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Department of Aeronautical and Astronautical Engineering

Final Report

THE EXOS SOUNDING ROCKET

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ABSTRACT

The Exos sounding rocket was developed to fill the needs of upper-air research for an economical vehicle carrying a 40-lb payload to a 300-mile altitude. The report describes the Exos in detail and gives the results of the first two flight tests. The major part of the report is devoted to a manual-type description of the assembly procedures. Part lists and procurement information are included.

OBJECTIVE

The project objective is to develop a reliable, economical rocket system suitable for carrying payloads of 40 lb to altitudes of 200-300 miles.

ACKNOWLEDGMENT

We wish to acknowledge the assistance of the Pilotless Aircraft Research Division of the National Advisory Committee for Aeronautics. Their cooperation in providing designs, advice, and the use of the launching facility is greatly appreciated. Further, we wish to acknowledge the support of the Air Force Cambridge Research Center of the United States Air Force. Their sponsorship made this project possible.

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1. INTRODUCTION

The Exos sounding rocket is a three-stage, solid-propellant sounding rocket capable of carrying 40 lb of instruments to a 300-mile altitude. It was developed by The University of Michigan with the cooperation of NACA under sponsorship of the Air Force Cambridge Research Center.

The first two stages, Honest John prime mover and Nike-Ajax booster, are fin-stabilized, while the third stage, a Thiokol* Recruit, employs a flared skirt. The first stage separates at burnout and the remainder of the rocket coasts for 25 seconds. The second stage is ignited by timer and batteries and at burnout the pressure drop signals third-stage ignition. A speed of over Mach 10 is achieved at third-stage burnout.

Aerodynamic heating is countered by a blunt nickel nose tip, Inconel nose cone, and inner radiation reflector. Acceleration at third-stage burnout is about 175 g's. However, a new motor now under consideration may reduce the maximum acceleration to 80 g's. It will be a direct substitution for the Recruit and may be available by March, 1959.

The Exos is pictured in Fig. 1. Figures 2 and 3 show the dimensions and trajectory. Two flight tests have verified the performance predictions. The preparation, assembly, and launching of an Exos can be done by only a small crew with modest equipment, and the total cost of the vehicle is under $20,000. It is a simple and economical means of lifting moderate payloads to the 300-mile region.

While the first flights were carried out from a modified Honest John launcher which uses a short rail, Exos is easily adaptable to zero-length launchings.

A complete description of the parts, equipment, and operations required to launch an Exos rocket is given in this report. It is hoped that research groups which desire to fly the Exos will find the following sections to be a suitable manual.

2. PERFORMANCE

2.1. DESIGNED

The Exos rocket was designed to carry at least 40 lb of payload to at least a 300-mile altitude. Simple trajectory calculations can be made on the basis of

*Thiokol Chemical Corporation, Elkton, Maryland.

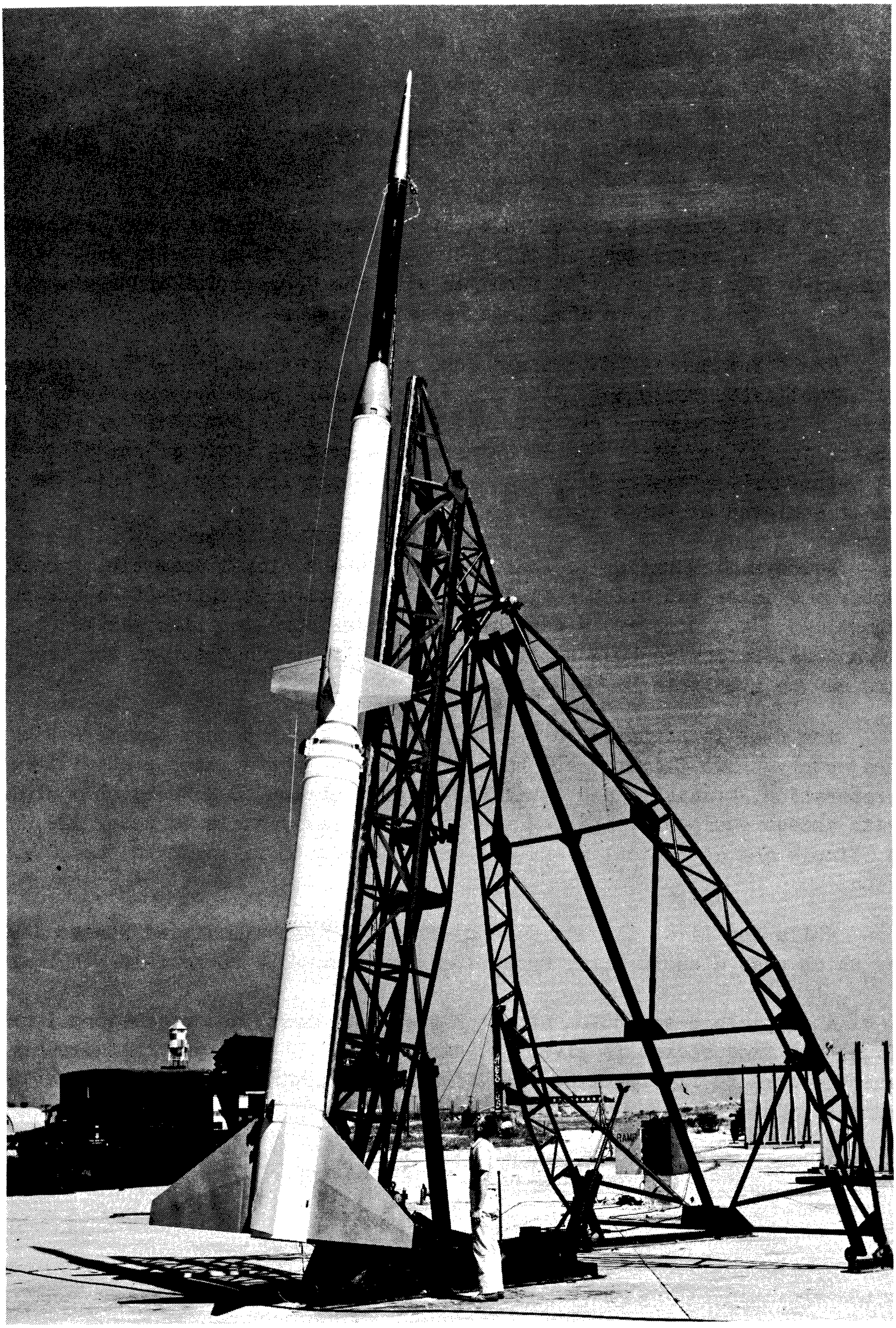


Fig. 1. Exos I on launcher.

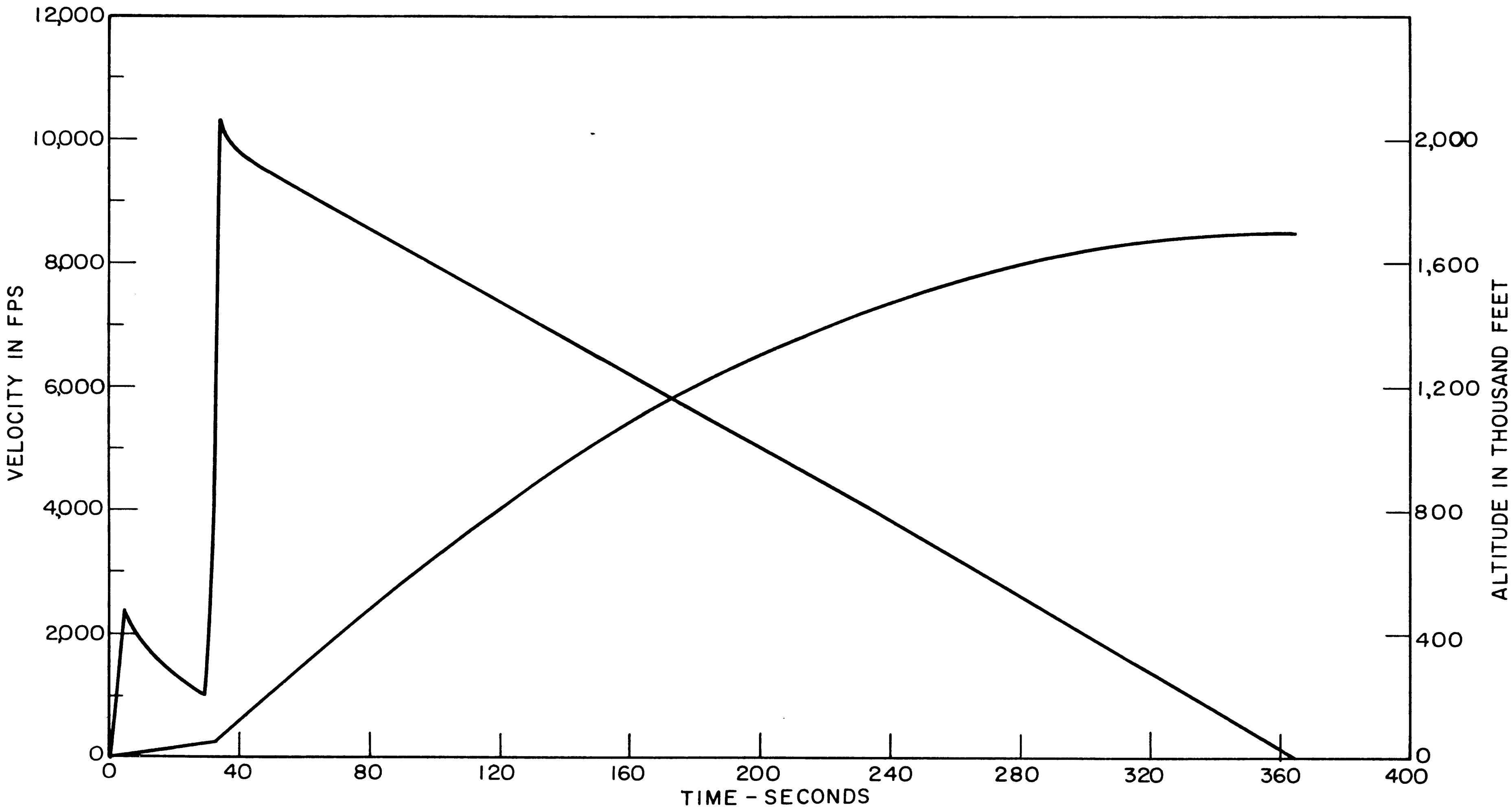


Fig. 3. Estimated trajectory of Exos with vertical launch.

a vertical launch and then modified to yield approximate flight characteristics for angles slightly off the vertical (with the obvious exception of horizontal range). When this was done, initially a third-stage loaded weight of 457 lb was used. Our predictions showed a peak altitude of 323 miles with vertical launch (see Fig. 3).

The method of extrapolating peak altitude at vertical launch to other launch angles is to multiply the peak by a factor equal to the square of the sine of the burnout angle. The burnout angle will not be the same as the launch angle, since the trajectory curves in the interim. Analysis shows that this curvature can be determined by integrating the equation:

$$\frac{d\Theta}{dt} = \frac{g \cos \Theta}{v} ,$$

where Θ is the angle of the velocity vector (or flight path) at any time with the local horizontal, v is the speed, and g is the gravitational acceleration.

The speed is known as a function of the time, Θ is the launch angle at $t = 0$, and gravity may be assumed constant for the early portion of the flight; thus the solution is straightforward. It is obvious that the rate of change of flight-path angle is greatest when the rocket moves slowly and is very small when Θ is near 90°. In the Exos trajectory, most curvature occurs early in the first-stage burning and during coast. The peak-altitude reduction factors for various launch angles are given in Table I.

TABLE I

PEAK-ALTITUDE REDUCTION FACTORS

Launch Angle	Peak Altitude Reduction Factor
90°	1.000
87.5°	.995
85°	.981
82.5°	.957
80°	.918
77.5°	.883
75°	.834

Changes in payload weight will alter the predicted peak altitude about one mile per pound. Since the third stage operates as a low-performance rocket (mass ratio less than 3) and the 40-lb payload is only about 1/5 of the burned-out weight, the changes in payload may be quite large without greatly affecting the performance or operation of the rocket. From this standpoint, Exos is extremely versatile in adapting to variously sized instrument packages.

Horizontal range is governed by burnout (and thus, launch) angle. A complete discussion of horizontal range and dispersion together with wind-weighting factors is given in Ref. 1. By the method of reference, Table II was constructed.

TABLE II

HORIZONTAL RANGE

Stage	75°	80°	90°
1	less than 8 miles	less than 6 miles	less than 3 miles
2	less than 90 miles	less than 60 miles	less than 30 miles
3	approx. 540 miles	approx. 300 miles	approx. 150 miles

The rapidly burning propellant in the final stage caused a high acceleration—approximately 175 g's. Although instrument packages are readily built to survive this acceleration, the requirement is stringent. Therefore, at the time of writing, a substitute third-stage rocket utilizing the same metal parts is being considered for development. Theoretically, it will boost the peak altitude 6 miles while reducing the maximum acceleration to 80 g's. It is hoped that this rocket will be available by March, 1959.

Because of aerodynamic heating considerations, the nose skin and tip of the Exos weigh more than is necessary for structural strength alone. As temperature data are accumulated, it may be feasible to reduce the heat-sink material by 5-10 lb, adding to the altitude or payload as desired.

In staging the vehicle, the optimum trajectory from a thrust and drag standpoint is not utilized because of the overriding consideration of aerodynamic heating. Thus the long coast period between first and second stages is designed to permit the rocket to attain an altitude of reduced density and bring the heating within tolerable limits during the high-speed portion of the flight.

Calculation of the skin temperature at a point 8 in. aft of the nose was made, under the assumption that the skin was .050 Inconel at that point. Actually the .050 Inconel skin began 13 in. aft of the nose. The temperature of the magnesium flared skirt was also calculated. These calculations were made by the method of E. R. Van Driest.[2,3] The results are shown in Fig. 4.

Stability calculations based on supersonic theory show the three-stage vehicle to have static stability in excess of 2-1/2 calibers, and the final two stages to have static stability in excess of 3 calibers. Based on the hypersonic theory of Ref. 4, the third stage has static stability in excess of 3 calibers.

A summary of flight parameters for critical points in the trajectory for a vertical launch is given in Table III.

