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AD383971

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31 Mar 1979, Group-4 document markings

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AD383971

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FINAL REPORT
ROCKEYE II WEAPON SYSTEM DEVELOPMENT PROGRAM
VOLUME I, PART A. (U)
DESIGN AND DEVELOPMENT HISTORY

for the

U. S. Naval Ordnance Test Station
China Lake, California
Contract N123(60530)33998A

31 March 1967

The Final Report consists of three books:

Volume I, Part A. Design and Development History
Volume I, Part B. Appendices to Volume I, Part A
Volume II. Engineering Support Activities

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FINAL REPORT
ROCKEYE II WEAPON SYSTEM DEVELOPMENT PROGRAM
VOLUME I, PART A (U)
DESIGN AND DEVELOPMENT HISTORY
OF THE MK 20 MOD O CLUSTER BOMB
WHICH CONSISTS OF THE
MK 7 MOD O DISPENSER
AND
MK 118 MOD O ANTITANK BOMB

NAVAL ORDNANCE TEST STATION
CHINA LAKE, CALIFORNIA

Development Period: 23 June 1963 to 31 March 1966
Contract Period: 23 June 1963 to 31 December 1966

31 MARCH 1967

Contract N123(60530)33998A

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I. INTRODUCTION

A. PURPOSE

This report was prepared for the Naval Ordnance Test Station, China Lake, in accordance with requirements specified in contract N123 (60530) 33998A. The report covers the development effort conducted by Honeywell pursuant to the Rockeye II program which was authorized for the purpose of providing tactical aircraft with weapons utilizing the sub-bomblet (cluster bomb) concept and having a high kill probability against tank, personnel, and material targets.

B. BACKGROUND

The Rockeye II was conceived as a second generation weapon system for high performance tactical aircraft. It was to differ from its predecessor, the Rockeye I weapon(which was an interim weapon utilizing existing hardware), in several important respects. Whereas the Rockeye I featured a rocket motor system to provide bomblet dispersion, the Rockeye II would utilize centrifugal force generated by spin imparted by canted fins on the dispenser to deploy the cargo munitions. In such a transition there would, of course, be a marked reduction in the complexity of dispersion hardware, a simplification certain to reflect in higher reliability. Further, the Rockeye II bomblet was to be capable of defeating (under optimum conditions) tanks comparable to the JS III. This would provide tactical aircraft with a weapon effective against the heaviest tank armor currently in use or foreseen in the near future. By establishing the upper limits of the kill requirement to coincide with the hardest target likely to be encountered in the battlefield environment, Navy planners were laying the groundwork for development of a weapon that would be capable of defeating almost the entire spectrum of tactical materiel targets (excluding deeply dug-in and/or structurally reinforced emplacements which, obviously, require much heavier ordnance to destroy). The bomblet would have, in addition, an anti-personnel capability of such lethality as to ensure a high kill probability against troops associated with tank or materiel targets or deployed in infantry formations.

C. RELATED DEVELOPMENT

Contract N123 (60530) 33998A encompassed development of the Rockeye II bomblet and dispenser, but did not extend to the fuzes for these items. The bomblet fuze (MK I, Mod 0) was developed concurrently by Honeywell under Contract No. N60921-7091 under the cognizance of the Naval Ordnance Laboratory, White Oak, Maryland (for further information see the Final Rockeye II Fuze Report, Honeywell, April, 1966). The dispenser fuze, originally identified as the EX66 Mod 0 and eventually designated the MK 339 Mod 0, was developed by MEL PAR under contract to NOL White Oak.

The evaluation effort associated with the Rockeye II development program (shipboard compatibility testing, aircraft delivery evaluation, etc.) was to be accomplished by the Naval Ordnance Test Station, China Lake.

D. DEVELOPMENT APPROACH

The development program was divided into phases of activity that enabled sequential progress toward explicit goals. Each phase consisted of task assignments requiring satisfactory completion before effort under the successive phase could be initiated, and the Naval Ordnance Test Station, China Lake, controlled and coordinated development activity in terms of phase to phase progression. This provided continual technical surveillance of the development, a requisite in a program in which the cognizant agency is concurrently conducting evaluation studies and investigation on the hardware being developed.

E. PLAN OF REPORT

The final report consists of two volumes: Volume I, Rockeye II Bomblet and Dispenser Development History; and Volume II, Engineering Support Activities, Rockeye II Development. In the first volume the chronological evolution of the bomblet and dispenser design is traced within the context of the analyses and evaluations upon which design modifications were predicated. The more specialized technical assistance provided by supporting engineer groups (Production Engineering, Quality Assurance, Reliability, etc.) is summarized for each of these functional activities in Volume II.

F. FORMAT, VOLUME I

In this volume the historical evolution of the design of the dispenser and the bomblet is described in separate sections. Actual design evolution is preceded by a discussion of basic requirements, as established in the RFP and subsequently modified, for each major unit. In the last subsection, the development goals and the development achievements are compared to illustrate the degree of success attained. A summary of development (Section II) precedes the detailed discussion, providing a synopsis of the program as a whole.

Volume I is divided into Part A, which contains the discussion of the chronological evolution of dispenser and bomblet design, and Part B, which includes all the appendices for Volume I. To facilitate locating and identifying drawings on the dispenser and bomblet, we have included the latest drawing tab run as Appendix A (Part B).

II SUMMARY

This report was prepared for the Naval Ordnance Test Station, China Lake, California, and covers the development of the Rockeye II dispenser and bomblet by Honeywell pursuant to contract N123 (60530)33998(A).

The purpose of the development authorized under this contract was to evolve to the production stage a cluster weapon highly effective against heavy tanks, materiel, and personnel.

The Rockeye II program was initiated on 23 June 1963, and the effort has been largely completed as of the date of this report.

The final design Rockeye II weapon (dispenser and bomblet) has demonstrated a high compatibility with performance and environmental requirements under a variety of test conditions. This demonstrated capability is evidence of the success of the development program. This capability, too, enhances the ability of Navy aircraft to directly, and decisively assist in tactical operations ashore. The anti-tank, anti-materiel, anti-personnel effectiveness of Rockeye II makes it a valuable addition to the ordnance of modern tactical aircraft.

The major problem encountered in development of the bomblet was defining a shaped charge design that provided the desired armor plate penetration. The problem was resolved consequent to a detailed and comprehensive parametric analysis that enabled establishing an optimum configuration highly lethal against both tank and personnel targets. It was found, however, that in some of the hardware lots produced after design finalization there was a marked degradation in penetration performance. An investigation disclosed

that more stringent controls of the production process were required to assure required penetration performance. The process control specifications were accordingly revised to assure consistent quality component hardware.

Development of an aerodynamic configuration meeting flight stability and terminal velocity specifications required a considerable portion of the bomblet design effort. Nonetheless, the design evolution progressed rapidly, largely through utilization of wind tunnel evaluation techniques to facilitate design selection and optimization; and the basic configuration, a spike nose, cylindrical/tapered body, 3-radial fin bomblet, was established in Phase I.

Subsequent minor modifications were made to provide compatibility with changes in the shaped charge design. The final aerodynamic configuration was tested under wind tunnel and actual flight conditions and demonstrated satisfactory performance with respect to functional requirements.

The major problems encountered in dispenser development concerned the tail section aerodynamic profile, the dispenser opening hardware, the explosive skin separation network, and suitable weapon aircraft delivery above speeds of 450 knots. Tail section development was facilitated, as with the bomblet aerodynamic configuration, largely through wind tunnel tests and evaluations. The final configuration consisted primarily of four folding, canted fins, airfoil in shape and cored out to reduce weight, and straight (parallel to dispenser primary axis) fin roots. The adequacy of this design has been established as a result of wind tunnel and flight tests under a broad spectrum of aerodynamic conditions except for high speed releases from multiple bomb racks.

Dispenser opening (bomblet release) was considerably improved during the program. Earlier weapons caused bomblet damage as the skin panels rotated and skewed into the bomblet cloud during the release sequence. Ultimately a dispenser configuration was developed that, using pre-split structure and a steel hinge plate at the aft end of the tailcone, provided a clam-shell like dispenser opening with minimal cargo damage.

The explosive skin separation network underwent several major design modifications during development. Part of the original network (the station 78.0 circumferential strand) was eliminated when it was determined during flight tests that it was not required for successful functioning. The explosive used was changed (RDX to CH-6) to ensure an end configuration completely safe with regard to the environments unique to the Navy, particularly shipboard conditions. Various design concepts were evaluated for the fuze lead-to-FLSC interface before a highly reliable configuration was developed.

III. DESIGN AND DEVELOPMENT, ROCKEYE II DISPENSER

The chronological evolution of the Rockeye II dispenser is described in this section of the report. First, the general and specific requirements for the dispenser as established in the RFP and modified by later directives are delineated. Then the design approach contained in the Honeywell proposal (this concept representing the initial design fix) is discussed. Subsequent modifications to this original design are next reported in chronological sequence on the basis of the tests, analyses, and investigations that indicated the necessity for design changes.

Finally, the development goals implicit in the requirements are compared to actual development achievements to illustrate the degree of success attained in the program.

A. DESIGN REQUIREMENTS

The design requirements were originally established in the form of a specification to the Rockeye II contract. Subsequent revisions to the contract amplified these design requirements in some areas but did not substantially change them. The following paragraphs contain summaries of the design requirements as expressed in the contract and are annotated to show subsequent modifications.

1. Physical Characteristics

This weapon (dispenser and cargo) shall not weigh more than 500 pounds nor exceed 13.0 inches in diameter or 91.0 inches in length. (The diameter and length maximums were subsequently modified to 13.2 and 91.3 inches, respectively.)

2. Functioning and Reliability

(a) The cluster dispenser shall be capable of dispensing the cargo bomblets without damage into an effective, randomly distributed pattern.

(b) The weapon shall have a ballistic dispersion (defined as the difference in trajectories of identically launched weapons) of less than 4 milliradians.

(c) The weapon shall be capable of effective delivery from the launching aircraft at the lowest safe altitude (as determined by bomblet fragmentation limits) and at all dive angles from 0° to 45°.

(d) The weapon shall be capable of carriage on the aircraft itemized in paragraph 3c at speeds up to Mach 1. 5 for up to four hours and shall be capable of delivery at aircraft speeds ranging from Mach 0. 3 to Mach 0. 9. (This requirement was subsequently modified to add the words, "up to Mach 1. 5 at 25, 000 feet above MSL for a minimum time duration of four hours.")

(e) The weapons shall exhibit stable flight characteristics when released at speeds ranging from Mach 0. 3 to Mach 0. 9 from the bomb racks and aircraft specified in paragraph 3c.

(f) The weapon when released at velocities ranging from Mach 0. 3 to Mach 0. 9 shall have a functioning reliability of at least 94%.

This specification was changed to read as follows:

The weapon when released at velocities ranging from Mach 0. 30 to 0. 90 shall have a functioning reliability of at least 0. 90. The reliability design goals of the weapon components shall be:

Bomblet exclusive of fuze	0. 97
Bomblet including fuze	0. 87
Dispenser exclusive of fuze	0. 99
Dispenser including fuze	0. 94

The confidence levels to which the reliability must be demonstrated in the final prototype weapons or components are:

Complete bomblet	95%
Complete dispenser	80%
Complete weapon	80%

3. Bomb Rack and Aircraft Compatibility

(a) The weapon shall be compatible with the following bomb racks:

Multiple Bomb Rack
Multiple Ejector Rack
Triple Ejector Rack
Universal Bomb Rack
Aero 7A-Bomb Rack
Aero 20A Bomb Rack
Aero 14E Bomb Rack
Aero 61A Bomb Rack
MAU 9A Bomb Rack

(This list was later revised to delete the Aero 14E, add the Aero 3A and the MK 51, and include the following proposed bomb racks:

Republic - Adjustable Ejector Rack

Hughes - MAU 48A

MAU 12A

Aero 15C

(b) The weapon shall be compatible with all in-service NATO and AF bomb racks.

(c) The weapon shall be compatible with the following aircraft when fitted with their respective armament bomb racks:

A-4C (A4D-2N and A4D-5)

A-5B, A-5C (A3 J-2 and A3 J-3)

A-6A (A2F)

A-1G (AD-5N, AD-6, AD-7)

F-8D, F-8E (F8U-2N, F8U-2NE)

F-4A (F4H)

AF-1E (FJ4-B)

(This list was subsequently deleted and the following list established.

A-4, B, C, E

A-5C

A-6A

A-1, E, G, H

F-8E

F4, B, C

F-100

F-104G

F-105

In addition, it was specified that the weapon would be compatible with the following proposed aircraft:

A-7	F-5
F-111A	YAT 28

(d) The weapon shall be compatible with all inservice NATO and AF aircraft when configured with their respective armament bomb racks.

(e) The weapon, when fitted to any of the bomb racks or aircraft cited, shall not interfere with the normal operation of the catapult bridle, the aircraft control surfaces, the landing wheels and related structures, and the operation of the aircraft in general.

(f) The weapon shall not require specialized equipment for transporting or aircraft loading.

4. Aerodynamics and Ballistics

(a) The cluster dispenser shape shall reflect minimum drag commensurate with the requirement for a maximum bomblet cargo.

(b) The weapons shall be statically and dynamically stable when released in either an ejected or gravity mode.

(c) The weapon shall separate cleanly from all bomb racks specified without extreme or erratic perturbations during or after release.

5. Structural Loads

The weapon shall be capable of withstanding any of the loads cited below or any possible combination of these loads.

(a) The weapon shall be capable of withstanding the aerodynamic loads encountered during flight of all the foregoing aircraft and during flight of the weapon after release.

(b) The weapon shall retain structural integrity during and after ejection from all the ejecter bomb racks previously indicated.

(c) The weapon shall retain structural integrity during and after tactical maneuvers, catapult takeoffs, and arrested landings of all aircraft cited previously.

6. Environmental Compatibility

(a) The weapon shall be capable of withstanding the vibration environments encountered during flight, catapult takeoffs, arrested landings, taxiing, or ground landings and takeoffs of the aircraft specified in the foregoing.

(b) The weapon shall not be affected functionally by the vibration environments associated with storage, handling, or transportation to the end-use activity.

(c) The weapon shall not be affected functionally by temperatures ranging from -65° F to +165° F; wind; fungus; snow; ice; rain; salt spray; dry wet, or frozen sand; or wind when in storage, shipment, or attached to parked or flying aircraft.

7. Safety

(a) The weapon shall be amenable to safe jettison at speeds ranging from Mach 0. 175 to Mach 1. 50.

(b) The weapon shall be safe when exposed to the electo-magnetic radiations of ship and shore communications equipment.

B. DESIGN AND DEVELOPMENT HISTORY

1. Original Design Approach

The design approach reflected in the Honeywell proposal provides a convenient initial design fix for reviewing the chronological evolution of the dispenser configuration. Consequently, it is described in this section as the original design approach, even though it was not in all details the initial program approach.

a. Physical Description

The proposed dispenser configuration is shown in Figure 1. The unit is cylindrical in shape and has a spherically blunted nose with a tangent ogive and a truncated tail with folding fins. It is 91 inches long and 13 inches in diameter, and the span of the fins when extended is 28 inches. The dispenser is attached to the aircraft by a standard 14-inch suspension. The lugs are located 6 inches aft and 8 inches forward of the dispenser center of gravity.

Nose and Center Section - The nose section extends from Station 0. 0 to Station 13. 0 and contains the basic nose structure which is fabricated from formed sheet aluminum. A full sheet metal bulkhead is located at Station 9. 5. The center, or cargo, section is located from this station aft to Station 78. 0.

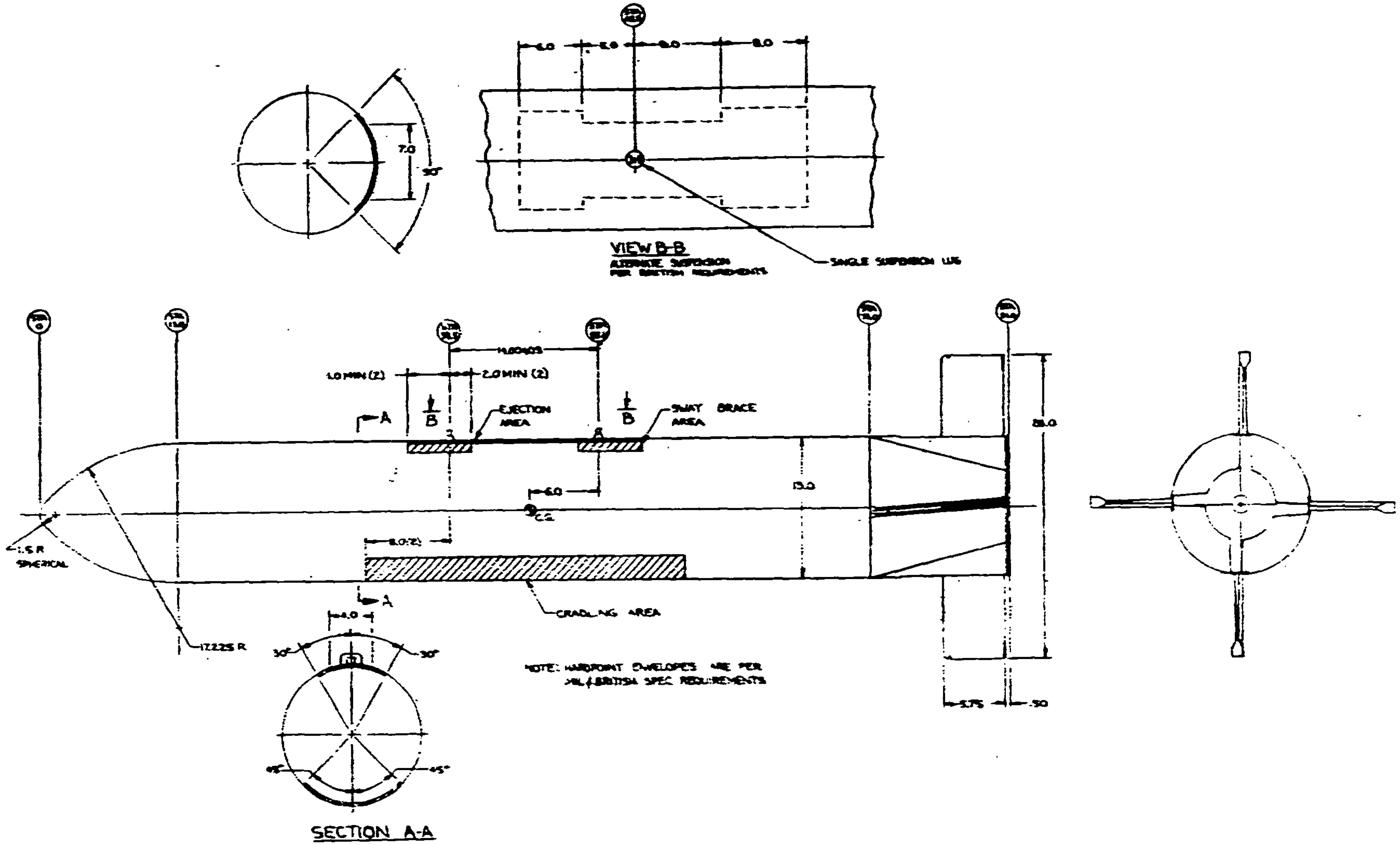

Figure 1 - PROPOSED DISPENSER DESIGN

The type of primary structure utilized here is essentially a monocoque shell, details of which can be seen in Figure 2. The lower 270° of the shell is a single section of rolled sheet, and extends from Station 13. 0 to Station 78. 0. The upper 90° of the shell consists of a strongback, which extends from Station 34. 0 to Station 62. 0, and a section of rolled sheet extending fore and aft of the strongback. This section of skin and strongback also serves as a door through which bomblets are loaded into the dispenser.

The strongback itself is made from an extrusion that has excess material removed where not required for strength. Three tapped holes in the strongback provide for either double or single-lug suspension. The size of the strongback fulfills the requirements of MIL-A-8591C and British store specifications.

Rings are located at Station 34. 0 and Station 57. 0. In addition to distributing loads from the lugs and sway braces to the shell, they also serve as back-up structure for cradling loads.

All joints utilize solid aluminum rivets or steel screws. The major longitudinal splices are located ±45° from the top center line and extend the full length of the cargo compartment. Circumferential splices are required at Station 13. 0 and Station 78. 0.

Tail Section Assembly

The dispenser tail section assembly (Figure 3) consists of a conical tail cone, four folding fins, and a fin release mechanism. The conical tail cone shape was dictated by aerodynamic drag considerations, and the use of fins that fold was necessitated by external clearance envelope restrictions.

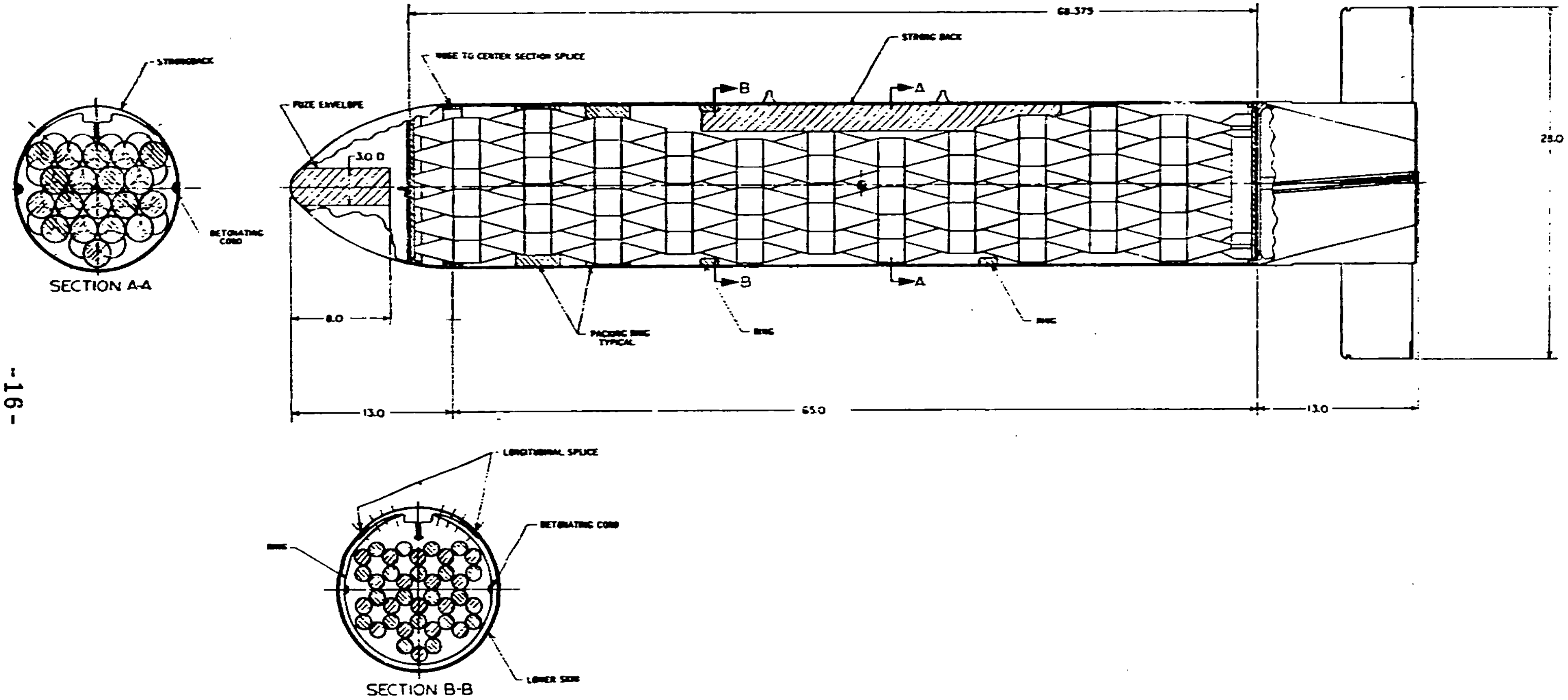

Figure 2 - MONOCOQUE SHELL DETAILS

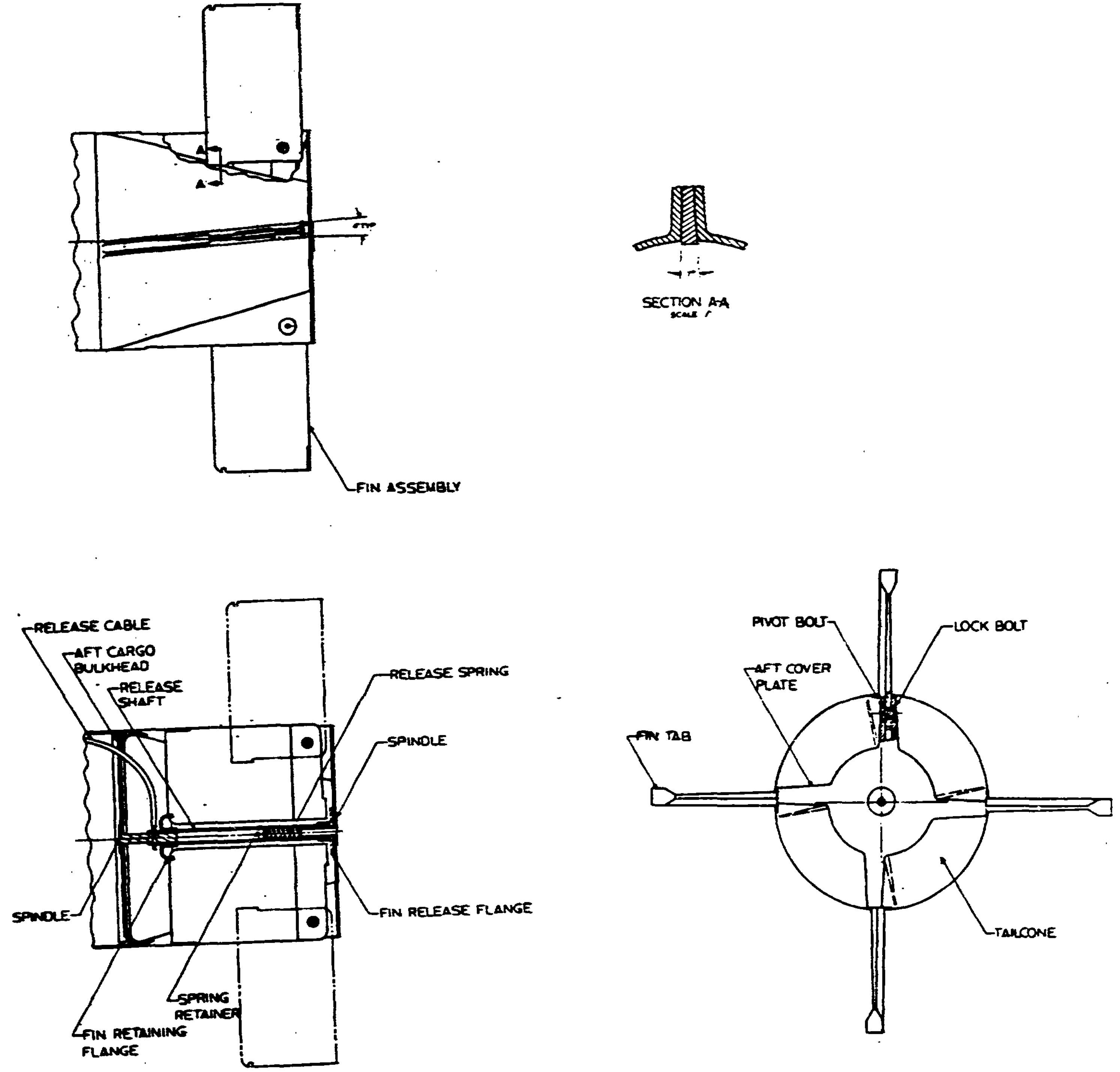

Figure 3 - DISPENSER AFT SECTION ASSEMBLY

The tail cone is designed as an aluminum sand casting (356-T6 or 220-T4 alloy) to minimize the cost of the aft section assembly. Slotted fin root fairings are integrally cast in the tail cone. These fairings provide the mounting for the fin pivots, guide the fin on extension, and provide structural support for the extended fin. Machined surfaces within the cast slots provide the fin guiding and alignment.

The forward end of the tail cone supports the aft cargo bulkhead. The forward end of the casting is externally machined to accommodate the dispenser skin, which is attached by flush head rivets. A plate at the aft end encloses the base of the tail cone and provides structural continuity across the back edge of the cast slots.

The fins are cast from 356-T6 to 220-T4 aluminum alloy for economy of construction. They are tapered from root to tip to minimize weight and drag. A small tab is attached to the tip of the fin trailing edge to provide an aerodynamic assist for opening the fin. An integrally cast boss at the root of the leading edge of the fin provides the fin extension snubbing and locking function. This boss, which is machined to a locking taper angle of approximately 7°, engages a mating taper machined into the tail cone at the base of the fin fairing. The fin is mounted in the fairing by means of a pivot bolt and locking bolt, which provides a hinge for fin rotation and controls the fin to guide surface clearance.

The fins are held in the closed position by a release mechanism located at the tail cone center line. This device consists of a hollow shaft with a fin retaining flange welded at the forward end and a fin release flange welded at the aft end. This assembly is supported at each end by spindles mounted in the aft plate and aft cargo bulkhead. A compression spring located inside the shaft loads the release mechanism in the forward direction. With the fins closed, the release mechanism is held against the spring loading by a lanyard-type release cable which extends through the shaft and forward spindle. In this position the retaining flange engages notches in each of the four fin tips and thereby locks the fins in the folded position.

b. Functional Description

The sequence of events from dispenser release to cargo deployment is shown in Figure 4. Prior to release the dispenser is suspended on existing aircraft store racks in a conventional lug and sway brace manner. As the dispenser clears the rack upon release, a preset fuzing timer located in the dispenser nose is actuated by a short lanyard attached to the rack. Concurrently, another lanyard actuates the folding fin extension mechanism. Four fins, which are folded forward in closed position, are released and then rotated aft to the open position by a spring actuated mechanism assisted by an aerodynamic tab on the fin. The rotational energy of opening is absorbed by a wedging action of the fin into a slot; this also serves as a lock in the open position. The fins are canted 4° to produce a continuous rolling moment on the dispenser during free-flight. This moment is utilized to produce a rotational velocity on the dispenser of sufficient magnitude to provide proper dispersion of the bomblets when the dispenser is opened in flight.

When the preset delay on the fuze timer expires, the fuze initiates an explosive train that detonates a network of Primacord to separate the skin section from the cargo. The centrifugal forces resulting from the dispenser rotation will then disperse the cargo of shaped charge bomblets.

