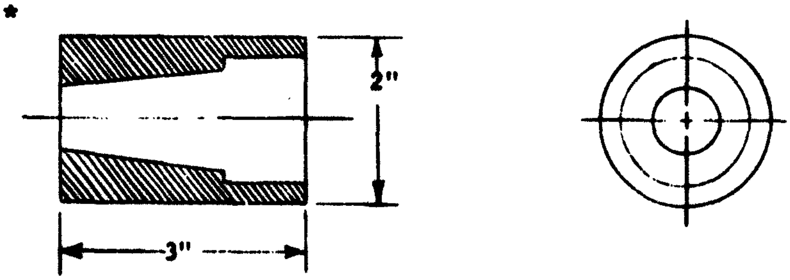

FLIGHT NUMBER 19

FLIGHT VEHICLE DATA

Propellant Grain: Stepped Configuration

Smoke Generator: None

Initiator: S-90 Squib

Igniter: 5 grams CAI-1

Delay: Double Delay Train

Explosive Charge: CAI-1, Fe_2O_3, and AP

Flare: RPI PPAL-X17-06 with CAI-1 igniter

Fin Area: 4 square inches

Nose Cone: Solid (30°)

Length: 24 inches

CG: 12.50 inches from the aft end

Weight: 5.26 pounds

FLIGHT DESCRIPTION

Launch was made from a split, circular tube at an angle of 85° Q.E. Ignition and flight were good but the delay train malfunctioned. The hardware was not recovered.

FLIGHT NUMBER 20

FLIGHT VEHICLE DATA

Propellant Grain: Stepped Configuration

Smoke Generator: None

Initiator: S-90 Squib

Igniter: 5 grams CAI-1

Delay: Double Delay Train

Explosive Charge: CAI-1 and AP

Flare: RPI PPAL-X17-06 with CAI-1 Igniter

Fin Area: 4 square inches

Nose Cone: Solid (30°)

Length: 21 inches

CG: 11.25 inches from the aft end

Weight: 4.95 pounds

FLIGHT DESCRIPTION

Launch was made from a split, circular tube at an angle of 85° Q.E. Ignition and flight were good but the delay train malfunctioned. The hardware was recovered.

FLIGHT NUMBER 21

FLIGHT VEHICLE DATA

Propellant Grain: Stepped Configuration

Smoke Generator: None

Initiator: S-90 Squib

Igniter: 6 grams CAI-1

Delay: Double Delay Train

Explosive Charge: CAI-1 and AP

Flare: RPI PPAL-X17-06

Fin Area: 4 square inches (bonded)

Nose Cone: Aluminum - 45° with RPI whistle

Length: 19.25 inches

CG: 9.00 inches from the aft end

Weight: 3.94 pounds

FLIGHT DESCRIPTION

Launch was made from a split, circular tube at an angle of 85° Q.E. The motor did not ignite until after the igniter charge had ejected the vehicle from the launcher. The motor ignited while lying on the ground and the delay train malfunctioned. The hardware was recovered.

FLIGHT NUMBER 22

FLIGHT VEHICLE DATA

Propellant Grain: 3 inch reverse cone * (see Figure 7, Appendix IV)

Smoke Generator: None

Initiator: S-90 Squib (potted with EC 801)

Igniter: 4 grams CAI-1

Delay: Double Delay Train

Explosive Charge: CAI-1 and AP

Flare: RPI PPAL-X17-06 with PAP-8 booster charge

Fin Area: 4 square inches (bonded)

Nose Cone: Solid (wood with RPI whistle)

Length: 23.25 inches

CG: 9.88 inches from the aft end

Weight: 4.17 pounds

FLIGHT DESCRIPTION

Launch was made from a split, circular tube at an angle of 85 ° Q.E. Ignition, flight and altitude, (approximately 3,500 feet) were all good. All other components functioned properly. The hardware was not recovered.

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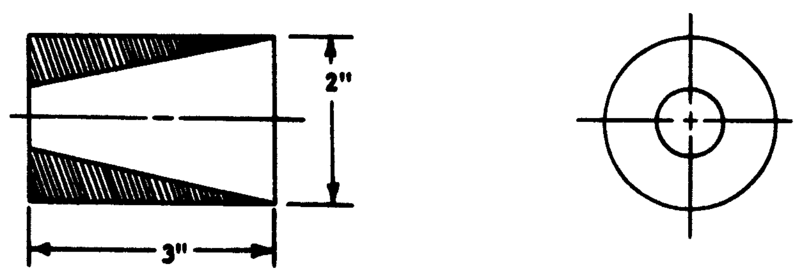

FLIGHT NUMBER 23

FLIGHT VEHICLE DATA

Propellant Grain: 3 inch reverse cone

Smoke Generator: .81 inch I.D. x 3 inches long (see Fig. 6, Appendix IV)

Initiator: S-90 Squib (potted with EC 801)

Igniter: 4 grams CAI-1

Delay: Double Delay Train

Explosive Charge: CAI-1 and AP

Flare: RPI PPAL-X17-06 with PAP-8 booster charge

Fin Area: 4 square inches

Nose Cone: Solid (30° wood with whistle)

Length: 24.75 inches

CG: 10.50 inches from the aft end

Weight: 5.05 pounds

FLIGHT DESCRIPTION

Launch was made from a split, circular tube at an angle of 85 ° Q.E. The motor did not ignite but the smoke generator ignited and burned while held in the launcher. A new igniter and smoke generator were installed and the unit re-fired. Ignition and smoke trail were good but the flight was unstable. The delay and all other components functioned properly after impact.

FLIGHT NUMBER 24

FLIGHT VEHICLE DATA

Propellant Grain: 3 inch reverse cone

Smoke Generator: None

Initiator: S-90 Squib (potted with EC 801)

Igniter: 4 grams CAI-1

Delay: Double Delay Train

Explosive Charge: CAI-1, Fe_2O_3, and AP

Flare: RPI PPAL-X17-06 with PAP-8 booster charge

Fin Area: 4 square inches with whistle holes.