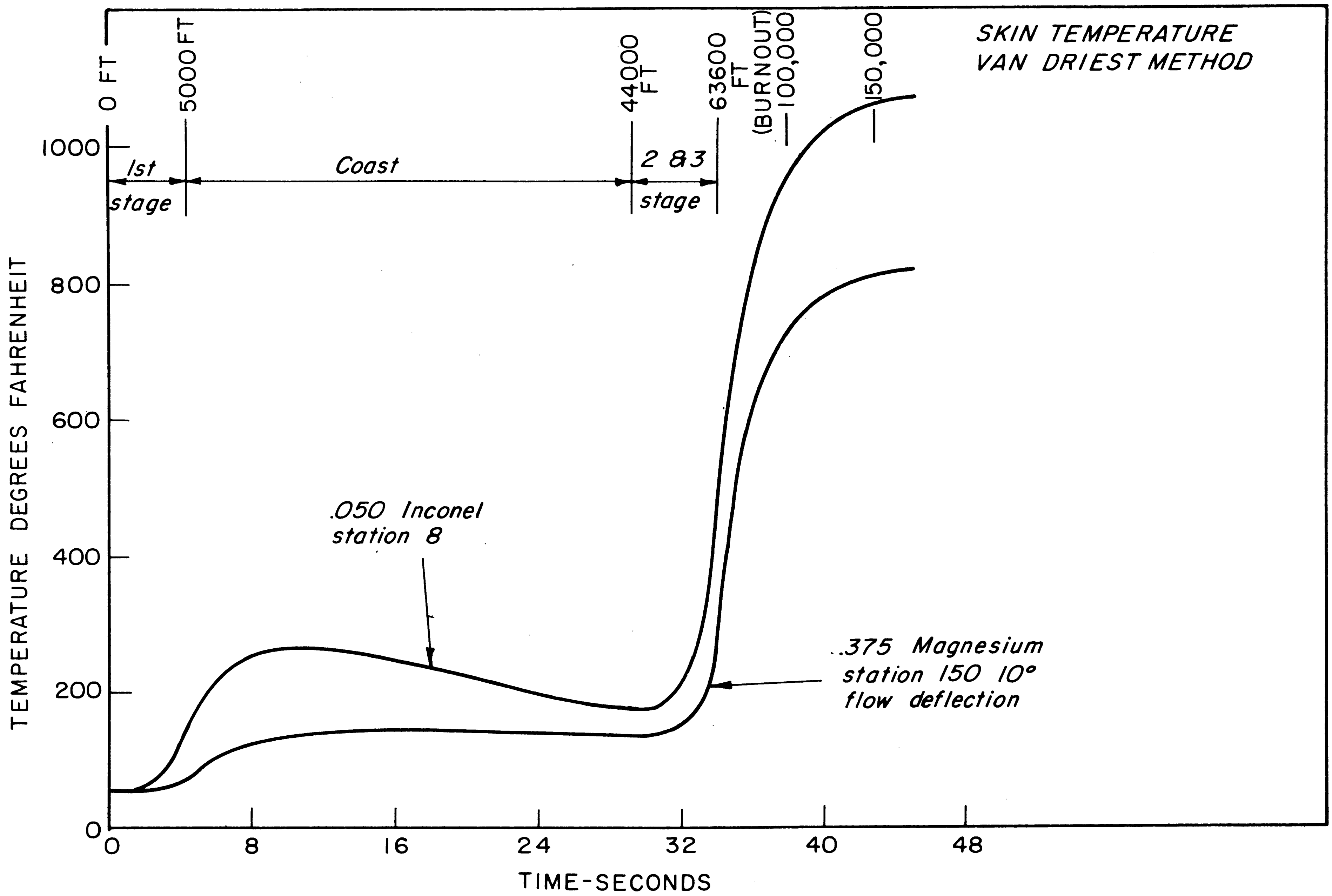


Fig. 4. Skin temperature of third stage as a function of time.

TABLE III

FLIGHT PARAMETERS

Action	Time (sec)	Weight (lbf)	Drag (lbf)	Altitude (ft)	Velocity (ft/sec)	Acceleration (g's)
1st Ignition	0	5821	0	0	0	14.5
1st Burnout	4.4	3864	12,000	5,000	2378	19
Separation	4.45	1739	3,885	-	-	-3
2nd Ignition	29.4	1739	145	44,000	995	27
2nd Burnout	32.4	1000	1,000	51,600	4380	47
3rd Ignition	32.4+	457	410	-	-	80
3rd Burnout	34.0	190	785	62,700	10294	175
Peak	365	190	0	323 mi.	0	-1

2.2. FLIGHT TESTS

The first Exos was flight-tested at NACA, Wallops Island, Va., on June 26, 1958. It was instrumented for measurement of flight conditions by Air Force Cambridge Research Center. The third stage weighed 467 lb. The launch angle was 75°. Takeoff, first-stage burning, and separation were normal. Visual tracking was lost during the coast period when the rocket entered a cloud. Radar beacon tracking failed at takeoff. Radar skin tracking failed at the time of visual loss. Telemeter reception failed at the time of second-stage ignition. Long-range radar tracking near Boston was good, but only three points were recorded. These points were too close together to establish an accurate trajectory; however, they were near the trajectory peak and verified that the rocket attained an altitude in the neighborhood of 240 miles. On the basis of weight and launch angle, the predicted peak was 260 miles. Therefore the vehicle was deemed to have operated successfully and substantially as predicted.

The second Exos was flight-tested at NACA, Wallops Island, Virginia, on September 25, 1958. It was instrumented for measurement of nose cone and skin temperatures, and acceleration in three planes by the Air Force Cambridge Research Center. The third stage weighed 464-1/2 lb. The launch angle was 80°. Operation through final-stage burnout was normal. Radar beacon operated for one minute, which will enable a drag-free trajectory to be computed. Long-range radar tracking near Boston was very good. Preliminary reduction of these data yields a peak altitude of 296 miles. On the basis of weight and launch angle, the predicted peak was 288 miles. Telemeter data were taken for 13 min., 20 sec., presumably the entire flight. These data are being reduced.

From the results obtained in these flight tests, we conclude that the Exos satisfactorily fulfills the design requirements and that performance predictions are substantially correct.

3. DESIGN FEATURES AND ORIENTATION

3.1. MOTORS

The Exos is a three-stage solid-propellant vehicle. The first stage is the Honest John rocket motor. The second stage is the Nike-Ajax anti-aircraft missile booster. The third stage is the Thiokol Chemical Corporation Recruit rocket modified to provide a nozzle with larger expansion ratio.

3.2. LAUNCHING AND HANDLING EQUIPMENT

The launcher used for the first Exos flights is a rail type with anti-tip-off feature which provides guidance for about 12 ft. It is a converted, prototype, Honest John launcher. The basic reason a rail-type launcher was chosen was the availability of this particular equipment. The Exos is suitable for zero-length launchings as well (see Fig. 5).

The standard Honest John riding lugs are used. The forward lug is shaped like an inverted "T" and rides in a slot in the center of the rail. The aft end is fitted with a pair of lugs which grasp the outer edges of the rail, similar to the Nike. The outer edges of the rail terminate at a distance from the rail's end which equals the distance between fore and aft riding lugs; thus all lugs leave the rail simultaneously and tip-off is avoided. The forward lug is higher than the after lugs, holding the rocket at an angle of 53' with respect to the rail. This provides sufficient lift at the tail to prevent it from striking the rail end when launched at low elevation angles. This feature is not necessary but does no harm when fired as a sounding rocket. The angle of attack is easily seen by eye as in Fig. 6, but should cause no concern. The final stages are cantilevered from the nose of the first.

The launching rail is mounted on a heavy trunnion and pedestal. The pedestal is bolted to the launch pad and offers no trainability. The rail is raised by a pair of hydraulic rams, powered by a 3-hp, 900-rpm, 220- or 440-v, 3-Ø electric motor and a positive displacement gear pump. Lowering is accomplished by gravity and controlled by a hydraulic valve. An A-frame supports the rail when it is in firing position. The A-frame is attached near the tip of the rail and terminates on two legs 16 ft apart which ride on rails attached to the launch pad. The legs are pinned to these rails in firing position; thus the stresses of the firing are not transmitted to the hydraulic system. Approximately 1 min. is required to raise the launching rail.

Since the Exos is placed on top of the launching rail, which is some 6 ft above the ground, a crane or high-lift fork truck is required. The preparation of each stage required a holding dolly for the motor, and strongbacks are required to lift the motors from above. No major piece of specialized equipment is necessary. The equipment which should be on hand for each operation is covered in Section 4 below.

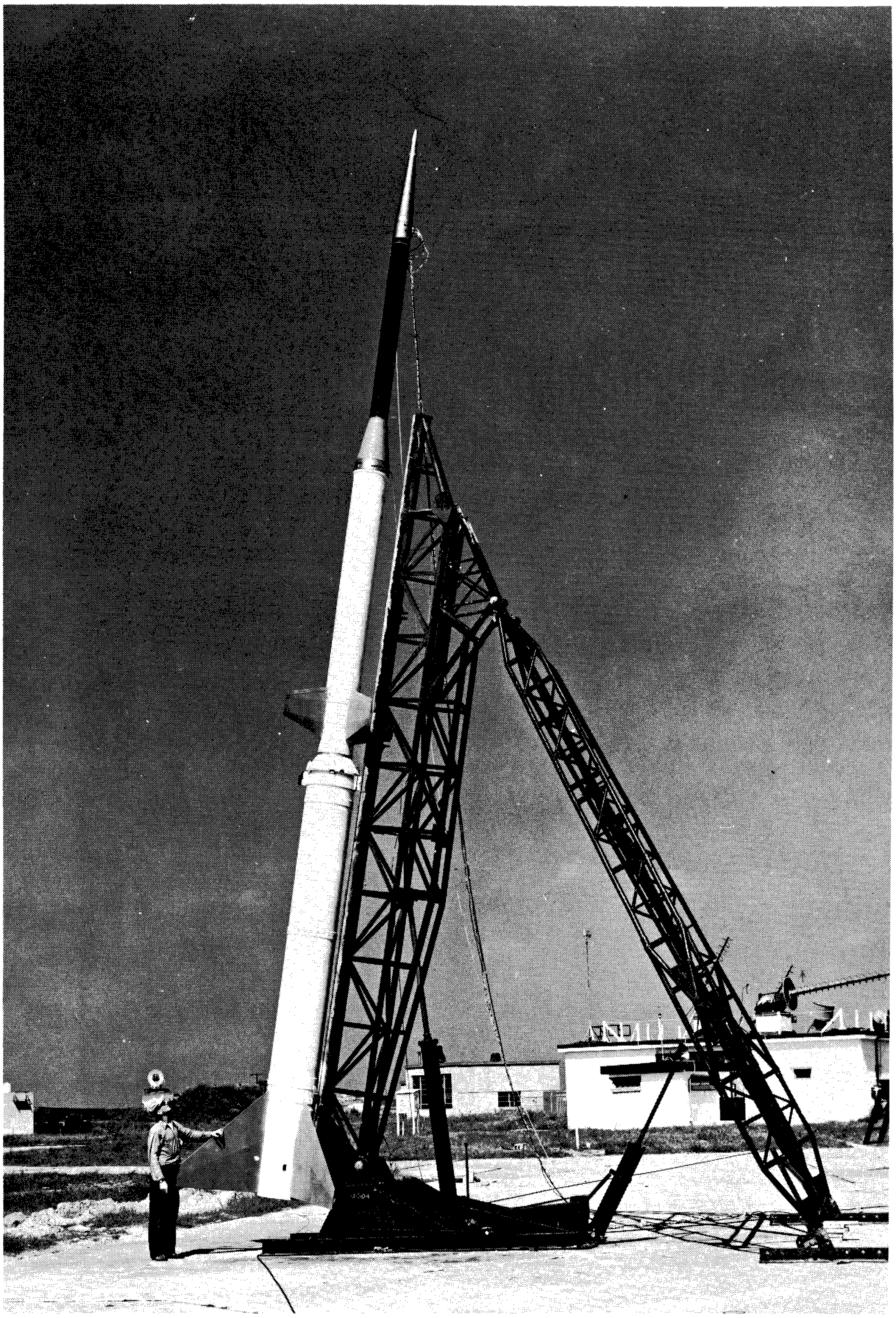


Fig. 5. Exos II on launcher.

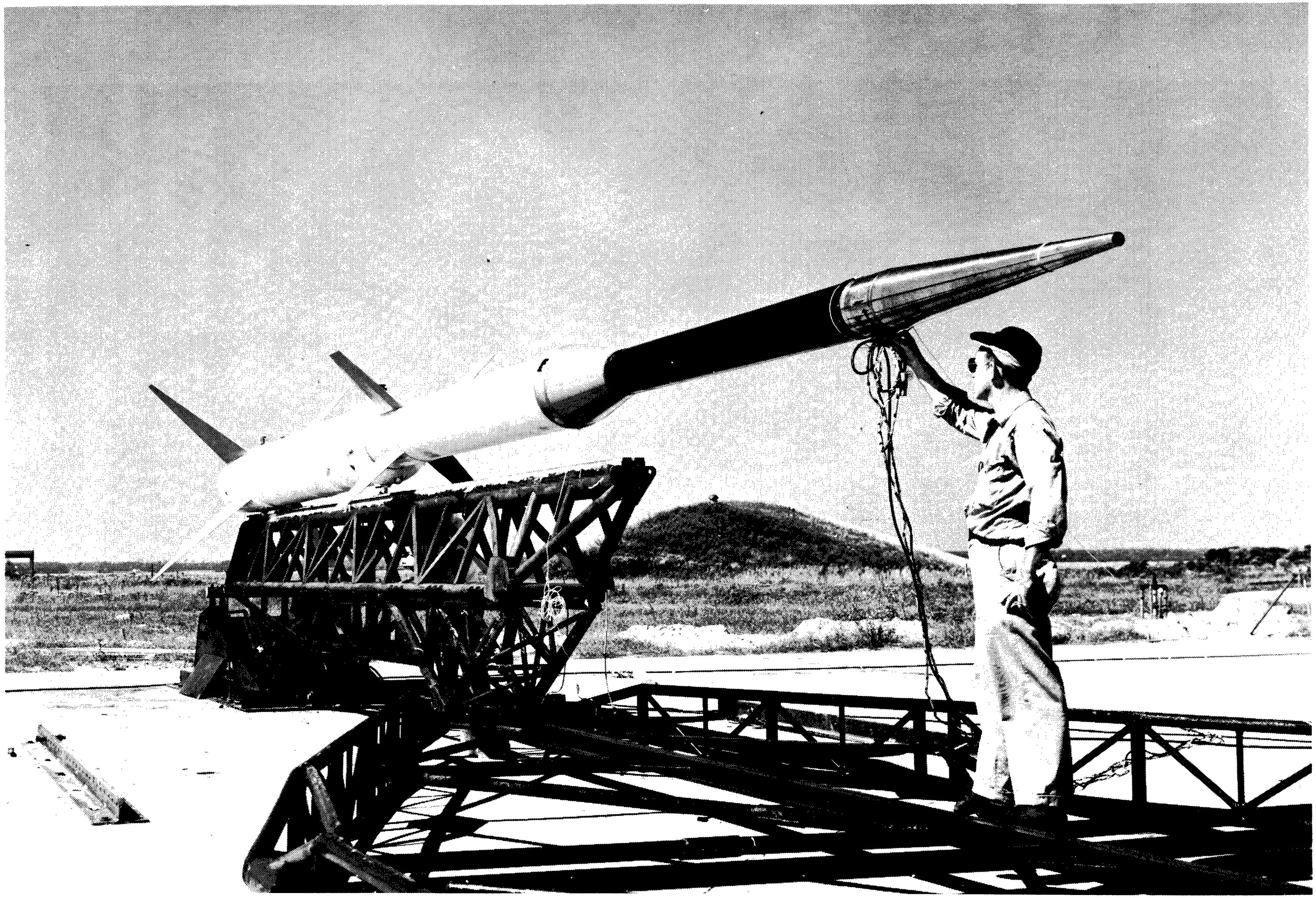


Fig. 6. Exos ready to be erected.

3.3. STABILITY

All stages are aerodynamically stabilized, the first and second stages by means of cruciform fins, the third by a flared skirt. On the Honest John, standard fins are used. However, each fin is supplied with a mounting bracket that holds the fin at a slight angle to the airstream, producing a roll. This cant is removed by modifying the bracket so that the fins are as well aligned as possible.

The Nike is fitted with 2.5 square-foot fins of design similar to that used in the Nike-Cajun (see Fig. 7 and Ref. 5), as the standard fins are too big and too weak for use in this application. Each fin is a clipped-tip delta, made of magnesium castings and plates, and welded to a magnesium shroud. The leading edges are cuffed with Inconel sheet to resist heating.