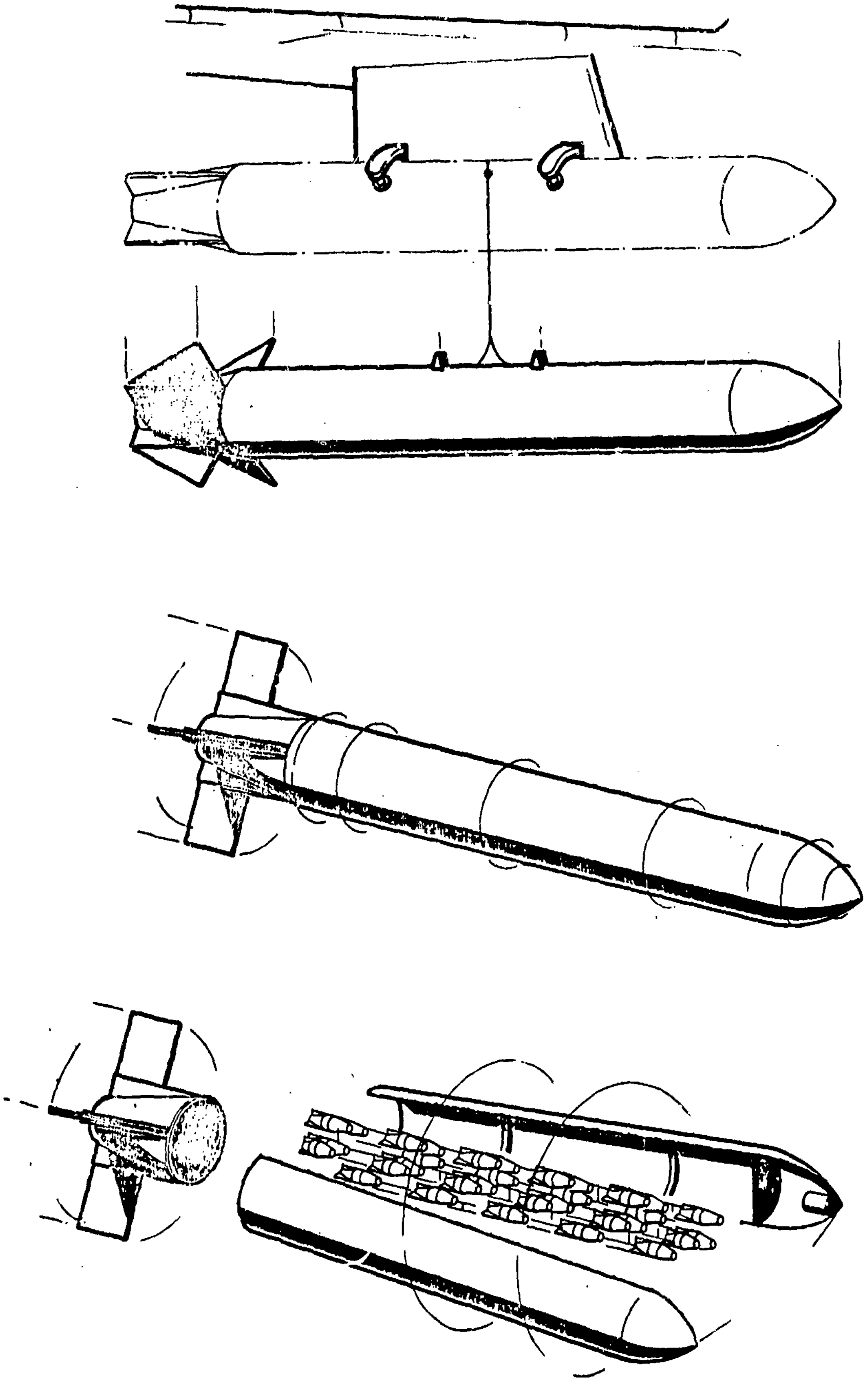

Figure 4 - DISPENSER OPERATIONAL SEQUENCE

2. Chronological Evolution of Dispenser Design

The historical evolution of the dispenser design is reported in this section, which is divided to coincide with the three major structural areas of the dispenser: nose section, main body (cargo) section, and tail section.

a. Nose Section Development

The nose section extends from Station 0.0 to Station 6.4 and contains the dispenser fuze, the forward portion of the fuze arming wire, and the fuze output lead. Direct access for fuze installation, removal, or adjustment is provided by a removeable fairing. The section is contoured to present a clean aerodynamic profile to the airstream.

By October, 1963, the preliminary design of the nose section had been defined as shown in Figure 5. Externally this configuration duplicated the design approach of the proposal document, but various internal structural interfaces were modified.

The fairing surface, originally a single unit that was cut and deployed by a section of the explosive skin separation network, was modified in the preliminary design to provide a pre-split configuration. This eliminated the necessity of running an extension of the explosive skin cutting network into the nose section. Since access to the fuze was required for installation, removal, and maintenance, reduction of the amount of explosives in this area was considered desirable. Screw fasteners were used to secure the fairings to the nose section.

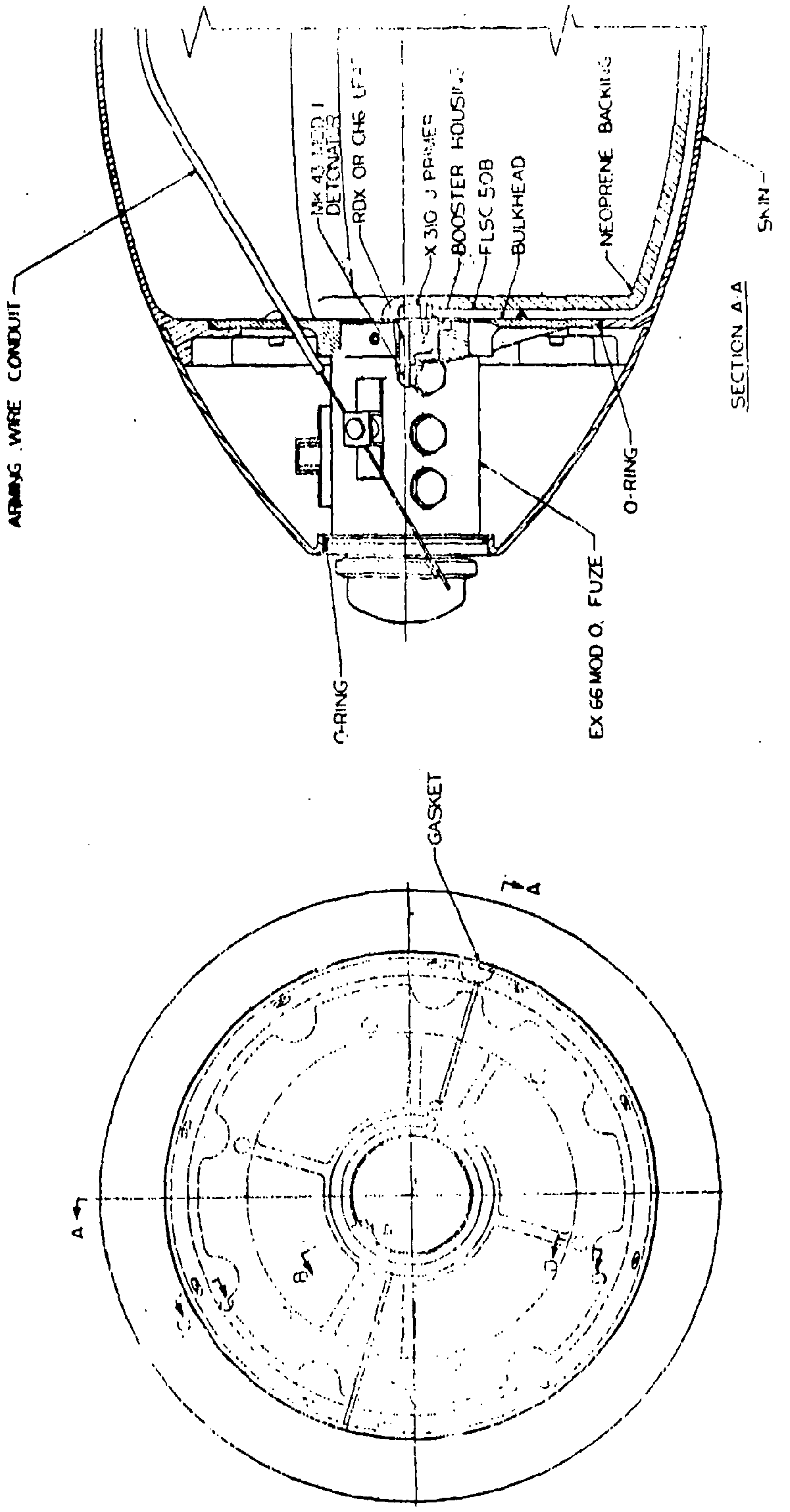

Figure 5 - DISPENSER NOSE SECTION LAYOUT

The primary fuze mounting in this approach was provided by a boss on the forward bulkhead that separated the cargo and nose sections and was also pre-split. The fuze was secured by two screws located 45° apart, when the fuze was seated, the fuze output was properly positioned to initiate the explosive skin separation network.

A window was added to the nose section (at approximately 300° clockwise from the top center line) during Phase II development. This enabled visual inspection of the dispenser fuze arming indicator with the weapon loaded on an aircraft. The size of the window was subsequently increased, the final dimensions being 2. 49 inches by 3. 13 inches by 1. 60 inches, to improve visibility.

Flight test results showed that the fuze was breaking free on dispenser opening and was potentially capable of interfering with bomblet release to the extent of causing some cargo damage. In addition, it was felt that the fuze could possibly activate a bomblet as a result of collision, thus creating a hazard to the delivery aircraft. Consequently, the securing interface was modified to ensure that the fuze remained with the lower half of the dispenser at opening (this modification concurrently partially corrected the uneven distribution of mass between the two halves on opening, thus contributing to a more effective cargo release). In this design, the fuze mounting structure was bolted to the lower half of the dispenser only as may be seen in Figure 6.

No further modifications of consequence were made to the dispenser nose assembly. The final design is described in Section III B. 3 of this report.

b. Cargo Section Structure Development

The cargo section extends from Station 6. 4 (approximately) to Station 78. 0 on the dispenser and consists of the body skin and support structure, the cargo packing, the explosive skin separation network, and the fuze arming/safing

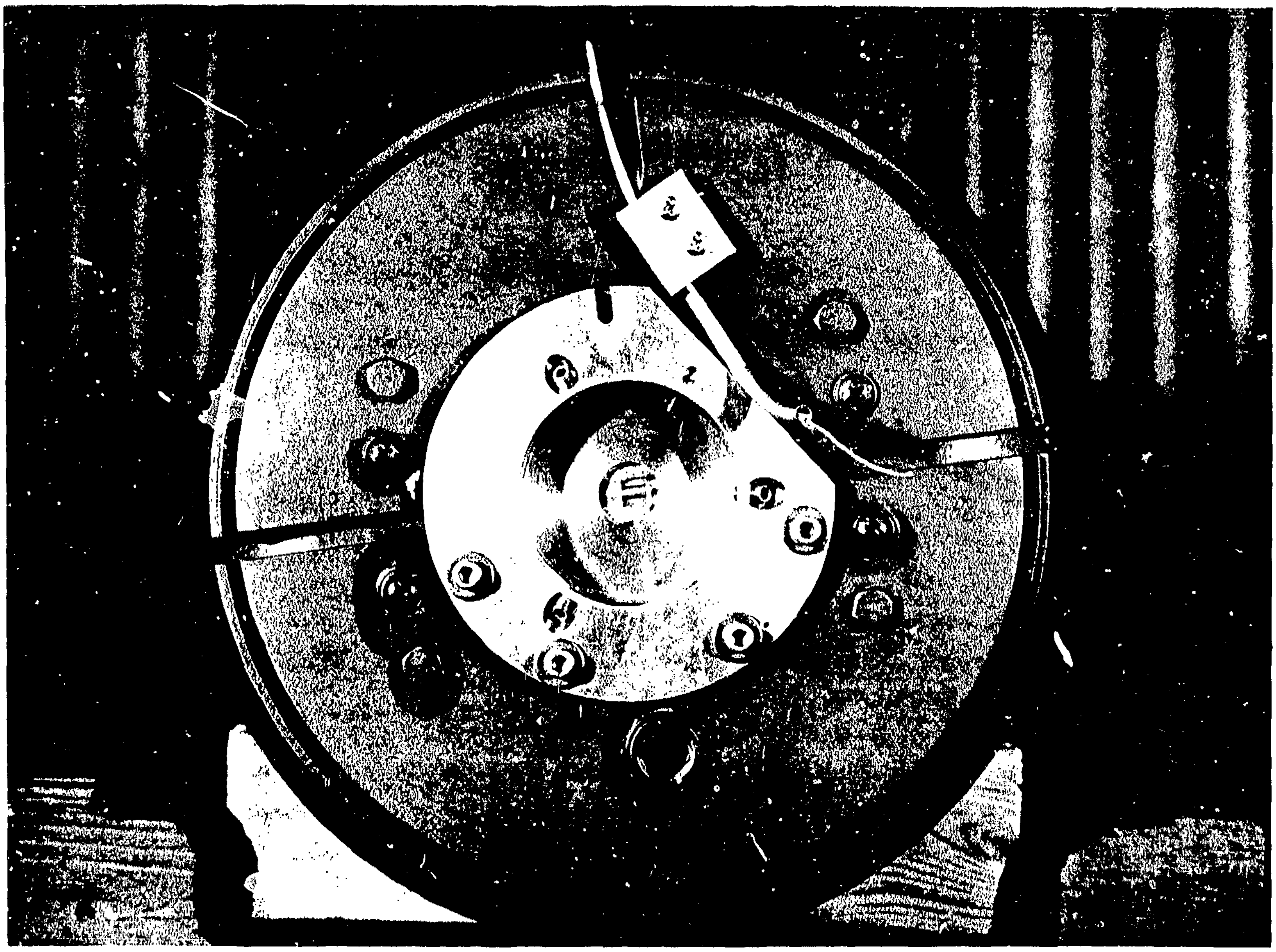

Figure 6 - FUZE MOUNTING STRUCTURE, NOSE SECTION

devices. The section serves to contain and protect the cargo during storage, handling and flight conditions, and when spun up by the tail section at release, gives a rotary thrust to the bomblets at the moment the dispenser is opened and the cargo is deployed.

(1) Body Skin and Structure

The preliminary design* of the body skin and structure is shown in Figure 7. The skin section in this configuration consisted of a one-piece, flow-turned or cold-extruded, 0.125-inch thick 6061 aluminum alloy structure with integral ogive and front bulkhead. This skin was reinforced for bomb rack hook and sway brace loading by use of a strongback of extruded 6066 aluminum mounted internally and running the full length of the skin section. The strongback was secured to the skin section with metal fasteners. The support ring provided in the proposal design was eliminated when the preliminary structural analysis determined that it was not necessary.

The forward bulkhead (Station 6.4) was initially a separate sand cast aluminum structure, but it eventually became an integral part of the skin. The aft bulkhead (Station 78.0) was an aluminum sand casting (A356) and was sealed with an O-ring. Spacers adjacent to each bulkhead and within the cargo mass were used to support the bomblets and to stiffen the cargo section.

Standoff pads, for multiple bomb racks, and standard 14-inch suspension lugs were secured to the strongback. The standoff pads were found to be necessary when a compatibility study revealed that there was an interference area between the MBR structure (bolt MS2006-30 on the centerline rack as shown in Figure 8) and the dispenser. In addition, provisions were incorporated for adapting the dispenser to single lug suspension per British Armament Design Memorandum No. 24 - Issue 3, Part 2, if required.

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* An interim design, roll up skins with a splice at Station 13.0, was used on early series A weapons to enable meeting delivery commitments.

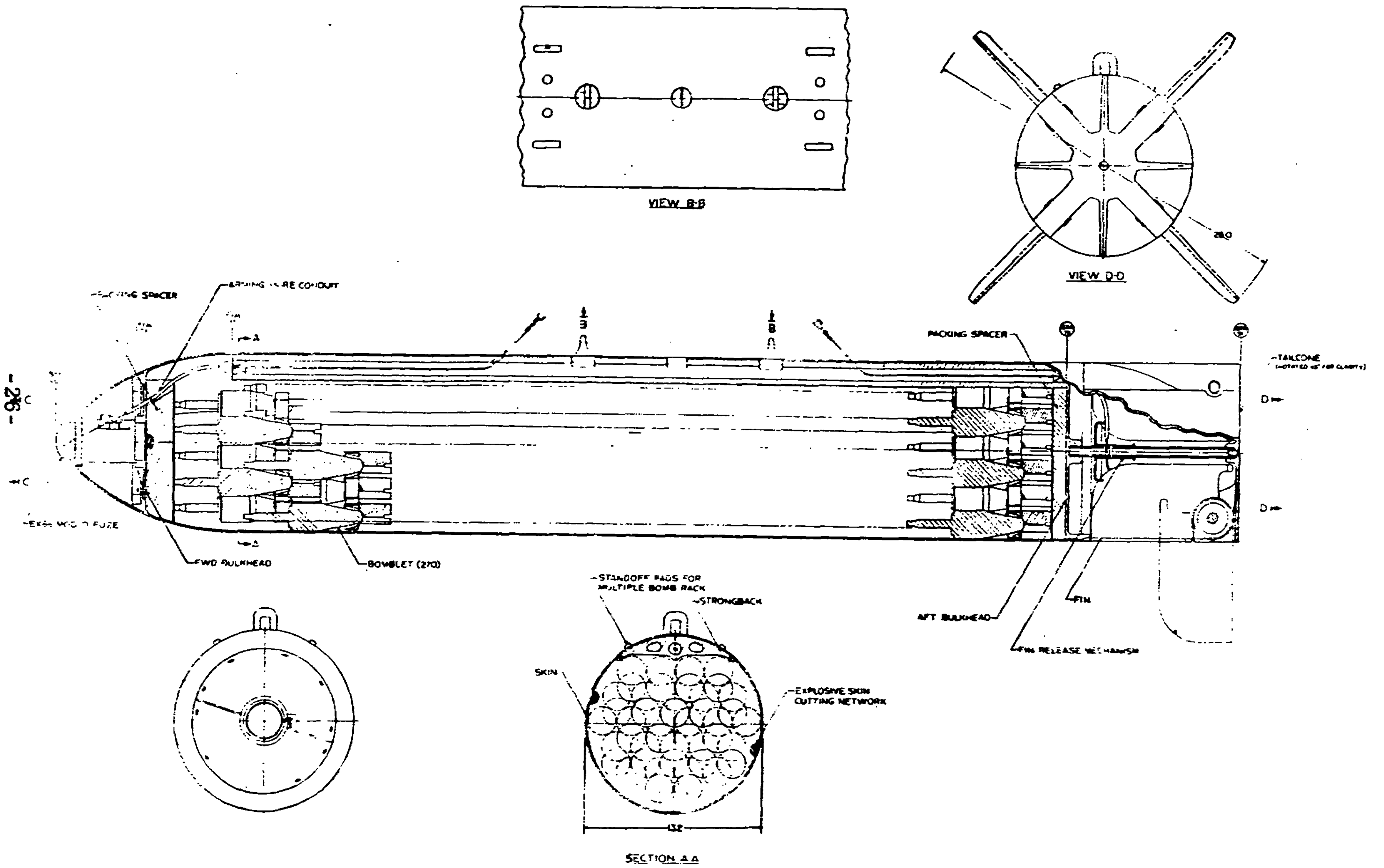


Figure 7 - DISPENSER PRELIMINARY LAYOUT

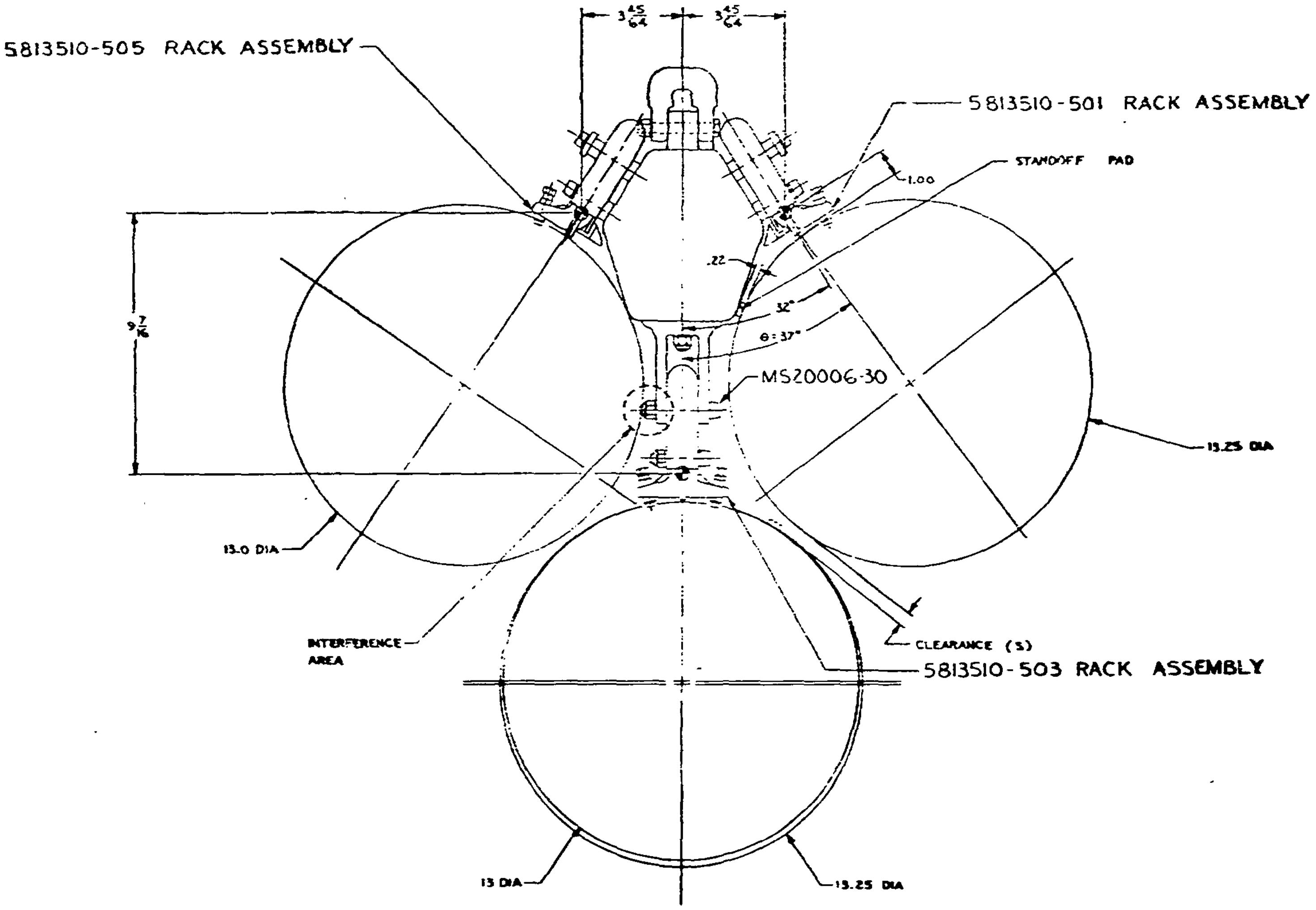


Figure 8 - DISPENSER FITMENT ON MULTIPLE BOMB RACK (MBR)

A study to determine the optimum dispenser diameter in terms of compatibility with the MBR was conducted, and station clearance values as a function of mounting angles shown in Figure 9 were established. These relationships were generated trignometrically on the basis of standard MBR hook dimensions. It was determined that the 13.2-inch diameter dispenser with the 0.22-inch standoff pads provides adequate clearance with a maximum misalignment between the MBR hooks and the dispenser of 5°. Information available from NOTS, China Lake, indicated that misalignment of up to ±7° could be tolerated without any bending or jamming.

Consequently, the dispenser diameter was established at 13.2 inches, a value which has not changed during the program. The weight and balance characteristics determined for this dispenser configuration (including the nose and tail sections) is shown in Table I for both the empty and fully loaded (270 bomblets) condition.

Structural testing was conducted on weapon A-1 by the Naval Ordnance Test Station at China Lake, and the dispenser was determined to be structurally adequate. An acceleration test of the dispenser on an AERO 7A and an MBR bomb rack was successfully completed using a centrifuge. No permanent deformation was noted, and the skin stress level appearing to be less than the preliminary analysis had indicated. In addition, the cargo section structure was subjected to vibration and ejection testing with satisfactory results.

The design of the one piece cargo section skin (forward bulkhead integral to skin structure) mentioned previously was completed in June, 1964. This design configuration enabled significant savings in production and provided an inherently stronger unit.

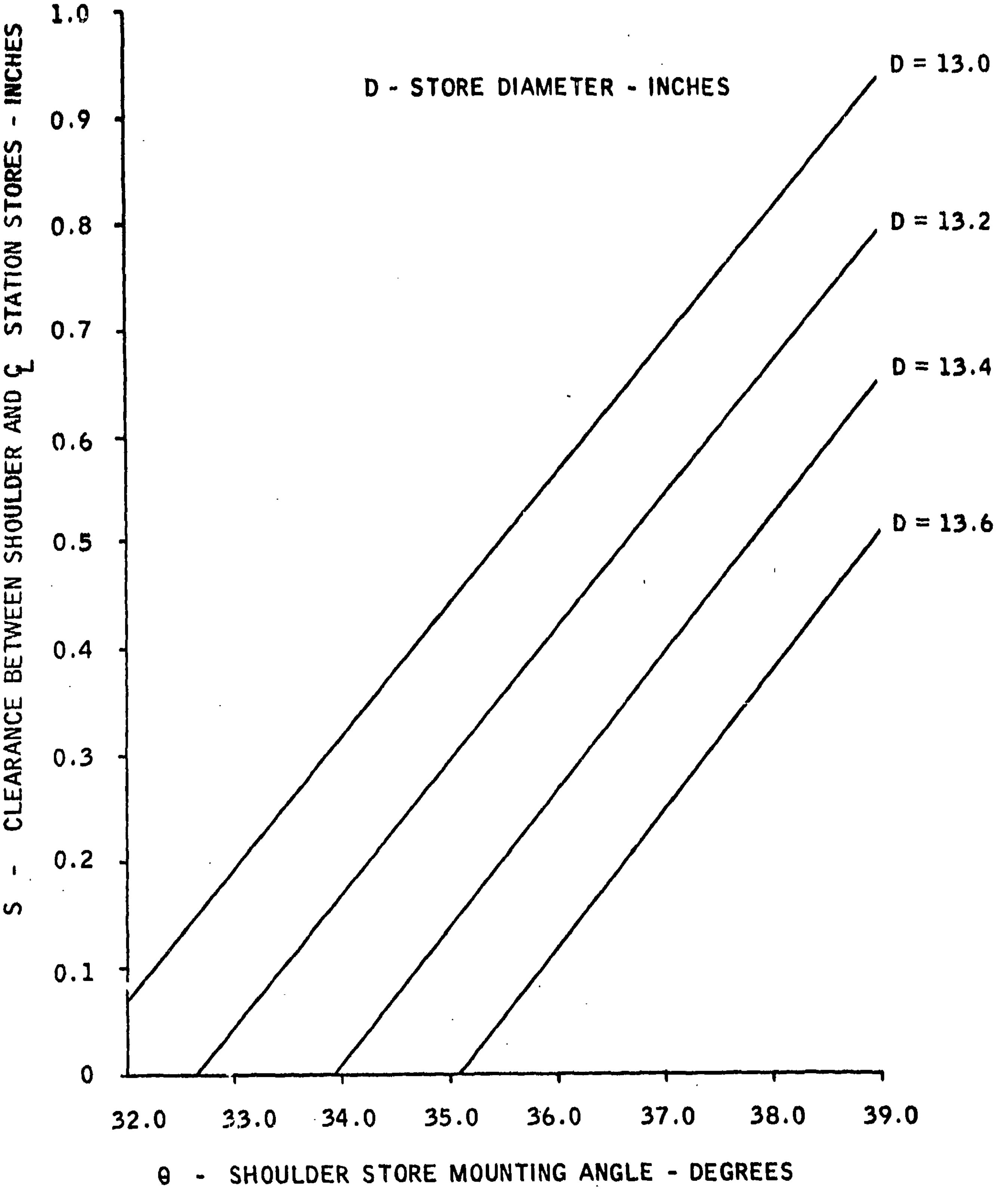


Figure 9 - NOMINAL CLEARANCE BETWEEN CENTERLINE AND SHOULDER STATION STORES ON MBR

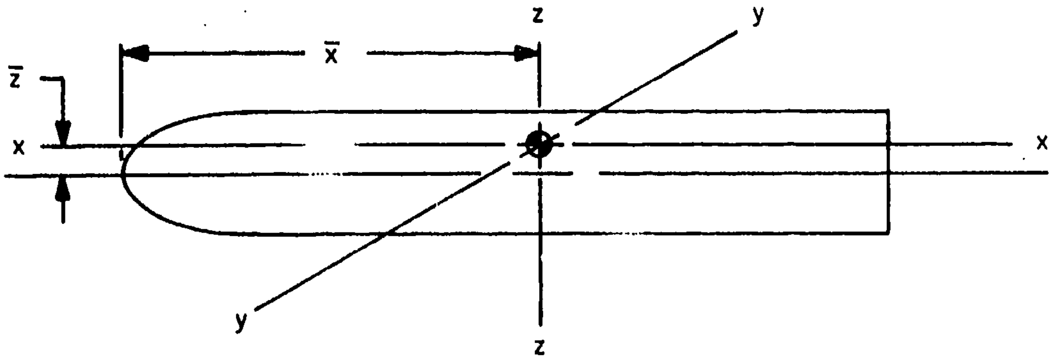
TABLE I

PRELIMINARY WEIGHT AND BALANCE SUMMARY

DISPENSER ONLY		FINS FOLDED	FINS OPEN
Weight - lb		133.6	133.6
$\bar{x}$	in	51.3	51.4
$\bar{z}$	in	1.8	1.8
I_{xx}	slug - ft^2	0.879	0.970
I_{yy}	slug - ft^2	19.60	19.80
I_{zz}	slug - ft^2	19.50	19.67
I_{xz}	slug - ft^2	0.294	0.299

DISPENSER WITH CARGO
(270 bomblets, 1.3 lb each)

Weight - lb		484.6	484.6
$\bar{x}$	in	45.4	45.4
$\bar{z}$	in	.30	.30
I_{xx}	slug - ft^2	2.30	2.39
I_{yy}	slug - ft^2	50.5	50.7
I_{zz}	slug - ft^2	50.7	50.9
I_{xz}	slug - ft^2	0.06	0.06



The functional flight tests of weapons A-2, A-3, and A-4 provided information indicating the necessity of design modifications to provide improved protection to the cargo and improved dispenser opening characteristics. Generally, the test results for these systems were sufficiently identical to permit description as following: The front row of bomblets pierced the front packing spacer plate and sustained extensive damage. The light half* of the skin section buckled during dispenser openings and subsequently broke loose from the tail assembly. These results were particularly evident in the condition of the hardware recovered from weapon A-4, as can be seen in Figure 10.