Nose Cone: Solid (30° wood)

Length: 21 inches

CG: 8.75 inches from the aft end

Weight: 3.55 pounds

FLIGHT DESCRIPTION

Launch was made from a split, circular tube at an angle of 85° Q.E. Ignition and flight were good (altitude approximately 3,500 feet). All components functioned properly but the flare failed to light. The hardware was not recovered.

FLIGHT NUMBER 25

FLIGHT VEHICLE DATA

Propellant Grain: 3 inch reverse cone

Smoke Generator: .81 inch I.D. x 3 inches long

Initiator: Olin-Metheson flame squib (potted with EC 801)

Igniter: 4 grams CAI-1

Delay: Double Delay Train

Explosive Charge: CAI-1 and AP

Flare: RPI PPAL-X17-06 with PAP-8 booster charge

Fin Area: 4 square inches

Nose Cone: Solid (30° wood)

Length: 24.75 inches

CG: 11 inches from the aft end

Weight: 5.17 pounds

FLIGHT DESCRIPTION

Launch was made from a split, circular tube at an angle of 85° Q.E. Ignition and smoke trail were both good but flight was unstable. The delay and other components functioned properly after impact. The hardware was recovered.

FLIGHT NUMBER 26

FLIGHT VEHICLE DATA

Propellant Grain: 2 inch reverse cone

Smoke Generator: None

Initiator: S-90 Squib

Igniter: 4 grams CAI-1

Delay: Double Delay Train

Explosive Charge: CAI-1 and AP

Flare: RPI PPAL-X17-06 with PAP-8 booster charge

Fin Area: 4 square inches

Nose Cone: Solid (30° wood)

Length: 16 inches

CG: 6.75 inches from the aft end

Weight: 2.58 pounds

FLIGHT DESCRIPTION

Launch was made from a split, circular tube at an angle of 85° Q.E. Ignition and altitude were good although flight was unstable. The delay train malfunctioned and the hardware was not recovered.

FLIGHT NUMBER 27

FLIGHT VEHICLE DATA

Propellant Grain: 3 inch reverse cone

Smoke Generator: None

Initiator: S-68 Squib (potted with EC 801)

Igniter: 4 grams CAI-1

Delay: Double Delay Train

Explosive Charge: CAI-1 and AP

Flare: RPI PPAL-X17-06 with PAP-11-H booster charge

Fin Area: 4 square inches

Nose Cone: Flat (no cone)

Length: 21.25 inches

CG: 9.13 inches from the aft end

Weight: 3.47 pounds

FLIGHT DESCRIPTION

Launch was made from a split, circular tube at an angle of 85° Q.E. Ignition was good but flight was unstable and the altitude attained was only approximately 40 feet. All other components functioned properly after impact, the flare ignited but went out. Failure of the fin bond caused the malfunction.

FLIGHT NUMBER 28

FLIGHT VEHICLE DATA

Propellant Grain: 3 inch reverse cone

Smoke Generator: .81 inch I.D. x 3 inches long

Initiator: S-68 Squib (potted with EC 801)

Igniter: 4 grams CAI-1

Delay: Double Delay Train

Explosive Charge: CAI-1 and AP (4.25 inches long)

Flare: RPI PPAL-X17-06

Fin Area: 4 square inches (welded)

Nose Cone: Hollow Aluminum with whistle

Length: 25.0 inches

CG: 9.69 inches from the aft end

Weight: 5.11 pounds

FLIGHT DESCRIPTION

Launch was made from a split, circular tube at an angle of 85° Q.E. Ignition and smoke trail were both good, but the flight was unstable. The delay, explosive charge and flare all functioned after impact. All hardware was recovered.

FLIGHT NUMBER 29

FLIGHT VEHICLE DATA

Propellant Grain: 2 inch hour glass (see Fig. 8, Appendix IV)

Smoke Generator: .81 inch I.D. x 3 inches long

Initiator: S-68 Squib (potted)

Igniter: 4 grams CAI-1

Delay: Double Delay Train

Explosive Charge: CAI-1 and AP (4.25 inches long)

Flare: RPI PPAL-X17-06

Fin Area: 4 square inches

Nose Cone: Solid (wood)

Length: 24.25 inches

CG: 10.50 inches from the aft end

Weight: 4.80 pounds

FLIGHT DESCRIPTION

Launch was made from a split, circular tube at an angle of 85° Q.E. Ignition, smoke trail and flight were all good, but the delay train malfunctioned. The hardware was not recovered.

FLIGHT NUMBER 30

FLIGHT VEHICLE DATA

Propellant Grain: 3 inch reverse cone

Smoke Generator: .81 inch I. D. x 3 inches long

Initiator: S-68 Squib (potted)

Igniter: 4 grams CAI-1

Delay: Double Delay Train

Explosive Charge: CAI-1 and AP (4.25 inches long)

Flare: RPI PPAL-X17-06

Fin Area: 8 square inches (double set, welded)

Nose Cone: Solid (wood)

Length: 25.25 inches

CG: 11.94 inches from the aft end

Weight: 4.81 pounds

FLIGHT DESCRIPTION

Launch was made from a split, circular tube at an angle of 85° Q.E. Ignition, smoke trail and flight were all good, although the flight was slightly unstable. The delay train, explosive charge, and all other components functioned properly except that the flare did not ignite. All hardware was recovered.

FLIGHT NUMBER 31

FLIGHT VEHICLE DATA

Propellant Grain: 3 inch reverse cone

Smoke Generator: .81 inch I.D. x 3 inches long

Initiator: S-68 Squib (potted)

Igniter: 4 grams CAI-1

Delay: Double Delay Train

Explosive Charge: CAI-1 and AP (4.25 inches long)

Flare: RPI PPAL-X17-06

Fin Area: 4 square inches (welded)

Nose Cone: Solid (wood)

Length: 24.25 inches

CG: 10.50 inches from the aft end

Weight: 4.80 pounds

FLIGHT DESCRIPTION

Launch was made from a split, circular tube at an angle of 85° Q.E. Ignition, smoke trail and flight were good, but the delay train malfunctioned. The hardware was not recovered.