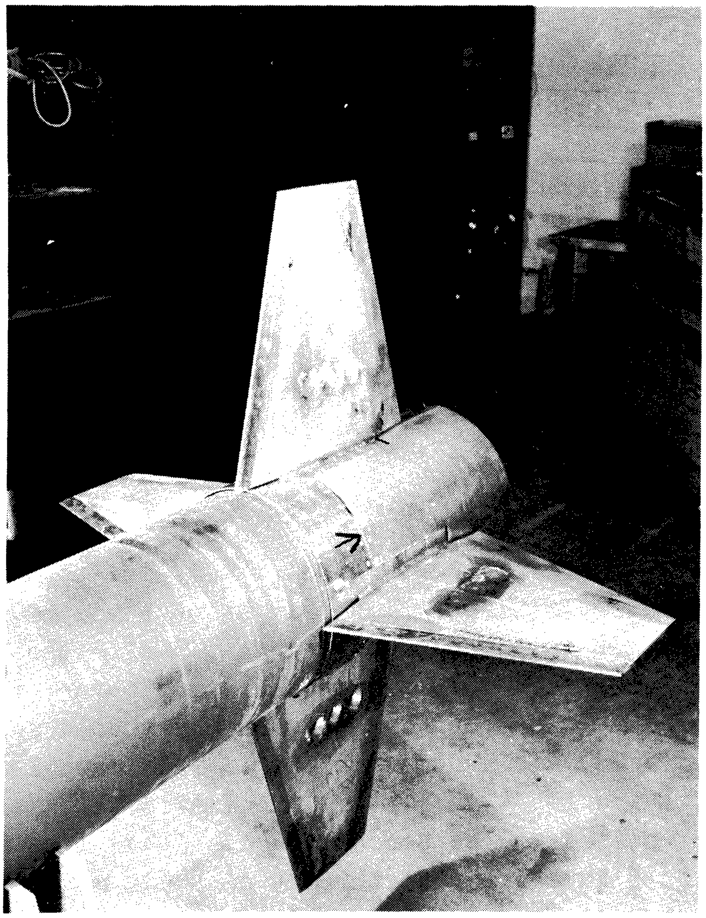


Fig. 7. Second-stage motor with 2-1/2 square-foot fins.

A skirt of 3/8-in magnesium with 10° half-angle is bolted to the aft end of the Recruit motor. (It is shown in Fig. 8.) This provides stability as well as the means of attaching the third stage to the second.

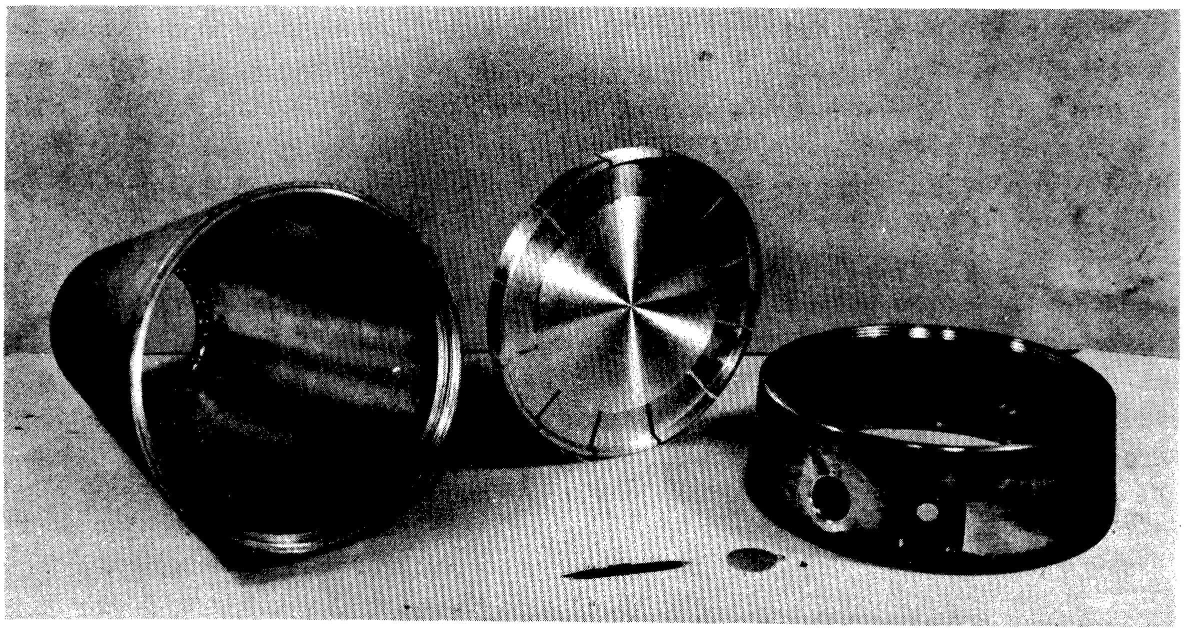


Fig. 8. Second- to third-stage coupling parts.

3.4. COUPLINGS AND FLIGHT PROGRAM

The flight program calls for the first stage to separate at burnout due to aerodynamic drag. A large magnesium casting, shown in Fig. 9, is bolted to the thrust face of the Honest John. The Nike is cantilevered from the two cylindrical surfaces, one of which seats in the nozzle throat and the other into a spacer ring that is glued into the Nike nozzle exit. A section is shown in Fig. 10. When differential drag has moved the first stage aft about 2 in., both cylindrical surfaces are freed.

A 25-sec coast period follows, during which time the rocket attains an altitude where the density is sufficiently low that aerodynamic heating is not severe. The second and third stages must be locked together during the coast period or they, too, would drag separate. Then the second stage burns, and at burnout third-stage ignition is signaled. The coupling between the second and third stage releases the third stage immediately upon ignition. This coupling consists of three parts, shown in Figs. 8 and 11. One part is the flared skirt of the third stage. Another is the casting bolted to the second stage. These mate together to form the thrust structure and both have internal threads on their mating surfaces. The third part is a diaphragm with external threads on its periphery. It is screwed halfway into each of the other two parts, thus locking them securely together. However, when the third stage ignites, the pressure of exhaust gases forces the diaphragm into a bowl-shape, freeing the threads. The space behind the diaphragm is used to contain the components of the second- and third-stage ignition system.

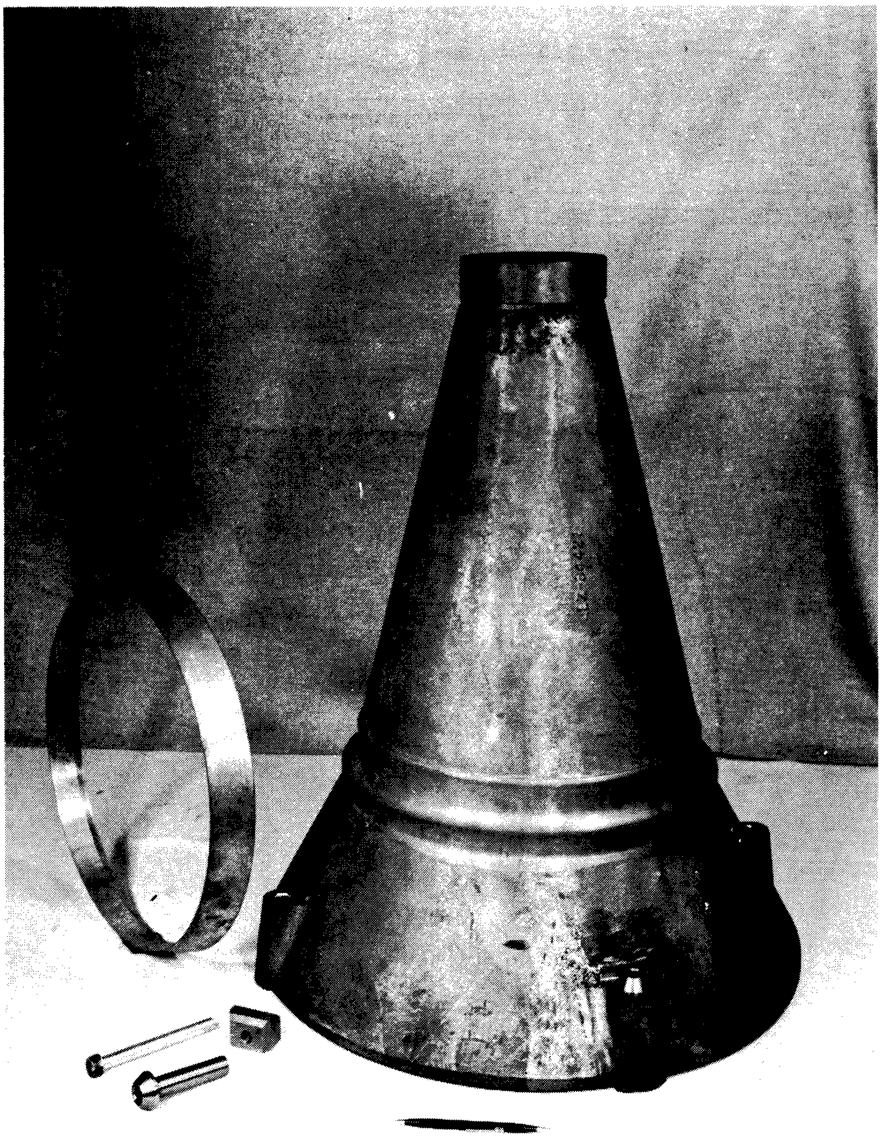


Fig. 9. First- to second-stage coupling.

3.5. INSTRUMENTED NOSE

The standard nose consists of a truncated cone-cylinder shown in Fig. 12. It is spun of Inconel sheet approximately .055 in. thick. The tip is solid nickel. A porcelain insulator separates the tip from the rest of the nose and provides a dipole antenna for 217-mc telemetry. The cone half-angle is arctan .075 or about 4°17'. The truncated cone, including tip, is 48 in. high. The cylinder length can be adjusted to provide more or less space, but is typically 9 in. high. A radiation shield, as in Fig. 13, may be added just under the conical surface since the outside surface temperature may be as much as 1000°F. The tip is truncated at 1.8-in. diameter to gain the well-known advantages of a blunt shape. Its advantage over other blunt designs is that laminar flow conditions are extended further back

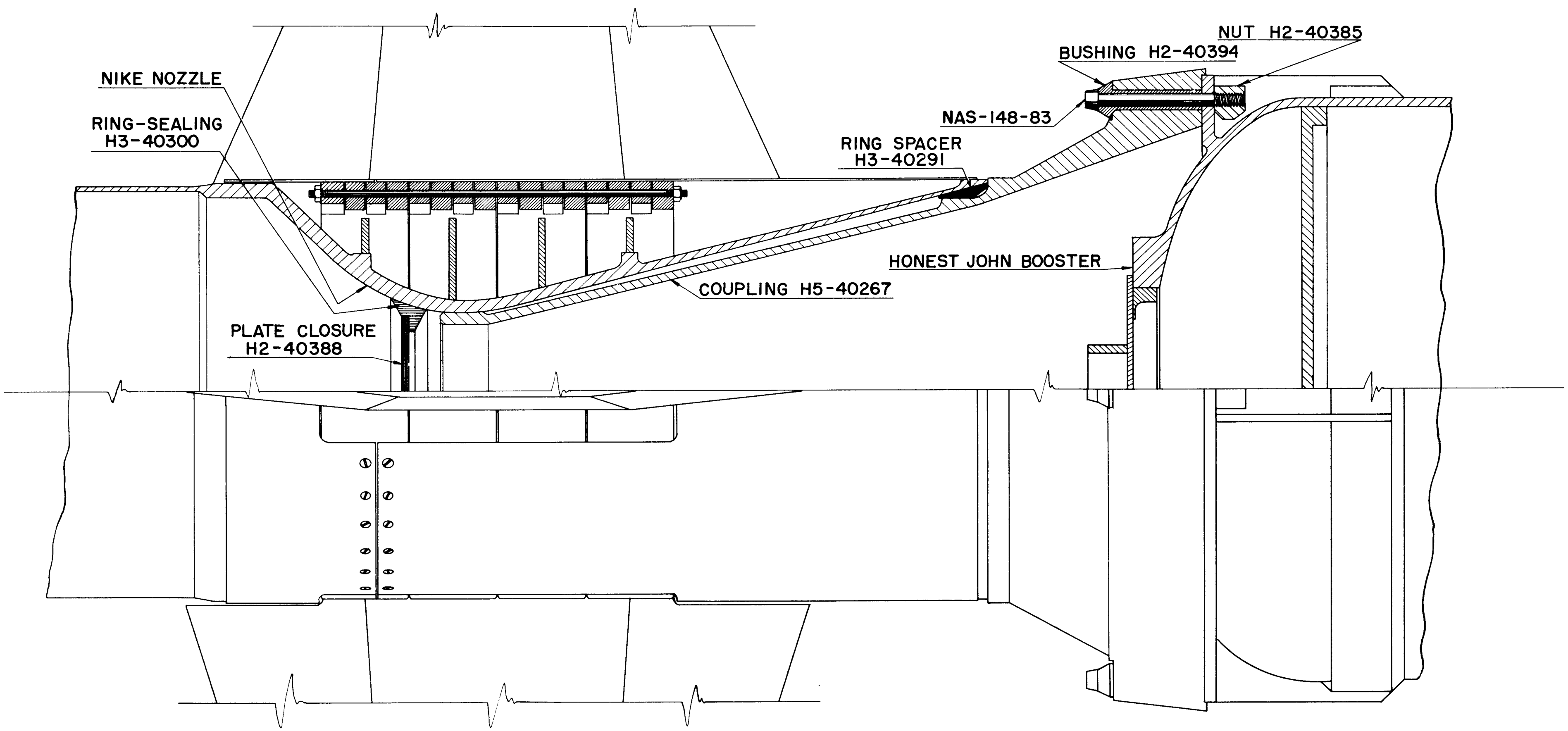


Fig. 10. First- to second-stage coupling assembly.

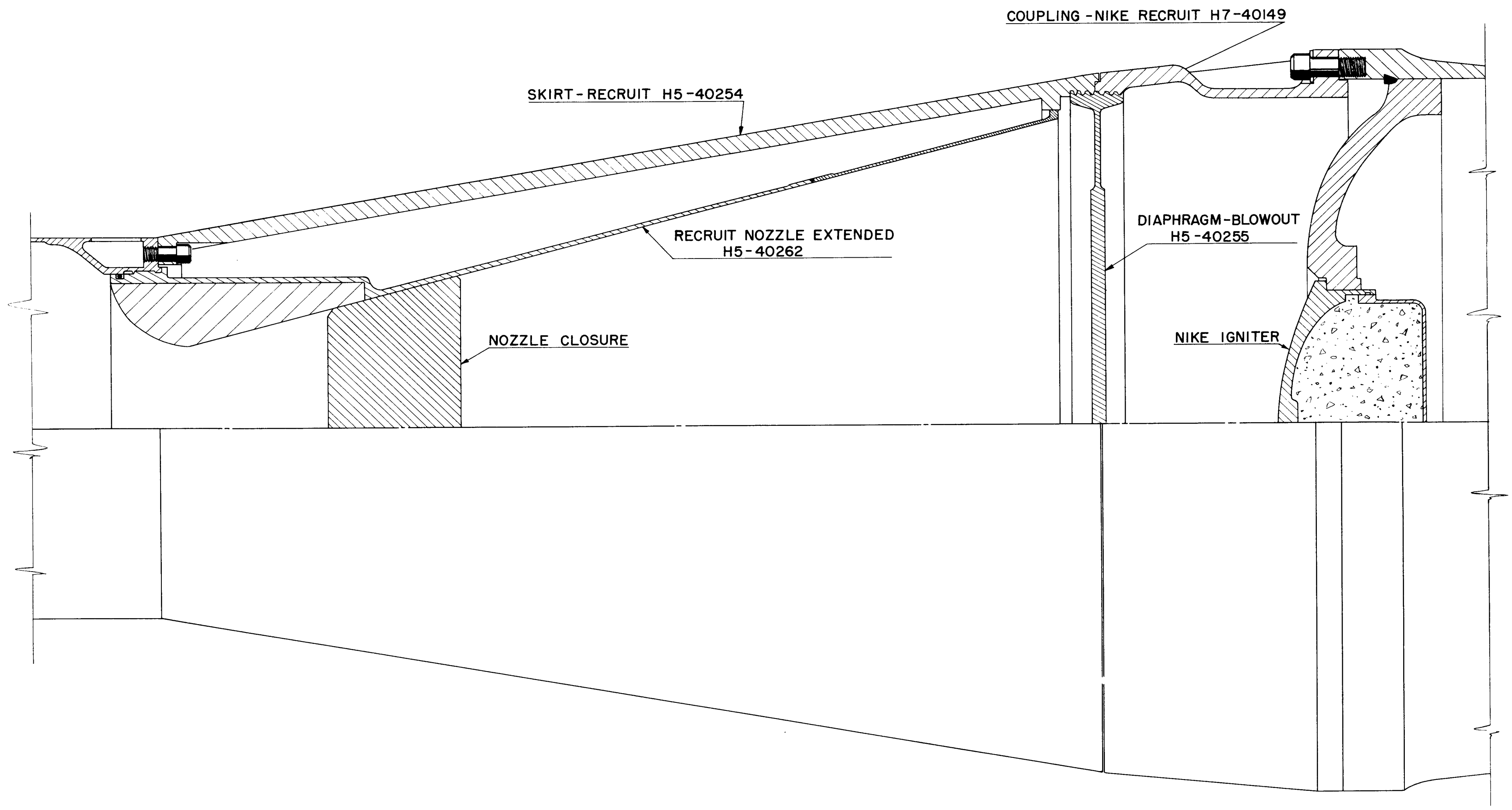


Fig. 11. Second- to third-stage coupling assembly.