Spacers that supported the bomblets through the body area were added ahead of the first row of bomblets to prevent damage caused by interference with the spacer plate. In addition, a more positive security arrangement - metal fasteners instead of adhesive bonding - was provided for the front row spacers. In tests of dispensers containing these modifications no damage to bomblets as a result of spacer interference was noted.

To improve dispenser opening characteristics, the fuze/backup structure interface was redesigned so that these units would remain with the lighter skin section at dispenser opening. This change was incorporated into weapon A-6, which was tested using an AERO 7A rack. The fuze function time was set at 4 seconds (1.2 seconds is the intended event time) and the resulting event environment was consequently atypical, rotary speed of the dispenser at opening being approximately 29 rps (about twice that anticipated at maximum delivery velocity). The explosive network severed the dispenser cleanly. The skin sections initially moved outward maintaining a parallel alignment, then rotated away from the bomblet cloud. Some collisions were evidenced by traces of bomblet paint on the dispenser halves. Twelve of the bomblets remained with the lower (lighter) skin section to ground impact.

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* As can be noted in Figure 11, the explosive skin separation network severs the dispenser in two sections. The strongback structure, the explosive backup, and the fuze remain with the upper portion, which consequently becomes the heavier portion by a factor of 3-1/2 to 1. The difference in mass results in a difference in the opening characteristics of the two halves.

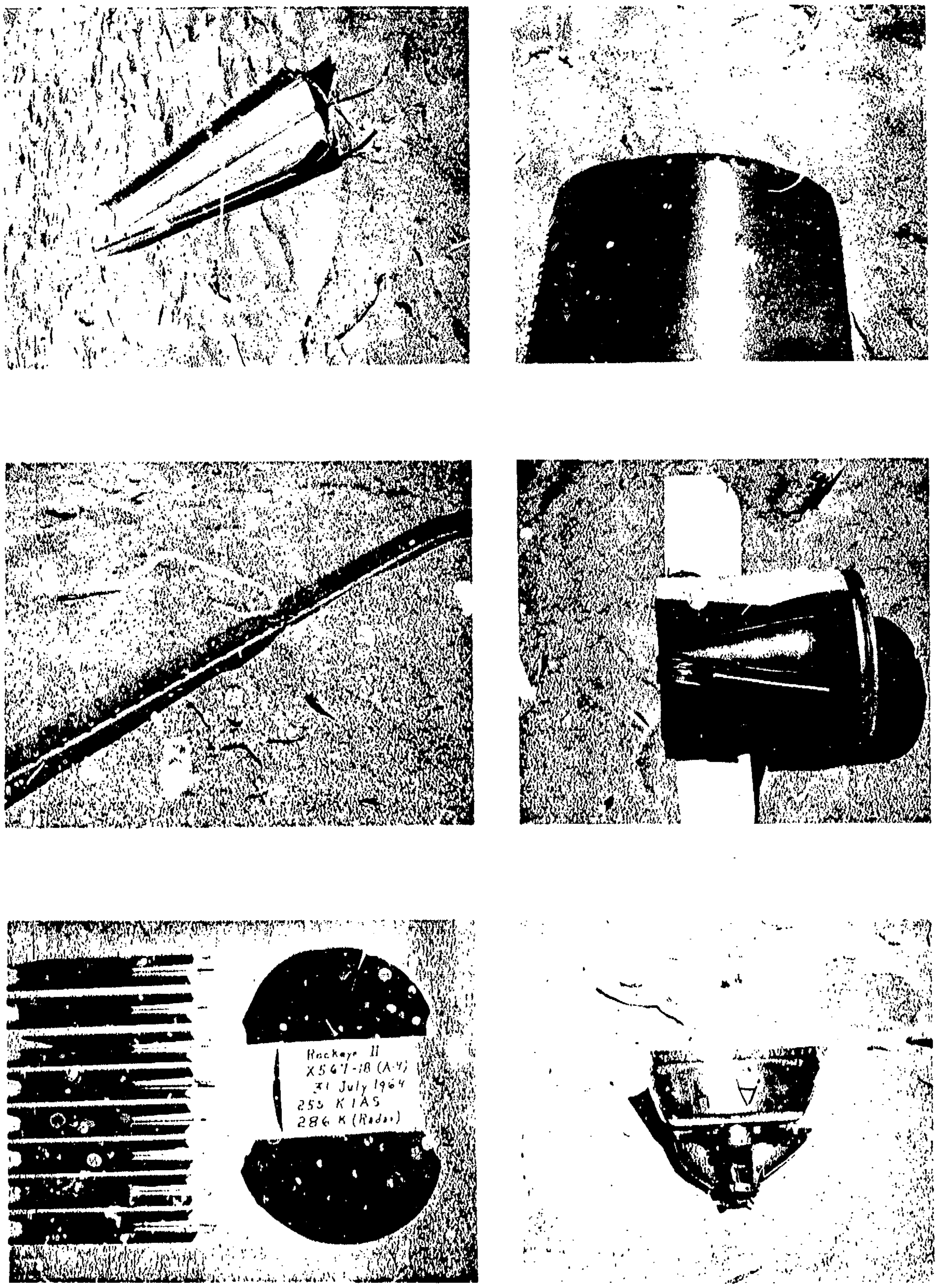

Figure 10 - WEAPON A-4 HARDWARE RECOVERED FROM TEST

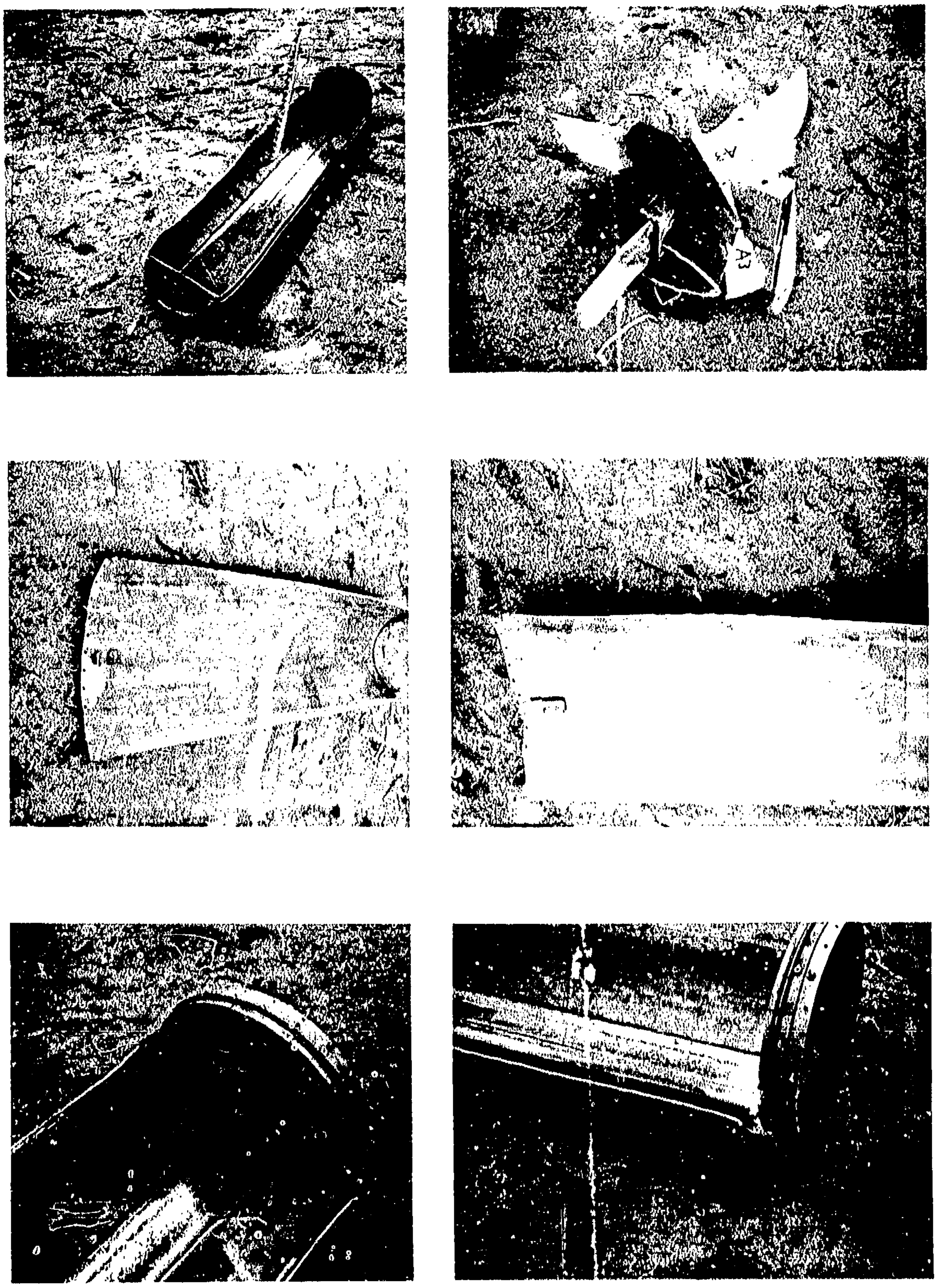

Figure 11 - TEST HARDWARE SHOWING TYPICAL DISPENSER OPENING

While the abnormal delivery conditions precluded absolute test assessments, it was felt that performance would have been better had the skin sections opened in a clam shell fashion. In attempts to assure this type of functioning even under extreme event conditions, steel cables were anchored to the dispenser/aft bulkhead interface of weapon A-7, and a pivoting hinge was fitted to A-8. In flight release tests, however, the anticipated improvement in opening was not realized, a result probably attributable to damage to the opening hardware. Neither unit demonstrated a complete clam shell opening, the skin sections in both cases lapsing into a rotary skewing motion.

Upon comparison of the test results on weapons A-6, A-7, and A-8 it was concluded that the direct, lateral release of skin sections as occurred on A-6 was preferable. This conclusion was based on the following considerations:

(1) On the films, the opening sequence appeared cleaner for A-6 than for A-7 or A-8.

(2) The number of bomblet fins damaged was about the same for all three weapons, this despite the fact that A-6 was opened under more extreme conditions.

(3) Bomblet fin damage at the rear of the cargo was greater in both A-7 and A-8 than in A-6.

Studies of the test films showed the natural tendency of the skins after being severed to translate tangentially and rotate about their lateral axes. Forcing the skins to pivot about the base produces very high skewing loads at the hinging joints, and also tends to entrap those bomblets located in the rear.

In weapons A-9 and A-10, a shortened (39 inches long) strongback was used to further reduce the mass asymmetry of the two halves, and thus improve opening characteristics. Weapon A-9 was subjected to a static load test per MIL-A-8591C to determine whether the modified strongback resulted in any degradation of the structural integrity of the dispenser. The loads were applied in increments of 20, 40, 60, 80, and 100% of the design limit. The weapon set-up for this test is shown in Figures 12, 13, 14, and 15. No deformation was sustained by the dispenser consequent to the test loads imposed, a result considered significant since no cargo bomblets were used.

In the flight tests, A-9 functioned satisfactorily, achieving a successful skin separation and good deployment of the cargo. The shortened strongback provided a more equal weight distribution between the two skin halves, thus apparently providing better opening characteristics. Bomblet fin damage was negligible, an improvement over previous performance probably attributable more to a change in the fin material (see Section IV B. 2) than to any dispenser modification. Weapon A-10 failed to function in flight test because initiation was not accomplished by the EX66 Mod 0 Fuze. The shortened strongback was used in every subsequent test weapon without failure.

In weapons B-12 through B-15, a modified hinging technique was used to determine if even further opening improvement could be effected. The modified configuration consisted of a pre-split tail cone with a 0.25-inch thick aluminum (2024-T3) plate bolted to the base. It was anticipated that this arrangement would force the dispenser halves to hinge at the aft end of the tail cone rather than at the aft bulkhead, the result being a reduction both of the skewing tendency and of the possibility of the tail section colliding with the bomblets.

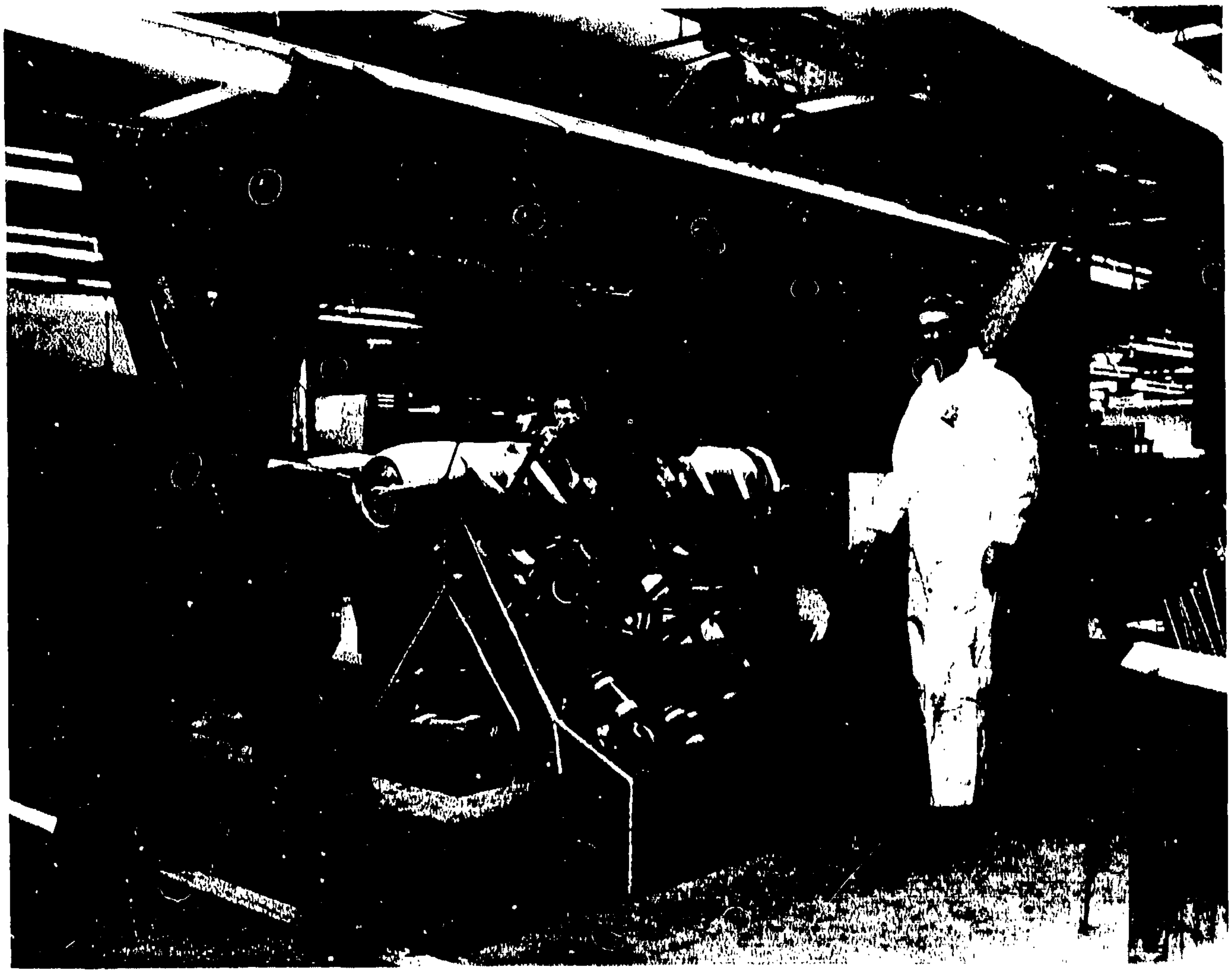

Figure 12 - TEST SETUP, WEAPON A 8

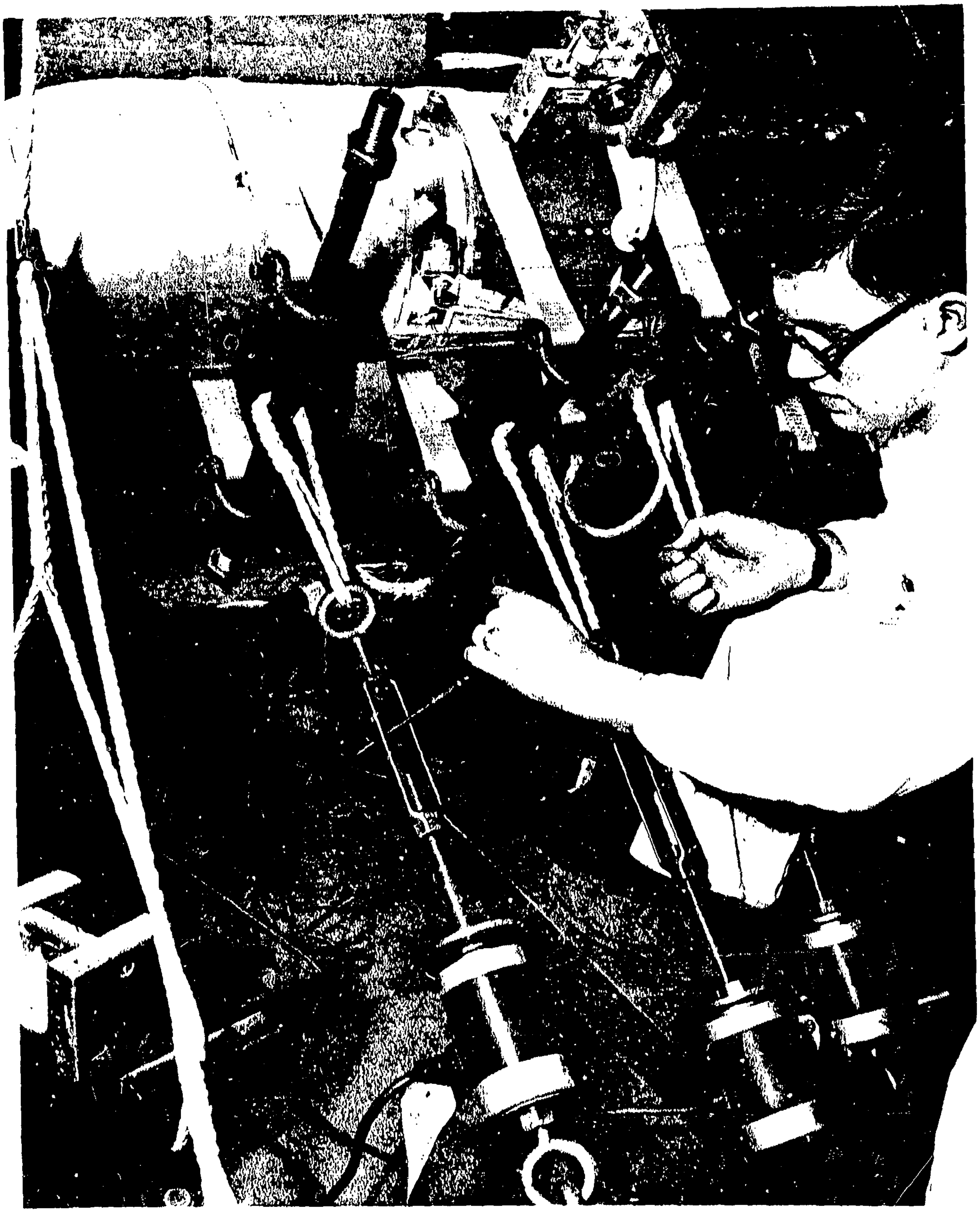

Figure 13 - TEST SETUP, WEAPON A-9

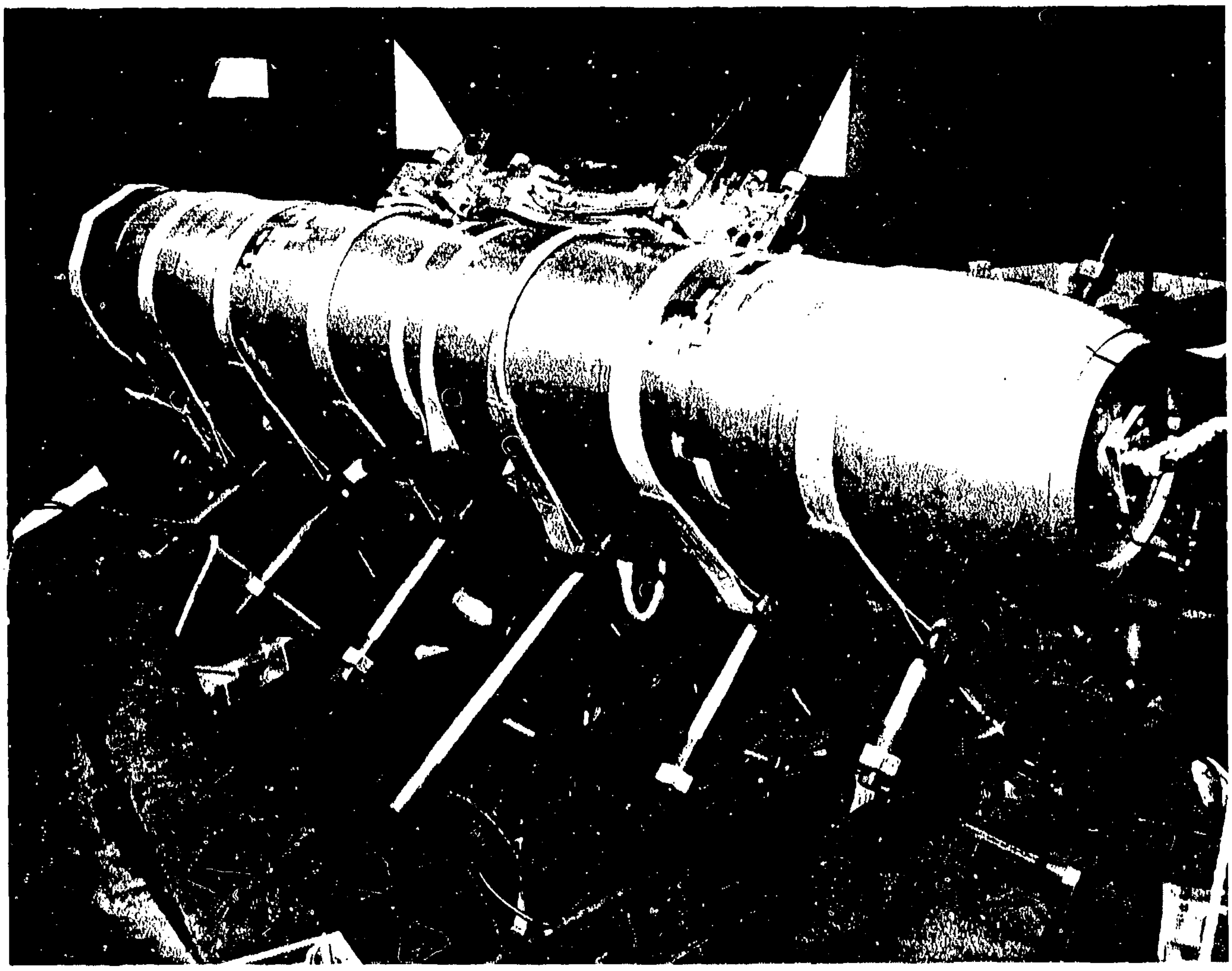

Figure 14 - TEST SETUP, WEAPON A-9

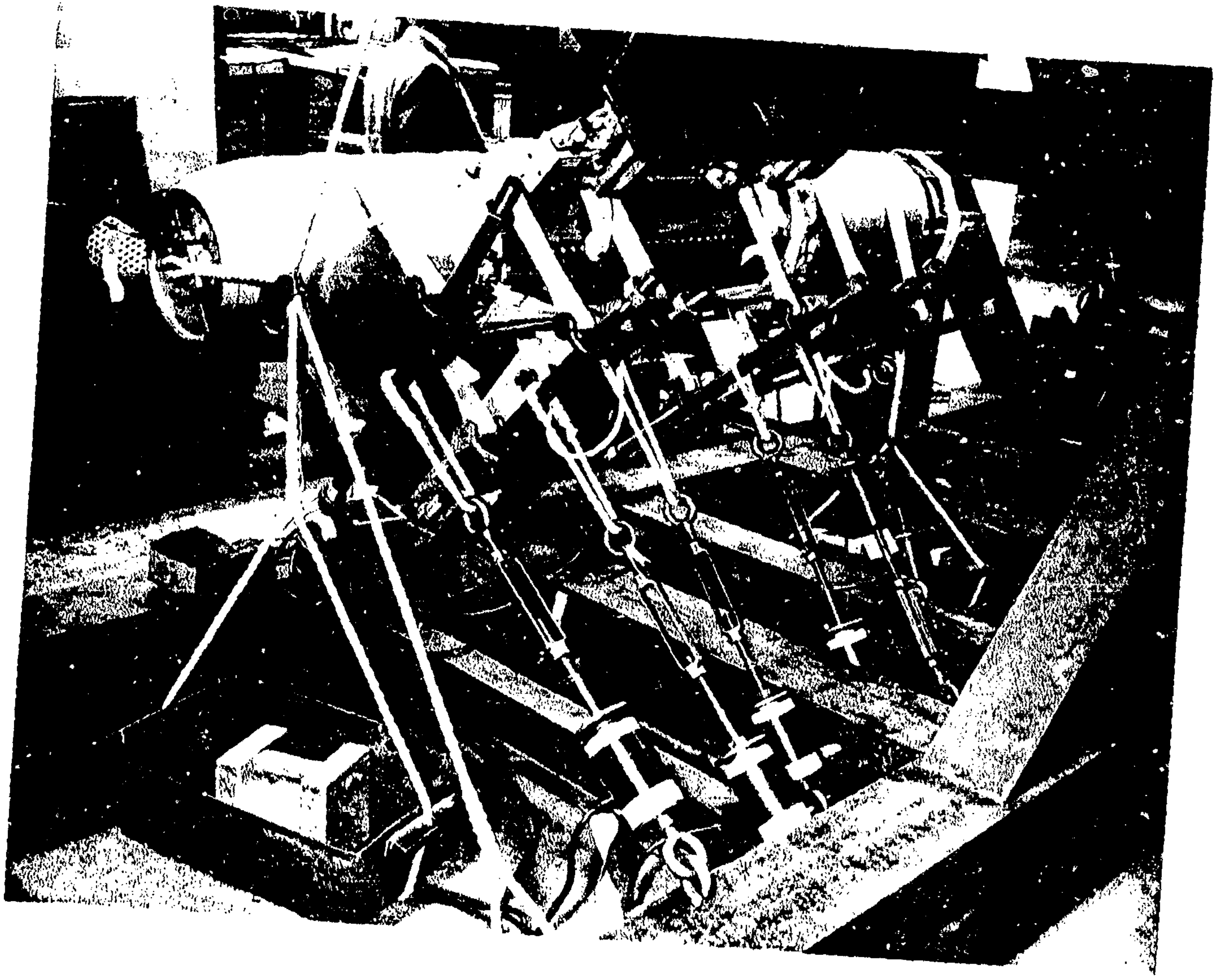

Figure 15 - TEST SETUP WEAPON A-9

In the flight tests of these weapons, significant improvement was noted in all functions related to the event cycle. The dispenser opened in classical clam shell fashion with very little skewing action. Variations in opening characteristics and dispenser induced bomblet damage were virtually eliminated in these weapons. In addition, good pattern concentrations were obtained, bomblet stragglers averaging less than 3%.

On the basis of these test results, the modifications cited in the foregoing were incorporated in the Phase III design and retrofitted in all Phase II weapons on hand.

After the strongback and AL-LSC shield designs had been fairly well finalized, the contracting agency suggested that a study be conducted to determine the feasibility of securing these structures to the skin section by plug welding rather than by screw attachments. It was felt that such a change would minimize potential leak paths as well as simplify assembly operations of the dispenser unit. Concern was expressed, however, relative to the possible annealing effect of the welds on the skin near the edge of the strongback. The structural test on weapon B-7 had indicated 31,000 psi stress levels in the skin at this location under a 155% of limit load. In addition, weld strength and integrity required complete definition for the shield application in view of the explosive forces entailed.

AL-LSC shield extrusions of 6061-T6 aluminum (more compatible with welding then the 2024-T4 aluminum used in the screw fastened shields) were procured and used in making up test specimens. In explosive tests, the shields separated from the skins in every case even though various weld patterns were used. On the basis of these results and in view of confirming data obtained in other tests, the screw fastening approach for the strongback and shields was retained in the final design. Seal screws were used to minimize potential leaks.

c. Cargo Packing Considerations

Cargo packing spacers are used to ensure a cohesive and, to the extent necessary, a rigid cargo pack. The spacers also provide protection to the bomblet against physical damage as a result of normal storage, handling, loading, and aircraft storage conditions.

The configuration of the various spacers used was determined on the basis of volume voids after the cargo pack had been defined. In the preliminary approach packing spacers of polyurethane foam, molded to interface the cargo bomblets and the dispenser structure, were used around the periphery of the pack. The nose portion of the bomblets rested against a metal covered plastic spacer. This spacer configuration was found adequate in terms of cargo rigidity and protection during ground testing.

In flight tests, however, as noted in the previous section, the fuze and AL-LSC outputs rammed the forward spacer into the bomblets. To preclude bomblet damage, wooden (and subsequently nylon) spacers were added ahead of the cargo to prevent munition contact with any forward metal structure. The resulting packing configuration at the forward bulkhead is shown in Figure 16. This was the only modification of significance made to the design of the packing spacers during Rockeye II development.