FLIGHT NUMBER 32

FLIGHT VEHICLE DATA

Propellant Grain: 3 inch reverse cone

Smoke Generator: .81 inch I.D. x 3 inches long

Initiator: S-68 Squib (potted)

Igniter: 4 grams CAI-1

Delay: Double Delay Train

Explosive Charge: CAI-1 and AP

Flare: RPI PPAL-X17-06

Fin Area: 8 square inches (double set welded)

Nose Cone: Solid (wood)

Length: 24.25 inches

CG: 11.25 inches from the aft end

Weight: 5.04 pounds

FLIGHT DESCRIPTION

Launch was made from a split, circular tube at an angle of 85° Q.E. Ignition, smoke trail, and flight were good, but the delay train malfunctioned. The hardware was not recovered.

FLIGHT NUMBER 33

FLIGHT VEHICLE DATA

Propellant Grain: 3 inch reverse cone

Smoke Generator: .81 inch I.D. x 3 inches long

Initiator: S-68 Squib (potted)

Igniter: 4 grams CAI-1

Delay: Double Delay Train

Explosive Charge: CAI-1 and AP

Flare: RPI PPAL-X17-06

Fin Area: 4 square inches (welded)

Nose Cone: Solid (wood)

Length: 24 inches

CG: 10.38 inches from the aft end

Weight: 4.81 pounds

FLIGHT DESCRIPTION

Launch was made from a split, circular tube at an angle of 85° Q.E. Ignition was good, but the motor and smoke generator remained in the tube and burned. The roll pins holding the forward closure to the motor case rolled out due to a lower strength aluminum in the forward closure.

FLIGHT NUMBER 34

FLIGHT VEHICLE DATA

Propellant Grain: 3 inch reverse cone

Smoke Generator: None

Initiator: S-68 Squib (potted)

Igniter: 4 grams CAI-1

Delay: Double Delay Train

Explosive Charge: CAI-1 and AP

Flare: RPI PPAL-X17-06

Fin Area: 4 square inches (bonded)

Nose Cone: Solid (wood)

Length: 21.25 inches

CG: 9.25 inches from the aft end

Weight: 3.50 pounds

FLIGHT DESCRIPTION

Launch was made from a split, circular tube at an angle of 75° Q.E. Ignition was good but the motor remained in the tube and burned. The roll pins holding the forward closure to the motor case rolled out due to a lower strength aluminum in the forward closure.

FLIGHT NUMBER 35

FLIGHT VEHICLE DATA

Propellant Grain: 3 inch reverse cone

Smoke Generator: None

Initiator: S-68 Squib

Igniter: 4 grams CAI-1

Delay: Double Delay Train

Explosive Charge: CAI-1 and AP

Flare: RPI PPAL-X17-06

Fin Area: 4 square inches

Nose Cone: Aluminum with whistle

Length: 21 inches

CG: 9.0 inches from the aft end

Weight: 3.35 pounds

FLIGHT DESCRIPTION

Launch was made from a split, circular tube at an angle of 75° Q.E. Ignition was good but the flight was unstable. All systems functioned properly after impact and the hardware was recovered.

FLIGHT NUMBER 36

FLIGHT VEHICLE DATA

Propellant Grain: 3 inch reverse cone

Smoke Generator: None

Initiator: S-68 Squib (not potted)

Igniter: 4 grams CAI-1

Delay: Double Delay Train

Explosive Charge: CAI-1 and AP

Flare: RPI PPAL-X17-06

Fin Area: 4 square inches

Nose Cone: Solid (wood)

Length: 21 inches

CG: 9.75 inches from the aft end

Weight: 4.03 pounds

FLIGHT DESCRIPTION

Launch was made from a split, circular tube at an angle of 75° Q.E. Ignition and flight were both good. All components functioned properly except the flare separated from the parachute. All hardware was recovered.

FLIGHT NUMBER 37

FLIGHT VEHICLE DATA

Propellant Grain: 3 inch reverse cone

Smoke Generator: None

Initiator: S-68 Squib

Igniter: 4 grams CAI-1

Delay: Double Delay Train

Explosive Charge: CAI-1 and AP

Flare: RPI PPAL-X17-06

Fin Area: 4 square inches (welded)

Nose Cone: Solid (wood)

Length: 20 inches

CG: 8.75 inches from the aft end

Weight: 3.22 pounds

FLIGHT DESCRIPTION

Launch was made from a split, circular tube at an angle of 85° Q.E. Ignition and flight were both good, but the delay train malfunctioned. The hardware was not recovered.

FLIGHT NUMBER 38

FLIGHT VEHICLE DATA

Propellant Grain: 3 inch reverse cone

Smoke Generator: None

Initiator: S-68 Squib

Igniter: 4 grams CAI-1

Delay: Double Delay Train

Explosive Charge: CAI-1 and AP

Flare: RPI PPAL-X17-06

Fin Area: 4 square inches

Nose Cone: Solid (30° wood)

Length: 21.25 inches

CG: 9 inches from the aft end

Weight: 3.40 pounds

FLIGHT DESCRIPTION

Launch was made from a split, circular tube at an angle of 85° Q.E. Ignition and flight were both good, but the delay train malfunctioned. The hardware was not recovered.