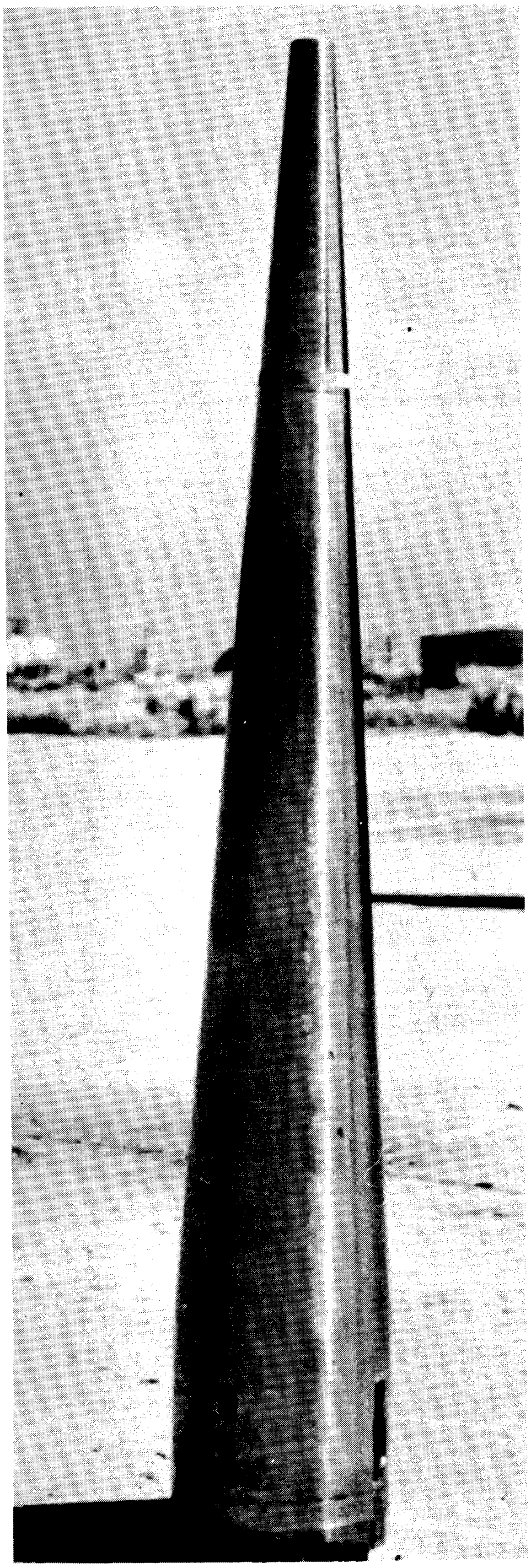


Fig. 12. Nose cone with tip.

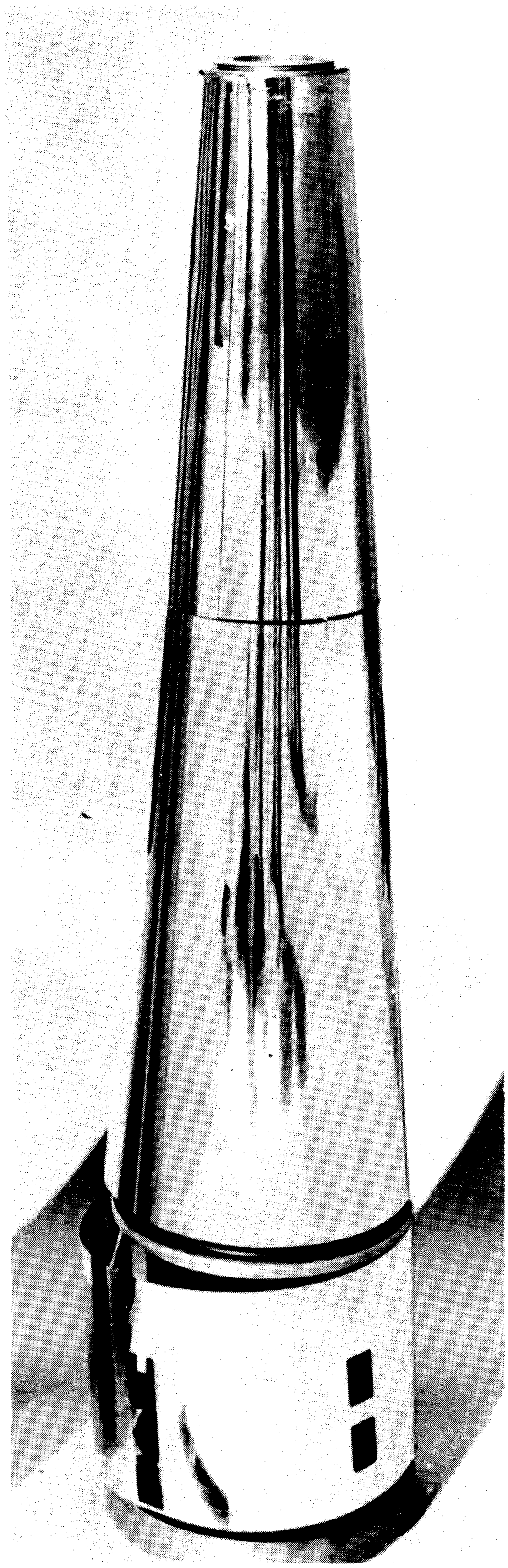


Fig. 13. Radiation shield.

on the nose, slightly reducing drag and heating. The nose is joined to the rocket by screwing to a mating ring which has been bolted to the Recruit head cap.

3.6. IGNITION APPARATUS

The standard igniter for the Honest John is utilized except that the elaborate mount to support the igniter against lateral accelerations when the rocket is transported in the field is unnecessary. The igniter when installed is simply suspended from its audio-jack-type plug. The circuit runs through the grain and external connection is made at the tail. The igniter is a low-resistance type and any type of standard firing circuit will suffice.

The second-stage igniter must be modified from a high-resistance type to a low-resistance type. This is necessary since the ignition is by battery in flight and high voltages are not available. The powder is removed and the squib harness removed and replaced. The powder is replaced and the igniter resealed. No change is made in the external circuit. The firing circuit that runs through the grain of the motor is removed, as is the nozzle seal. A better nozzle seal is installed which will hold over three atmospheres of pressure (see Fig. 10). This insures satisfactory ignition of the rocket at altitude.

The third-stage igniter is provided with a lead cable through the rocket grain. A plug is cemented into the nozzle to retain the pressure, as in the second stage. This plug has AN connectors fore and aft, wired together. Thus the igniter lead is connected to the forward side, the plug cemented into the nozzle, and the connector on the aft side is exposed for subsequent hookup.

While the first stage is ignited from a ground firing circuit, subsequent stages are ignited in flight. The circuitry necessary to accomplish this function is located on the after side of the blowout diaphragm. It is shown in Fig. 14. At the time of first-stage ignition, an acceleration switch is closed, causing a battery-operated, chronometrically-governed timer to begin running. This timer continues to run until the proper time for second-stage ignition, when it closes a microswitch. The switch shunts the battery power, which has been running the timer, through the second-stage igniter. The battery pack is made of 8 Yardney HR-1 Silvercels in series. Thus the second stage ignites. The increase in second-stage chamber pressure is transmitted from a pressure tap on the second-stage head cap, through a flexible hose to a pressure switch. This pressure increase unlatches the switch. Then at burnout when the pressure again decreases, the pressure switch is free to close, and does so, sending the current from the third-stage battery pack (six HR-1 Silvercels in series) through the third-stage igniter.

Since a fundamental safety consideration is never to have firing current in the vicinity of an armed rocket while working on it, some attention must be directed toward the installation of battery packs in the Exos. This can be done without violating safety principles by providing a charging plug on the rocket

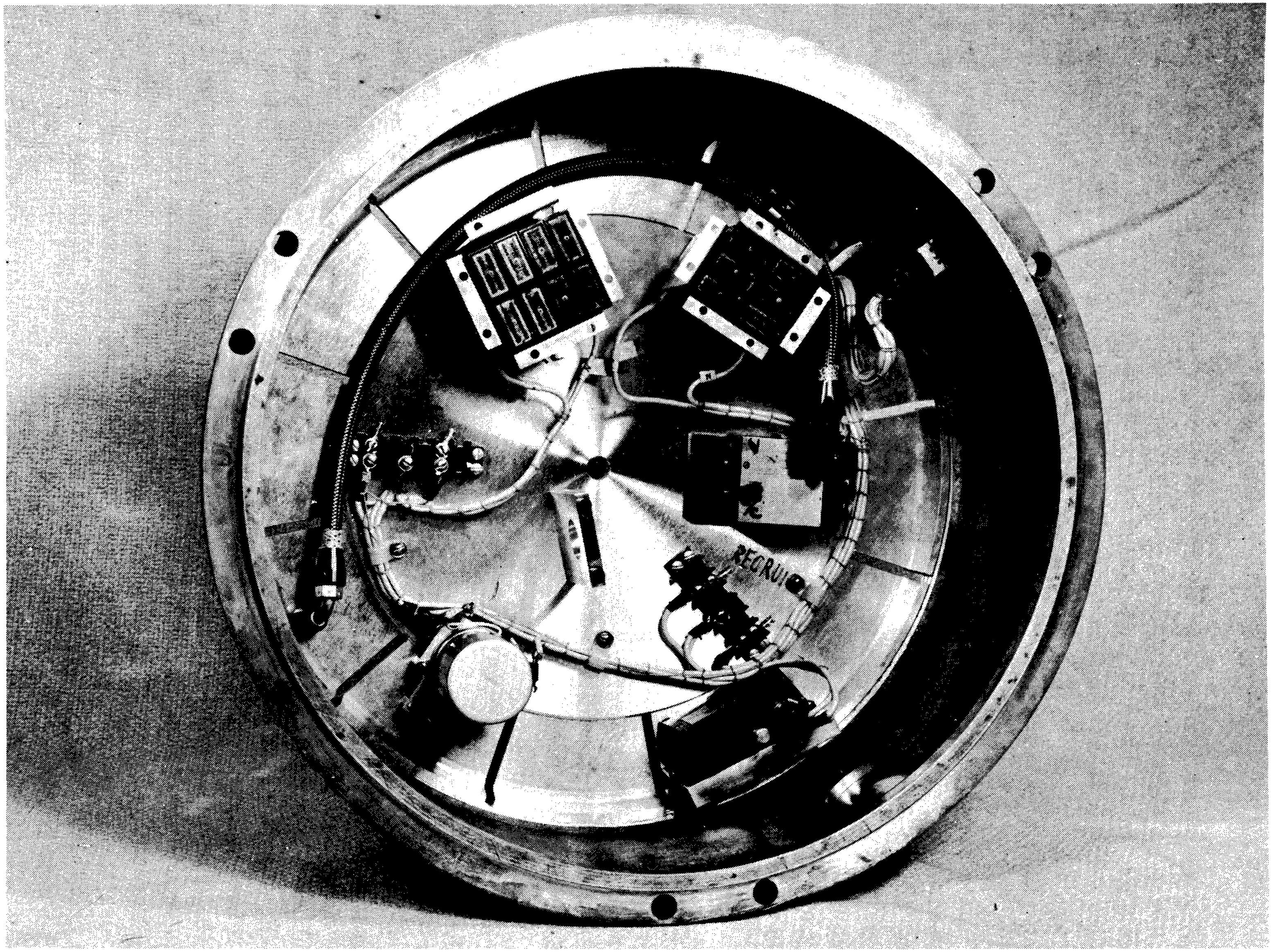


Fig. 14. Ignition circuitry installed.

exterior and loading the battery packs in a totally discharged condition. Neither should it be assumed that the batteries are totally discharged; they should be continuously shorted until installation is complete and all personnel are cleared from the launching area. Then the short is removed and the charging cable connected. After the man making this connection is safely clear, the charging is begun. A charging rate of 1 amp for 30 min is recommended. A 2-min discharge may be desirable to ensure that the charge has been successful. In the event a "hold" is necessary and the rocket must be disassembled, the entire procedure in reverse order is employed.

3.7. ORIENTATION

In assembling the various components of the Exos, some foresight must be exercised to insure the proper orientation of all parts with respect to each other and the ground. Following is a complete list of components requiring special orientation (reference to Fig. 6 may be helpful).

First Stage:

Riding lugs in the vertical plane

Second Stage:

Fins in line with first-stage fins
Battery charging socket as near 6 o'clock as possible
Pressure tap on head cap in line with pressure switch on blowout diaphragm

Third Stage:

Instrumentation electrical connector sockets (if any) as near 6 o'clock as possible

It is recommended that all mating parts be assembled well in advance of final assembly to verify correctness of fit. At this same time the orientation should be determined and appropriate markings made on the parts.

The first stage rides on top of the launching rail. It comes equipped with two sets of riding lugs, for symmetry, and either set may be used. The fins are automatically positioned at 45°. Thus there is no problem associated with first-stage orientation and no marking is required.

The second-stage orientation is determined by the following procedure. Screw the diaphragm into the flared skirt as far as it will go. Then screw the coupling casting onto the diaphragm until it stops.

Then position the assembly just ahead of the Nike with the charging socket at 6 o'clock. Rotate the Nike in 120° intervals until the orientation is found which puts the pressure tap on the head cap as nearly in line with the pressure switch on the diaphragm as possible. When this is done, the Nike fins will either be in their proper flight position (45°) or will require a 30° rotation to get them there (causing the battery-charging socket to be at 5 o'clock or at 7 o'clock). After positioning the Nike fins at 45°, mark "TOP" on the Nike, coupling casting, diaphragm, and flared skirt.

Since the third-stage motor can be bolted onto the flared skirt at 15° intervals, and the nose can be bolted onto the motor at 15° intervals, there is no problem in getting the instrumentation connector socket close to 6 o'clock.

4. ASSEMBLY

4.1. FIRST-STAGE ASSEMBLY

The major operations required to make an Exos first stage from a standard Honest John booster (M6) are:

1. Eliminate fin cant.
2. Check fin alignment.
3. Install first- to second-stage coupling.

A list of the parts and special equipment on hand for these three operations follows.

Part-Name	Drawing or Catalog Number	Number Required
Honest John booster	M6A10	1
Honest John fin	Fin, 762 mm Rocket, M136A2	4
Fin base fitting	1340-333-0506-S008	4
Bushing, Fin base fitting	H2-40298	8
Bolt	AN8-34A	8
Clip-H.J. fin	H3-40386	4
Bolt	5306-333-0480-S008	8
Bolt	5306-333-0479-S008	4
Washer	5310-333-0544-S008	8
Fairing	1340-344-1229-S008	1
Coupling, H.J. to Nike	H5-40267	1
Bolt	NAS-148-83	4
Bushing, H.J. coupling	H2-40394	4
Nut, H.J. coupling	H2-40385	4
Clinometer	Watts 90° Clinometer	1
Motor alignment fitting	H3-40297	1
Fin measuring device	H5-40268	1
Allen wrench long handle 1 in. across hex flats		1
Torque wrench 600 ft-lb capacity w/socket for 1 in. Hex Snap-On Tool Co.		1
Allen wrench, long handle 5/8 in. across hex flats		1
Allen wrench Long handle 1/2 in. across hex flats		1

1. Elimination of Fin Cant.—The first step in elimination of the fin cant is to revise the standard Honest John fin-base fitting by reboring the two-1-in.-diameter bolt holes to a new diameter of 1-1/8 in. on the longitudinal axis of the part per drawing H3-40298. Two bushings are pressed in the newly bored holes in the fin-base fitting.