The original design objective with respect to the cargo configuration was to evolve a spacer-cargo interface that could be pre-packed and inserted into the dispenser as a unitized assembly. This objective was attained with development of the loading tray and packing arrangement shown in Figure 17. In this approach a full cargo load of bomblets is assembled on the loading tray. With the longitudinal spacers added, the entire cargo unit is inserted into the dispenser in one operation as shown in Figure 18. Two polyurethane spacers,

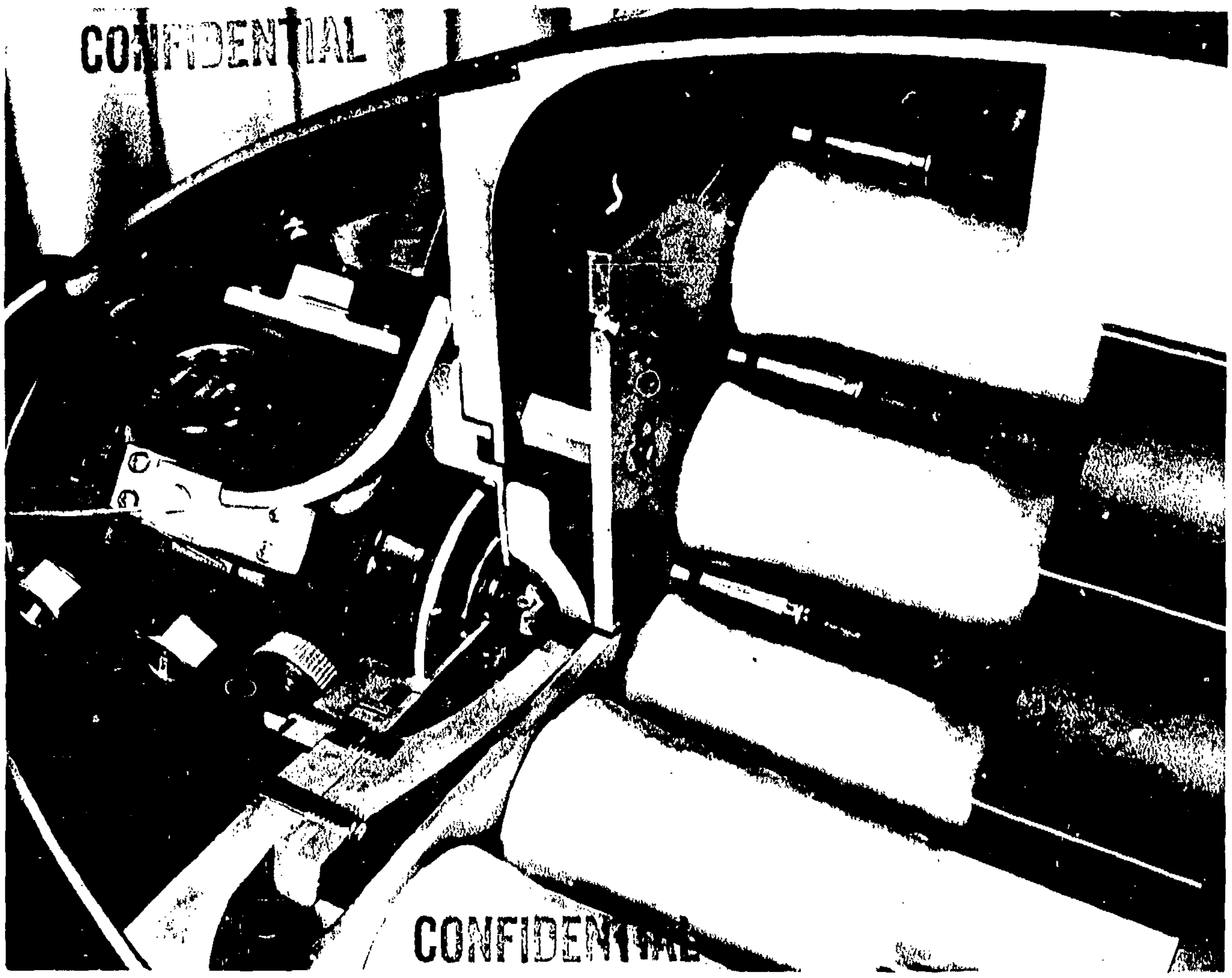

Figure 16 - BOMBLET PACKING INTERFACE, FORWARD BULKHEAD

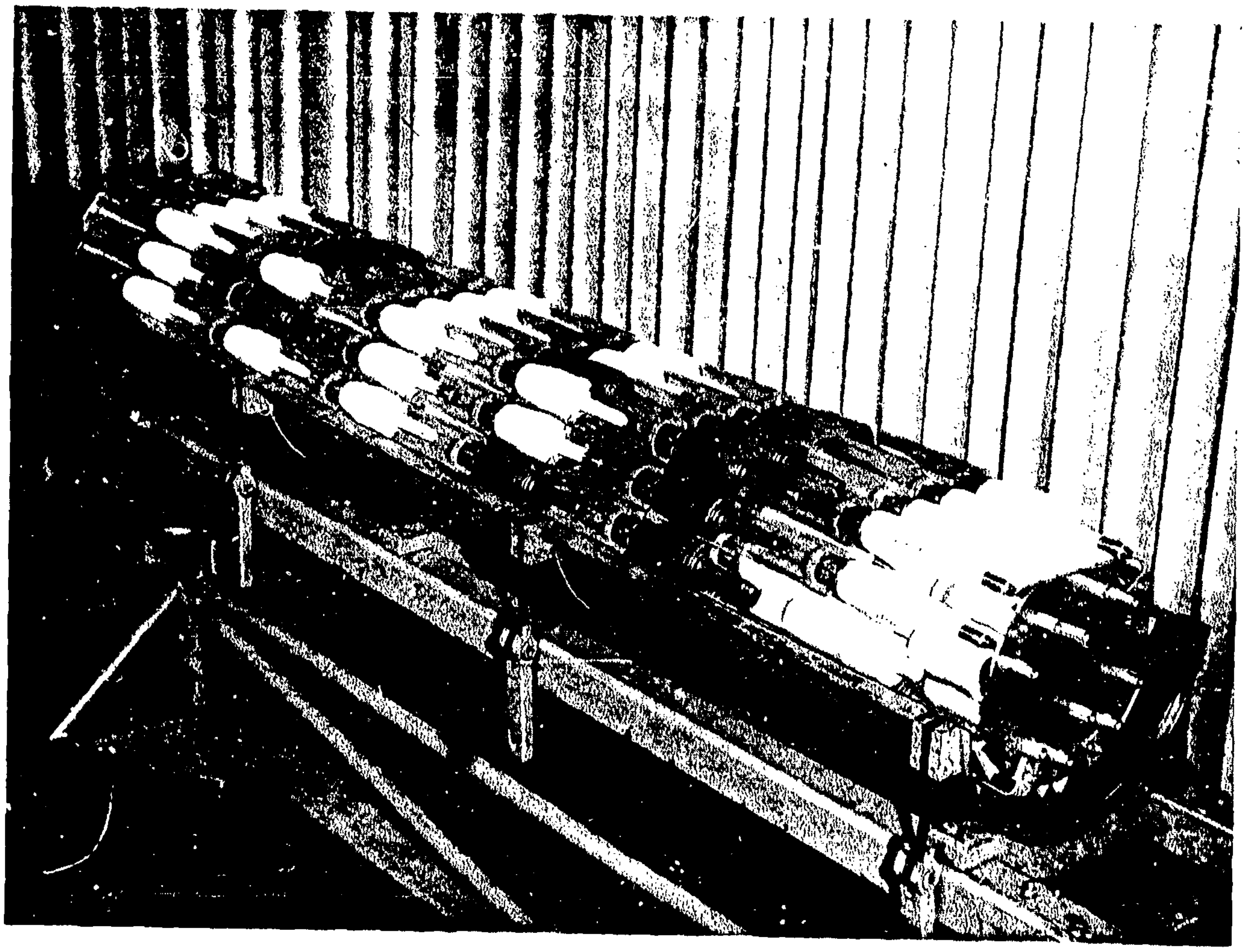

Figure 17 - DISPENSER LOADING TRAY

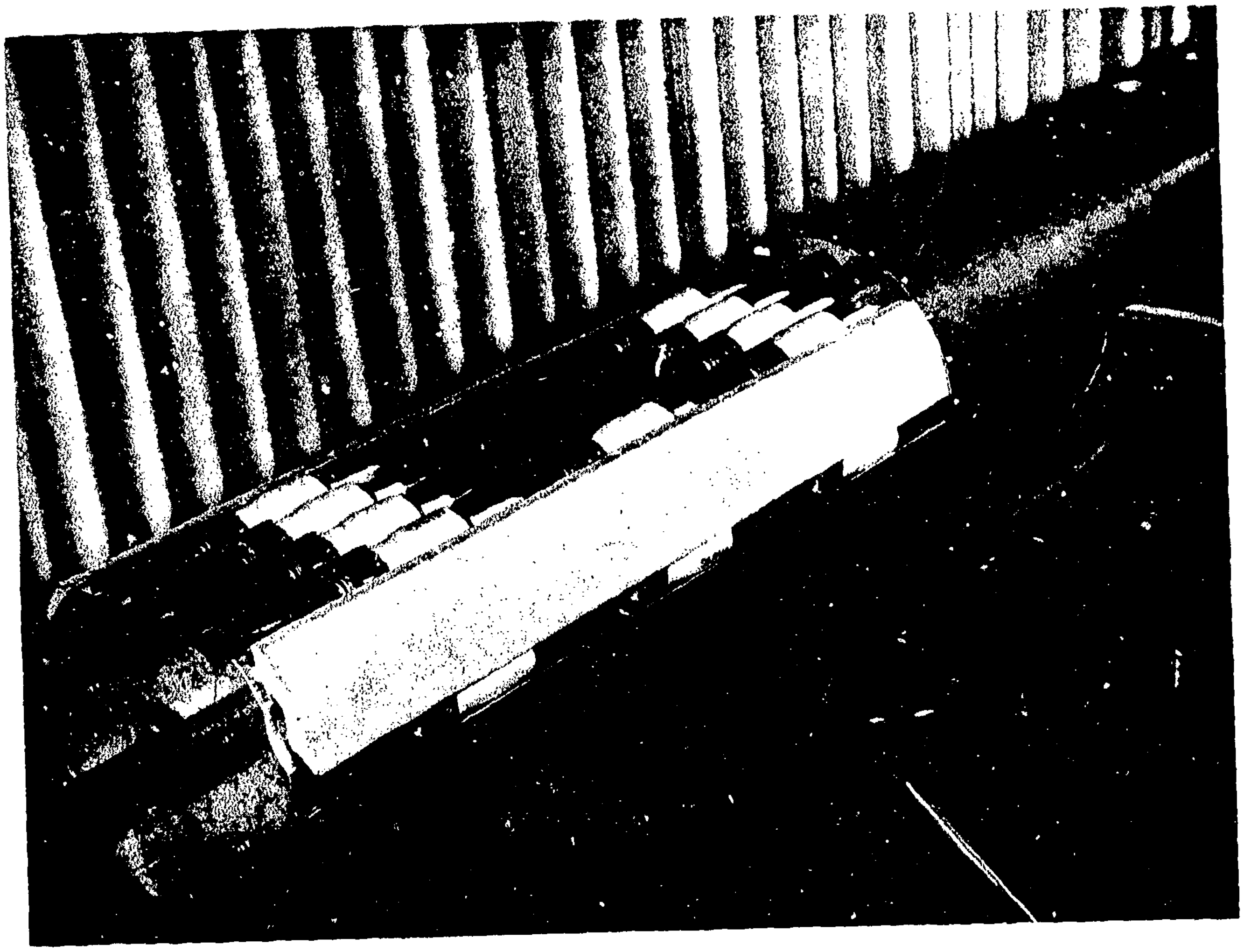

Figure 18 - LOADING BOMBLETS INTO DISPENSER

one ahead of and one behind the strongback, are installed in the dispenser itself (see Figure 19) before the cargo is loaded. With the cargo fully seated, the forward plate is attached to the forward bulkhead with seal screws to provide a firm forward support surface for the cargo. Support at the aft end is provided by individual spacers that hold the bomblets away from the sealing plate as shown in Figure 20.

The contracting agency specified a cargo load of 223 bomblets as a development objective. Through maximum utilization of space, a load of 247 Rockeye II units was achieved. An important factor in this achievement was the development of a bomblet configuration having an effective interface nesting capability. This is discussed in detail in the bomblet section of the report.

Several dispenser design features also contributed to the high packing efficiency realized in the final design. Offsetting the explosive network shields approximately 17° from the horizontal resulted in a shield location that would not interfere with a maximum bomblet load. Increasing the dispenser diameter to 13.2 inches provided the additional space required to accommodate the most efficient cargo package. By stressing design simplicity, engineers were able to provide packing spacers meeting all functional requirements without reducing the cargo load.

d. Explosive Skin Separation Network

The explosive skin separation network extends from Station 6.4 to Station 78.0 and consists of the explosive used to sever the skin section and the retaining and protective structure for those explosives. The network is activated by the dispenser fuze and provides a means for freeing the bomblets for dispersion.

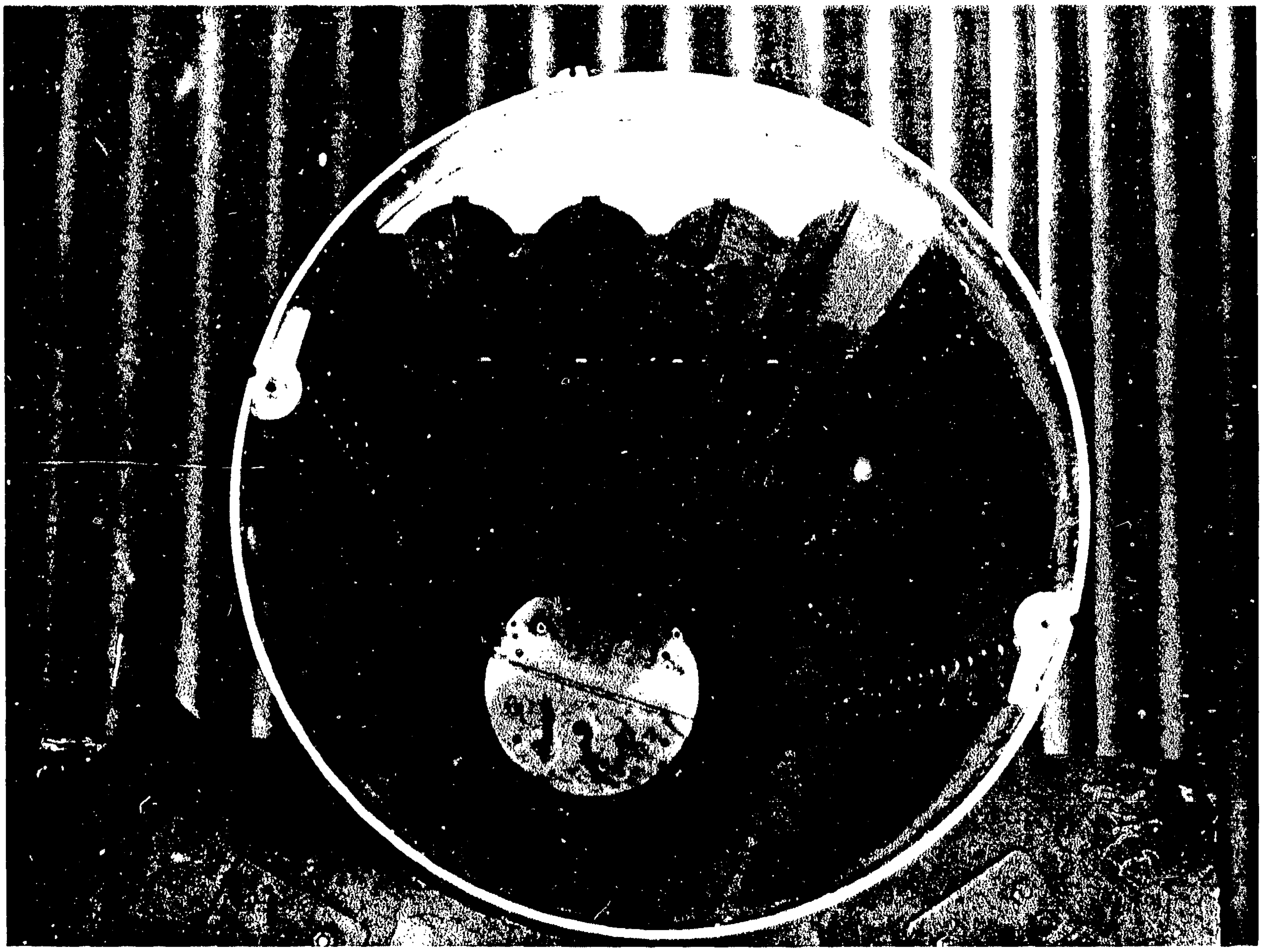

Figure 19 - POLYURETHANE SPACERS ADJACENT TO STRONGBACK

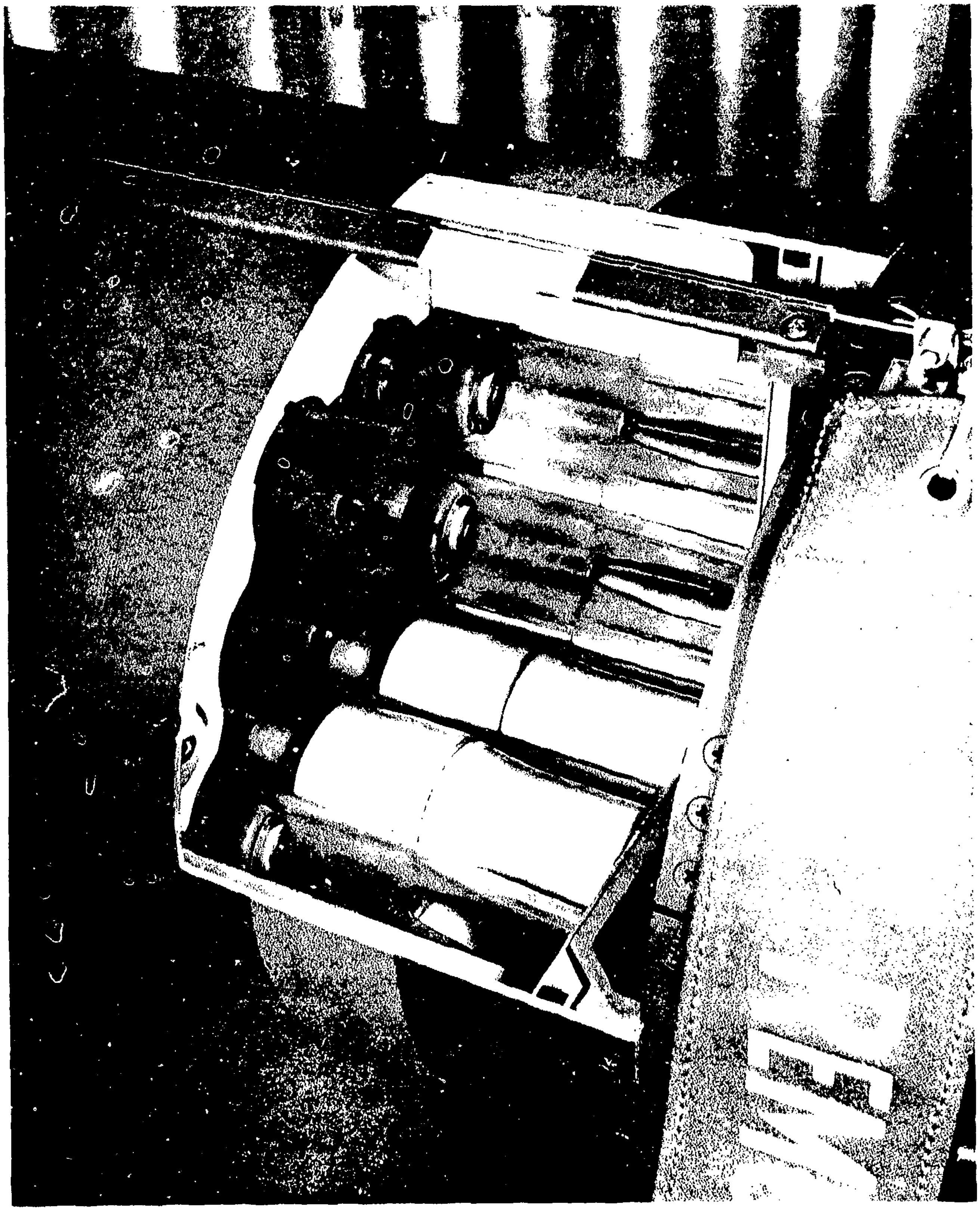

Figure 20 - CARGO SPACERS AT SEALING PLATE

The preliminary design approach is shown in Figure 21, which is annotated to indicate design changes made up to weapon A-4. It is noted that the longitudinal strands are off center; i. e., are located 17° out from the 90° and 270° positions as viewed from the nose section. This mounting arrangement was selected because a cargo packing study had disclosed that the explosive networks shields would least interfere with the cargo load if located in these off center positions. In addition, this orientation provided the most effective dispenser opening.

The major difference between this preliminary configuration and the proposal design was in the type of explosive used - Primacord in the earlier concept, flexible linear shaped charge in the preliminary design. Initial testing had disclosed that Primacord produced backblast sufficiently severe in intensity to constitute a damage hazard to the cargo munitions. Fifty-grain per foot FLSC exhibited significantly less backblast; and, in addition, the use of FLSC enabled more even cuts along the skin surface. Consequently, the change was made to 50-grain FLSC.

The functional sequence of the explosive skin separation network in this preliminary design is described in the following paragraphs.

The explosive skin separation network was initiated by the EX 66 Fuze. At the expiration of a pre-set time delay, the fuze fired a MK 43 Mod 0 detonator that propagated to an RDX lead column (the initial element in the dispenser explosive network) which then transmitted to an RDX booster. The booster initiated two X-310 primers that detonated two strands of MDF, these units in turn firing, through X310J end primers, an RDX detonating cord that fractured the front bulkhead and two strands of FLSC that severed the cargo section longitudinally to the tail section. A circumferential strand of FLSC at this location severed the tail assembly from the workload.

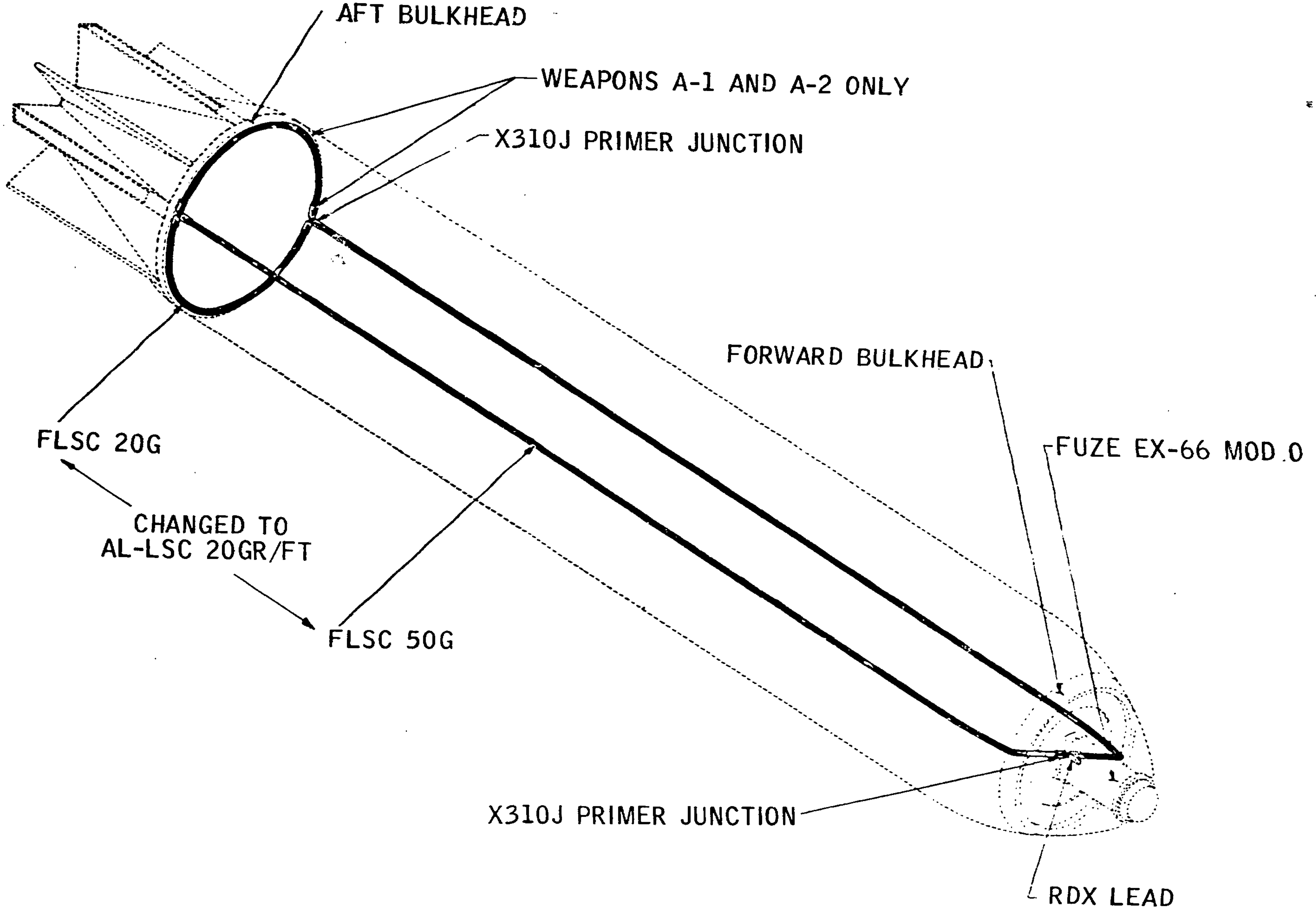

Figure 21 - EXPLOSIVE TRAIN

The two X-310 primers interfacing the lead element provided redundancy of function in that initiation of either of these units would result in explosive dissemination throughout the network.

Testing to determine the reliability of this configuration in propagating across joints and in cutting the dispenser skin and structure was initiated as soon as the design was established. Early testing showed that the 50-grain FLSC backblast was also severe enough to cause cargo damage, particularly to the bomblet fins. The explosive charge of the FLSC was reduced from 50 to 20 grains per foot, and an aluminum backup shield was used to replace the original rubber backup. These modifications decreased backblast to such an extent that bomblet fins in direct contact with the shield sustained no damage when the FLSC was detonated. A parallel series of tests established that the 20-grain/foot FLSC would reliably cut the skin section. Concurrently with these modifications, the lead FLSC was changed to aluminum FLSC (AL-LSC), which provides cleaner skin cutting, less backblast, less sensitivity to tolerances in standoff distance, eliminates the corrosion problem that exists with lead, and is considerably lighter.

Preliminary testing was completed on all other interfaces of the network, and minor problems were encountered and resolved. Improvements were made in the method of securing the AL-LSC to the dispenser and in the propagation interface at various joints.

In the preliminary design and tests, RDX was used in all network components except the X310 primers. During a technical review meeting with NOTS personnel, it was jointly agreed that using CH-6*, a less sensitive explosive, in the network in lieu of RDX would provide an end item more compatible with Navy safety requirements.

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* CH-6 is essentially RDX that has been mechanically desensitized (crystals coated) to provide a safer and more stable explosive.

In the transition from RDX to CH-3, it was anticipated that some modification of the explosive configuration might be required. Of particular concern were propogation interfaces and the grain loading required to ensure complete severence of the skin section. Ten X-310V primers loaded with CH-6 were obtained in April 1964, and testing disclosed that much higher inputs were required to initiate these units than the RDX primers. Consequently, use of CH-6 primers at propagation points would have required stringent control over the air gap distances.

Subsequently, a design concept in which Detasheet was used as the explosive interface between the fuze lead output and the AL-LSC and in which the Station 78.0 circumferential cut was eliminated, thus enabling elimination of all primers from the system, was evolved. Cord type Detasheet C was obtained and tested in this configuration, and it was determined that fuze lead-to-Detasheet propagation would be assured only if the two were in direct contact. Since this condition could not be guaranteed during long term storage and handling of the dispenser and removal and replacement of the fuze, alternate design approaches were investigated. Ultimately, it was found that a CH-6 booster enclosed in a thin wall aluminum cup similar to the lead and secured in the shaped charge "V" groove opposite the fuze output provided a satisfactory propagation bridge. Initiation with this interface was accomplished repeatedly across relatively large air gaps. In addition, the reliability of this configuration was not subject to degradation as a consequence of dispenser storage handling conditions or fuze installation and removal.

The CH-6 booster configuration was subsequently specified for the Phase II dispenser design. Concurrent testing had established that a CH-6 load of 20 grains per foot would reliably cut the dispenser skin; and this load was, therefore, specified for the shaped charge. The shaped charge was to be procured already contained in irradiated, low density polyethylene mounting strips with built in standoff to simplify installation. Previously the shaped charge had been mounted in the AL-LSC at Honeywell using mechanical staking and adhesive bonding. In addition, the proposed elimination of the circumferential cut at Station 78. 0 was effected in Phase II units. In the flight test of A-4, it was proved that this cut is not necessary provided alternate means are used to ensure structural failure between the skin section - tail assembly interface at dispenser event.

The configuration as evolved up to this point was such that it was necessary for the AL-LSC to be installed during mounting of the backup structure. Acting upon a recommendation by NOTS representatives, engineers conducted an investigation to determine whether the AL-LSC could be inserted after the backup structure had been emplaced. Development of such a technique would enable all hardware assembly to be completed at the contracting facility and all explosives installation to be made at the loading plant.

Difficulties were encountered in installing the semi-rigid AL-LSC, and use of the more flexible FLSC was considered. Tests, however, demonstrated that FLSC produced a significantly greater backblast than AL-LSC and would require additional backup structure to protect the cargo. FLSC was, therefore, dropped from further developmental considerations.

Subsequently, it was determined that inserting the AL-LSC in two strands that butted together at the fuze interface facilitated loading. Testing disclosed that the butted strand could be initiated with the lead/booster unit, although some diminution of reliability was entailed. To ensure a high propagation reliability for this interface, engineers investigated alternate loading techniques; and it was determined that minor modifications to the structural hardware enabled loading the AL-LSC in a single strand with special tools. The modifications consisted of enlarging the clearing groove in the shields and moving the joint between the left and right shield to the centerline directly below the fuze output. The configuration was used in weapons C-31 through C-60.

e. Fuze and Fin Arming System

The fuze and fin arming system consists of those components required to initiate the fuze arming sequence and release the tail fins upon dispenser ejection. In the proposal document, it was recommended that conventional arming wires running from the fuze and fin locations through internal conduits to outlet positions convenient to the arming solenoids be used. Subsequently, the contracting agency proposed evaluation of a fuze arming device that would prevent arming unless the dispenser was free of the bomb rack and would provide the pilot with two time options for fuze setting.

A sketch of the device is shown in Figure 22. The assembly basically functions as a sensing mechanism, precluding arming when contact with the rack is felt and permitting arming when no contact pressure is sensed. The unit would be structurally secured to the dispenser strongback, and arming lanyards would be routed through conduit to the fuze location in the nose section. After securing the dispenser to the aircraft, the ground crew would insert the ends of the arming wires in the T_a and T_b keeper holes (Figure 22) and hook the other ends to the proper arming solenoids. Removal of the safety pin would complete the installation.

In evaluating the practicability of incorporating such a device in the dispenser, engineers found several design problems, the most difficult of which was providing physical compatibility with the various bomb racks specified for the Rockeye II. The most feasible common sensing point, considering the dimensional variations between the applicable racks, would probably be up through the support lug on the 14-inch suspension system. It was felt that use of this location (the concept sketch, Figure 22, is based on sensing at the support lug) would eliminate the necessity for a detailed investigation of bomb rack dimensional characteristics with relation to a common sensing point. The support lug location was, however, incompatible with the NATO single-lug suspension system.