FLIGHT NUMBER 39

FLIGHT VEHICLE DATA

Propellant Grain: 3 inch reverse cone

Smoke Generator: None

Initiator: S-68 Squib

Igniter: 4 grams CAI-1

Delay: Double Delay Train

Explosive Charge: CAI-1 and AP

Flare: RPI PPAL-X17-06

Fin Area: 4 square inches (welded)

Nose Cone: Solid (30° Wood)

Length: 20.5 inches

CG: 8.75 inches from the aft end

Weight: 8.75 pounds

FLIGHT DESCRIPTION

Launch was made from a split, circular tube at an angle of 85 ° Q.E. Motor failure occurred due to a poor bond of the aft retainer to the motor case. Gas flow caused the motor case to fail

FLIGHT NUMBER 40

FLIGHT VEHICLE DATA

Propellant Grain: 3 inch reverse cone

Smoke Generator: .81 inch I.D. x 3 inches long

Initiator: S-68 Squib

Igniter: 4 grams CAI-1

Delay: Double Delay Train

Explosive Charge: CAI-1 and AP

Flare: RPI PPAL-X17-06

Fin Area: 4 square inches

Nose Cone: Solid (30° Wood)

Length: 21 inches

CG: 9.0 inches from the aft end

Weight: 3.46 pounds

FLIGHT DESCRIPTION

Launch was made from a split, circular tube at an angle of 85° Q.E. Motor failure occurred due to a poor bond between the forward motor closure and the propellant grain.

FLIGHT NUMBER 41

FLIGHT VEHICLE DATA

Propellant Grain: 3 inch reverse cone

Smoke Generator: .81 inch I.D. x 3 inches long (inert)

Initiator: S-68 Squib

Igniter: 4 grams CAI-1

Delay: Double Delay Train

Explosive Charge: CAI-1 and AP

Flare: RPI PPAL-X17-06

Fin Area: 4 square inches

Nose Cone: Solid (30° Wood)

Length: 22 inches

CG: 10.25 inches from the aft end

Weight: 4.32 pounds

FLIGHT DESCRIPTION

Launch was made from a split, circular tube at an angle of 85° Q.E. Ignition was good but flight was unstable. The delay functioned after impact. All hardware was recovered.

FLIGHT NUMBER 42

FLIGHT VEHICLE DATA

Propellant Grain: 3 inch reverse cone

Smoke Generator: .81 inch I.D. x 3 inches long (inert)

Initiator: S-68 Squib

Igniter: 4 grams CAI-1

Delay: Double Delay Train

Explosive Charge: CAI-1 and AP

Flare: RPI PPAL-X17-06

Fin Area: 4 square inches

Nose Cone: Solid

Length: 22 inches

CG: 12.13 inches from the aft end

Weight: 5.23 pounds

FLIGHT DESCRIPTION

Launch was made from a split, circular tube at an angle of 85 ° Q.E. Ignition, flight and altitude were good. All other components functioned properly and the hardware was recovered.

FLIGHT NUMBER 43

FLIGHT VEHICLE DATA

Propellant Grain: 3 inch reverse cone

Smoke Generator: .81 inch I.D. x 3 inches long (i[illegible]rt)

Initiator: S-68 Squib

Igniter: 4 grams CAI-1

Delay: Double Delay Train

Explosive Charge: CAI-1 and AP

Flare: RPI PPAL-X17-06

Fin Area: 4 square inches (welded)

Nose Cone: Solid

Length: 22.0 inches

CG: 12.13 inches from the aft end

Weight: 5.23 pounds

FLIGHT DESCRIPTION

Launch was made from a split, circular tube at an angle of 85° Q.E. Ignition, flight and altitude were good. All other components functioned properly except that the hardware separated from the parachute and was not recovered.

FLIGHT NUMBER 44

FLIGHT VEHICLE DATA

Propellant Grain: 3 inch reverse cone

Smoke Generator: .81 inch I.D. x 3 inches long (inert)

Initiator: S-68 Squib

Igniter: 4 grams CAI-1

Delay: Double Delay Train

Explosive Charge: CAI-1 and AP

Flare: RPI PPAL-X17-06

Fin Area: 4 square inches (welded)

Nose Cone: Solid

Length: 22.75 inches

CG: 12.13 inches from the aft end

Weight: 5.33 pounds

FLIGHT DESCRIPTION

Launch was made from a split, circular tube at an angle of 75° Q.E. Ignition, flight and altitude were all good. The delay train, flare parachute and all other components functioned properly. All hardware was recovered.

FLIGHT NUMBER 45

FLIGHT VEHICLE DATA

Propellant Grain: 3 inch reverse cone

Smoke Generator: .81 inch I.D. x 3 inches long (inert)

Initiator: S-68 Squib

Igniter: 4 grams CAI-1

Delay: Double Delay Train

Explosive Charge: CAI-1 and AP

Flare: RPI PPAL-X17-06

Fin Area: 4 square inches (welded)

Nose Cone: Hollow with lead ballast

Length: 22.75 inches

CG: 11.75 inches from the aft end

Weight: 5.0 pounds

FLIGHT DESCRIPTION

Launch was made from a split, circular tube at an angle of 75° Q.E. An "O" ring omitted during assembly caused the motor case to fail at the forward end.

FLIGHT NUMBER 46

FLIGHT VEHICLE DATA

Propellant Grain: 3 inch reverse cone (13° half angle)

Smoke Generator: .81 inch I.D. x 3 inches long

Initiator: S-68 Squib

Igniter: 4 grams CAI-1

Delay: Double Delay Train

Explosive Charge: CAI-1 and AP

Flare: RPI PPAL-X17-06

Fin Area: 4 square inches

Nose Cone: Solid

Length: 22.75 inches

CG: 12 inches from the aft end

Weight: 5.56 pounds

FLIGHT DESCRIPTION

Launch was made from a split, circular tube at an angle of 75° Q.E. Ignition was good but the altitude was poor due to flight instability. The delay and explosive charge functioned after impact. The hardware was not recovered.

FLIGHT NUMBER 47

FLIGHT VEHICLE DATA

Propellant Grain: 3 inch reverse cone (13° half angle)

Smoke Generator: .81 inch I.D. x 3 inches long

Initiator: S-68 Squib

Igniter: 4 grams CAI-1

Delay: Double Delay Train

Explosive Charge: CAI-1 and AP

Flare: RPI PPAL-X17-06

Fin Area: 4 square inches (welded)

Nose Cone: Solid

Length: 22.75 inches

CG: 12 inches from the aft end

Weight: 5.56 pounds

FLIGHT DESCRIPTION

Launch was made from a split, circular tube at an angle of 88° Q.E. Ignition and altitude were both good, but the delay train malfunctioned and the hardware was not recovered.