The reboring of the fin-base fitting is not a field operation and makes it necessary to obtain the 4 fin root fittings, which normally come mounted on the Honest John, well before the firing date.

Each H.J. fin has an alignment pin extending radially toward the center of the motor from the root edge of the fin. In the standard H.J. with the fin canted, this pin falls between two of the 1/2-in. socket-head cap screws which hold the nozzle on the motor body. When the cant is taken out of the fin, as in the Exos application, a new socket for this alignment pin must be provided. This is accomplished by removing the two appropriate socket-head cap screws and bolting on the alignment clip with two longer bolts, AN8-34A. The first field operation after getting the motor out of its box is to strip off the warhead pedestal which incidentally contains four live spin rockets. Secondly, take off the fin fairing and remove the fin-base fittings if they have not already been removed for reboring. The motor should be held now on a dolly whose fore and aft ends can be separately raised and lowered. It is very convenient if the dolly is located under a hoist to facilitate rolling.

2. Fin Alignment.—The motor alignment fitting is bolted on the thrust face of the H.J. in such a manner that the table on the front face of the fitting is as nearly horizontal in both planes as possible. (The fitting attached to the Nike is shown in Fig. 15.) The motor is rolled and the dolly ends raised or lowered until this table is exactly horizontal in both planes as measured by the clinometer. Two fins should now be bolted on and should lie in a horizontal plane. The bolts should be good and tight but torquing up is unnecessary.

The next step is to draw three lines on the horizontal fins parallel to the motor axis and spaced span-wise 4 in. from fin root, center span, and 3 in. from fin tip, respectively.

The fin-measuring device is clamped over the leading and trailing edge of the fin at one of the lines just drawn, and when both sets of jaws on the fin-measuring device are seated and the thumb screws tightened, a clinometer reading is taken at the mid-chord point of the bars which connect the two sets of jaws. The setup is shown in Fig. 16. The clinometer is read in minutes of arc and the reading recorded right on the fin at the line being measured. "Plus" readings are deviations which would cause clockwise roll of the rocket in flight. The measurements along the three lines are averaged and a single plus or minus figure is assigned to each fin.

The criteria for acceptance of a single fin alignment are:

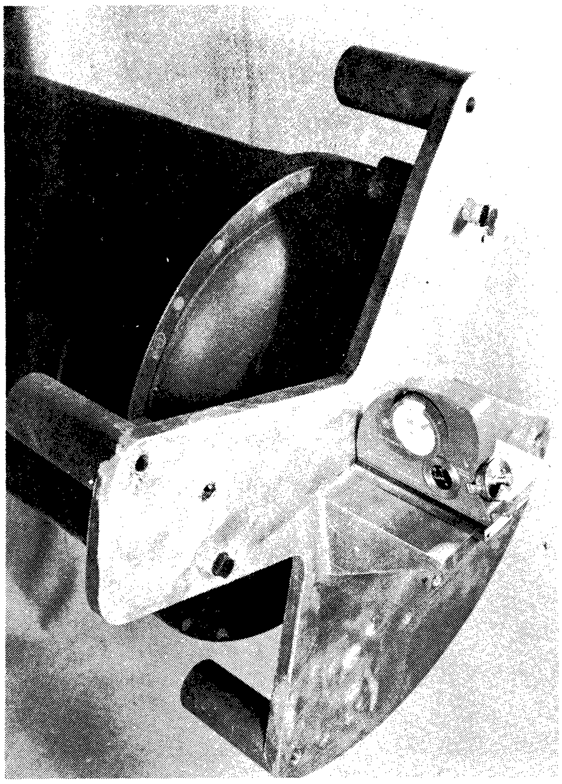


Fig. 15. Motor alignment fitting on second stage.

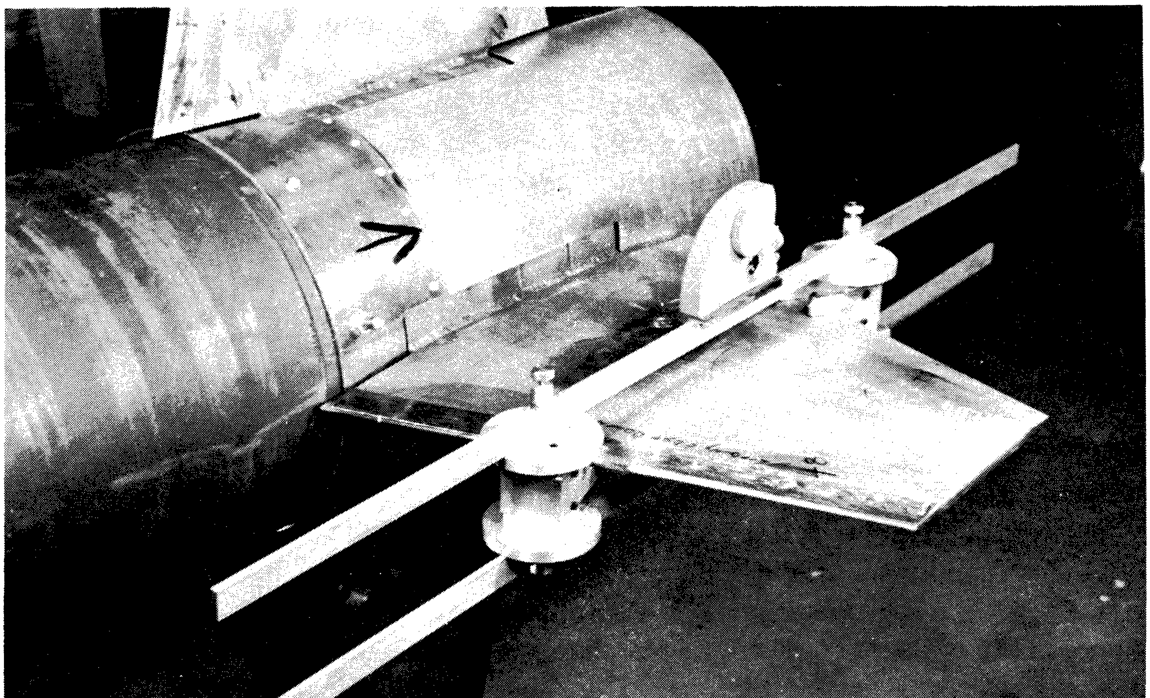


Fig. 16. Fin-measuring device on second-stage fin.

a. The difference between any two readings on a given fin shall not be more than 20 minutes.

b. The average of the three readings on a given fin shall not be greater than 10 minutes.

While it is the feeling of the writers that, if all four fins meet the above two specifications, the set of fins is good enough, it is obvious that less roll will result if the algebraic sum of the four averages is within a few minutes of zero.

It is possible to change the clinometer readings on a given fin by the simple expedient of making one of the holes in the fin-base fitting sloppy by removing the bushing. The fin and fin-base fitting are then canted slightly to take out a few minutes of misalignment.

At the same time the fin alignment clip may be adjusted slightly on its own bolt holes or filed to give a little more adjustment. If and when the fin has been adjusted to an acceptable reading, the 1-in. bolt through the hole that still has the bushing is torqued up and the unbushed bolt is backed almost out. The space in the fin-base fitting around the bolt is filled as nearly as possible with Armstrong A-1 adhesive and the second bolt torqued up. The hardened A-1 is then in effect a nonconcentric bushing.

After the two horizontal fins are installed acceptably, they are marked as to where they go and are removed for a 90° rolling of the motor. The alignment fixture is reset, the leveling checked, and the second pair of fins are fitted. The fairing has four 5/8-in.-diameter holes to pass the fin-alignment pins. These are located to accommodate the standard H.J. canted fin and must be elongated to approximately 1 in. by 5/8 in. to pass the fin pin in the uncanted position. The AN8-34A hex-head bolts holding the alignment clip must be tightened so that the points of the hex head allow the fairing to slip on. A switch with a red metal tube is mounted on the fairing. This is removed completely and discarded.

3. Installation of coupling.—The installation of the coupling, H.J. to Nike, is straightforward. The bushings H2-40394 are inserted in the four bolt holes in the base of the coupling and the NAS-148-83 bolts inserted in the bushings. The H.J. coupling nuts H2-40385 are held behind the untapped holes in the H.J. thrust face and the coupling lifted into position so that the long NAS bolts can be turned into the nuts through the thrust face. Occasionally the untapped holes in the thrust face are not centered on the cavity formed by two welded-on stiffeners, or the weld bead interferes with the complete seating of the nut on the aft side of the thrust plate. In these instances, some filing, grinding, or machining of the nut is required. After fitting of the nuts, they should be marked as to which cavity they go in, to facilitate assembly of the Exos on the launcher. The coupling is then removed from the first stage.

4.2. SECOND-STAGE ASSEMBLY

To modify the standard Nike Ajax booster (M5) for use as the second stage of Exos, the following operations are required.

1. Remove unnecessary hardware.
2. Attach and align fins.
3. Install spacer ring in nozzle.
4. Install pressure seal in nozzle.
5. Pressure test.

A list of the parts and special equipment which should be on hand for these operations follows.

Part Name	Drawing or Catalog Number	Number Required
Nike Ajax booster	M5	1
Nike fin, 2.5 sq ft w/cuff	H7-40137	4 (1 set)
Shroud, fwd.	H3-40293	1
Shroud, aft	H3-40292	1
Hinge pin	H1-41985	4
Nut	5/16 in.	7
Cap screw, socket head	3/8 in.-24 x 5/8 in.	4
Cap screw, hex head	1/4 in.-28 x 5/8 in. w/grip threaded	4
Bolt	5/8 in.-18 x 5/8 in. w/special head	3
Ring, sealing	H3-40300	1
Plate, closure	H2-40388	1
Screw, self-tapping	F.H. 10-32 x 1/2 in.	48
Ring, spacer	H3-40291	1
Coupling, Honest John to Nike	H5-40267	1
Motor alignment fitting	H3-40297	1
Clinometer	Watts 90° Clinometer	1
Fin-measuring device		1
Pressure-regulator assembly, terminating with 1/4-in. flared tube nut		1
Nike igniter dome	A.O. No. 8025059	1
Armstrong A-1 adhesive		1 qt.
Paint remover	Fed. Spec. TT-R-2510	1 qt.
Pressure seal jig	H5-40269	1
4-ft furniture clamp		3
Methyl-ethyl-ketone		1 qt.
Nike igniter spanner wrench	A.O. No. 8014473	1

1. Removal of Hardware.—After uncrating the motor and placing it on a suitable dolly or horse, the removable hardware is discarded. On the tail this includes the fin shroud, fin attachment brackets (including studs), AN connector and ignition wire, and bakelite nozzle seal. On the head end, the thrust structure and Cannon connector are removed. All parts may be discarded except the Cannon connector and the 5/8-in.-18 x 3/4-in. bolts with special heads which are found on the forward end of the shroud. Should the bolts be lost, socket-head cap screws may be substituted. The Cannon connector will be mounted on the blowout diaphragm for eventual hookup of the igniter.

The booster should be visually inspected by removing the head-end plastic plug and checking for cracks or obvious defects in the grain. The resonance-rods jam nuts should be run up finger-tight on the spider. They are sometimes found loose after shipping and handling.

2. Fin Attachment and Alignment.—First slip the forward shroud onto the nozzle and slide forward on the motor out of the way. The fin quadrants are assembled together with three hinge pins and six nuts, taking care that the quadrants corners stamped 'A,' 'B,' 'C,' and 'D' are juxtaposed. Then the fins are placed on and wrapped around the nozzle, holding them forward so that the quadrant lands do not slide off the nozzle lands. The fourth pin is inserted from the rear. This pin should require some driving with a mallet but should not chew out large amounts of magnesium from the quadrant. It is not necessary to screw this pin into the anchor nut until the alignment is satisfactorily completed. When the pin is in, the weight of a man on a fin tip should slightly rotate the fins on the nozzle. If the fins are loose, shimming the nozzle lands is required. In the majority of cases the fins will be tight and the quadrant lands will need to be scraped with a bearing scraper and the paint removed from the nozzle lands. Undersize hinge pins are another remedy if available. Eccentric pliers to hold the quadrants together while driving in the pin are a great help.

After the fin fit is deemed satisfactory the fin alignment is checked. The motor alignment fitting is bolted to the thrust face with the table horizontal. Then with the clinometer on the table measuring in the vertical plane along the longitudinal axis, the motor is leveled.

With one pair of fins horizontal, the fin-measuring device is clamped onto the fin parallel with the longitudinal axis and about 4 in. in from the tip. The clinometer is laid on the device and a reading taken. Angles of misalignment which tend to rotate the rocket clockwise when viewed from the tail are considered positive. The clinometer reading is then marked on the fin, and the procedure repeated at mid-span and near the root. Three readings are taken on the opposite fin in the same manner; after which the motor is rotated 90°, the motor alignment fitting relocated, the motor re-leveled, and measurements taken on the remaining two fins. Reference to Figs. 15 and 16 may be helpful.

No single fin should have average misalignment exceeding 15' and the algebraic sum of the four average misalignments should not exceed 25'. Normally this sum will be less than 15'.

Providing the fins meet the alignment specifications, they are ready for rigid attachment to the motor. The forward shroud is slipped back and the three 5/8-in. bolts, four 3/8-in. socket-head cap screws, and four 1/4-in. cap screws are started in their respective holes and the fins rotated on the motor to fit into the shroud notches. The fins should be jockeyed forward as far as possible, and at least far enough so that the after quadrant lands are resting fully on the after nozzle land. The 11 bolts securing the forward shroud may then be tightened. Next the twenty-four 10-32 screw holes are drilled and countersunk, and the self-tapping screws inserted through the shroud into the quadrants.

The assembly is completed by slipping on the after shroud, drilling, countersinking, and driving the self-tapping screws.

3. Installation of Spacer Ring in Nozzle.—The spacer ring is cemented to the nozzle with Armstrong A-1 adhesive. First, the paint inside the nozzle exit must be removed in a band about 4 in. wide. This is accomplished by use of a good quality paint remover, wire brush, and clean rags. Care should be exercised in getting the paint out of the rather rough grooves in the machined surface. This may require considerable patience and elbow grease.

Next, the ring should be fitted. It is essential that the ring be entirely within the nozzle so that the thrust is applied to the nozzle, not the ring (see Fig. 10). On the other hand, the ring must not fit so far into the nozzle that its bearing surface is materially reduced. In addition, the adhesive thickness must be greater than .008 and less than .035 in. The recommended procedure is to attach four shims built of electrical tape, each about .020 in. thick and 1/4 in. square to the nozzle, 1 in. from the exit.

Then the spacer ring is inserted and pressed in firmly against the shims. The aft end of the ring should be flush to 1/32 in. inside of the nozzle exit. If it protrudes, then the shims are reduced in thickness and another measurement taken; if the ring goes in too far, the shims are increased in thickness. The shim thickness must remain between .008 and .035 in. to insure the proper adhesive thickness; therefore if the ring cannot be made to fit properly by varying the shims in this range, the ring must be discarded or machined.

The final step is to mix about 6 oz of the A-1 adhesive according to directions. Coat the inner surface of the ring and the mating surfaces of the coupling with a thin layer of petroleum jelly to facilitate removal of any excess or spilled adhesive, being careful to get none on the external surface of the ring. Coat the external surface of the ring and the internal surface of the nozzle with adhesive and press the ring into place, taking care not to loosen the shims. Press the coupling into the nozzle. Attach the furniture clamps between the after end of the coupling and the heads of the 5/8 in. bolts which hold the forward shroud to the nozzle. Tighten the clamps until the ring is pressed into the same position as when dry-fitted. Use methyl-ethyl-ketone to remove A-1 from skin. Allow several hours at room temperature before removing the clamps and coupling. Allow

24 hr before stressing the ring.