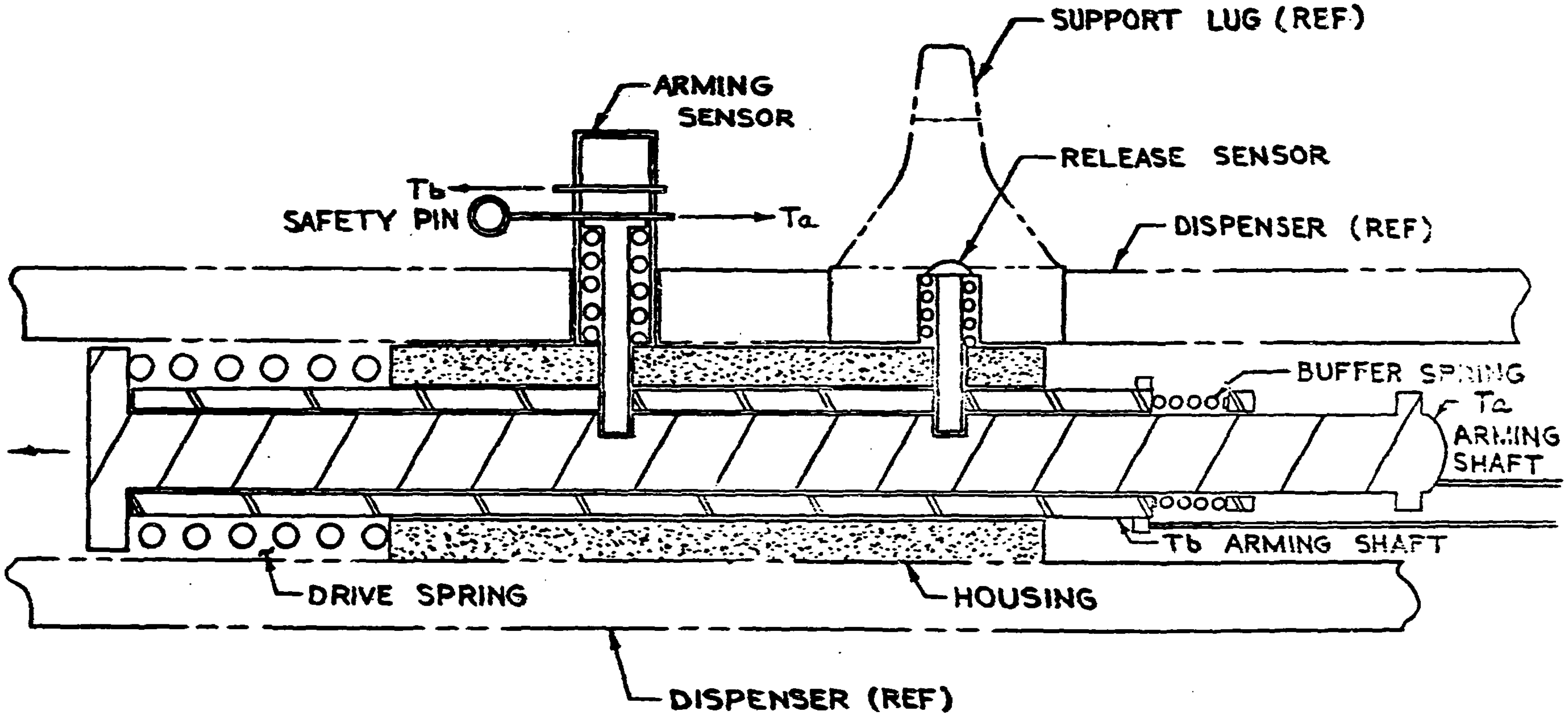

Figure 22 - SCHEMATIC OF ARMING MECHANISM AND RACK SENSOR

The external extension of the sensing device was determined to be unacceptable because of bomb rack clearance restrictions. Consequently, such a device would have to be recessed into the strongback structure. More than one device or multiple sensing outlets would have to be provided to ensure compatibility with the solenoid locations in the various bomb racks. Both requirements -- recessing the device and providing multiple sensing points -- would increase the weight, cost, and complexity of the dispenser and could significantly affect weapon reliability.

In addition, it was found the proposed device would only partially resolve any previously experienced arming wire problems. The arming wire of the sensor device was as amenable to accidental withdrawal as a fuze arming wire. While the rack sensor could prevent an event function when the dispenser was attached to the aircraft, it could not prevent function once the dispenser was released. The pilot might, then, jettison the dispenser in what he thought to be a safe mode, only to have the dispenser arm and event, possibly over friendly troops.

On the basis of these study findings and with the concurrence of the contracting agency, the sensor arming device was dropped from further developmental consideration. The preliminary design of the arming system then became essentially the same configuration recommended in the proposal document, i. e., stainless steel arming wires running from center dispenser locations through conduits to nose (fuze) and tail (fin) section outlets. The intersection of arming wire and fuze is shown in Figures 23 and 24.

This design configuration was tested and performed successfully in early A-series weapon tests. However, shifting of the arming wires to accommodate rack-solenoid positions was difficult. Design evaluation disclosed areas of possible improvement; a modified arming interface incorporating these

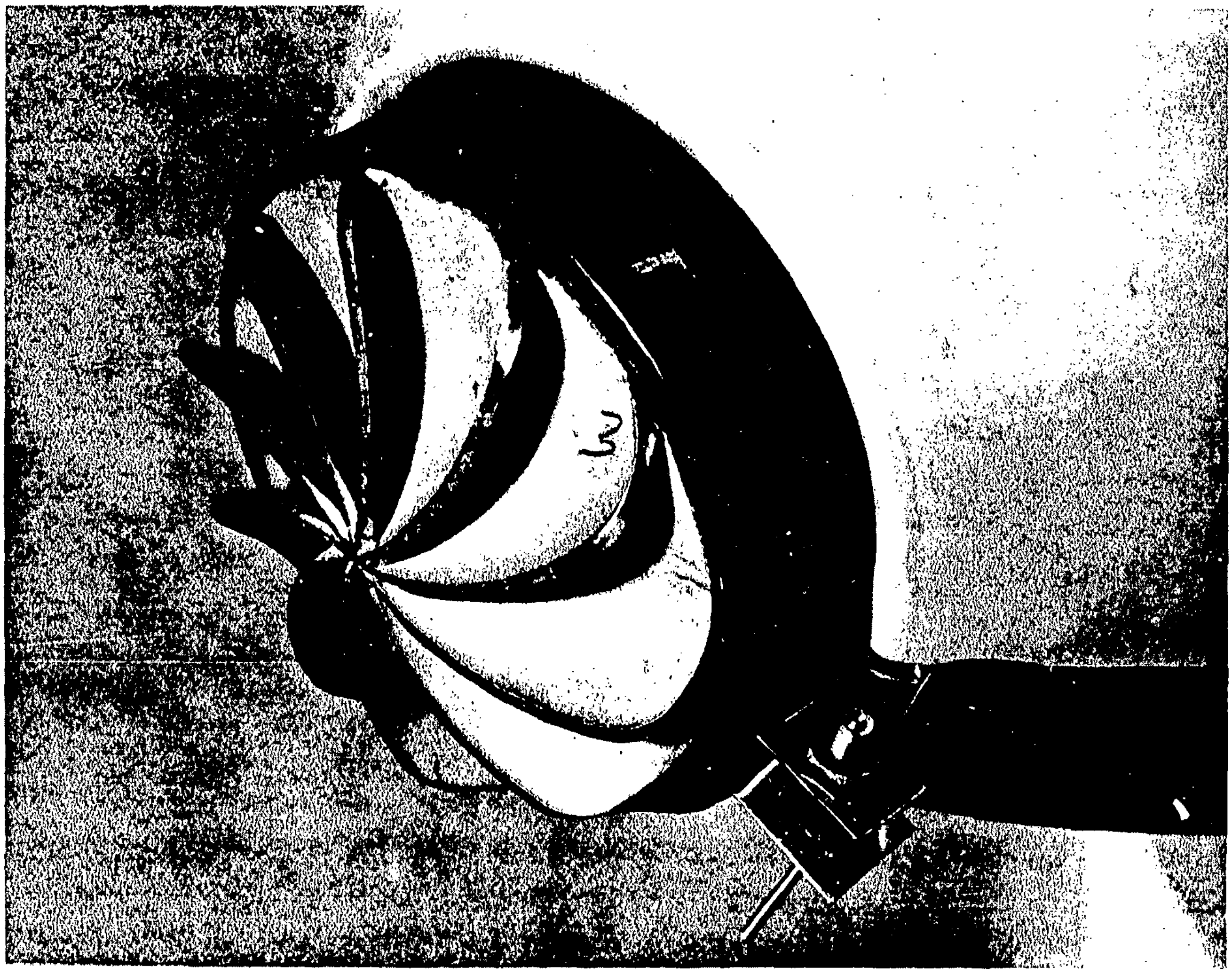

Figure 23 - ARMING WIRE - FUZE VANE

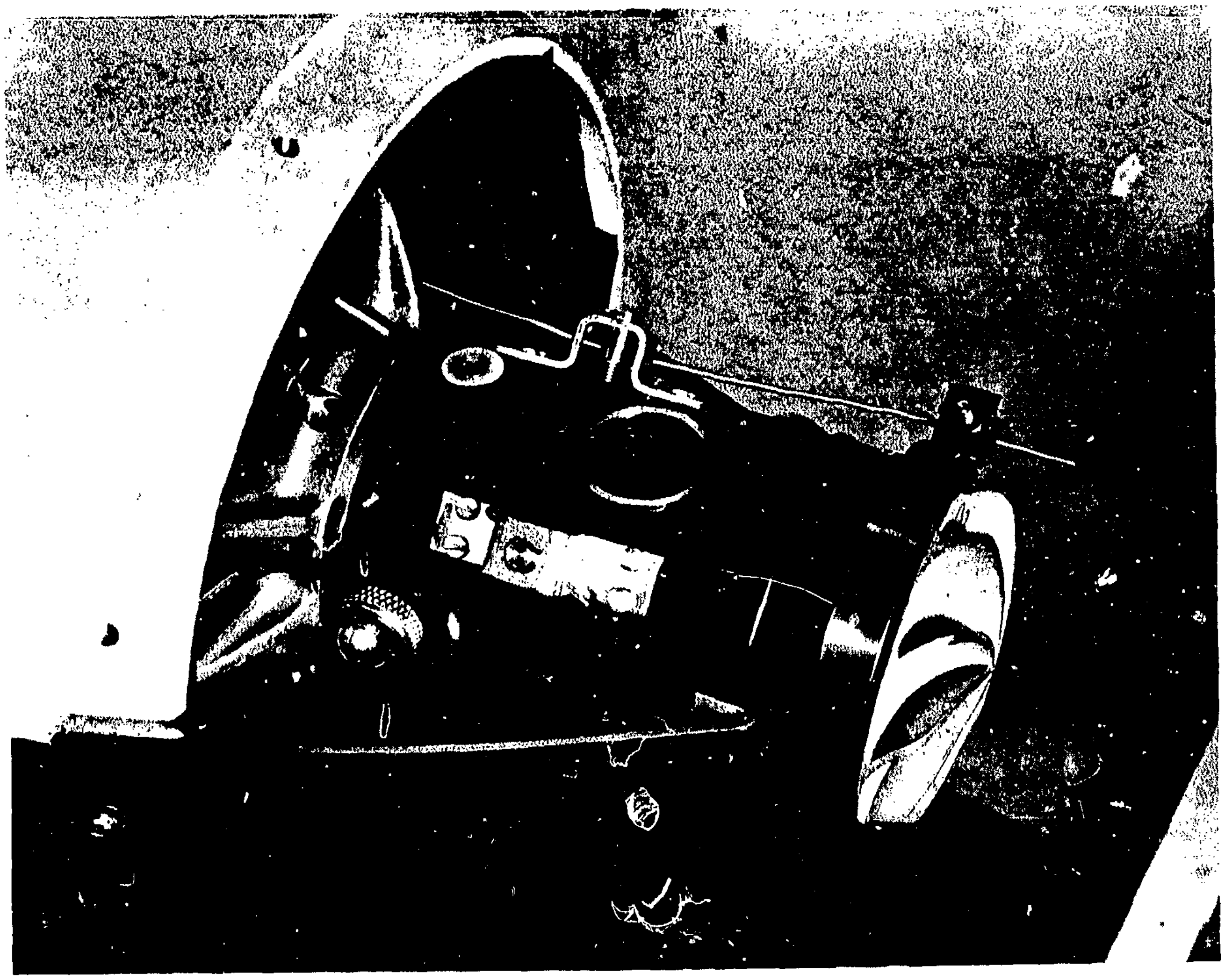

Figure 24 - ARMING WIRE - FUZE

improvements was developed in October 1964. The revised approach used a flexible cable attached to a solid wire by a small tapered sleeve joint as the arming wire. This combination retained the shear strength and fatigue characteristics of the previous design, but permitted the wire to be retained by the weapon after release rather than remaining with the aircraft. This was a significant achievement considering the possible aircraft damage that would be inflicted by the stainless steel arming wires of the Rockeye II dispenser. In addition, it eliminated the necessity of removing and reinstalling the wires for various bomb racks.

The wires remained internal to the weapon (routed through the strongback as previously) except for small loops that protruded out of the top the dispenser at locations providing compatibility with the various rack solenoid positions. A short clip-on swivel was snapped to the appropriate loop and inserted into the solenoid. The solid wire end of the combination was inserted in the fuze or fin mechanism, and the flexible end was securely attached by a loop to a pin joint inside the center hole of the strongback. Upon release of the weapon, the two flexible wires doubled out of holes in the top of the dispenser until the flexible wire extracted the solid wire from the aperture. The clip-on swivels and the loops were the only components remaining attached to the bomb rack solenoid.

Prototype samples of the modified arming wire were fabricated and strength tested, but functional checks revealed that excessively high pull out forces were required for wire extraction. The design was subsequently modified to incorporate an external conduit system consisting of grooved aluminum extrusions, mounted slightly offset from the dispenser top centerline on the outer skin surface, for the arming wires.

Teflon tubing was used to encase the arming wires to provide an interference fitting with the opening in the groove of the aluminum extrusion. This arrangement protected and secured the wires in the groove under airload and vibration conditions but allowed the wire to strip out when pulled by a short extension lead to the bomb rack solenoid. The wire and tubing could easily be reinstalled in the groove if accidentally pulled out in handling operations.

The extension lead and conduits in this design are shown in Figure 25 and the intersection of the arming wire with the fuze is illustrated in Figure 26.

The external conduit arming wire system provided the following advantages over previous design:

(1) Eliminated the possibility of damage to the aircraft by retaining the wires with the weapon.

(2) Eliminated the necessity for reinstalling wires for various bomb rack solenoid locations.

(3) Improved weapon sealing by reducing the number of leak paths into the cargo section.

(4) Reduced weapon cost by simplifying structure.

The external conduit approach created some problems in bomb rack compatibility which were subsequently resolved by cutouts for the swaybraces and ejector pistons. The modified arming design was incorporated in late A-series weapons and was used in all B-series dispensers. No arming wire failures were encountered in these tests. The external conduit represents the final design configuration of the arming system.

A patent application has been filed on the external conduit arming wire system.

Figure 25 - ARMING WIRE CONDUITS

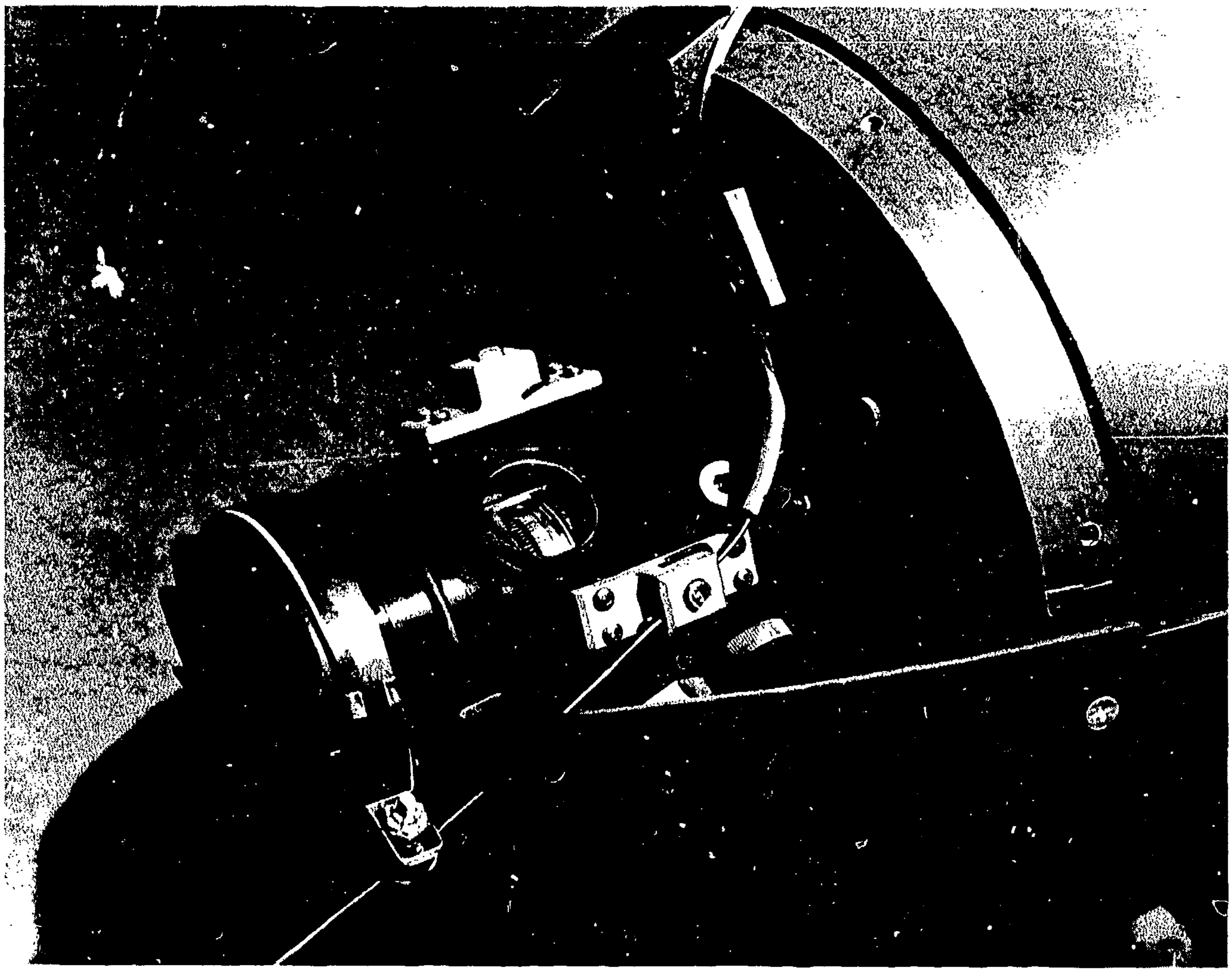

Figure 26 - ARMING WIRE CONDUIT AT FUZE INTERFACE

f. Tail Section Assembly Development

The tail section runs from Station 78.0 to 91.0 and consists of the aft bulkhead; the tailcone case; spring loaded folding, canted fins; and a mechanism to deploy the fins to the fold-out position. The assembly provides structure to complete and seal the cargo section; and the fins, which are folded to clear the aircraft and bombrack in flight, rotate outward to stabilize and rotate the dispenser after release. The spin of the dispenser imparts a centrifugal force to the cargo that facilitates bomblet dispersal at weapon opening.

Upon award of the contract, a series of analyses and studies to evaluate the aerodynamic compatibility of the proposal document fin design (four folding fins, 4° fin cant) was initiated. It was theoretically determined that the dispenser with this fin configuration would be unstable during the brief period in the flight regime between aircraft release and fin deployment and the predicted instability was sufficient to constitute a possible aircraft interference problem. Consequently, safe separation criteria were established as shown in Figure 27 based on clearance of a horizontal plane passing through the dispenser rack attachment points.

The pitching attitude of the proposal dispenser-fin configuration resulting from free release is shown in Figure 28 superimposed on the boundary curves of the safe separation graph. As can be seen from this figure, the fins would have to be deployed at a vertical separation distance of greater than 1.5 feet (to ensure safe separation) at a launch velocity of Mach 0.9 and an initial pitch altitude of -2° with respect to the aircraft. At this distance, the dispenser would have an undesirable pitch attitude of -15° and would be tumbling at the rate of -2.5 radians/second. The behaviorial patterns reflected in this figure represent conservative estimates since interference

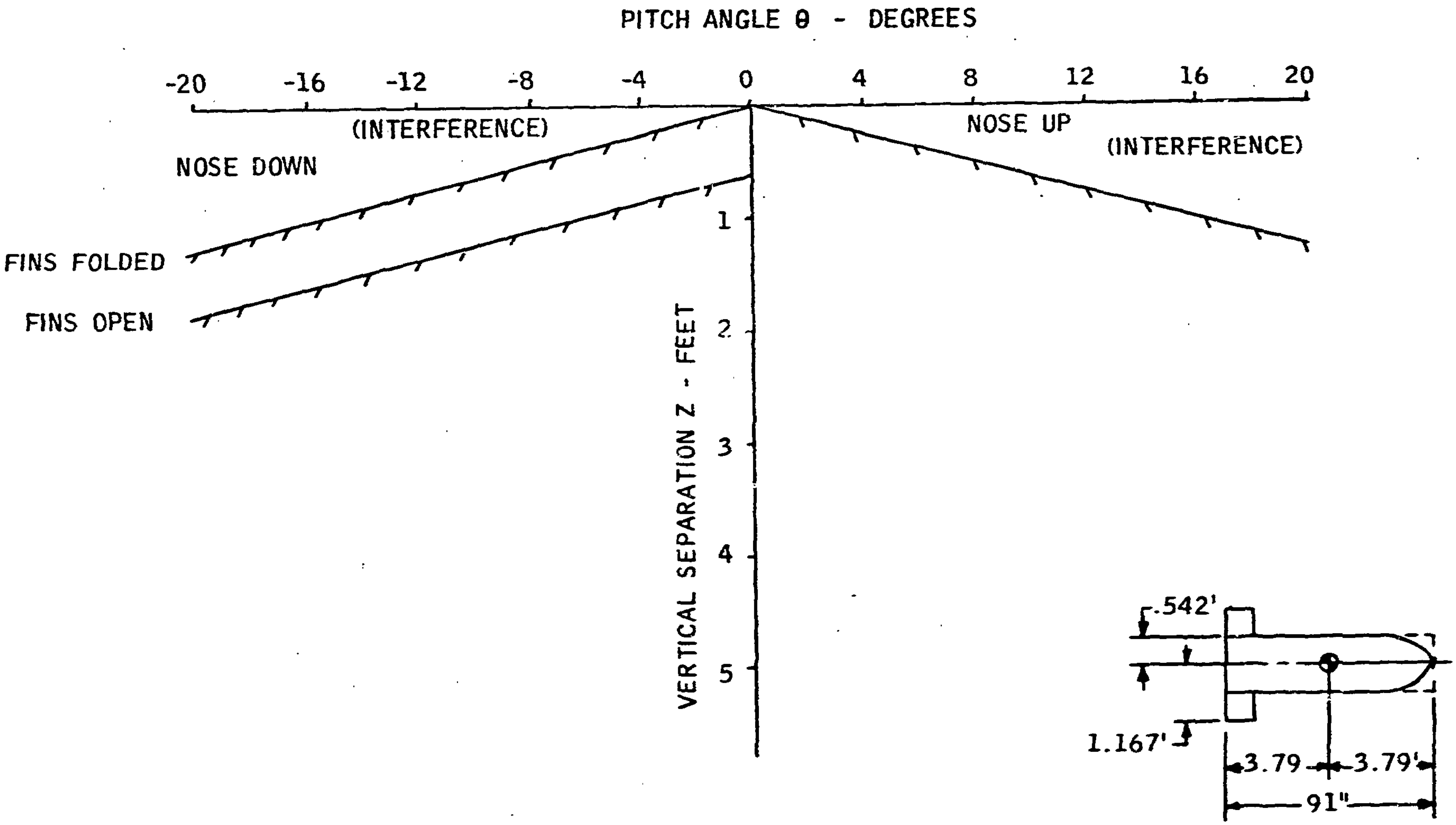

Figure 27 - SAFE SEPARATION CRITERIA FOR CONFIGURATION SHOWN

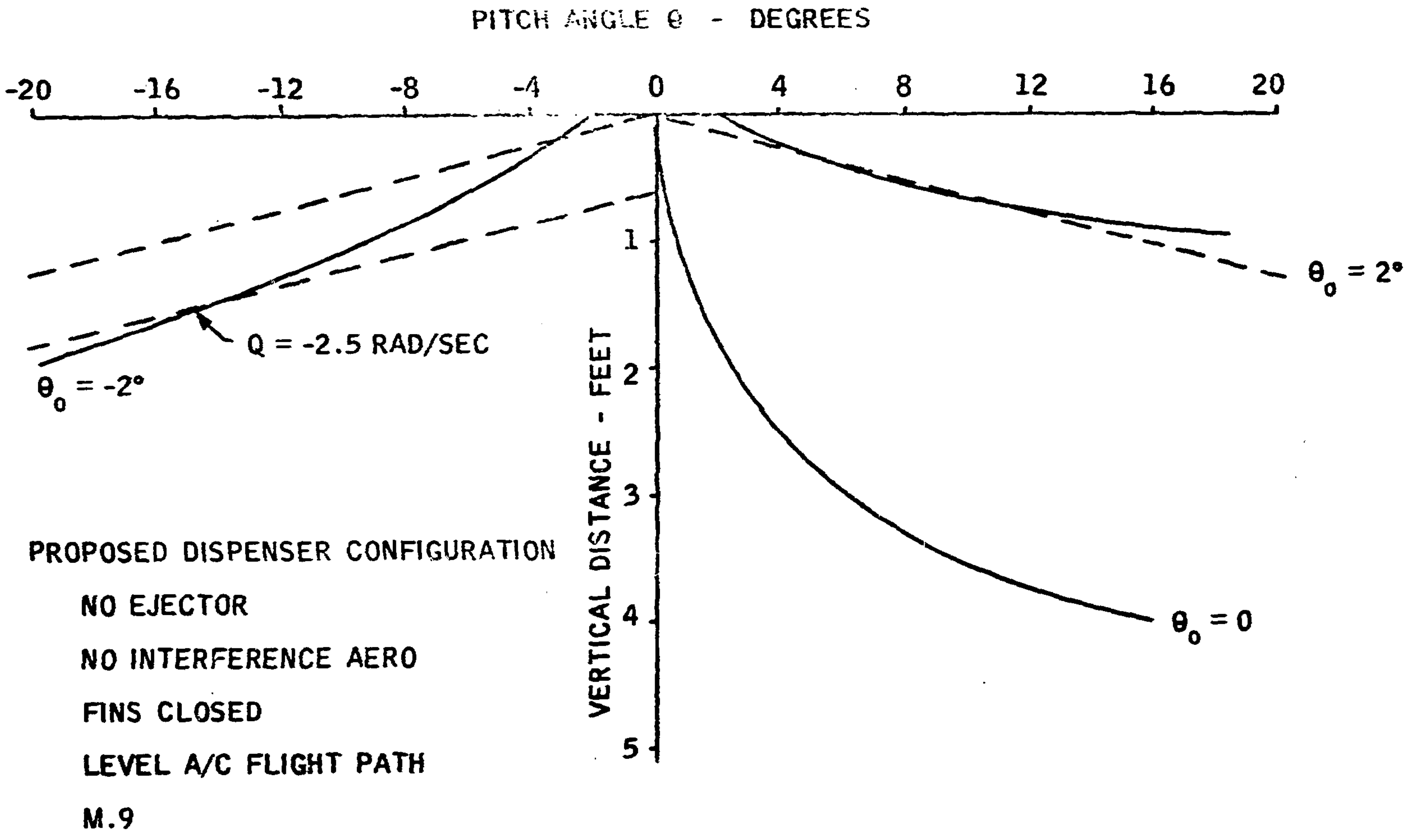

Figure 28 - VERTICAL DROP DISTANCE OF DISPENSER C. G. VERSUS DISPENSER PITCH ANGLE FOR PROPOSED CONFIGURATION

aerodynamics* were not included in the analysis. The results, however, showed that the proposed configuration would oscillate significantly subsequent to fin opening and thus would result in unpredictable dispenser opening characteristics.

An analysis of ejected (Aero 7A Bombrack) release was made and the results were used to construct the graph shown in Figure 29. For this study, the standard Aero 7A ejector force-time characteristics were used with the ejection force exerted at the dispenser cg and 0.6 inch aft of the cg. The release conditions plotted were for initial pitch angles of -2°, 0°, and +2° (relative to the free stream) and launch velocities ranging from Mach 0.7 to 0.9. The graph shows that the dispenser separates safely from the aircraft when ejected and that the fins can be deployed after the dispenser has cleared the aircraft by 0.75 feet. With an initial pitch angle of -2° and an ejection force applied 0.6 inch aft of the cg, the dispenser would rotate to a pitch angle of approximately +2° in 0.75 foot of vertical travel. It was estimated that the opened fins would be capable of adequately stabilizing the dispenser in such a case.

It was concluded, however, that because of the dispenser instability prior to fin opening and the possibility of interference in non-ejected release, alternate fin configurations should be investigated. Two concept designs - a four-fin model with a ring tail and a six-fin configuration without a ring tail, both shown in Figure 30 - were evolved and evaluated. Canted fin roots were used in these two concepts. It was felt that the ring tail design (the ring in this approach was essentially an annular fin the same diameter as the dispenser body and intersecting the four folding fins at the circumference of the tail base)

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* Which can, of course, be the dominating factor in weapon behavior at separation. However, including interference aerodynamics in this early study was, because of the complexity of possible combinations (aircraft, pylon station, bomb rack, flight conditions), manifestly impracticable and uneconomical.