FLIGHT NUMBER 48

FLIGHT VEHICLE DATA

Propellant Grain: 3 inch reverse cone

Smoke Generator: .81 inch I.D. x 3 inches long

Initiator: S-68 Squib

Igniter: 4 grams CAI-1

Delay: Double Delay Train

Explosive Charge: CAI-1 and AP

Flare: RPI PPAL-X17-06

Fin Area: 4 square inches

Nose Cone: Solid

Length: 22.75 inches

CG: 12.25 inches from the aft end

Weight: 5.62 pounds

FLIGHT DESCRIPTION

Launch was made from a split, circular tube at an angle of 88° Q.E. Ignition and flight were both good. All other components functioned properly except the parachute was burned and allowed an excessive rate of descent. All hardware was recovered.

FLIGHT NUMBER 49 - Night Flight

FLIGHT VEHICLE DATA

Propellant Grain: 3 inch reverse cone

Smoke Generator: .81 inch I.D. x 3 inches long (inert)

Initiator: S-68 Squib

Igniter: 4grams CAI-1

Delay: Double Delay Train

Explosive Charge: CAI-1 and AP

Flare: RPI PPAL-X17-06

Fin Area: 4 square inches (welded)

Nose Cone: Solid

Length: 22.75 inches

CG: 12 inches from the aft end

Weight: 5.54 pounds

FLIGHT DESCRIPTION

Launch was made from a split, circular tube at an angle of 88 ° Q.E. Ignition and altitude were both good, but the delay train malfunctioned The delay chuffed due to failure of the graphite nozzle in the motor. The hardware was recovered.

FLIGHT NUMBER 50

FLIGHT VEHICLE DATA

Propellant Grain: 3 inch reverse cone

Smoke Generator: .81 inch I.D. x 3 inches long (inert)

Initiator: S-68 Squib

Igniter: 4 grams CAI-1

Delay: Double Delay Train

Explosive Charge: CAI-1 and AP

Flare: RPI PPAL-X17-06

Fin Area: 4 square inches (welded)

Nose Cone: Solid

Length: 22.75 inches

CG: 12.13 inches from the aft end

Weight: 5.51 pounds

FLIGHT DESCRIPTION

Launch was made from a split, circular tube at an angle of 88° Q.E. Ignition, flight and delay were all good. All other components functioned except the parachute did not open. All hardware was recovered.

FLIGHT NUMBER 51

FLIGHT VEHICLE DATA

Propellant Grain: 3 inch reverse cone

Smoke Generator: .81 inch I.D. x 3 inches long

Initiator: S-68 Squib

Igniter: 4 grams CAI-1

Delay: Double Delay Train (.75 inches long)

Explosive Charge: CAI-1 and AP

Flare: RPI PPAL-X17-06

Fin Area: 4 square inches (welded)

Nose Cone: Solid

Length: 22.75 inches

CG: 12.5 inches from the aft end

Weight: 5.49 pounds

FLIGHT DESCRIPTION

Launch was made from a split, circular tube at an angle of 88° Q.E. Ignition and flight were both good but the delay train malfunctioned. The hardware was not recovered.

FLIGHT NUMBER 52

FLIGHT VEHICLE DATA

Propellant Grain: 3 inch reverse cone

Smoke Generator: .81 inch I.D. x 3 inches long

Initiator: S-68 Squib

Igniter: 4 grams CAI-1

Delay: Double Delay Train

Explosive Charge: CAI-1 and AP

Flare: RPI PPAL-X17-06

Fin Area: 4 square inches (welded)

Nose Cone: Solid

Length: 22.75 inches

CG: 11.94 inches from the aft end

Weight: 5.64 pounds

FLIGHT DESCRIPTION

Launch was made from a split, circular tube at an angle of 88° Q.E. Ignition and flight were both good but the delay train malfunctioned. The hardware was not recovered.

FLIGHT NUMBER 53

FLIGHT VEHICLE DATA

Propellant Grain: 3 inch reverse cone

Smoke Generator: .81 inch I.D. x 3 inches long

Initiator: S-68 Squib

Igniter: 4 grams CAI-1

Delay: Double Delay Train

Explosive Charge: CAI-1 and AP

Flare: RPI PPAL-X17-06

Fin Area: 4 square inches (welded)

Nose Cone: Solid

Length: 22.75 inches

CG: 11.75 inches from the aft end

Weight: 5.17 pounds

FLIGHT DESCRIPTION

Launch was made from a split, circular tube at an angle of 88 ° Q.E. Ignition and flight were both good but the delay malfunctioned. The delay train chuffed due to failure of the graphite nozzle in the motor. The hardware was recovered.

FLIGHT NUMBER 54

FLIGHT VEHICLE DATA

Propellant Grain: 3 inch reverse cone

Smoke Generator: .81 inches I.D. x 3 inches long (inert)

Initiator: S-68 Squib (not potted)

Igniter: 4 grams CAI-1

Delay: Double Delay Train

Explosive Charge: CAI-1 and AP

Flare: RPI PPAL-X17-06

Fin Area: 4 square inches (welded)

Nose Cone: Solid

Length: 22.75 inches

CG: 12 inches from the aft end

Weight: 5.57 pounds

FLIGHT DESCRIPTION

Launch was made from a split, circular tube at an angle of 88° Q.E. Ignition and flight were good but the explosive charge did not ignite. All other components, including the flare and parachute, functioned properly and the hardware was recovered.