4. Installation of Pressure Seal in Nozzle.—The pressure seal consists of a rubber ring and a phenolic diaphragm. The diaphragm, ring, and pressure seal jig should be fitted dry to insure correct mating. Then they are removed and the convergent portion of the nozzle is carefully cleaned with methyl-ethyl-ketone. The external surface of the ring should be wire-brushed until the fibers are well broken. Coat the threads on the diaphragm stud with petroleum jelly. Mix a few ounces of A-1 and coat the cleaned convergent portion of the nozzle, the external surface of the ring, and the mating surfaces of ring and diaphragm. Insert the diaphragm into the nozzle, then the ring, mate the two and slip into position by holding the stud. Use care not to smear A-1 adhesive onto the threads. Thread the center rod of the jig to the stud, then place the jig in the nozzle and tighten the handle. Do not use more than moderate finger pressure, since the purpose of the jig is only to align the seal in the nozzle, and not to extrude the adhesive out of the bonded surfaces. The adhesive must be .008 in. thick to attain full strength. It is important to remove all excess adhesive before it sets—otherwise the coupling when inserted will have insufficient clearance. A few drops of adhesive in the nozzle throat may be enough to cause binding. If adhesive must be removed after setting, the use of a power drill with rotary file will speed the operation. Allow to dry 24 hr before pressure-testing.

5. Pressure Test.—The motor is pressure-tested to insure that the seal is working properly. The plastic plug is removed from the head cap and the igniter dome inserted. The threads should be greased before insertion to insure a good seal. Tighten with the igniter spanner wrench. The regulator assembly is attached to an inert gas supply and to the flared tube nipple on the head cap. The motor is pressurized to 15 psig and allowed to stand for about 5 min. The pressure drop should be less than 1 psig. Then the gas is bled out and the regulator assembly removed. The diaphragm is designed to break between 45 and 60 psig. Do not stand in front of or behind the motor during pressure-testing.

4.3. THIRD-STAGE ASSEMBLY

The four major operations for assembly of the third stage are as follows:

1. Install the nozzle.
2. Install the igniter.
3. Install the nozzle plug.
4. Install the blowout diaphragm, coupling, and ring.

The following parts and special equipment should be on hand.

Part Name	Drawing or Catalog Number	Number Required
Recruit rocket	XM19E1	1
Igniter	Type XI-10	1
Coupling, Nike to Recruit	H7-40149	1
Recruit igniter extension cable	See 4.4.1	1
Diaphragm, blowout, with ignition circuit complete		1
Extended nozzle	H5-40262	1
Flare skirt	H5-40254	1
Ring-coupling	H3-40302	1
Nozzle closure	Thiokol CR-10,215C	1
6-32 x 1/2-in. round head machine screw		2
6-32 lock nut		2
5/16 in.-24 x 3/4 in. socket-head cap screw		24
1/4 in.-28 x 3/4 in. socket-head cap screw		24
Wrench—nozzle tightening	H5-40270	1
Strap wrench for 9-in. diameter		2
Speed wrench with socket and 7/32 in. hex-drive		1
Scotchcast resin No. 4 size A		2
Paper cups		6
1/2 in. paint brush		2
Igniter checker	H1-42178	1

1. Installation of Nozzle.—It is assumed that prior to this operation the orientation of the various stages and couplings has been determined and marked as outlined in the section on orientation.

(a) Clean the threads on the nozzle and on the Recruit.

(b) Screw the nozzle in tight against the shoulder using the nozzle wrench H5-40270.

(c) Put a mark on the inside of the nozzle near the aft edge which is in line with a mark on the OD of the Recruit body near the aft end. These marks must be located where they can be seen when the nozzle is finally screwed inside of the flared skirt.

(d) Remove the nozzle, keeping track of the number of turns it takes.

(e) Install the flared skirt using twenty-four 5/16-in. socket-head cap screws. None should be really tightened until all 24 are well started. A speed wrench with proper socket and hex drive is desirable for inserting these bolts.

(f) Try the nozzle in again dry (with no Scotchcast) to determine that there is no interference with the skirt. Screw the nozzle in all the way. Check with the number of turns and with the previously applied reference marks.

(g) Remove nozzle and mix the Scotchcast following instructions on the package. Pour the mixed Scotchcast into a paper cup and immediately apply the resin with a paint brush to the end of the grain, the internal nozzle threads, and the male threads and "O"-rings on the nozzle itself. Insert the nozzle and, keeping track of the number of turns, seat it firmly against the shoulder. This operation must be done quickly as the resin sets quickly.

2. Installation of igniter.

(a) Test the igniter with the igniter checker. A suitable checker circuit is shown in Fig. 17. Resistance should be approximately 1 Ω.

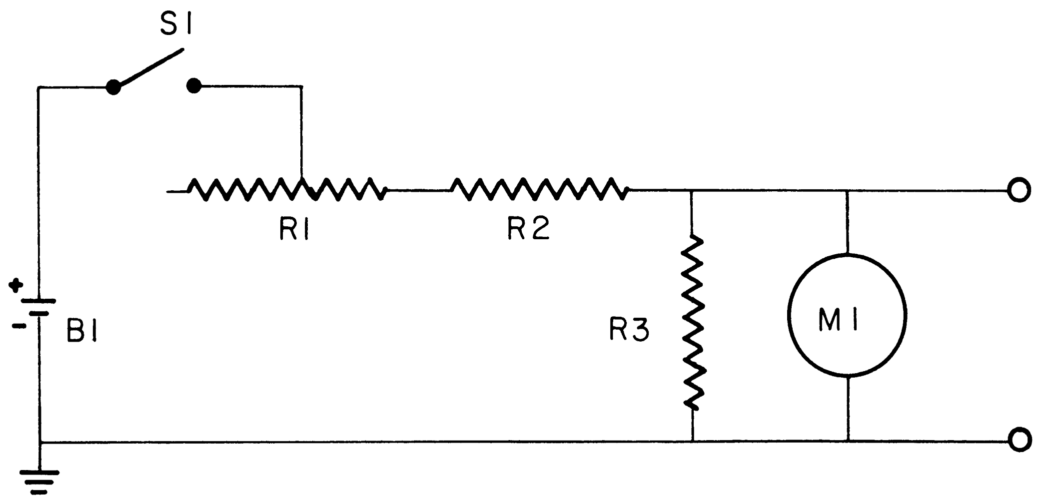
(b) Inspect the end of the igniter leads to be sure they are shorted together with the shorting plug.

(c) Inspect and clean with methyl-ethyl-ketone the igniter seat on the rocket and the mating face of the igniter itself.

(d) Smear the "O"-rings and groove liberally with the Dow silicone grease provided with each igniter.

(e) Tie the string which runs through the grain to the end of the igniter leads and feed the igniter lead through the grain until the igniter is fully inserted. Bring all screws up finger-tight before wrench-tightening any. Tighten up opposite screws in turn a few degrees at a time to a maximum torque of 20 in.-lb. In the Exos vehicle the pressure tap in the igniter cap is not used. If the instrumentation is designed to start close to the igniter cap, the capped pressure tap as it comes from the manufacturer may interfere with the instrumentation. The interference can be eliminated by using a 1/4 in.-18 Allen hex socket pipe plug.

3. Installation of Nozzle Plug.—The nozzle closure is a truncated cone of high-density foam plastic with interconnected AN connectors molded in the forward and aft faces. The first step is to insert a shorting plug on the aft connector. Secondly, remove the shorting plug from the igniter leads and insert the igniter lead connector into the forward side closure plug. Scotchcast resin is used to cement the nozzle closure in place. The resin is mixed according to the directions on the package and then painted on both the nozzle and the closure. The closure is inserted and held in position for approximately 5 min. A 24-hr cure is recommended.



B1 - 1.5v. Burgess 8R dry cell
M1 - Weston 301 milliameter - 1 MA. 27 Ω
R1 - 50 Ω ww
R2 - 120 Ω 1/2w. ±10% ww
R3 - 3.0 Ω 1/2w ±10% ww
S1 - SPST toggle switch

Note: Adjust R1 for full scale deflection before use. Max. current 12.5 MA.

Fig. 17. Schematic diagram of igniter checker.

4. Installation of Blowout Diaphragm, Coupling, and Coupling Ring.—Install the H3-40302 coupling ring on the head end, using the 1/4 in.-28 x 3/4-in. cap screws. Just prior to Exos assembly on launcher, install the blowout diaphragm with ignition circuitry by screwing it into the flared skirt, after connecting the Recruit igniter extension cable to the connector on the aft side of the nozzle plug and feeding the leads through the 1/2-in. hole in the diaphragm. Attach the Recruit leads to the terminal strip. Screw the coupling, H7-40149, on the diaphragm and mount the battery-charging socket with 6-32 screws.

4.4. IGNITION CIRCUIT PREPARATION

Preparation of the ignition circuitry involves:

1. Mounting and wiring the second- and third-stage ignition components on the blowout diaphragm.

2. Construction of a battery charger.

3. Modifying the XM24A1 igniter.

The first two operations should be done well in advance of the firing date.

Wiring the blowout diaphragm:

The parts required are:

Part Name	Drawing or Catalog Number	Number Required
Blowout diaphragm	H5-40255	1
Hose assembly	Aeroquip 601002-4-022	1
Hose support clamp	3/4 in.	1
Spaghetti	3/4 in.	2 ft
Pressure switch	H2-40376	1
Repeat cycle timer	Haydon 3600 series with 5800 series motor, adjustable cam, one switch, 12-v, 1-1/3 rpm	1
Acceleration switch	Maxson 132-9	1
Battery, Yardney Silvercel	HR-1 stud and nut terminal	14
Intercell connector for HR-1 (long)	YEC 2385	10
Intercell connector for HR-1 (short)	YEC 2387	2
Cinch-Jones barrier terminal strip	6-140	2
Cinch-Jones socket	S-304-FP	1
Battery box with cover (large)	H1-42156	1
Battery box with cover (small)	H1-42156	1
Insulator (large)	H1-42175	1
Insulator (small)	H1-42175	1
Mounting block, G-switch	H1-42163	1
Mounting block, plug	H1-42164	1
Fiberglas-insulated stranded wire	No. 18 AWG	100 ft
Socket-head cap screw	1/4 in.-28 x 1/2 in.	4
Socket-head cap screw	8-32 x 5/8 in.	2
Round-head machine screw	6-32 x 5/8 in.	1
Round-head machine screw	6-32 x 7/8 in.	8
Round-head machine screw	8-32 x 1/4 in.	16
Round-head machine screw	1/4 in.-28 x 3/4 in.	8
Lock nut	8-32	16
Lock nut	6-32	5
Lock nut	1/4-28	8
Connector	AN-3106-10SL-3P	1
Cable clamp	AN-3057-3	1
Cable-two conductor-stranded	No. 16 AWG	2 ft
Solder lug, ring type	No. 5	2

The blowout diaphragm should be screwed into the flared skirt as far as it will go; then the coupling casting screwed onto the diaphragm. Locate the position where the acceleration switch is desired adjacent to a blowout port in the coupling. Then using H5-40271 as a guide, construct battery packs as per H1-42174 and drill the required holes. Mount the various components and wire them in accordance with H2-40398. The timer should be set for approximately 29.6 sec. Use socket-head cap screws in tapped holes. Cable all wiring and tie down at appropriate positions with cable clamps (not included in parts list). Note that the components are on the aft side of the diaphragm and tend to be pulled off by the high accelerations. Thus the battery packs are placed in the boxes, terminal side down, pressed into the insulators. For initial checkout of wiring, the packs may be set inverted in the boxes relative to the flight position. This enables a convenient checkout without danger of battery leakage. Once the packs are installed for flight, a worthwhile precaution is to turn the diaphragm over and let it be suspended with the batteries upright until assembly of the diaphragm to the third-stage motor.

Figure 14 shows a completed diaphragm except for battery box covers. Construct a Recruit igniter extension cable with the AN-3106-10SL-3P connector, two-conductor cable, and solder lugs, which connects the Recruit nozzle closure with the terminal strip on the diaphragm. It will be attached during third-stage assembly. The male Cannon connector is obtained from the Nike head cap and attached to the terminal strip. Note the position of the AN 822-4 elbow and Aeroquip hose. The hose will be bent 180° and the 90° fitting brought into position of attachment to the nipple of the Nike head cap. In some cases the position of the hose support clamp may need to be altered.

Constructing a battery charger:

The parts required for the battery charger are:

Part Name	Drawing or Catalog Number	Number Required
12-v storage battery	Automobile type	2
Aluminum chassis 12 x 8 x 3 in.		1
Cinch-Jones barrier terminal strip	3-142	1
d-c Ammeter 0-15A		2
d-c Voltmeter 0-30V		2
Gang switch, 4-wafer, 3-position		1
Cinch-Jones plug	P-304-FHT	2
Cinch-Jones plug	P-304-FP	1
Cinch-Jones plug	P-304-CCT	1
Cinch-Jones socket	S-304-CCT	1
Cord, rubber jacketed, 4 conductor-stranded, No. 18 AWG	Belden 8454	300 ft
Potentiometer, 16 Ω, 50 w.		1
Potentiometer, 12 Ω, 50 w.		1

Wire the chassis as per H2-40398. Figure 18 shows a completed charger.

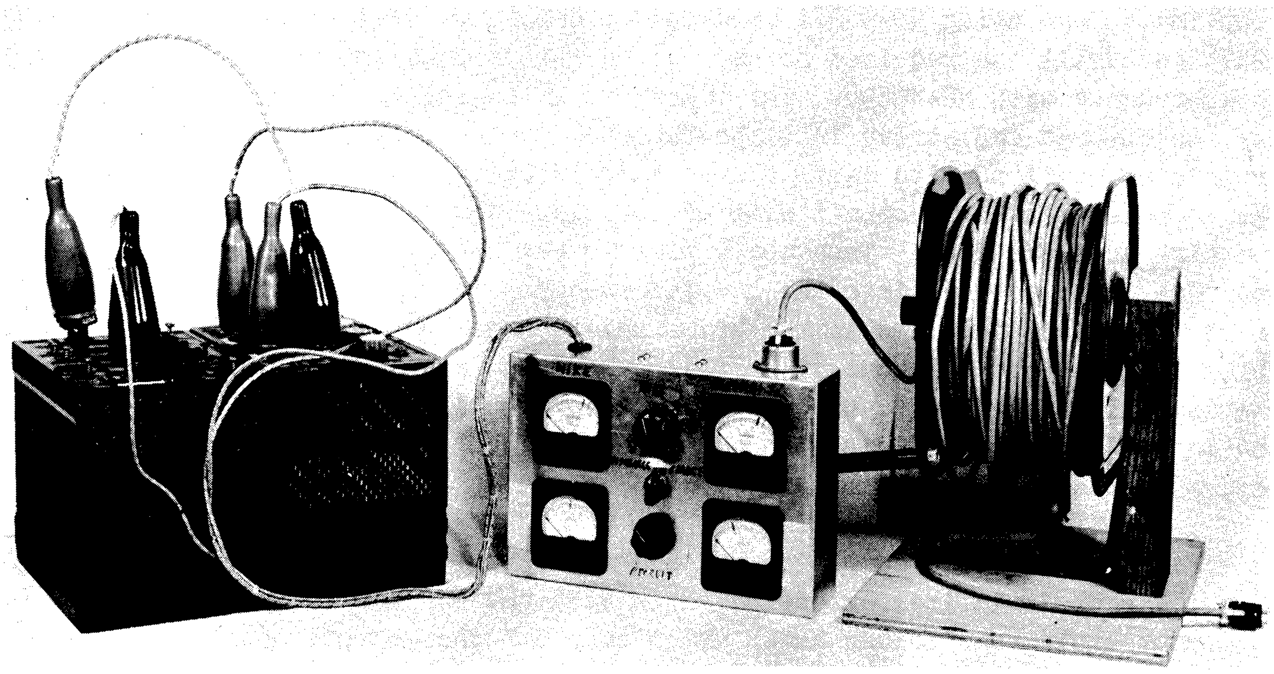


Fig. 18. Ignition battery charging equipment.