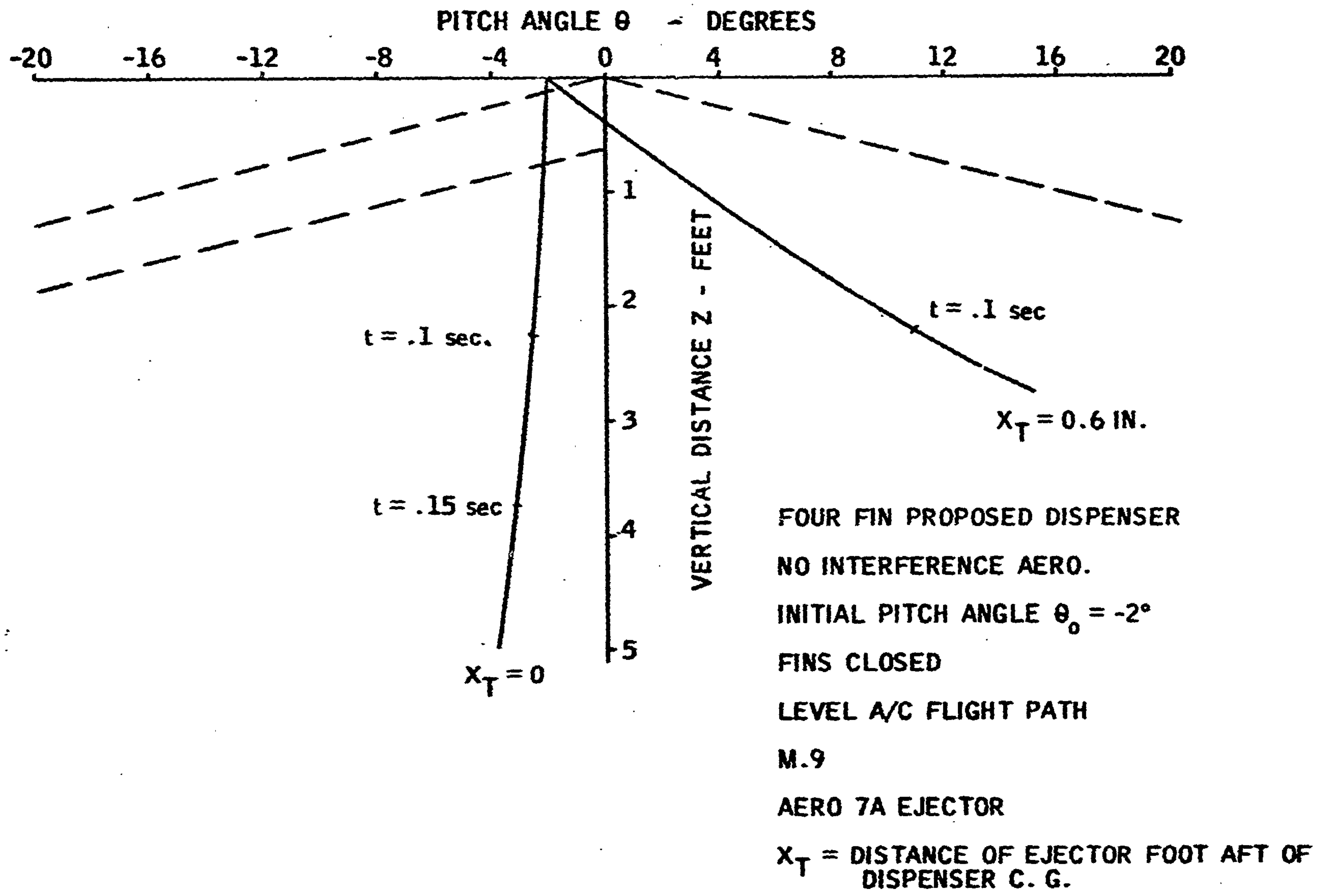


Figure 29 - DISPENSER VERTICAL DROP DISTANCE VERSUS PITCH ANGLE FOR THE PROPOSED DISPENSER (WITH EJECTOR)

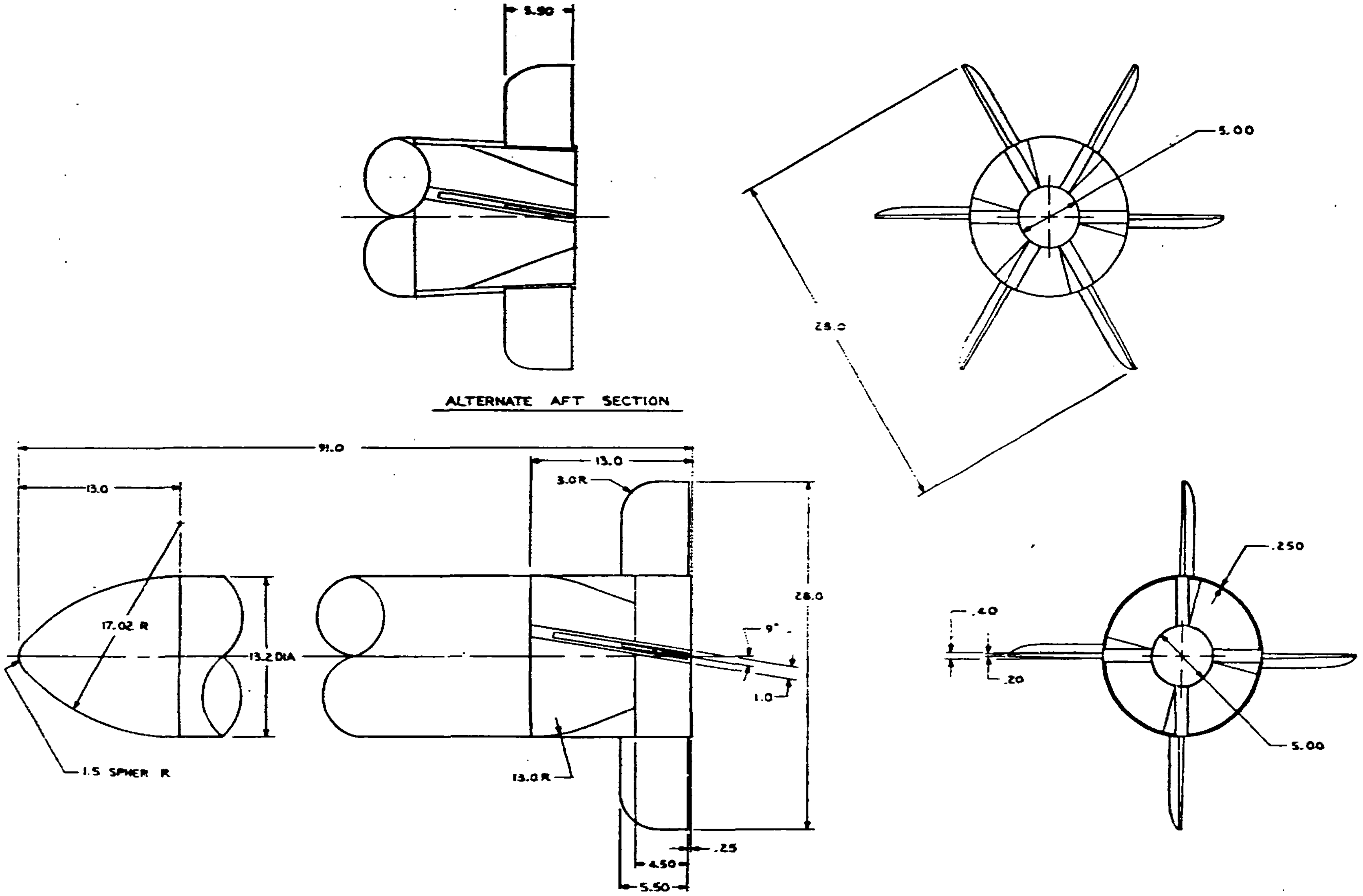


Figure 30 - PRELIMINARY ROCKEYE II EXTERNAL CONFIGURATION

would provide a larger restoring moment for greater release and free flight stability. The six-fin configuration, because of its increased fin area, was expected to provide a similar effect. The anticipated result was a decrease in weapon instability prior to fin opening. It was recognized that neither approach could provide even neutral stability with the fins closed. Both assemblies were characterized by similar inherent disadvantages - high captive flight drag and added tail section weight. However, it was felt these disadvantages were acceptable should either configuration provide a significant improvement in fins closed stability.

Theoretical analyses were made to define the aerodynamic coefficients as a function of Mach number and angle of attack for the four-fin configuration;and the data obtained are shown in Table II, III, and IV. Aerodynamic coefficients in Table II are preliminary estimates for a tail section having the rectangular fin plan form shown in Figure 30, and those in Table IV are outputs from an aerodynamic equation program on the IBM-1620 digital computer. There is little variation in the aerodynamic coefficients in these tables; and, consequently, the associated performance parameters do not vary appreciably for the three sets of data. The static aerodynamic characteristics were evaluated, and the damping deriviatives were estimated as follows:

Pitch Damping

$$C_{mg} = -2C_{L\alpha\ f}\left(\frac{\ell_t}{d}\right)$$

Spin Moment Coefficient

$$C_{\ell} = C'_{L\alpha\ f}\ \epsilon\left(\frac{r_f}{d}\right)$$

Spin Damping Derivative

$$C_{\ell_p} = -2C'_{L\alpha f}\left(\frac{r_f}{d}\right)^2$$

TABLE II

FOUR FIN RING TAIL DISPENSER AERODYNAMICS (FIRST ESTIMATE)

MACH NO.	C_A		C_{M_q}		C_{l_p}		C_l					
							FINS FOLDED			FINS OPEN		
	FINS FOLDED	FINS OPEN	FINS FOLDED	FINS OPEN	FINS FOLDED	FINS OPEN	$\delta = 3^\circ$	$\delta = 5^\circ$	$\delta = 9^\circ$	$\delta = 3^\circ$	$\delta = 5^\circ$	$\delta = 9^\circ$
0	.2118	.2498	-42.4	-107.8	-.247	-6.41	.0147	.0245	.0441	.213	.354	.637
.2	.2118	.2498	-42.4	-107.8	-.247	-6.41	.0147	.0245	.0441	.213	.354	.637
.4	.1994	.2344	-46.1	-114.1	-.252	-6.67	.0150	.0251	.0450	.222	.369	.665
.6	.1929	.2249	-52.4	-128.8	-.257	-7.21	.0153	.0256	.0460	.240	.399	.718
.8	.1900	.221	-57.5	-142.4	-.274	-8.33	.0164	.0272	.0490	.277	.461	.829
.9	.2058	.2358	-57.8	-153.6	-.294	-9.45	.0175	.0292	.0525	.314	.523	.940
1.2	.796	.834										
1.4	.765	.803										
1.6	.726	.764										

α MACH	C_N											
	FINS FOLDED						FINS OPEN					
	0°	4°	8°	12°	16°	20°	0°	4°	8°	12°	16°	20°
0	0	.2471	.5239	.8328	1.1758	1.5549	0	.4948	1.0230	1.5903	2.2022	2.8636
.2	0	.2471	.5239	.8328	1.1758	1.5549	0	.4948	1.0230	1.5903	2.2022	2.8636
.4	0	.2608	.5517	.8749	1.2329	1.6277	0	.5193	1.0724	1.6652	2.3036	2.9930
.6	0	.2845	.5993	.9471	1.3307	1.7526	0	.5634	1.1612	1.8000	2.4863	3.2259
.8	0	.304	.6385	1.0068	1.4116	1.8556	0	.6264	1.2881	1.9926	2.7472	3.5587
.9	0	.3039	.6384	1.0066	1.4113	1.8554	0	.6691	1.3741	2.1231	2.9241	3.7842

α MACH	C_M											
	FINS FOLDED						FINS OPEN					
	0°	4°	8°	12°	16°	20°	0°	4°	8°	12°	16°	20°
0	0	.0349	.0623	.0752	.0673	.0327	0	- .709	-1.436	-2.1	-3.01	-3.89
.2	0	.0349	.0623	.0752	.0673	.0327	0	- .709	-1.436	-2.1	-3.01	-3.89
.4	0	-.00629	-.02085	-.0509	-.104	-.1856	0	- .782	-1.584	-2.425	-3.32	-4.28
.6	0	-.0772	-.1633	-.217	-.398	-.56	0	- .913	-1.85	-2.83	-3.87	-4.975
.8	0	-.1356	-.281	-.445	-.639	-.869	0	-1.102	-2.275	-3.41	-4.66	-5.98
.9	0	-.1351	-.281	-.443	-.638	-.868	0	-1.23	-2.49	-3.8	-5.18	-6.65

TABLE III

FOUR FIN RING TAIL DISPENSER AERODYNAMICS (SECOND ESTIMATE)

MACH NO.	C_A		C_{M_α}		C_{l_p}		C_l					
							FINS FOLDED			FINS OPEN		
	FINS FOLDED	FINS OPEN	FINS FOLDED	FINS OPEN	FINS FOLDED	FINS OPEN	δ = 3°	δ = 5°	δ = 9°	δ = 3°	δ = 5°	δ = 9°
0	.2118	.2498	-42.4	-107.8	-.247	-6.41	.0147	.0245	.0441	.213	.354	.637
.2	.2118	.2498	-42.4	-107.8	-.247	-6.41	.0147	0245	.0441	.213	.354	.637
.4	.1994	.2344	-46.1	-114.1	-.252	-6.67	.0150	.0251	.0450	.222	.369	.665
.6	.1929	.2249	-52.4	-125.8	-.257	-7.21	.0153	.0256	.0460	.24	.399	.718
.8	.1900	.221	-57.5	-142.4	-.274	-8.33	.0164	.0272	.0490	.277	.461	.829
.9	.2058	.2358	-57.5	-153.6	-.294	-9.45	.0175	.0292	.0525	.314	.523	.940
1.2	.796	.834										
1.4	.765	.803										
1.6	.726	.764										

α / MACH	C_N											
	FINS FOLDED						FINS OPEN					
	0°	4°	8°	12°	16°	20°	0°	4°	8°	12°	16°	20°
0	0	.2227	.4748	.7582	1.0746	1.4258	0	.4618	.9565	1.4892	2.0649	2.6882
.2	0	.2227	.4748	.7582	1.0746	1.4258	0	.4618	.9565	1.4892	2.0649	2.6882
.4	0	.2294	.4882	.7786	1.1023	1.4612	0	.4698	.9725	1.5134	2.0978	2.7301
.6	0	.2403	.5103	.8122	1.1478	1.5192	0	.5099	1.0534	1.6362	2.2643	2.9425
.8	0	.2647	.5595	.8867	1.2488	1.6480	0	.5776	1.1897	1.8432	2.5447	3.3001
.9	0	.2768	.5837	.9235	1.2987	1.7116	0	.6359	1.3072	2.0215	2.7861	3.6079

α / MACH	C_M											
	FINS FOLDED						FINS OPEN					
	0°	4°	8°	12°	16°	20°	0°	4°	8°	12°	16°	20°
0	0	.108	.209	.299	.371	.42	0	-.609	-1.242	-1.895	-2.6	-3.5
.2	0	.108	.209	.299	.371	.42	0	-.609	-1.242	-1.895	-2.6	-3.5
.4	0	.0882	.1697	.238	288	.314	0	-.633	-1.28	-1.97	-2.7	-3.49
.6	0	.0882	.1032	.1373	1513	.1397	0	-.753	-1.525	-2.33	-3.2	-4.36
.8	0	-.0179	-.0442	-.0864	-.1517	-.2465	0	-.956	-1.935	-2.96	-4.04	-5.2
.9	0	-.0398	-.117	-.197	-.300	-.437	0	-1.132	-2.29	-3.58	-4.98	-6.5

TABLE IV

FOUR FIN RING TAIL DISPENSER AERODYNAMICS (THIRD ESTIMATE)

MACH NO.	C_A		C_{M_q}		C_{l_p}		C_l					
							FINS FOLDED			FINS OPEN		
	FINS FOLDED	FINS OPEN	FINS FOLDED	FINS OPEN	FINS FOLDED	FINS OPEN	$\delta = 3°$	$\delta = 5°$	$\delta = 9°$	$\delta = 3°$	$\delta = 5°$	$\delta = 9°$
0	.2118	.2498	-35.8	- 98.2	-.286	-6.14	.0178	.0295	.0534	.204	.340	.611
.2	.2118	.2498	-35.8	- 98.2	-.288	-6.14	.0178	.0295	.0534	.204	.340	.611
.4	.1994	.2344	-37.7	-100.5	-.294	-6.17	.0182	.0303	.0545	.205	.341	.614
.6	.1929	.2249	-40.6	-111.2	-.306	-6.94	.0189	.0316	.0568	.230	.383	.690
.8	.1900	.221	-47.1	-129.2	-.328	-8.07	.0202	.0338	.0608	.268	.446	.802
.9	.2058	.2358	-50.2	-144.4	-.343	-9.27	.0212	.0354	.0636	.307	.512	.922
1.2	.796	.834										
1.4	.765	.803										
1.6	.726	.764										

α	C_N											
	FINS FOLDED						FINS OPEN					
MACH	0°	4°	8°	12°	16°	20°	0°	4°	8°	12°	16°	20°
0	0	.207	.439	.683	.920	1.123	0	.446	.909	1.363	1.756	2.017
.2	0	.207	.439	.683	.920	1.123	0	.446	.909	1.363	1.756	2.017
.4	0	.214	.452	.702	.944	1.149	0	.454	.925	1.386	1.784	2.047
.6	0	.225	.474	.734	.984	1.192	0	.494	1.005	1.503	1.931	2.206
.8	0	.249	.523	.806	1.074	1.290	0	.561	1.141	1.702	2.181	2.478
.9	0	.266	.555	.854	1.136	1.360	0	.624	1.266	1.888	2.417	2.738

α	C_M											
	FINS FOLDED						FINS OPEN					
MACH	0°	4°	8°	12°	16°	20°	0°	4°	8°	12°	16°	20°
0	0	-.006	-.005	.030	.153	.440	0	- .730	-1.436	-2.035	-2.386	-2.275
.2	0	-.006	-.005	.030	.153	.440	0	- .730	-1.436	-2.035	-2.386	-2.275
.4	0	-.027	-.046	-.028	.080	.361	0	- .754	-1.483	-2.105	-2.473	-2.368
.6	0	-.060	-.112	-.126	-.041	.229	0	- .876	-1.727	-2.462	-2.919	-2.851
.8	0	-.134	-.261	-.344	-.315	-.068	0	-1.082	-2.138	-3.068	-3.679	-3.678
.9	0	-.139	-.270	-.357	-.326	-.061	0	-1.228	-2.431	-3.499	-4.217	-4.247

where:

$C_{L\alpha f}$ = $\frac{dC_L}{d\alpha}$ of the fins

ℓ_t = Length from the tail center of pressure to the cg.

d = Body diameter (reference length)

r_f = Distance from the body centerline to the fin center of pressure.

δ = Fin cant angle

$C'_{L\alpha f}$ = $\frac{dC_L}{d\alpha}$ of the fins corrected for spin

The term $C_{L\alpha f}$ used for static stability and pitch damping includes the effect of fin orientation and fin-to-body carryover, both of which are influential in pitch but not in roll. The term $C'_{L\alpha f}$ is, therefore, corrected to compensate for these effects.

The fin span required to provide static stability was investigated. Curves were established as shown in Figure 31, illustrating the static margin of the dispenser with various fin configurations.

Subsequently, a performance analysis of the four-fin ring tail dispenser was conducted. In this study, the initial dispenser pitch attitude was a -2° and the following functional parameters were varied as indicated: fin cant angle 3° to 9° ; initial launch velocity, mach 0. 3 to 0. 9; and lanyard length to initiate fin deployment 1 to 2 feet. The geometric and inertia values used for the dispenser in this study were preliminary estimates of the weapon characteristics and are listed in Table V.

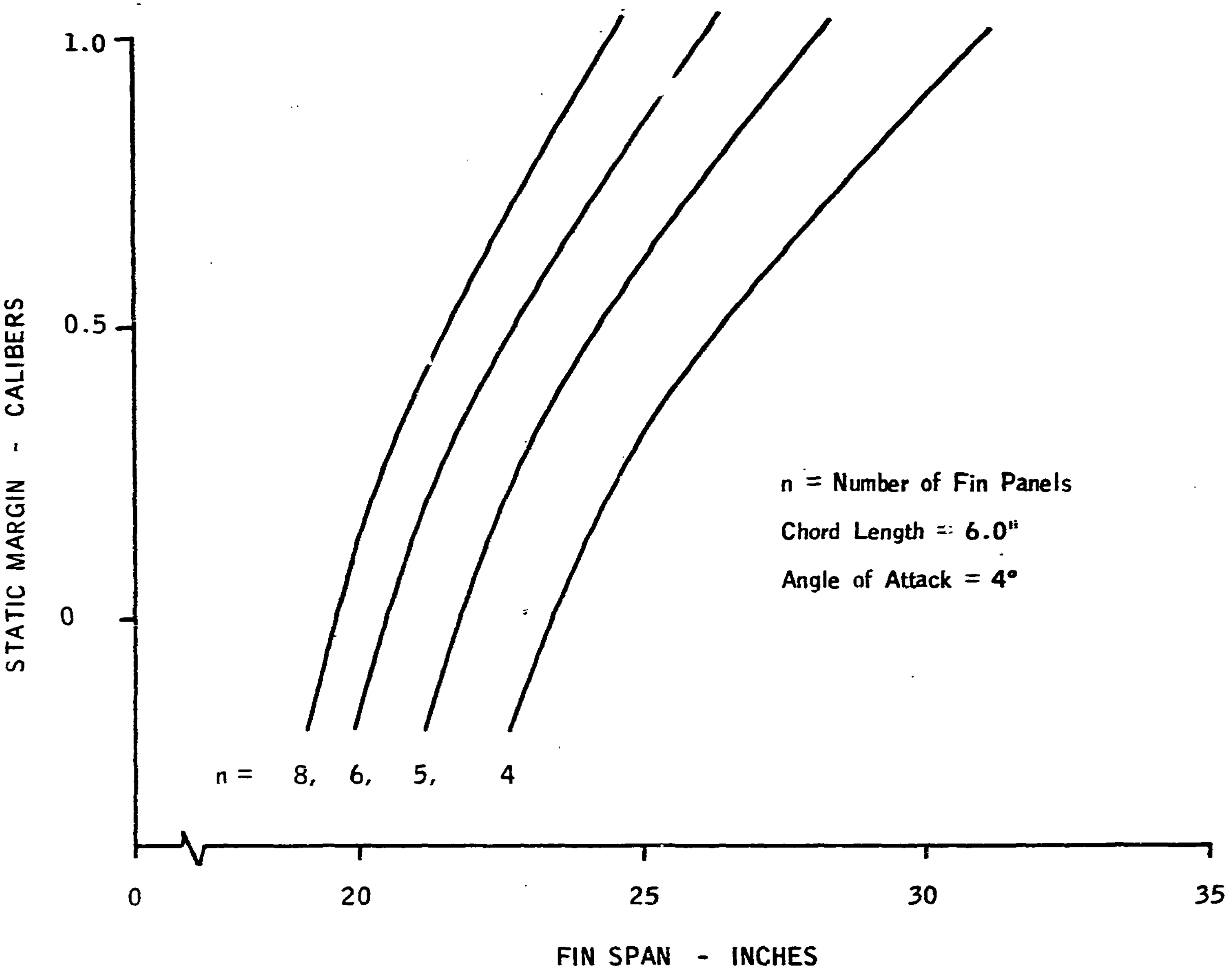


Figure 31 - ESTIMATED DISPENSER STATIC MARGIN VERSUS SPIN SPAN

TABLE V

DISPENSER GEOMETRIC AND INERTIA PROPERTIES USED IN PERFORMANCE ANALYSES

Geometric Properties	
Aerodynamic Reference Length ~ D	1.0833 Ft.
Aerodynamic Reference Area ~S	0.922 Ft.^{2}
Inertia Properties	
Mass ~ M	13.69 Slugs
Yaw Moment of Inertia ~ I_{zz}	67.0 Slug Ft.^{2}
Pitch Moment of Inertia ~ I_{yy}	67.0 Slug Ft.^{2}
Roll Moment of Inertia ~ I_{xx}	2.01 Slug Ft.^{2}

Safe separation was calculated for the four-fin, ring tail dispenser, and the clearance profile calculated is shown superimposed on the safe separation boundary curves (as plotted in Figure 27)in Figures 32 and 33. These data reflect vertical drop distance versus pitch attitude for lanyard lengths of 1 and 2 feet. It is evident from these curves that the dispenser must descend more than 0. 75 foot before fin deployment to avoid interference with the aircraft. Consequently, there will be a 3-inch clearance between the open dispenser fins and the dispenser rack for a lanyard length of 1 foot and at least a 15-inch clearance for a lanyard length of 2 foot. Aerodynamic performance characteristics for a range of separation conditions are shown in Table VI. These data indicate that the pitch angle and rate of the four-fin ring tail configuration are small compared to those of the original design, and they show that, in all cases studied, safe separation from the aircraft is achieved. Again it should be noted that interference aerodynamics were not included in the analysis. The spin-up or roll rate (P) attributable to the fin root fairings is small at fin deployment.

Trajectories of the four-fin, ring tail dispenser were established and studied for initial launch velocities of Mach 0. 3, 0. 6, and 0. 9, and for an initial pitch attitude of -2°. Lanyard lengths of 1 and 2 feet were selected and fin cant angles of 3°, 5°, and 9° were used. The preliminary trajectories derived on the basis of first estimates of aerodynamic characteristics are shown in Figure 34 to reflect updated estimates. It is evident that there is very little difference between the trajectories in Figures 34 and 35, an anticipated result since the aerodynamic coefficients that were inputs to the equations of motion did not vary appreciably between the two estimates. It is also apparent from these data that variations in fin cant angle and lanyard length do not have a pronounced effect on dispenser trajectory.

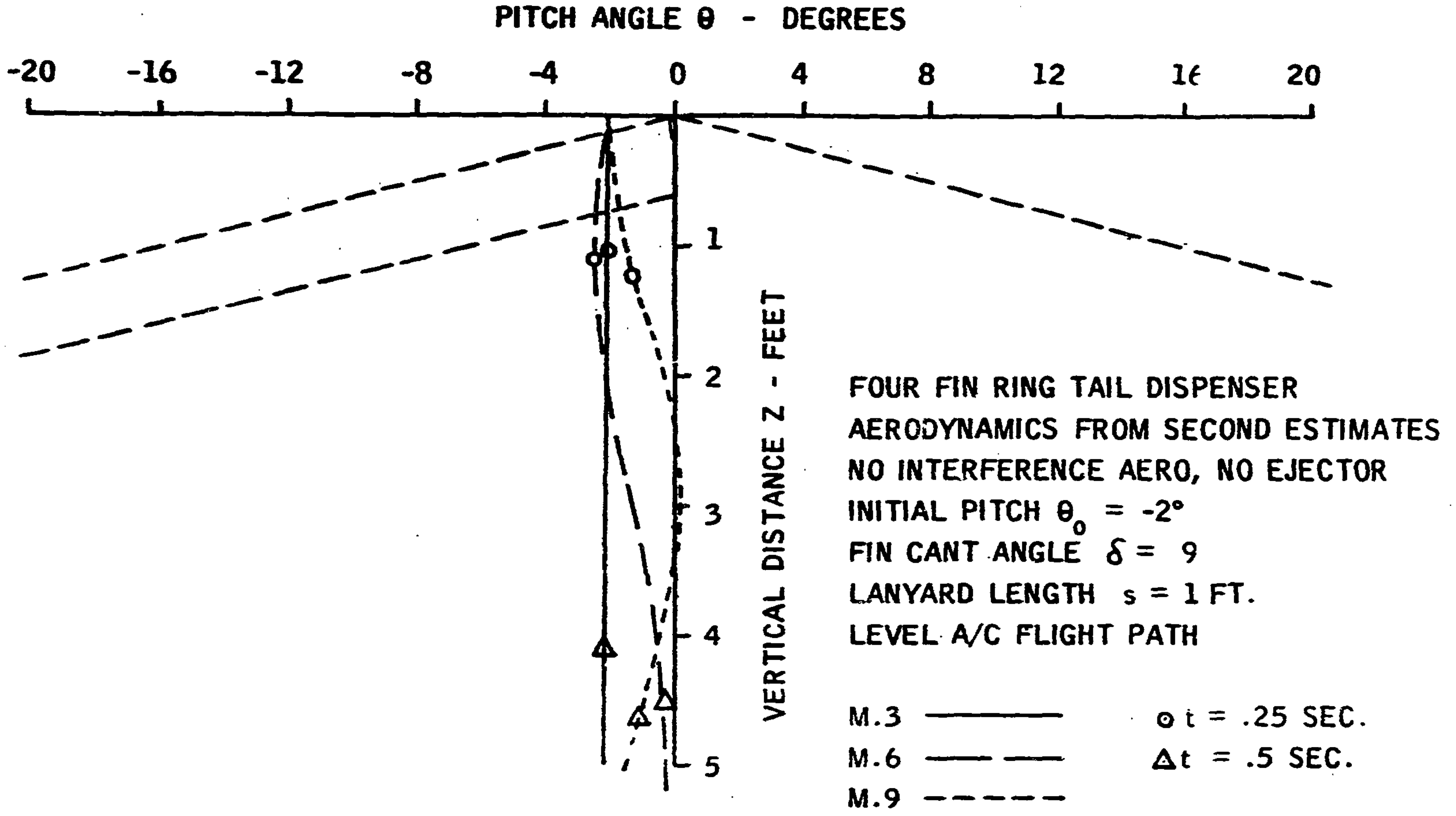
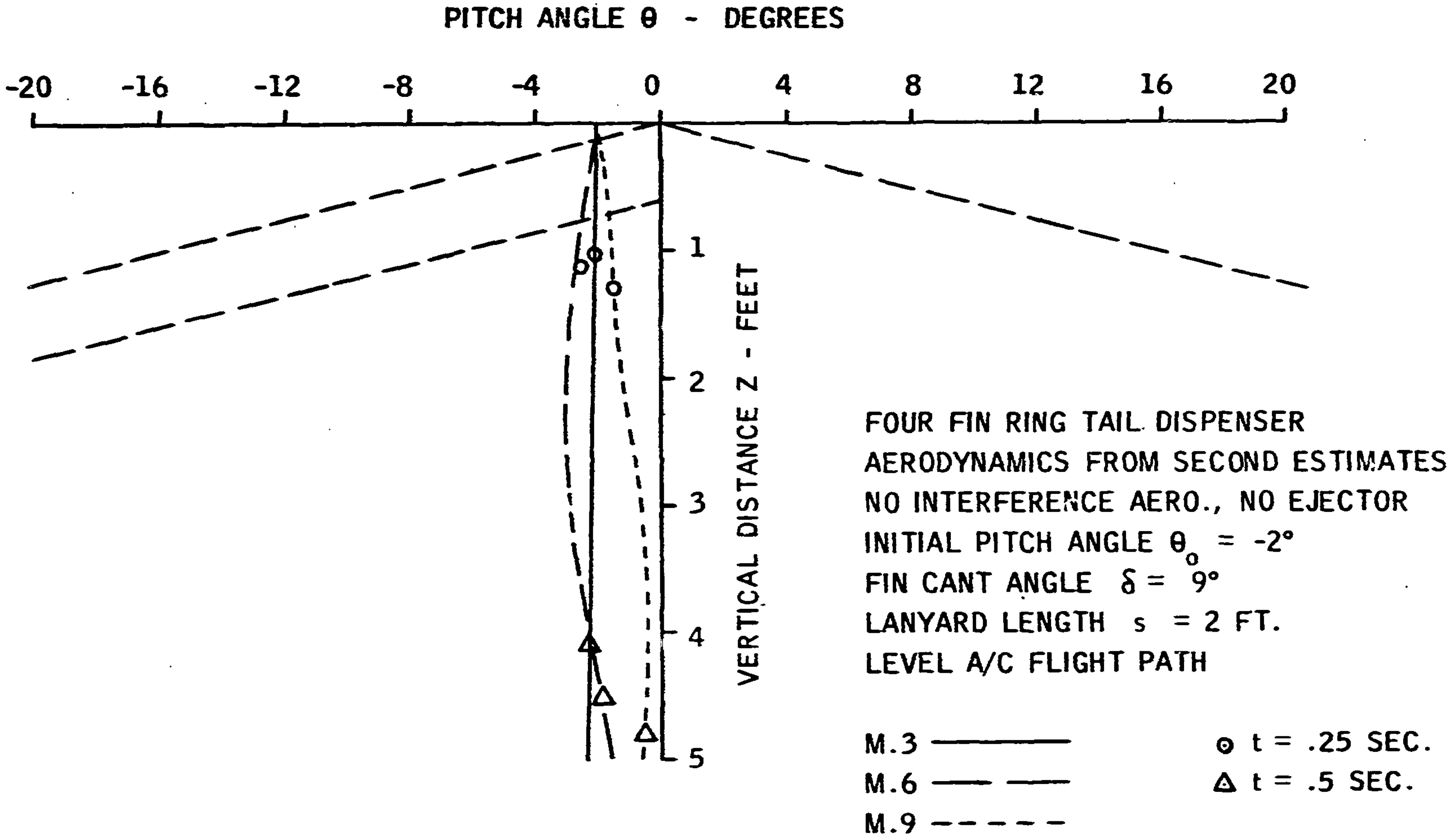


Figure 32 - DISPENSER VERTICAL DROP DISTANCE VERSUS PITCH ANGLE FOR THE FOUR FIN RING TAIL CONFIGURATION - LANYARD LENGTH = 1-FT.