FLIGHT NUMBER 55 - Flight No. 1 for Mr. Brown, OCD, Night

FLIGHT VEHICLE DATA

Propellant Grain: 3 inch reverse cone

Smoke Generator: .81 inch I.D. x 3 inches long (inert)

Initiator: S-68 Squib (not potted)

Igniter: 4 grams CAI-1

Delay: Double Delay Train

Explosive Charge: CAI-1 and AP

Flare: RPI PPAL-X17-06

Fin Area: 4 square inches (welded)

Nose Cone: Solid

Length: 22.75 inches

CG: 12.25 inches from the aft end

Weight: 5.4 pounds

FLIGHT DESCRIPTION

Launch was made from a split, circular tube at an angle of 88° Q.E. Ignition and flight were both good, but the delay train malfunctioned. The malfunction was caused from EC 801 inhibitor on the motor grain, resulting in a rapid pressure drop inside the motor chuffing the delay train. The hardware was recovered.

FLIGHT NUMBER 56 - Flight No. 2 for Mr. Brown, OCD, night

FLIGHT VEHICLE DATA

Propellant Grain: 3 inch reverse cone

Smoke Generator: .81 inch I.D. x 3 inches long

Initiator: S-68 Squib (not potted)

Igniter: 4 grams CAI-1

Delay: Double Delay Train

Explosive Charge: CAI-1 and AP

Flare: RPI PPAL-X17-06

Fin Area: 4 square inches (welded)

Nose Cone: Solid

Length: 22.75 inches

CG: 12.0 inches from the aft end

Weight: 5.58 pounds

FLIGHT DESCRIPTION

Launch was made from a split, circular tube at an angle of 88° Q.E. Ignition and smoke trail were both good but the delay train malfunctioned. The delay train chuffed due to the failure of the graphite nozzle in the motor. The hardware was recovered.

FLIGHT NUMBER 57 - Flight No. 3 for Mr. Brown, OCD, night

FLIGHT VEHICLE DATA

Propellant Grain: 3 inch reverse cone

Smoke Generator: .81 inch I.D. x 3 inches long

Initiator: S-68 Squib (not potted)

Igniter: 4 grams CAI-1

Delay: Double Delay Train

Explosive Charge: CAI-1 and AP

Flare: RPI PPAL-X17-06

Fin Area: 4 square inches (welded)

Nose Cone: Solid

Length: 22.75 inches

CG: 12 inches from the aft end

Weight: 5.57 pounds

FLIGHT DESCRIPTION

Launch was made from a split, circular tube at an angle of 88° Q.E. Ignition was good but the smoke generator was left at the launcher and burned on the ground. The other components, including the flare and parachute, functioned properly. The hardware was recovered.

FLIGHT NUMBER 58 - Flight No. 4 for Mr. Brown, OCD

FLIGHT VEHICLE DATA

Propellant Grain: 3 inch reverse cone

Smoke Generator: .81 inch I.D. by 3 inches long

Initiator: S-68 Squib (not potted)

Igniter: 4 grams CAI-1

Delay: Double Delay Train

Explosive Charge: CAI-1 and AP

Flare: RPI PPAL-X17-06

Fin Area: 4 square inches (welded)

Nose Cone: Solid

Length: 22.75 inches

CG: 12 inches from the aft end

Weight: 5.59 pounds

FLIGHT DESCRIPTION

Launch was made from a split, circular tube at an angle of 88° Q.E. Ignition and smoke trail were good but the delay train malfunctioned. The hardware was not recovered.

FLIGHT NUMBER 59 - Flight No. 5 for Mr. Brown, OCD

FLIGHT VEHICLE DATA

Propellant Grain: 3 inch reverse cone

Smoke Generator: .81 inch I.D. x 3 inches long

Initiator: S-68 Squib (not potted)

Igniter: 4 grams CAI-1

Delay: Double Delay Train

Explosive Charge: CAI-1 and AP

Flare: RPI PPAL-X17-06

Fin Area: 4 square inches (welded)

Nose Cone: Solid

Length: 22.75 inches

CG: 12 inches from the aft end

Weight: 5.59 pounds

FLIGHT DESCRIPTION

Launch was made from a split, circular tube at an angle of 88 ° Q.E. Ignition and smoke trail were good but the delay train malfunctioned. The hardware was not recovered.

FLIGHT NUMBER 60 - Flight No. 6 for Mr. Brown, OCD

FLIGHT VEHICLE DATA

Propellant Grain: 3 inch reverse cone

Smoke Generator: .81 inch I.D. x 3 inches long

Initiator: S-68 Squib (not potted)

Igniter: 4 grams CAI-1

Delay: Double Delay Train

Explosive Charge: CAI-1 and AP

Flare: RPI PPAL-X17-06

Fin Area: 4 square inches (welded)

Nose Cone: Solid

Length: 22.75 inches

CG: 11.88 inches from the aft end

Weight: 5.59 pounds

FLIGHT DESCRIPTION

Launch was made from a split, circular tube at an angle of 88 ° Q.E. Ignition and smoke trail were good but the delay train malfunctioned. The vehicle was not recovered.

FLIGHT NUMBER 61

FLIGHT VEHICLE DATA

Propellant Grain: 3 inch reverse cone

Smoke Generator: .81 inch I.D. x 3 inches long

Initiator: S-68 Squib

Igniter: 4 grams CAI-1

Delay: Double Delay Train

Explosive Charge: CAI-1 and AP

Flare: RPI PPAL-X17-06

Fin Area: 4 square inches (welded)

Nose Cone: Solid

Length: 22.75 inches

CG: 12 inches from the aft end

Weight: 5.64 pounds

FLIGHT DESCRIPTION

Launch was made from a split, circular tube at an angle of 88° Q.E. Ignition and smoke trail were good. The altitude attained was low due to instability. The 8-shroud line parachute opened perfectly but the flare did not ignite. All hardware was recovered.