Modifying the XM24A1 igniter:

The parts and special equipment required for igniter modification are:

Part Name	Number Required
XM24A1 igniter	1
Hercules match squib	2
Resistor, 1 Ω, 1/2-w, wirewound, ± 10%	2
Plastic cap, H2-40399	1
Spaghetti tubing No. 20	1 ft
Spaghetti tubing No. 24	1 ft
Solder lug, ring tongue, No. 6	2
Screw, self-tapping, 6-32 x 1/4	6
Scotch No. 33 electrical tape, 1/2 in.	1 ft
A-1 adhesive	3 oz
Medium-size electric soldering iron	1
Diagonal cutters	1
Spintight wrench, 5/16 in.	1
Safety glasses or eye shield	1
Scalpel, sharp pen knife, or single-edge razor blade	1
Glass or ceramic bowl, 2-qt capactiy	1
Igniter checker, H1-42178	1

Caution: This operation involves handling a large quantity of black powder in proximity with detonators and should be considered hazardous. Observe the usual safety precautions of: no visitors, matches, lighters, or tobacco; one man to observe from a safe distance. Disconnect soldering iron from electrical source prior to soldering squib leads. Protect eyes with glasses or shield while working on squib harness. Work on a bench with no electrical connections, preferably with a grounded, metal top. Wear conducting footwear and take pains to keep hands grounded. Take special precautions to avoid static electrical buildup.

Unbox the igniter. Arrange the can and cardboard liner to support the inverted igniter. With the knife or blade cut the top out of the phenolic cap as close to the side as possible. (Do not cut the top off by cutting the side as this will slightly reduce the volume.) Discard the top. Carefully pour the black powder mixture into the bowl. Cover the bowl to prevent foreign objects from entering. Remove the bowl several feet from the bench. Now remove the entire squib harness with the spintight wrench and discard. Cut the squib and resistor leads to about 3 in., and, using spaghetti insulation and electrical tape, solder the squib harness as shown in H2-40398, using the solder lugs at terminal points. Continuity- and resistance-check the squib harness. Install the harness on the studs and wrap electrical tape around the soldered end of the lugs. Continuity- and resistance-check the igniter from the Cannon connector. Place the plastic cap on the top and press down firmly. Make index mark. Drill six equally spaced No. 36 holes through the cap edge and phenolic side. Remove the cap. Refill the igniter with the black powder mixture, being careful to fill the space under and around the harness solidly with powder. Tap and shake gently to settle the powder until all powder is used. If after several attempts the powder cannot be entirely returned to the igniter, the small remainder may be discarded. Place the new plastic cap on the top and press down firmly. Insert the six 6-32-x-1/4-in. self-tapping screws. Mix a small quantity of A-1 adhesive and run a bead around the edge of the new plastic cap and screws to hold it in place and seal it to the atmosphere. Allow 24 hr at room temperature to dry. Check the igniter for continuity and resistance.

4.5. EXOS ASSEMBLY

The following parts and equipment are required for assembly of the Exos on the launcher:

Part Name	Number Required
First-stage assembly complete	1
Second-stage assembly complete	1
Third-stage assembly complete with coupling and ignition circuitry attached	1
Honest-John igniter	1
Nike igniter, modified	1
Honest John to Nike coupling	1
Coupling bushings, H2-40394	4
NAS 148-83	4
Nuts, Honest John coupling H2-40385	4
7/16 in.-20 x 1-1/4-in. socket head cap screws	6
NAS 143-7C washer	6
Modified bomb lift trailers (AF stock No. 8220-753300)	2
High lift fork truck, 4000-lb capacity	1
Mobile crane, 2000-lb capacity	1
Strongback, 4000-lb	1
Booster hoist beam (A.O. No. Y015-8003042) and 2 sling assemblies (8013975)	1
Torque wrench, 200-ft-lb capacity	1
1/2-in. hex drive for torque wrench	1
5/16-in. long handle Allen wrench with pipe extension	1
3/4-in.-diameter steel rod, 4 ft long	1
Nike igniter spanner wrench, A.O. No. 8014473	1
Igniter checker H1-42178	1

After the launcher has been installed and checked out—that is, operated a few times—the launching rail is let down and blocked to a horizontal position. The block, approximately 1 ft high, is placed under the bar on which the forward leg of the launcher pivots.

The first stage is brought to the launching area on the modified bomb dolly and the caps of the rear riding lugs are removed as well as the whole forward riding lug. The forward riding lug is inserted at the forward end of the launching rail and slid aft approximately 12 ft. A fork lift truck able to lift at least 4000 lb to a fork height of at least 12 ft is required. A suitable strongback is centered on the forks, well out near the ends of the forks. The first stage is lifted and maneuvered over the launching rail with the aft riding lugs within an inch of the stops. As the motor is lowered, the front riding lug is adjusted fore and aft until it comes under the mating pad on the motor and a couple of the six bolts are started. The aft end of the motor is then let down and the aft riding lug caps screwed on. After all bolts are in the riding lugs, the motor should be moved aft until it is seated against the stops.

Next the Honest John igniter is checked for proper resistance - approximately 1.0 ohm for igniter only without leads - and installed in the motor. The igniter is physically mounted on the phone jack electrical connection. The leads then lead aft through the grain and nozzle, ending outside the rocket in a shorted connector. The igniter closure is then screwed in with Permatex No. 2 on the threads and seated tightly.

The Honest John to Nike coupling with its bushings and bolts inserted through the holes in the coupling is inserted in the nozzle of the Nike. This procedure is followed to minimize the chances of damage to the taper ring which is glued into the Nike nozzle. The Nike with coupling is then lifted into position. If the launcher used for Exos I and II is employed, a crane with a horizontal reach of at least 8 ft is required. The standard Nike strongback is adequate for this operation. The four NAS bolts in the coupling are mated with the proper square nut behind the Honest John thrust face and are torqued to 150 ft-lb.

The approximate circumferential orientation should be attained in lifting the Nike from its dolly and the exact aligning of the Nike fins with the Honest John fins done by rotating the Nike after the coupling has been bolted on the Honest John but before the strongback has been removed. Check to see that the Nike is seated all the way aft on the coupling before removing the strongback.

Next the Nike igniter is final checked for resistance (nominally 1.0 ohm and installed in the Nike bottle using Permatex No. 2 on the threads and the special Nike igniter spanner wrench.

The third stage is lifted into position using a strongback and the same crane. Ordinarily the nose cone will have been mounted on the third stage prior to adding the third stage to the Exos. The three parts of the Nike to Recruit coupling are assembled on the third stage prior to lifting into place. The crane brings the Recruit into close axial alignment with the first and second stage and separated from the head end of the Nike by about 6 or 8 in. (see Fig. 19). At this time the pressure switch hose is connected to the pressure tap on the Nike. The connector to the Nike igniter is coupled to the connector from the diaphragm-mounted firing circuit and the coupled connectors clamped into the plug mounting block. The third stage is then moved aft and aligned so that the six 7/16-in. socket-head cap screws with NAS washers can be inserted through the coupling casting and into the Nike thrust face. These bolts should be tightened with approximately 150 ft-lb of torque. The firing circuit battery-charging plug is now inserted and the battery-charging cable tied to the rocket. The cord which ties the cable to the rocket is so arranged that a sharp pull will untie a slip knot and only the friction of the pins in the battery charging socket supports the weight of 40 to 50 ft of cable. The ground power and control cables to the instrumentation pull-away plugs are tied to the rocket in the same way. If all pull-away plugs are closely grouped, one support cord is sufficient. A good quality 1/8-in.-diameter woven line similar to Venetian-blind operating line is recommended.

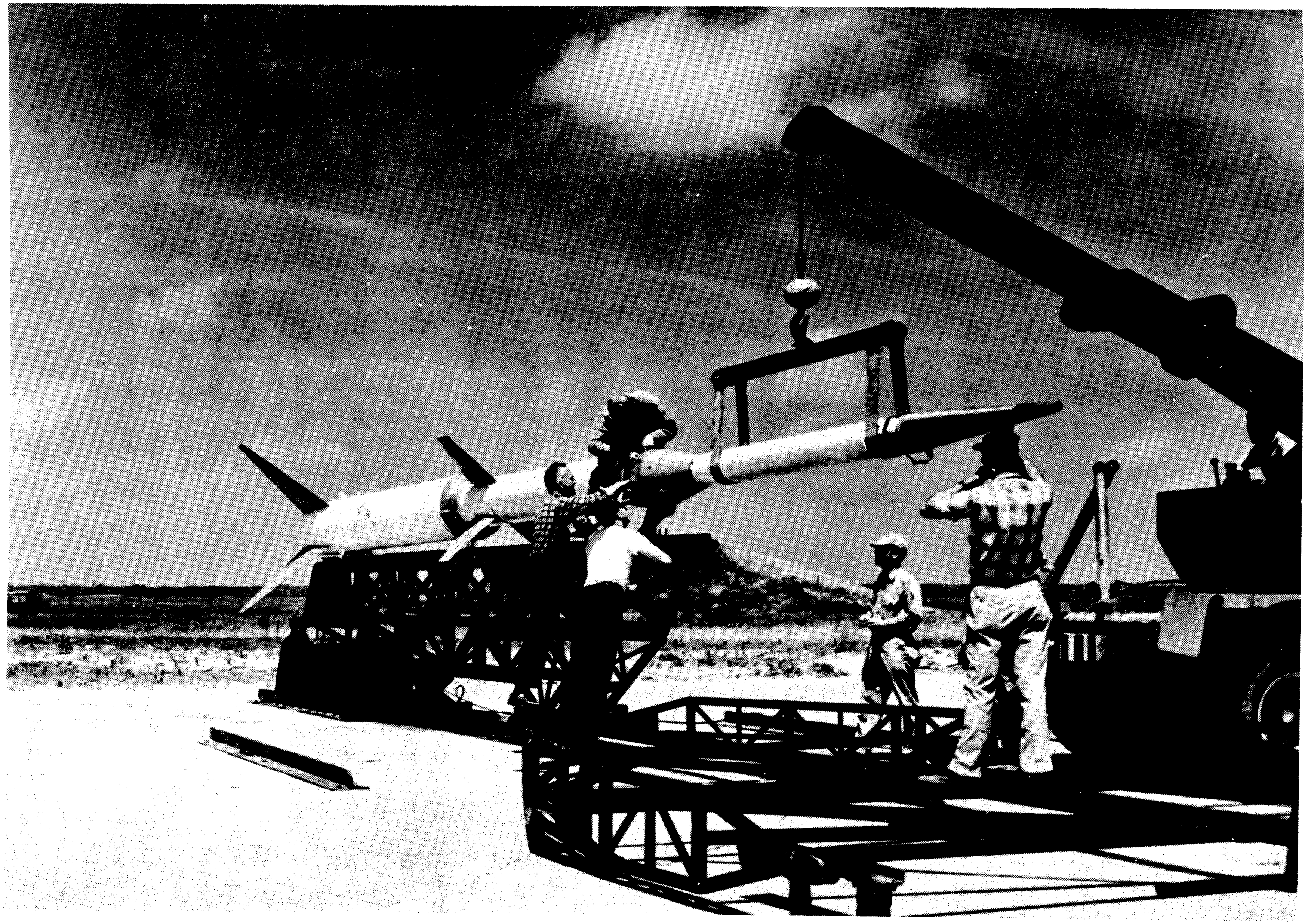


Fig. 19. Third-stage assembly installation.

5. VEHICLE PROCUREMENT AND COSTS

The following table gives the source and cost of the major items of hardware. These costs are 1957-58 prices and do not include any tooling costs. Where there was a substantial tooling cost, the fact is noted.

Item	Source	Unit Cost	Total Cost
Honest John motor w/igniter	Ordnance Corps	$7,595.00	$ 7,595.00
Honest John fin	Ordnance Corps	145.00	580.00
Honest John fin-mounting fitting	Ordnance Corps	37.00	148.00
Honest John fin-mounting bolts	Ordnance Corps	3.35	27.00
Honest John fin-mounting bolts	Ordnance Corps	2.00	8.00
Honest John fin fairing	Ordnance Corps	118.00	118.00
Nike-Ajax booster w/igniter	Ordnance Corps	2,949.00	2,949.00
Recruit rocket w/igniter	Thiokol Chem. Corp.	5,000.00	5,000.00
Honest John fin-mounting fitting alteration	Local shop	18.50	74.00
Nike fins 2-1/2 sq ft complete	Magline, Inc.	928.00	928.00
Honest John to Nike coupling	Magline, Inc.	248.00	248.00
Nike to Recruit coupling 3 parts	Magline, Inc.	483.00	483.00
Recruit nozzle extension	McGregor Mfg. Co. Tooling $350.00	178.00	178.00
Spacer ring	Magline, Inc.	38.00	38.00
Nike sealing ring	Det. Rubber Products Tooling $120.00	3.00	3.00
Nike sealing diaphragm	Local shop	8.00	8.00
Recruit nozzle closure	Thiokol Chem. Corp.	25.00	25.00
Timer	A. W. Haydon Co.	125.00	125.00
Acceleration sensitive switch	W. L. Maxson Corp.	90.00	90.00
Pressure switch	Local shop	200.00	200.00
Pressure hose	Aeroquip	5.00	5.00
Batteries	Yardney Electric Corp.	7.50	105.00
Misc. wiring circuit hardware		35.00	35.00
Misc. bolts, bushings, nuts, etc.		130.00	130.00
	Total vehicle parts cost		$19,100.00

Aeroquip Corp.
Jackson, Michigan

Detroit Rubber Co.
10401 Northlawn
Detroit, Michigan

A. W. Haydon Co.
232 North Elm Street
Waterbury 20, Connecticut

W. L. Maxson Corp.
475 Tenth Avenue
New York 18, New York

Magline, Inc.
Pinconning, Michigan

McGregor Mfg. Corp.
2975 Maple Road
Birmingham, Michigan

Thiokol Chemical Corp.
Elkton Division
Elkton, Maryland

Yardney Electric Corp.
40-46 Leonard Street
New York 13, New York

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1. Fischbach, F. F., The Dispersion of a Three-Stage Solid-Propellant Sounding Rocket (Exos), Technical Memorandum (unpublished), The University of Michigan, January, 1958.

2. Van Driest, E. R., "Turbulent Boundary Layer in Compressible Fluids," J. Aero. Sci., 18, 145 (1951).

3. Van Driest, E. R., "Turbulent Boundary Layer on a Cone in a Supersonic Flow at Zero Angle of Attack," J. Aero. Sci., 19, 55 (1952).

4. Grimminger, G., Williams, E. P., and Young, G. B. W., "Lift on Inclined Bodies of Revolution in Hypersonic Flow," J. Aero. Sci., 17, 675 (1950).

5. Hansen, W. H., and Fischbach, F. F., The Nike-Cajun Sounding Rocket, The University of Michigan Engineering Research Institute Report 2453-1-F, March, 1957.

APPENDIX

ACCELERATION AND SKIN TEMPERATURE DATA FROM EXOS II

The data contained in this appendix are from telemeter records of the Air Force Cambridge Research Center and published by their courtesy. The data are preliminary and subject to revision.

Figure A-1 shows longitudinal acceleration measured near the base of the nose by a 0-200 g Humphrey accelerometer, model LA 03-0138-1. The estimated probable error is 8% during first- and second-stage burning, and 5% during third-stage burning. A graph of predicted acceleration is included for comparison. Note that the instrument is not capable of showing the drag deceleration.

Figure A-2 shows lateral acceleration in each of two perpendicular planes. Both accelerometers were -5 to +5 g Giannini model 24117P (oil-damped). Probable errors are 20% for accelerations around 0.15 g and 7% for accelerations around 3.0 g.

Figure A-3 shows the internal skin temperature of the cone 15 in. from the nose tip. A Transonics resistance thermometer, type 1375D (32° to 1500°F) was applied to the .055 Inconel surface with Sauereisen cement. The probable error is ± 50° or slightly greater at temperatures around 300°F.