FLIGHT NUMBER 62

FLIGHT VEHICLE DATA

Propellant Grain: 3 inch reverse cone

Smoke Generator: .81 inch I.D. x 3 inches long

Initiator: S-68 Squib

Igniter: 4 grams CAI-1

Delay: Double Delay Train

Explosive Charge: CAI-1 and AP

Flare: RPI PPAL-X17-06

Fin Area: 4 square inches (welded)

Nose Cone: Solid

Length: 22.75 inches

CG: 12 inches from the aft end

Weight: 5.91 pounds

FLIGHT DESCRIPTION

Launch was made from a split, circular tube at an angle of 88° Q.E. Ignition, smoke trail and flight were all good. All components functioned properly except the flare did not ignite. All hardware was recovered.

FLIGHT NUMBER 63

FLIGHT VEHICLE DATA

Propellant Grain: 3 inch reverse cone

Smoke Generator: .81 inch I.D. x 3 inches long

Initiator: S-68 Squib

Igniter: 4 grams CAI-1

Delay: Double Delay Train

Explosive Charge: CAI-1 and AP

Flare: RPI PPAL-X17-06 (no shock absorber)

Fin Area: 4 square inches (welded)

Nose Cone: Solid

Length: 22.75 inches

CG: 12 inches from the aft end

Weight: 5.92 pounds

FLIGHT DESCRIPTION

Launch was made from a split, circular tube at an angle of 88° Q.E. Ignition, smoke trail and flight were good. All components functioned properly with exception of the flare which did not ignite. All hardware was recovered.

FLIGHT NUMBER 64

FLIGHT VEHICLE DATA

Propellant Grain: 3 inch reverse cone

Smoke Generator: .81 inch I.D. x 3 inches long

Initiator: S-68 Squib

Igniter: 4 grams CAI-1

Delay: Double Delay Train

Explosive Charge: CAI-1 and AP

Flare: RPI PPAL-X17-06 (connected to parachute with a shock absorber)

Fin Area: 4 square inches (welded)

Nose Cone: Solid

Length: 22.75 inches

CG: 12 inches from the aft end

Weight: 5.75 pounds

FLIGHT DESCRIPTION

Launch was made from a split, circular tube at an angle of 88° Q.E. Ignition and smoke trail were good but flight was unstable due to failure of the aft smoke closure. Ejection was just prior to impact. All other components functioned properly with exception of the flare, which did not ignite. All hardware was recovered.

FLIGHT NUMBER 65

FLIGHT VEHICLE DATA

Propellant Grain: 3 inch reverse cone

Smoke Generator: 1 inch I.D. x 3 inches long

Initiator: S-68 Squib

Igniter: 3 grams CAI-1

Delay: Double Delay Train

Explosive Charge: CAI-1 and AP

Flare: RPI PPAL-X17-06 (CAI-1 powder added)

Fin Area: 4 square inches (welded)

Nose Cone: Solid

Length: 22.75 inches

CG: 12.25 inches from the aft end

Weight: 5.57 pounds

FLIGHT DESCRIPTION

Launch was made from a split, circular tube at an angle of 88 ° Q.E. Ignition, smoke trail and flight were good. The CAI-1 powder in the flare caused an explosion at ejection which burst the tube and shattered the flare. The parachute and motor case were recovered.

FLIGHT NUMBER 66

FLIGHT VEHICLE DATA

Propellant Grain: 3 inch reverse cone

Smoke Generator: .81 inch I.D. x 3 inches long

Initiator: S-68 Squib

Igniter: 3 grams CAI-1

Delay: Double Delay Train

Explosive Charge: CAI-1 and AP

Flare: RPI PPAL-X17-06 (connected to parachute with a shock absorber)

Fin Area: 4 square inches (welded)

Nose Cone: Solid

Length: 22.75 inches

CG: 12 inches from the aft end

Weight: 5.79 pounds

FLIGHT DESCRIPTION

Launch was made from a split, circular tube at an angle of 88° Q.E. Ignition, smoke trail, and flight were good. All components functioned properly with exception of the flare which did not ignite. All hardware was recovered.

FLIGHT NUMBER 67

FLIGHT VEHICLE DATA

Propellant Grain: 3 inch reverse cone

Smoke Generator: 1 inch I.D. x 3 inches long

Initiator: S-68 Squib

Igniter: 3 grams CAI-1

Delay: Double Delay Train

Explosive Charge: CAI-1 and AP

Flare: RPI PPAL-X17-06 (connected to parachute with a shock absorber)

Fin Area: 4 square inches (welded)

Nose Cone: Solid

Length: 22.75 inches

CG: 12 inches from the aft end

Weight: 5.66 pounds

FLIGHT DESCRIPTION

Launch was made from a split, circular tube at an angle of 88° Q.E. Ignition, smoke trail, and flight were good and all components functioned properly with exception of the flare which did not ignite. The flare was ignited after recovery and burned satisfactorily. All hardware was recovered.

FLIGHT NUMBER 68

FLIGHT VEHICLE DATA

Propellant Grain: 3 inch reverse cone

Smoke Generator: .81 inch I.D. by 3 inches long

Initiator: S-68 Squib

Igniter: 3 grams CAI-1

Delay: Double Delay Train

Explosive Charge: CAI-1 and AP

Flare: RPI PPAL-X17-06 (connected to parachute with a shock absorber)

Fin Area: 4 square inches (welded)

Nose Cone: Solid

Length: 20.75 inches

CG: 9 inches from the aft end

Weight: 4.22 pounds

FLIGHT DESCRIPTION

Launch was made from a split, circular tube at an angle of 88° Q.E. Ignition, smoke trail and flight were good and all components functioned properly except that the flare did not ignite. The flare was returned on the parachute. All hardware was recovered.

FLIGHT NUMBER 69

FLIGHT VEHICLE DATA

Propellant Grain: 3 inch reverse cone

Smoke Generator: .81 inch I.D. x 3 inches long

Initiator: S-68 Squib

Igniter: 4 grams CAI-1

Delay: Double Delay Train

Explosive Charge: CAI-1 and AP

Flare: RPI PPAL-X17-06 (connected to parachute with a shock absorber)

Fin Area: 4 square inches (welded)

Nose Cone: Solid

Length: 20.75 inches

CG: 9 inches from the aft end

Weight: 4.24 pounds

FLIGHT DESCRIPTION

Launch was made from a split, circular tube at an angle of 80° Q.E. Ignition, smoke trail and flight were good. The delay train malfunctioned due to EC 801 inhibitor on the grain. All hardware was recovered.

FLIGHT NUMBER 70

FLIGHT VEHICLE DATA

Propellant Grain: 3 inch reverse cone

Smoke Generator: .81 inch I.D. x 3 inches long

Initiator: S-68 Squib

Igniter: 4 grams CAI-1

Delay: Double Delay Train

Explosive Charge: CAI-1 and AP

Flare: RPI PPAL-X17-06 (connected to parachute with a shock absorber)

Fin Area: 4 square inches (welded)

Nose Cone: Solid

Length: 22.75 inches

CG: 12 inches from the aft end

Weight: 5.87 pounds

FLIGHT DESCRIPTION

Launch was made from a split, circular tube at an angle of 80 ° Q.E. Ignition, smoke trail and flight were good and all components functioned properly with exception of the flare which did not ignite. The flare, nose cone, and parachute were recovered.

APPENDIX IV

EARLY VEHICLE DESIGNS

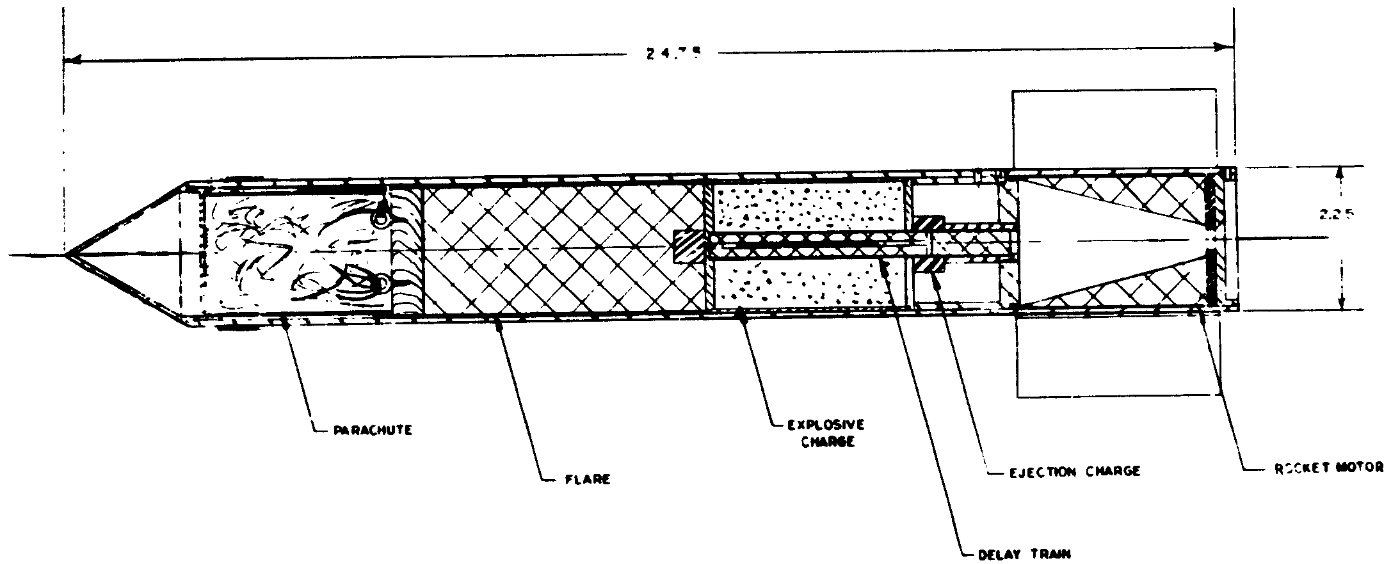

Figure 7 — POWS Rocket Vehicle P/N 2589-11 (Design No. 1)

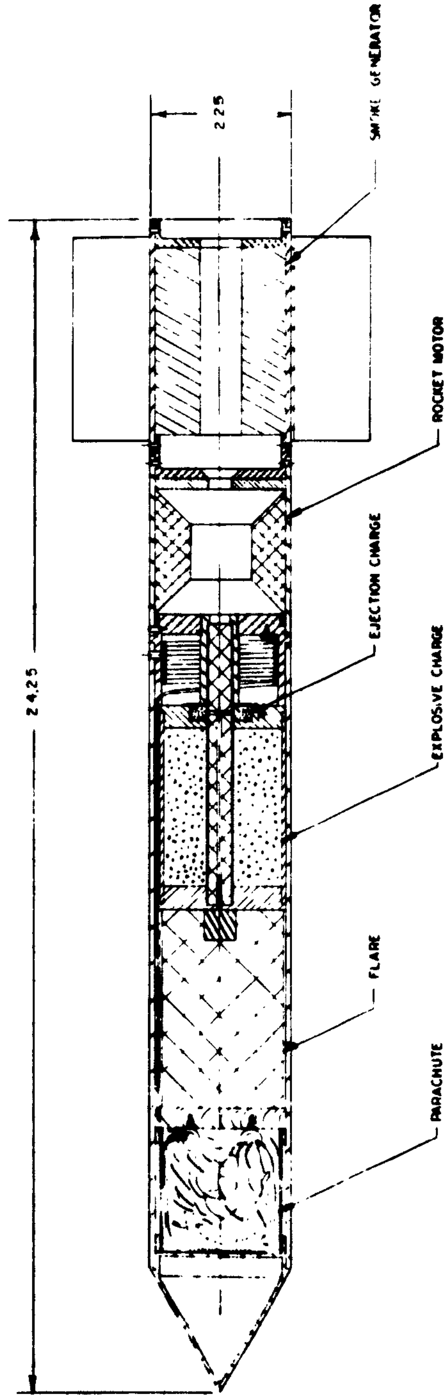

Figure 8 — POWS Rocket Vehicle P/N 2589-12 (Design No. 2)