Figure A-4 shows the internal skin temperature of the cylindrical portion of the nose, 55 in. from the tip. An Arthur G. Ruge Associates type SN-1 Stikon resistance thermometer (-100° to 500°F) was applied to the .078 stainless-steel surface with Sauereisen cement. The probable error is ± 20°. There may be an additional error due to strains along the longitudinal axis of the rocket during periods of acceleration.

The effect of the cement on the time response of the thermometers has not been determined. The nominal time constant (time required to attain 63% final value) for both thermometers is 1/2 second.

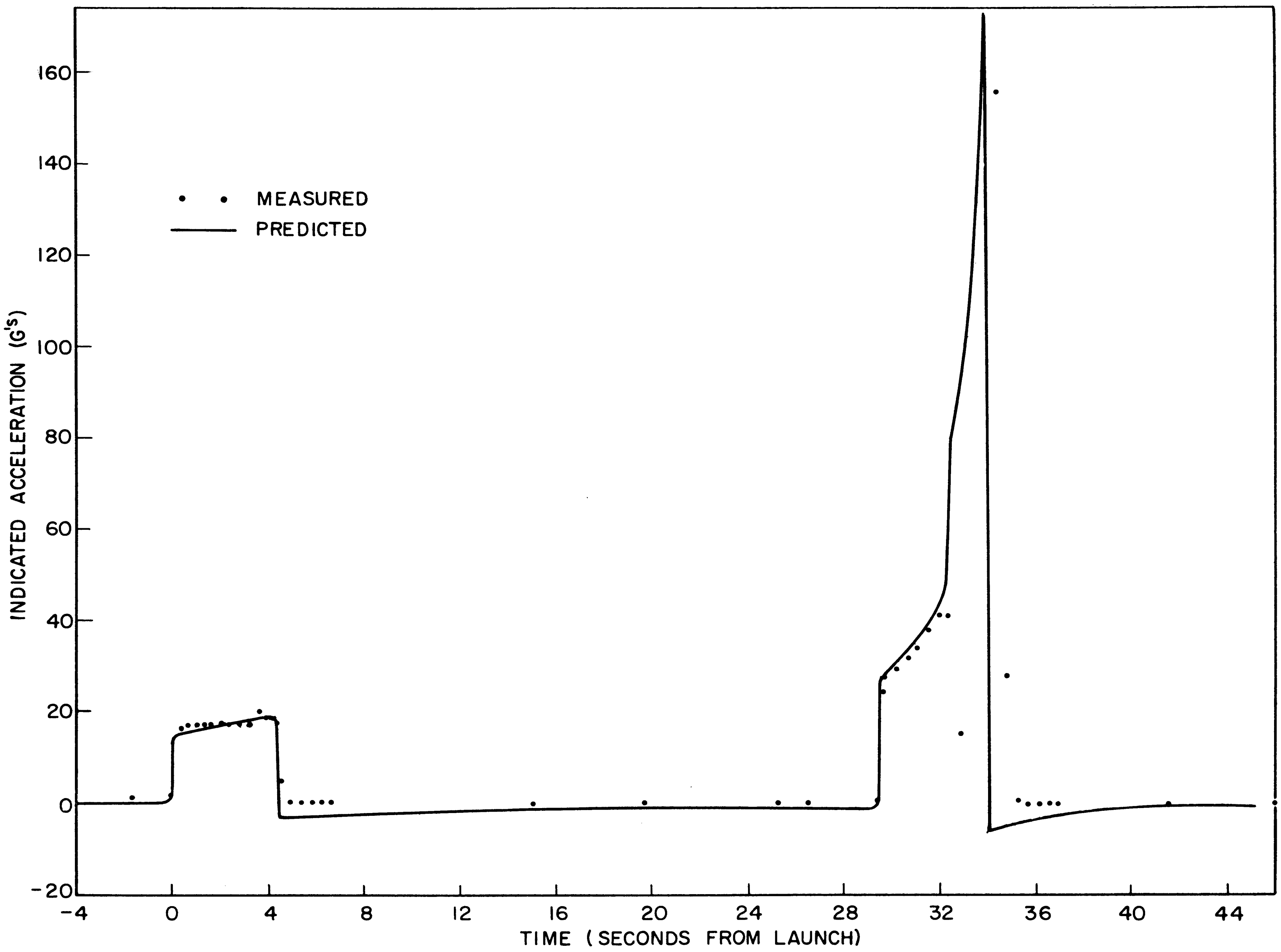

Fig. A-1. Longitudinal acceleration.

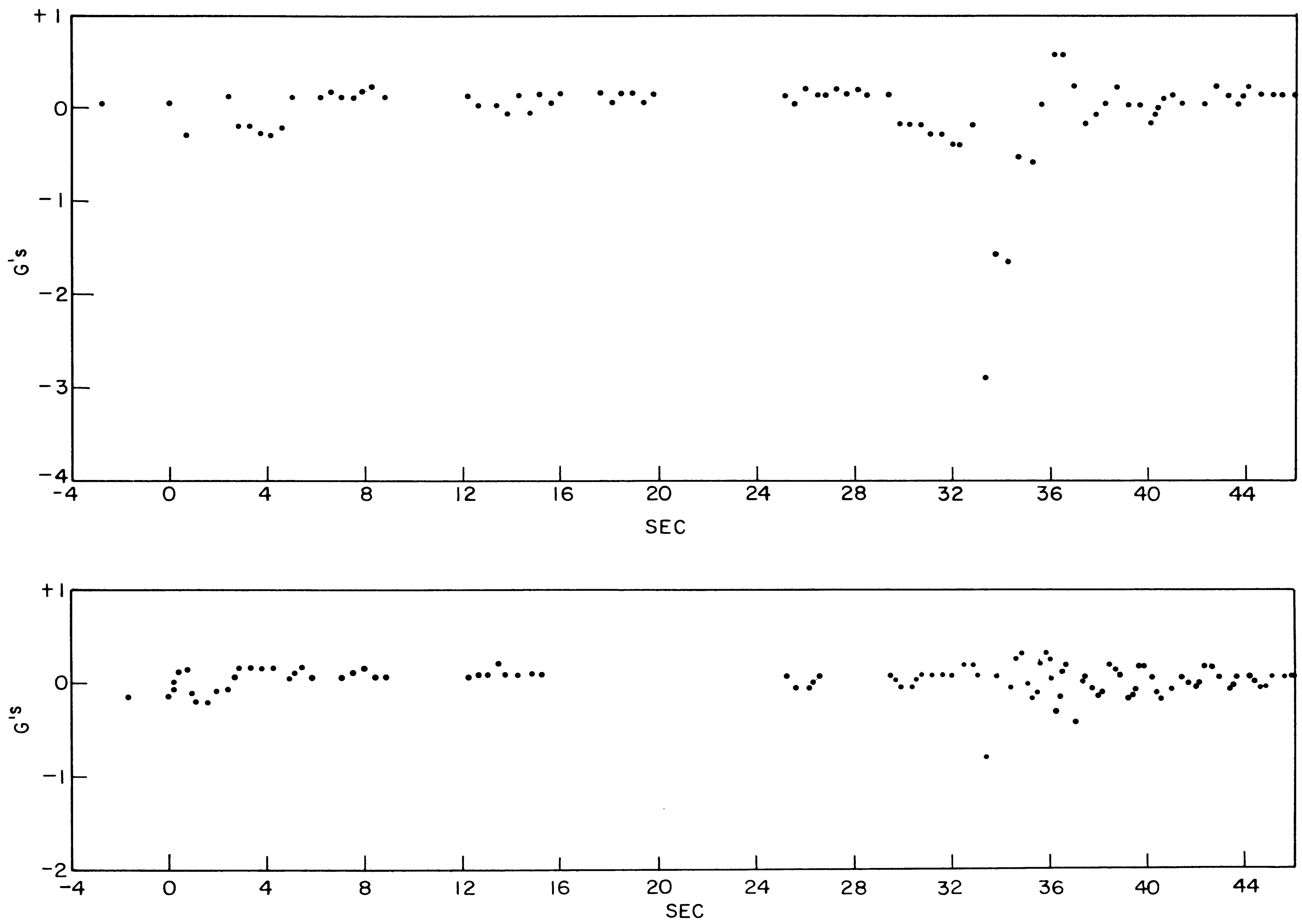

Fig. A-2. Lateral acceleration in two perpendicular planes, measured at base of nose.

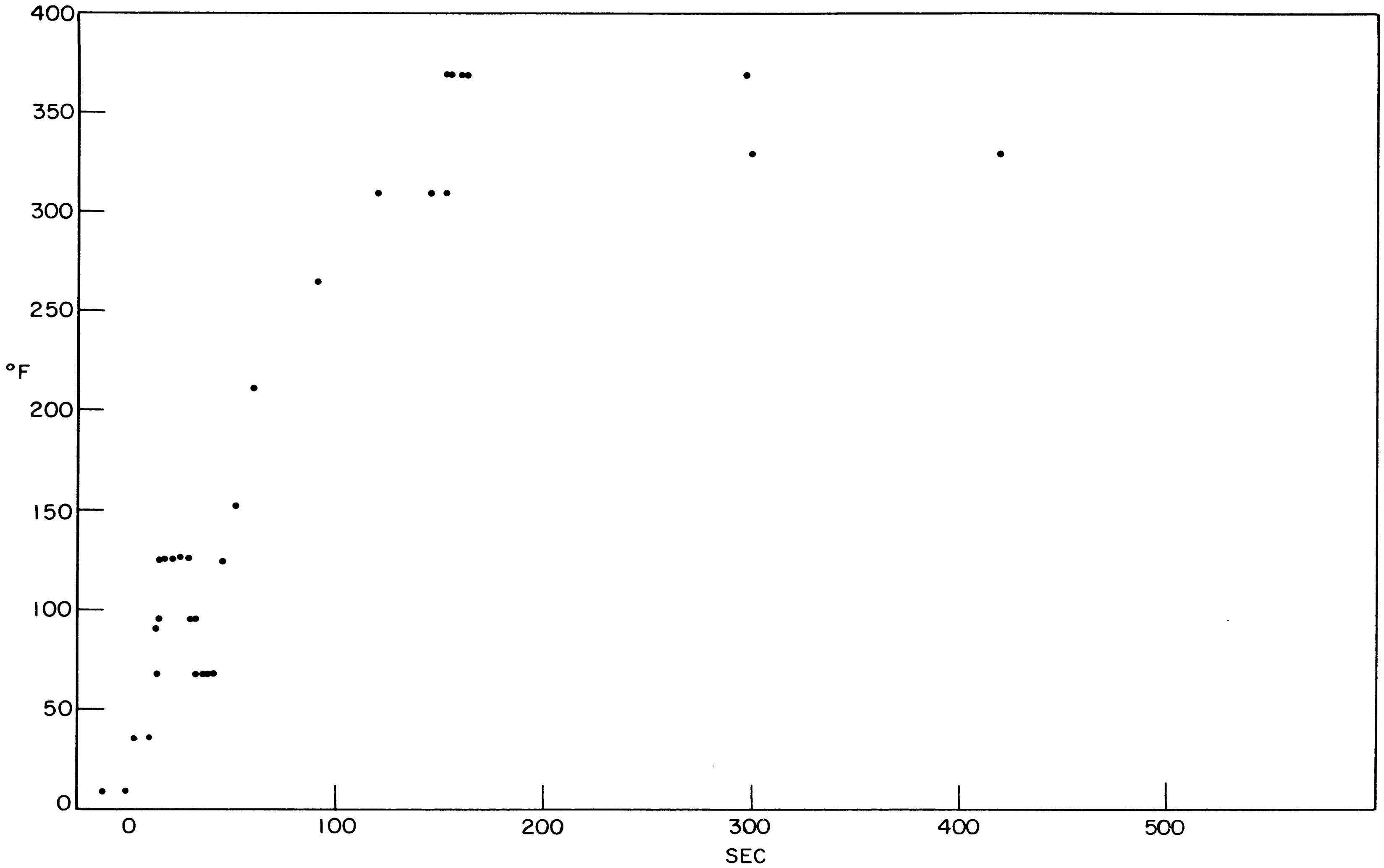

Fig. A-3. Internal skin temperature 15 in. from nose tip.

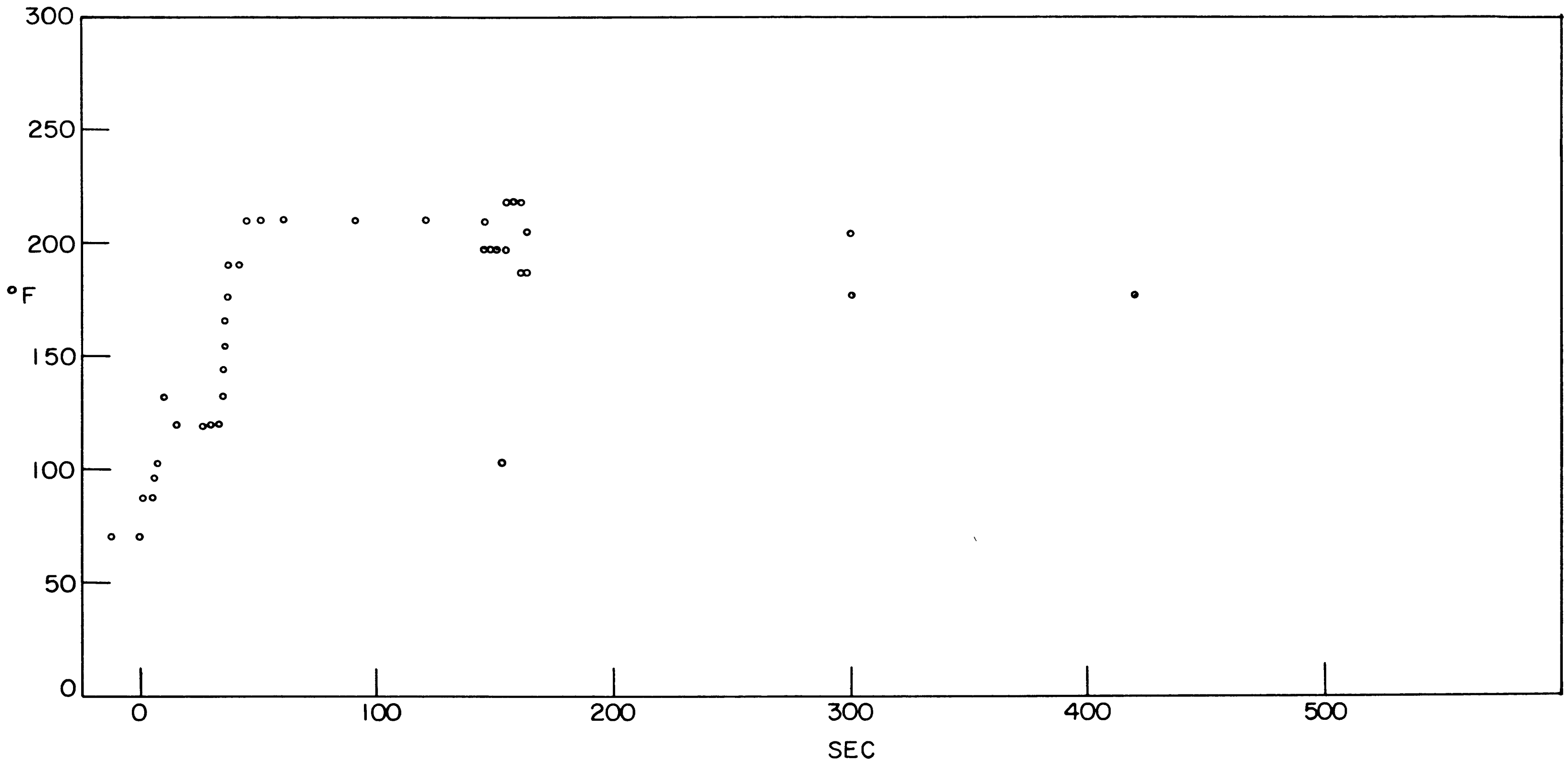

Fig. A-4. Internal skin temperature 55 in. from nose tip.