FOUR FIN RING TAIL DISPENSER
AERODYNAMICS FROM SECOND ESTIMATES
NO INTERFERENCE AERO., NO EJECTOR
INITIAL PITCH ANGLE θ_o = -2°
FIN CANT ANGLE δ = 9°
LANYARD LENGTH s = 2 FT.
LEVEL A/C FLIGHT PATH

Figure 33 - DISPENSER VERTICAL DROP DISTANCE VERSUS PITCH ANGLE FOR THE FOUR FIN RING TAIL CONFIGURATION - LANYARD LENGTH = 2-FT.

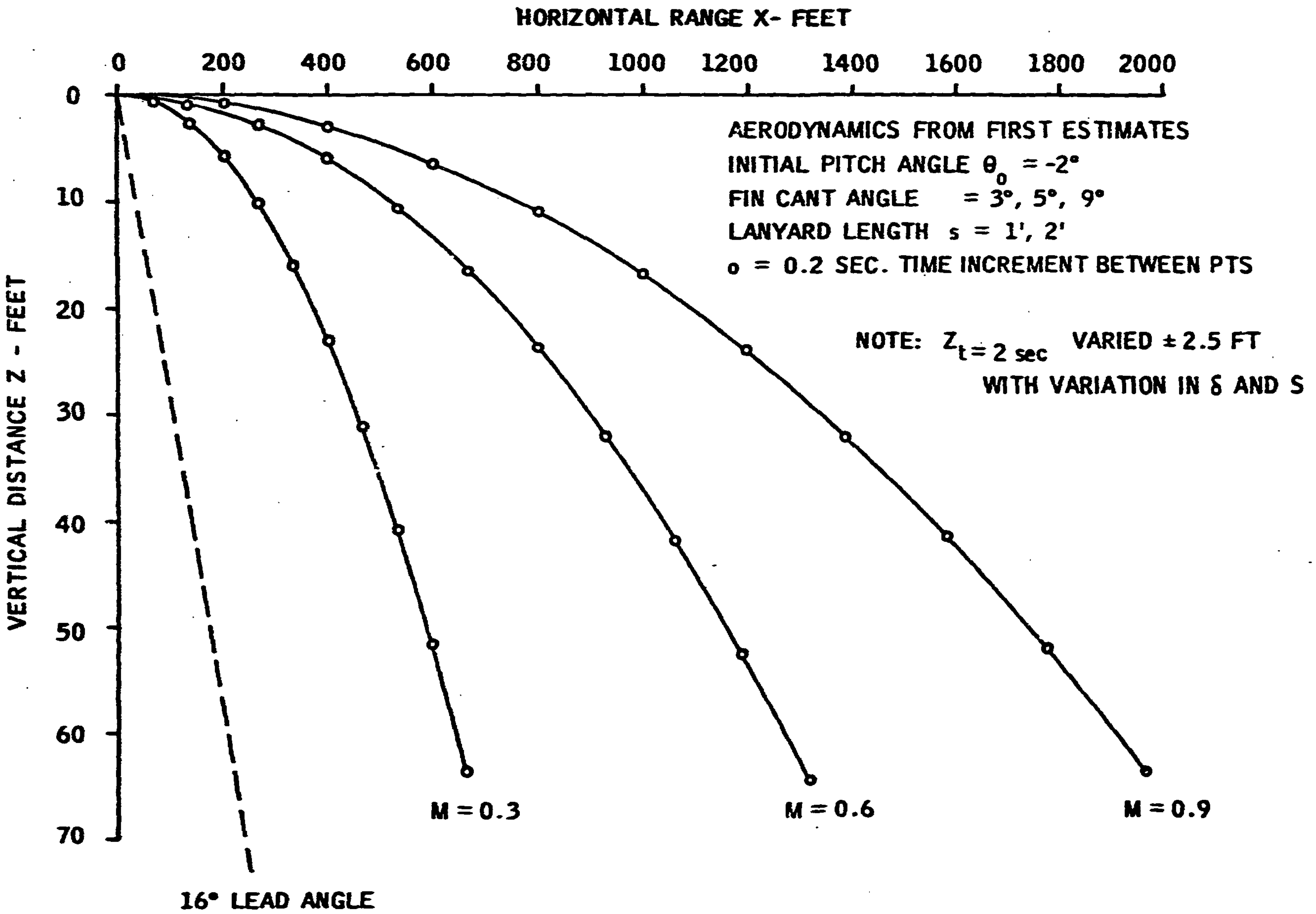
TABLE VI

FOUR FOLDING FIN RING TAIL DISPENSER FIN OPENING CHARACTERISTICS

		S = 1				S = 2		
		δ = 3°	δ = 5°	δ = 9°		δ = 3°	δ = 5°	δ = 9°
M .3	t	.250	.250	.250		.350	.350	.350
	Δ h	.25	.25	.25		1.25	1.25	1.25
	θ	-2.02	-2.02	-2.01		-2.03	-2.03	-2.03
	Q	-.0017	-.0017	-.0017		-.0024	-.0024	-.0024
	P	.278	.464	.833		.375	.626	1.12
	ø	1.76	2.94	5.28		3.44	5.75	10.32
M .6	t	.235	.235	.235		.330	.330	.330
	Δ h	.28	.28	.28		1.30	1.30	1.30
	θ	-1.60	-1.60	-1.60		-1.30	-1.30	-1.30
	Q	.054	.054	.052		.057	.054	.046
	P	1.09	1.82	3.27		1.32	2.21	3.97
	ø	6.40	10.7	19.2		12.5	21.0	37.7
M .9	t	.215	.215	.215		.305	.305	.305
	Δ h	.34	.34	.34		1.37	1.37	1.37
	θ	-.78	-.78	-.78		.002	.002	.001
	Q	.155	.147	.122		.116	.093	.022
	P	2.63	4.38	7.88		3.53	5.88	10.58
	ø	13.7	22.9	41.2		27.5	45.9	82.4

LEGEND:

S = LANYARD LENGTH - FT.
δ = FIN CANT ANGLE
M = MACH NUMBER
t = TIME CORRESPONDING TO S-SEC.
Δh = CLEARANCE BETWEEN DISPENSER AND A HORIZONTAL PLANE THROUGH ATTACHMENT POINTS - FT
θ = PITCH ATTITUDE AT TIME t - DEGREES
Q = PITCH RATE - RAD/SEC.
P = ROLL RATE - RAD/SEC.
ø = ROLL ANGLE - DEGREES



AERODYNAMICS FROM FIRST ESTIMATES
INITIAL PITCH ANGLE $\theta_0 = -2°$
FIN CANT ANGLE = 3°, 5°, 9°
LANYARD LENGTH s = 1', 2'
o = 0.2 SEC. TIME INCREMENT BETWEEN PTS

NOTE: $Z_{t=2\ sec}$ VARIED ± 2.5 FT WITH VARIATION IN δ AND S

Figure 34 - TRAJECTORIES OF FOUR FIN RING TAIL DISPENSER

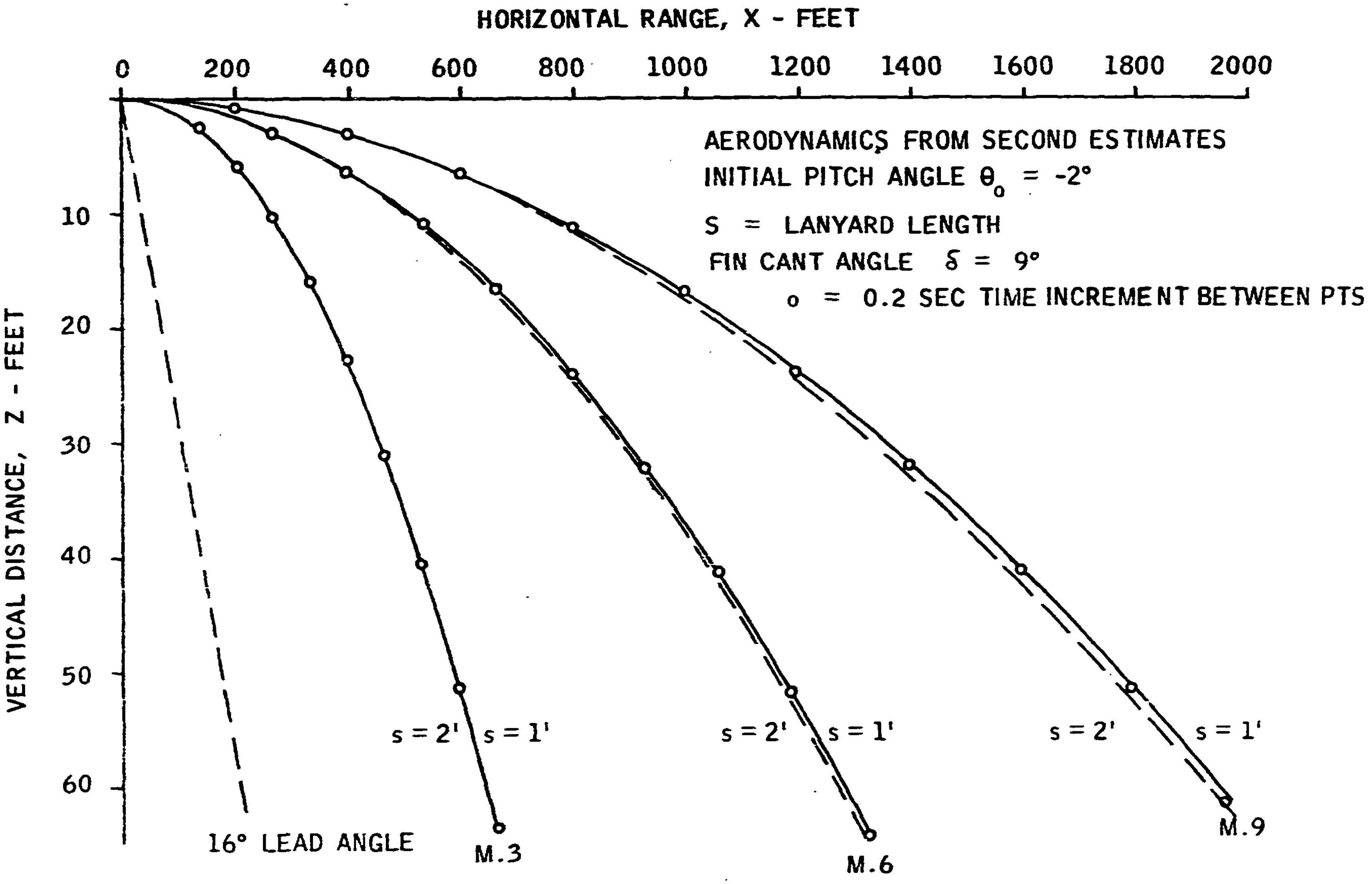


Figure 35 - TRAJECTORIES OF FOUR FIN RING TAIL DISPENSER

Spin histories were plotted as shown in Figures 36, 37, 38, and 39 for various release conditions. These data were then used to calculate the values shown in Table VII for dispenser spin and drop heights for various cargo release times. It was concluded that a fin cant angle of approximately 9° is required to obtain a bomblet pattern radius of 100 feet for low aircraft delivery altitudes and high aircraft speeds.

The stability of the dispenser (4-folded fin, ring tail configuration) was determined on the basis of pitch histories for various launch conditions. The curves in Figure 40 show that the dispenser orients along its flight path without oscillating, a characteristic of this configuration when launched at a speed (Mach 0. 3) less than its terminal velocity. At a release speed of Mach 0. 6 (pitch attitude -2°), the dispenser oscillates to a maximum of -0. 15° and damps to approximately 0. 25 amplitude in 0. 7 seconds, indicating a high degree of damping; minimal oscillation and effective damping are also evident at Mach 0. 9 release as may be seen in Figure 41.

Test models of the 4-fin and 6-fin designs were made up as shown in Figure 42 and evaluated in the Douglas Aero-physics Lab (DAL) wind tunnel to determine basic aerodynamic coefficients, stability thresholds, and dispenser spin rates. Subsequently, a second series of wind tunnel tests was conducted at the University of Minnesota's facility at Rosemount to augment the DAL data. The results of both wind tunnel tests were then analyzed to determine the performance of the two configurations. The aerodynamic coefficients of the concepts are shown in Figures 43, 44, and 45. The moment coefficient versus angle of attack for Mach 0. 6 and 0. 7 is shown in Figure 43. These data reveal the instability of the dispensers prior to fin opening, and it can be seen that the two configurations are unstable by about the same extent. At Mach 0. 9, the dispensers attain a fairly stable attitude, the four-fin ring tail, however, being

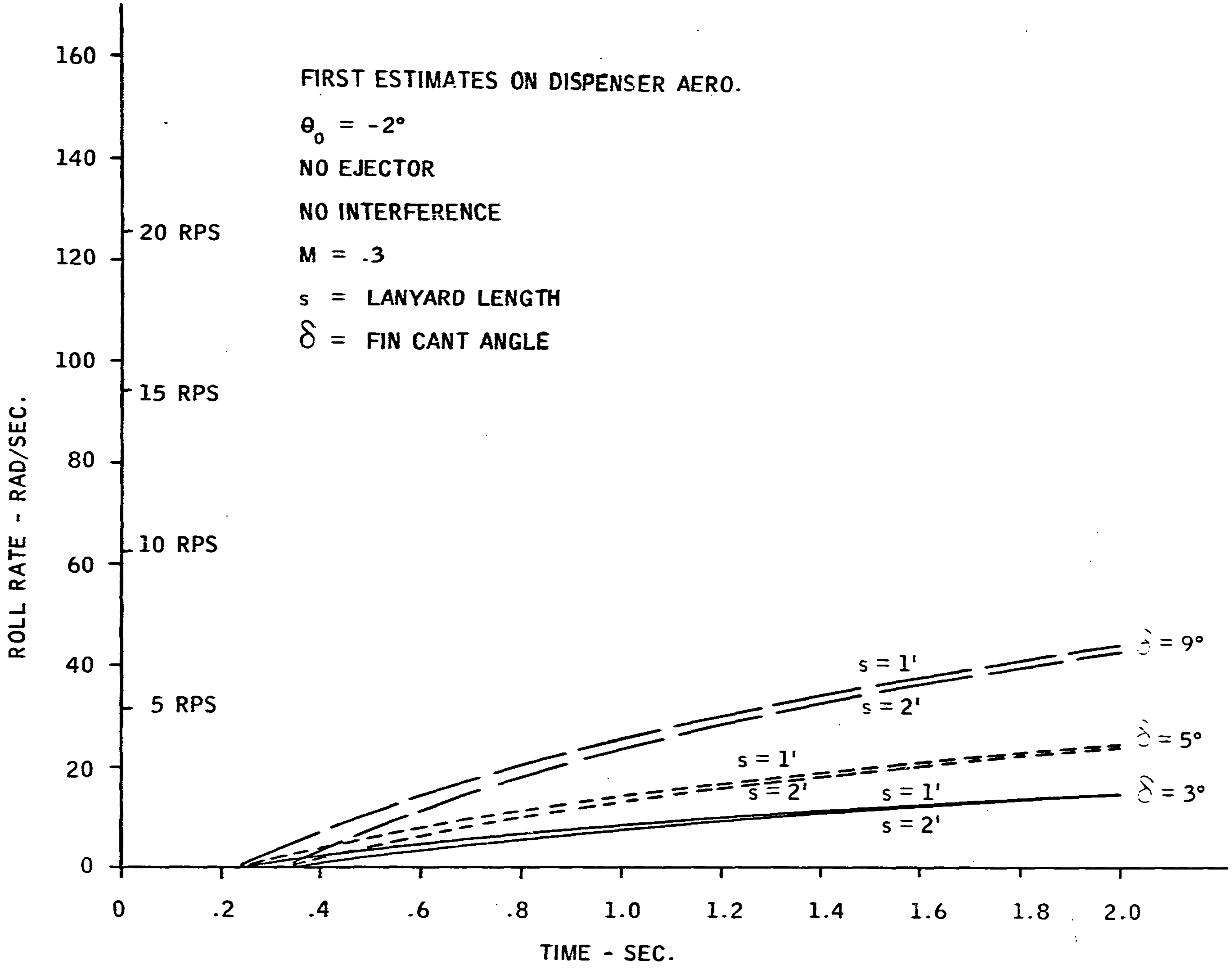


Figure 36 SPIN HISTORIES OF FOUR FIN RING TAIL DISPENSER (M 0.3)

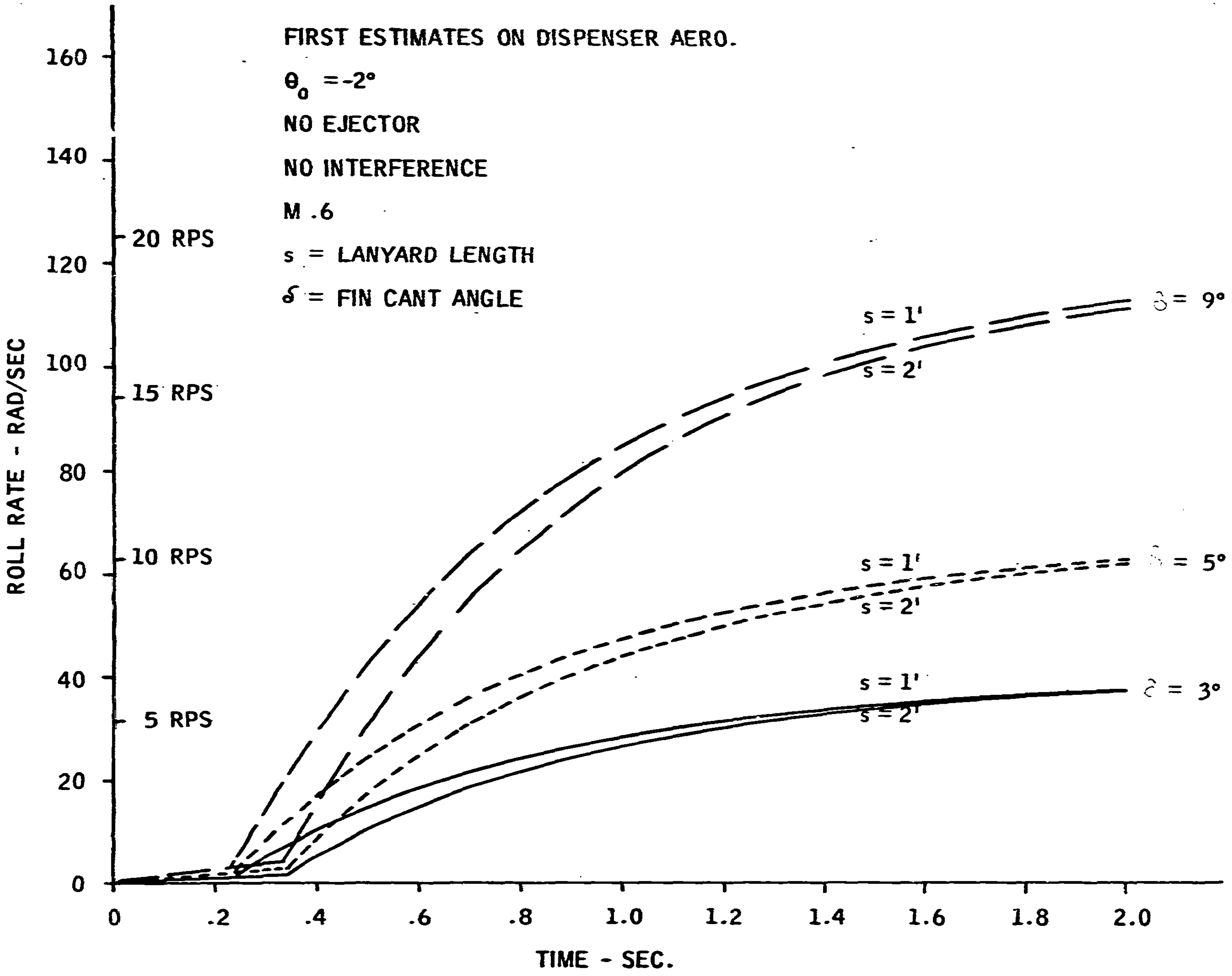


Figure 37 - SPIN HISTORIES OF FOUR FIN RING TAIL DISPENSER (M = 0.6)

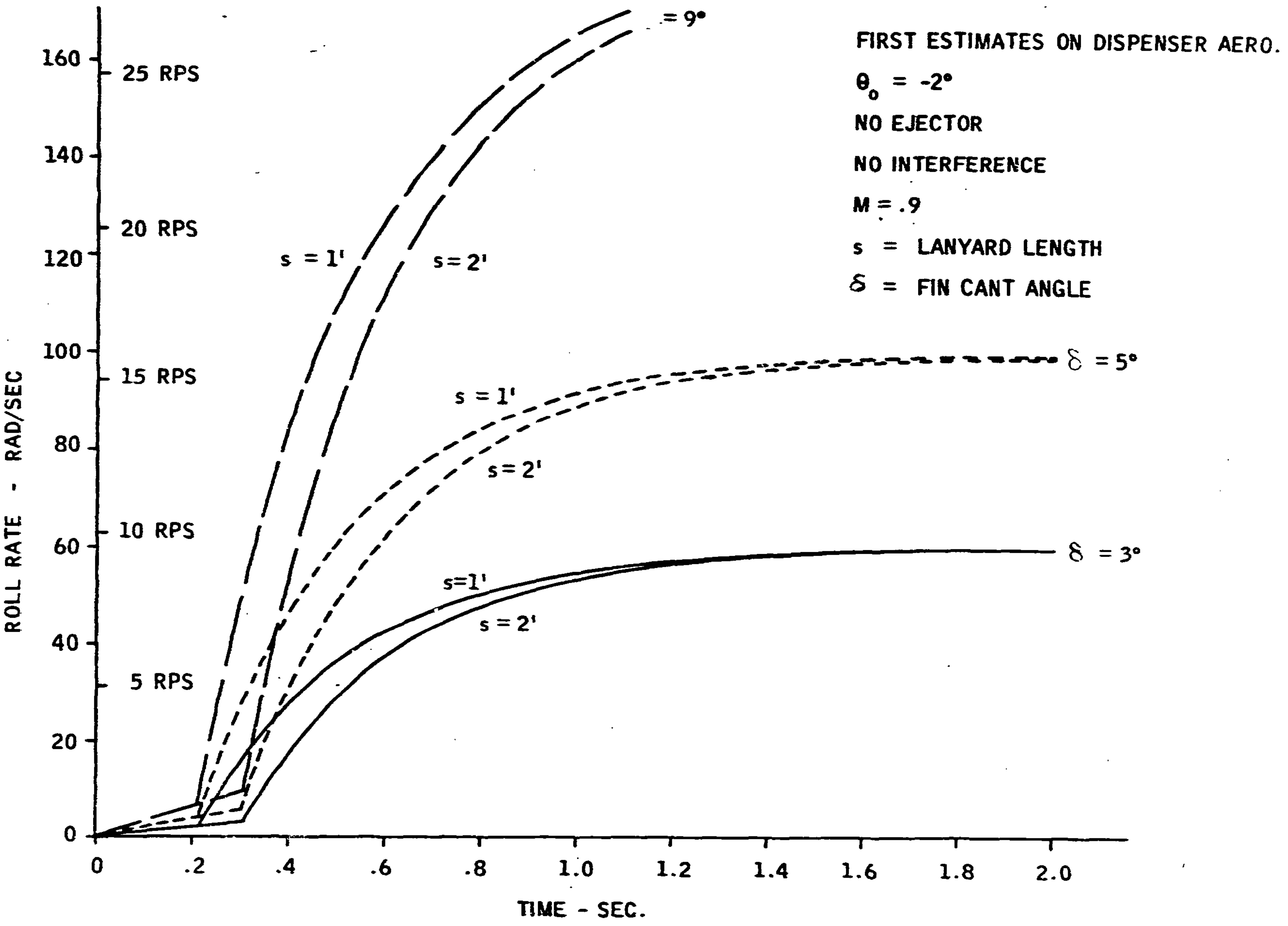


Figure 38 - SPIN HISTORIES OF FOUR FIN RING DISPENSER (M = 0.9)

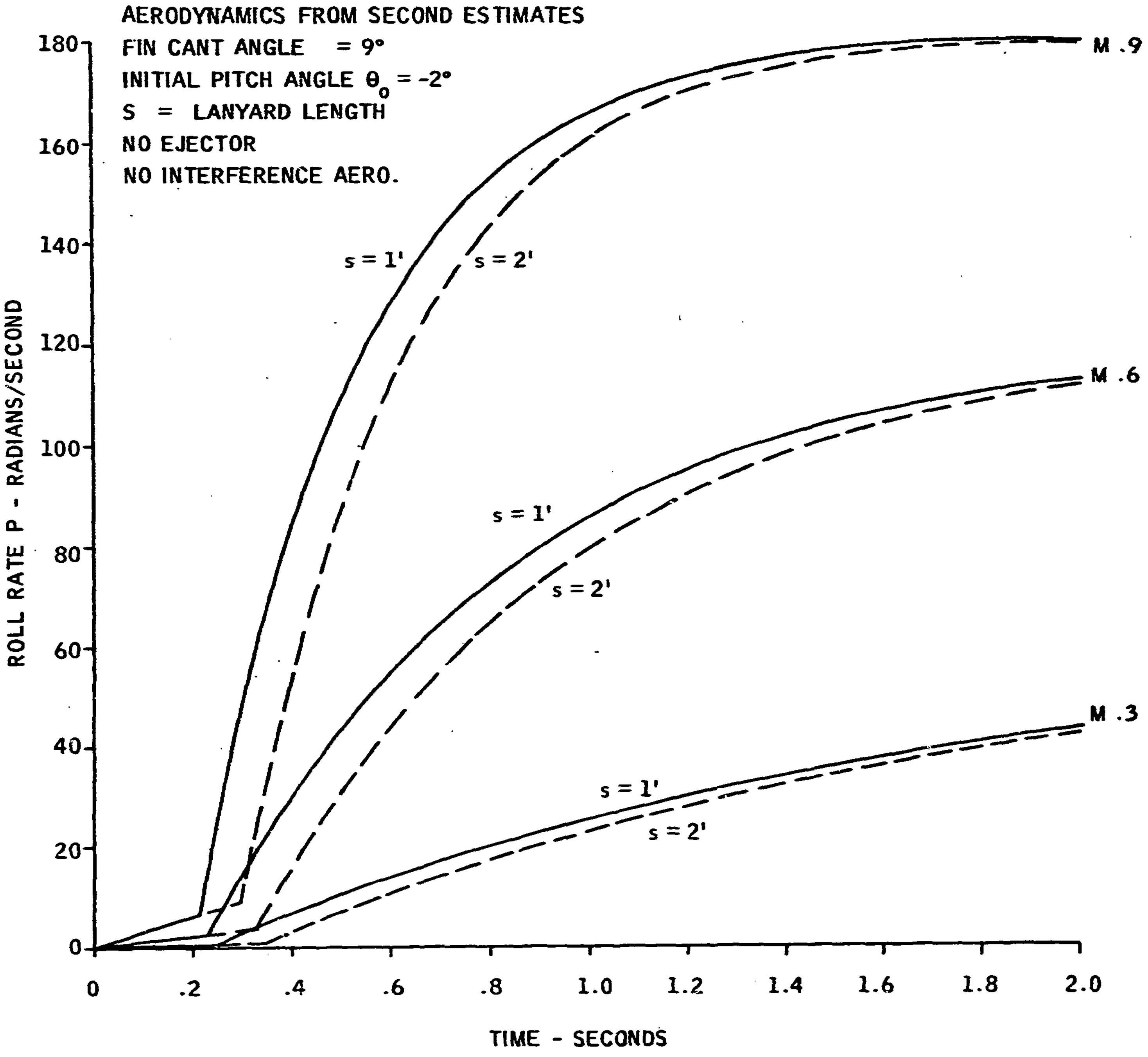


Figure 39 - SPIN HISTORIES OF FOUR FIN RING TAIL DISPENSER (δ = 9°)

TABLE VI DISPENSER SPIN AND DROP DISTANCE AT TIME OF CARGO RELEASE - FOUR FOLDING FIN RING TAIL DISPENSER

MACH NUMBER		t = .5			t = 1.0			t = 1.5		
		δ = 3°	δ = 5°	δ = 9°	δ = 3°	δ = 5°	δ = 9°	δ = 3°	δ = 5°	δ = 9°
M = .3	h	4.09	4.09	4.09	16.0	16.0	16.0	35.9	35.9	35.9
	P	3.53	5.87	10.6	8.54	14.2	25.6	12.1	20.1	36.2
M = .6	h	4.37	4.37	4.36	16.6	16.6	16.5	36.7	36.6	36.2
	P	14.4	24.0	43.2	28.6	47.5	85.5	35.0	58.2	104.7
M = .9	h	4.55	4.55	4.52	17.0	16.9	16.5	37.2	36.8	35.2
	P	36.3	60.5	109.0	55.2	92.0	166.3	59.1	98.4	178.7

LEGEND:

S = LANYARD LENGTH - FEET

t = TIME OF DISPENSER CARGO RELEASE - SECONDS

δ = FIN CANT ANGLE - DEGREES

M = INITIAL LAUNCH MACH NUMBER

h = DISPENSER DROP DISTANCE RELATIVE TO AIRCRAFT AT TIME OF CARGO RELEASE - FT

P = DISPENSER ROLL RATE, OR SPIN, AT TIME OF CARGO RELEASE - RAD/SECOND

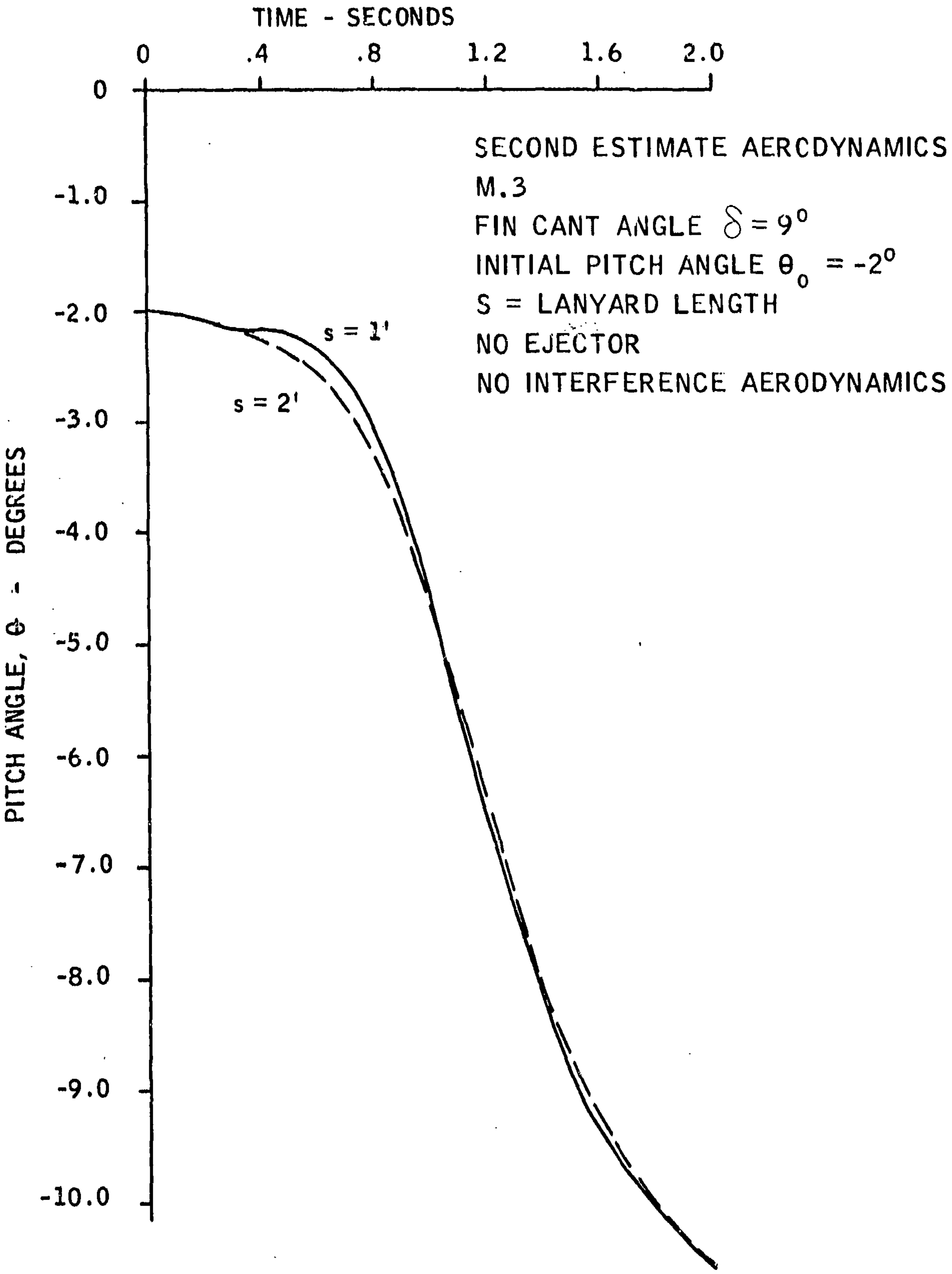


Figure 40 - PITCH ANGLE VERSUS TIME FOR THE FOUR FIN RING TAIL DISPENSER (M. 3)

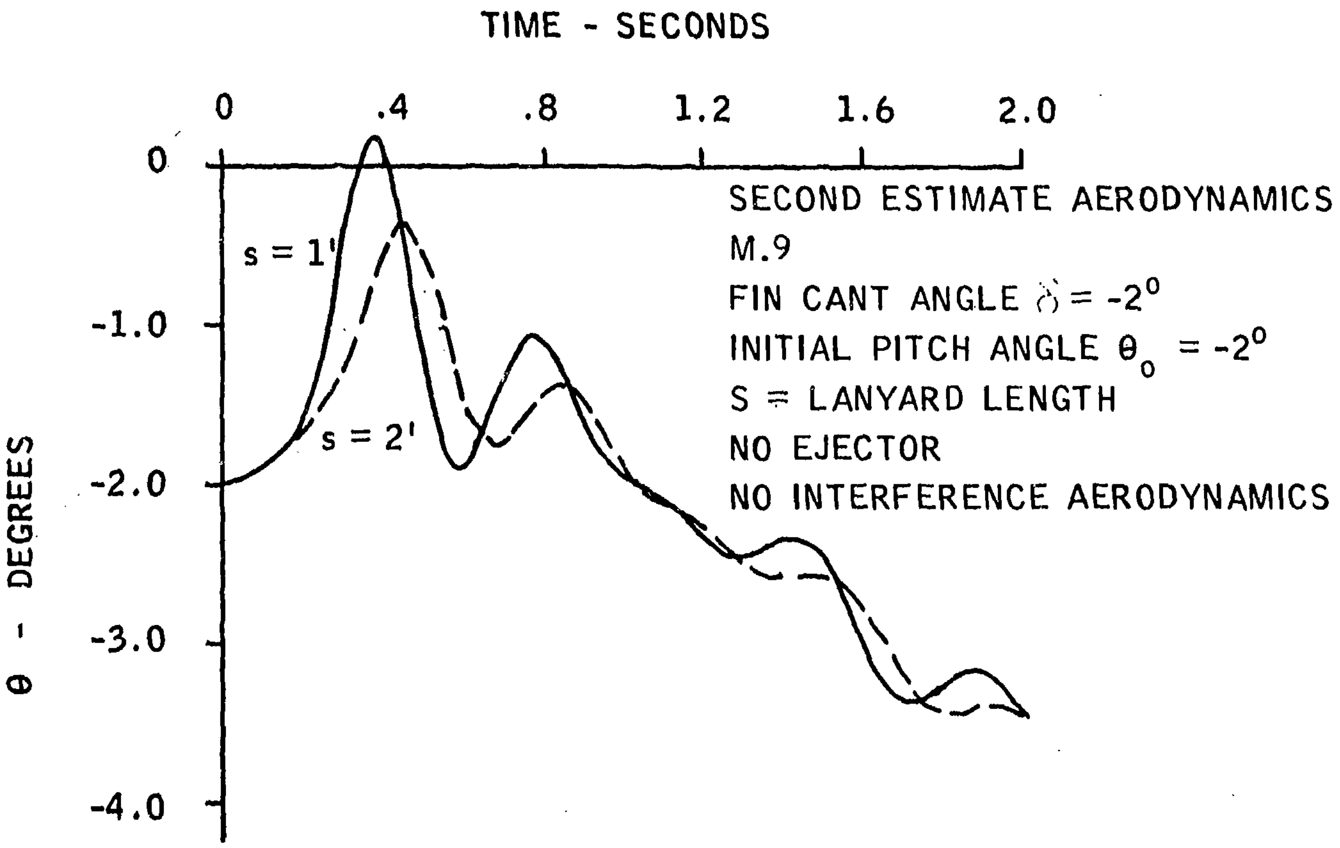


Figure 41 - PITCH ANGLE VERSUS TIME FOR THE FOUR FIN RING TAIL DISPENSER (M.9)

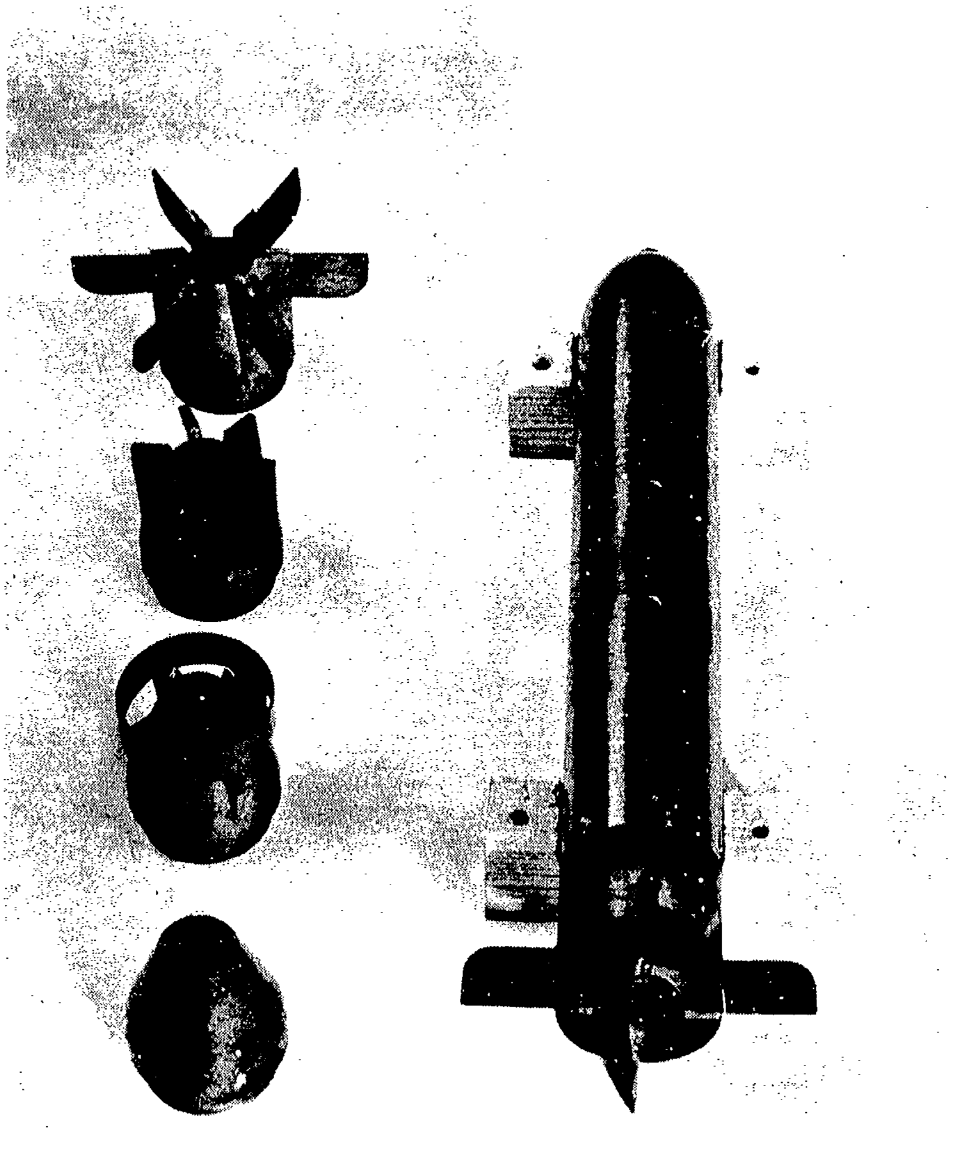


Figure 42 - DISPENSER WIND TUNNEL MODEL CONFIGURATIONS

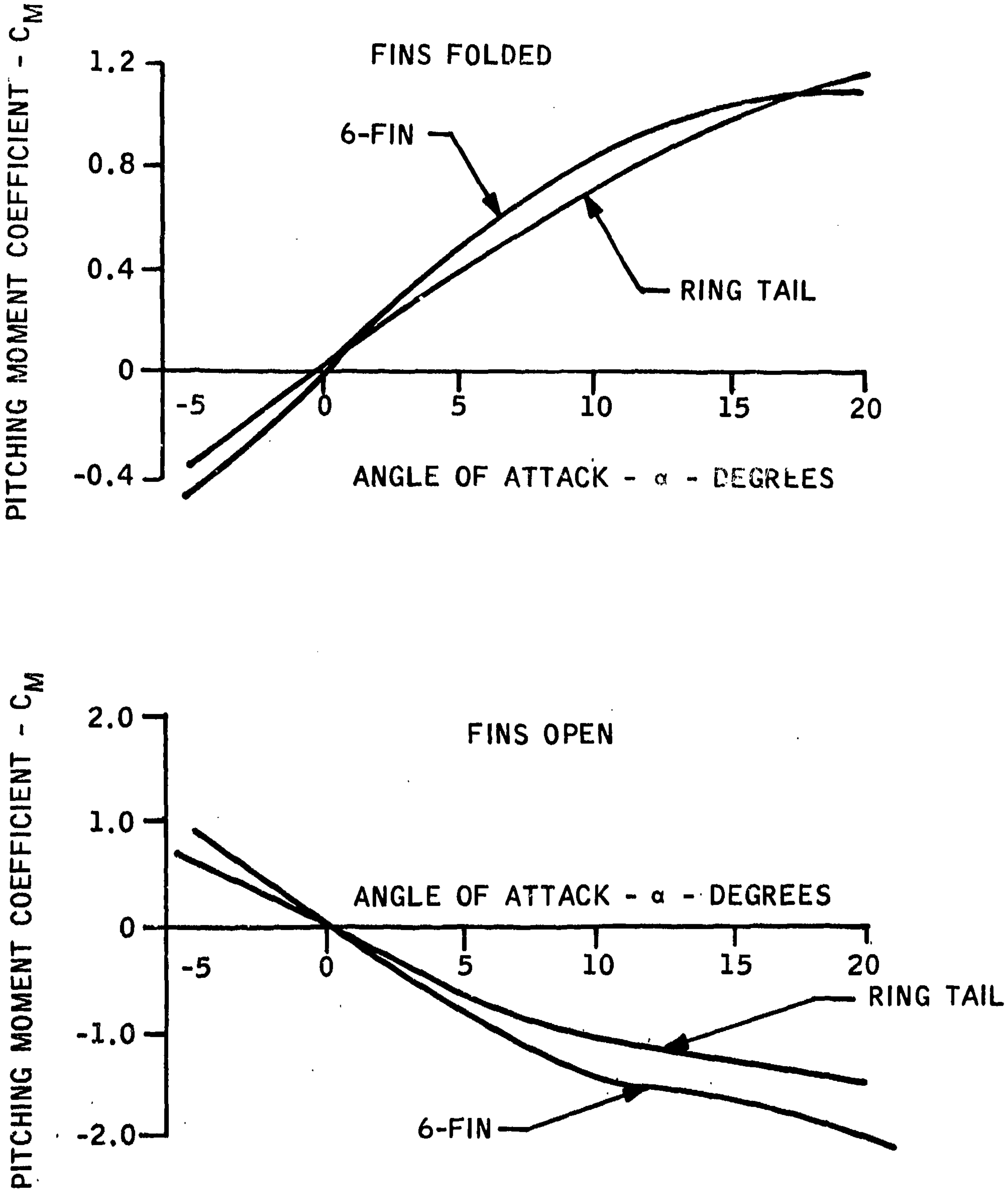


Figure 43 - FOUR-FOLDING-FIN RING TAIL AND SIX-FOLDING-FIN DISPENSER - WIND TUNNEL PITCHING MOVEMENT COEFFICIENTS FOR FINS FOLDED AND FINS OPENED

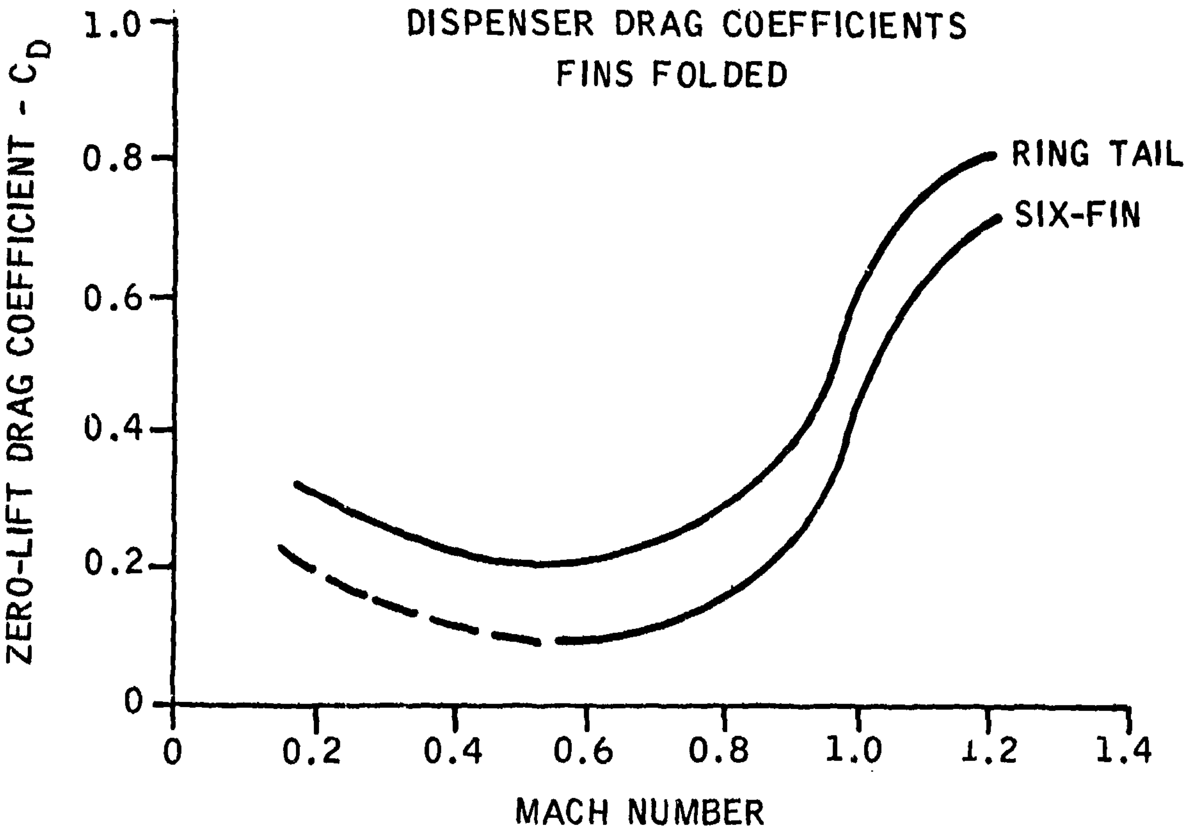


Figure 44 - FOUR-FOLDING-FIN RING TAIL AND SIX-FOLDING-FIN DISPENSER DRAG COEFFICIENTS FOR FINS FOLDED - WIND TUNNEL DATA

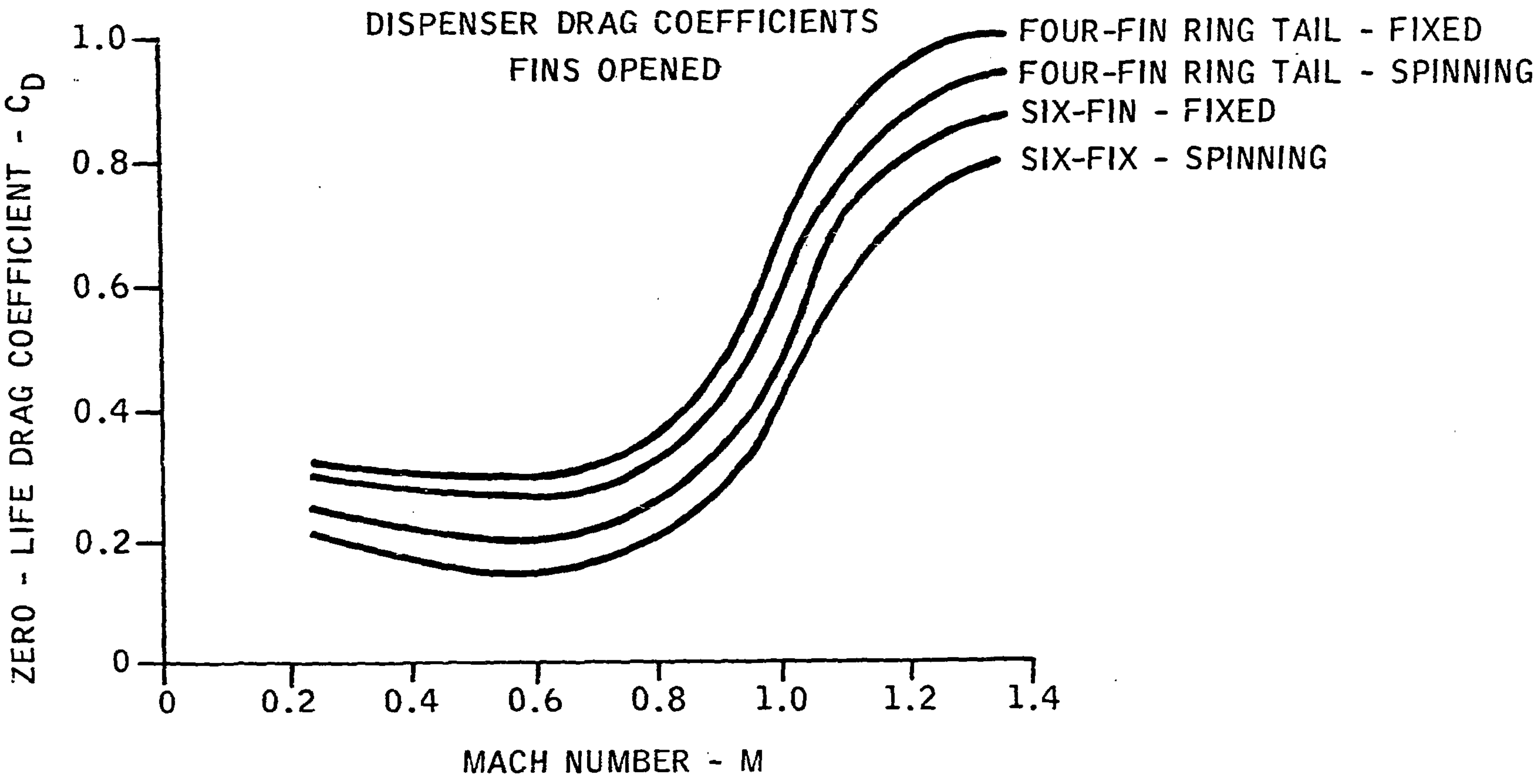


Figure 45 FOUR-FOLDING-FIN RING TAIL AND SIX FOLDING-FIN DISPENSER DRAG COEFFICIENTS FOR FINS OPENED - WIND TUNNEL DATA

less stable than the six-fin model. As the graph in Figure 44 indicates, the drag of the ring tail design is practically double that of the six-fin unit at low speeds with fins folded. The curve in Figure 45 shows that the ring tail contributes a drag increase of approximately 30% at subsonic velocities with the fins extended.

At this time, the four-fin with shroud and the six-fin concepts were discarded on the premise that the test results did not indicate sufficient improvement in performance to justify the weight and drag penalty when compared with the original configuration. The analytical data accumulated, however, were used as a basis for derivation of design alternatives potentially providing the desired stability and flight characteristics. Two basic fin configurations, shown with the variant root fin approaches in Figures 46, 47, 48, and 49, were established and evaluated in a second test series at DAL. Analysis of the tests results revealed considerable improvement in performance with these models. The intermediate fin extensions of configuration 4 (Figure 47), while providing some decrease of pre-fin open instability, interfered with the A4D flaps with the dispenser carried in the aft shoulder station of a wing mounted MBR. Consequently, concept 3 (Figure 46) was selected for the Phase I design.

The wind tunnel tests and related analyses constitued the major portion of the development effort in defining the tail assembly configuration. Consequently, a summary of these activities is included hereto as Appendix B. The concept 3 design remained the basic configuration throughout Rockeye II development; and consequently, it is appropriate that the design be described in some detail. The primary differences between this and the original design approach were: (1) the original design had flat plate fins, Phase I had airfoil fins and (2) the original design had canted root fairings with straight fins, Phase I had straight root fairings with canted fins.

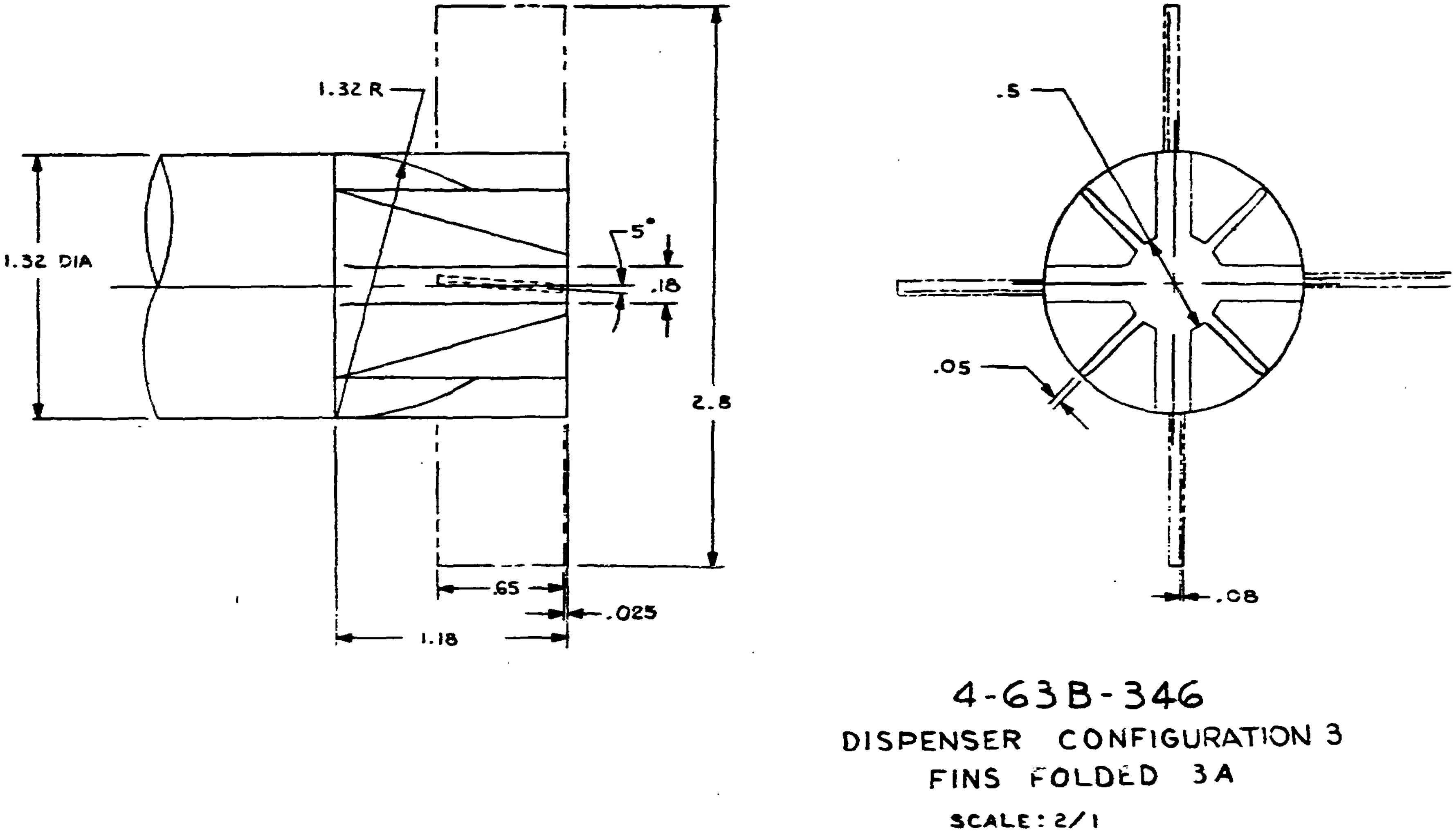
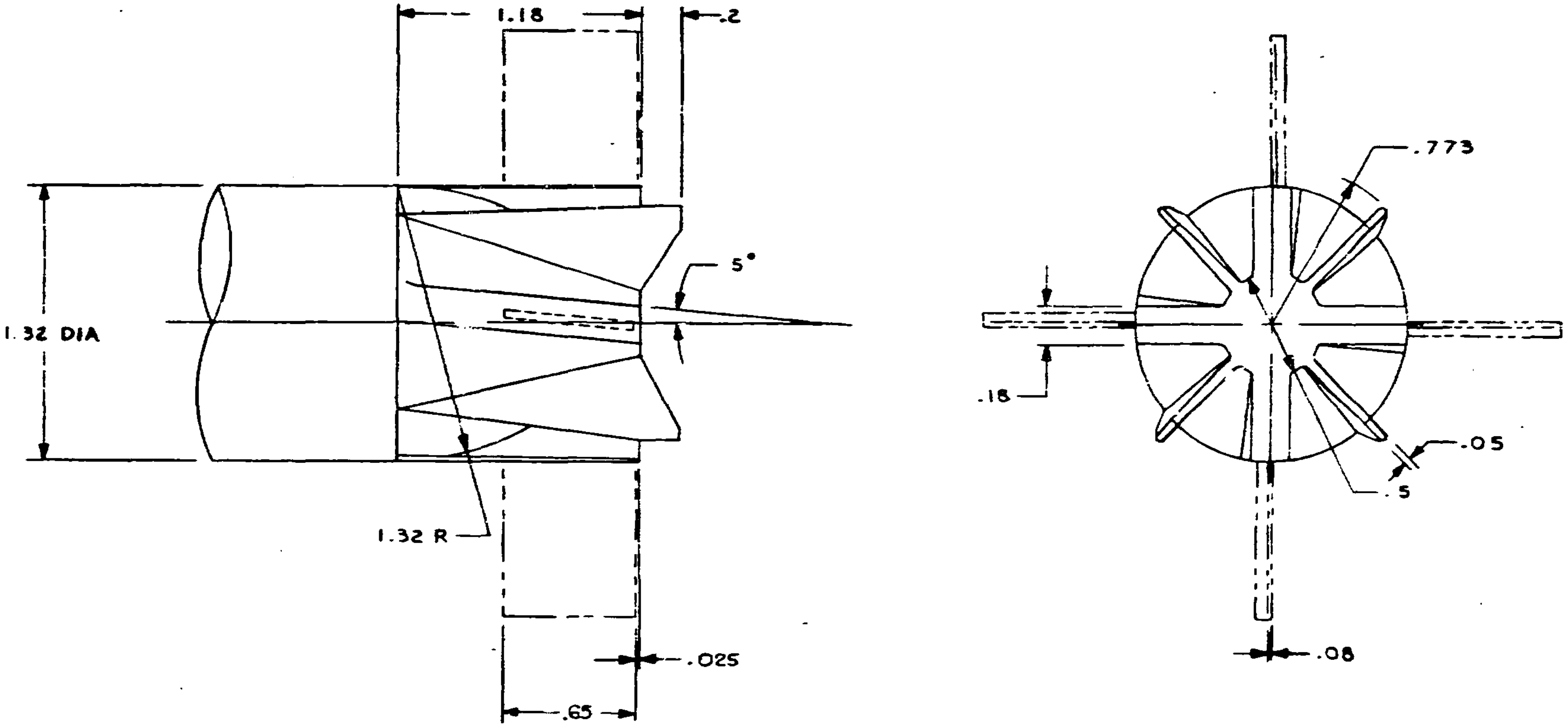


Figure 46 - DISPENSER CONFIGURATION 3, FINS FOLDED 3A



4-63B-347
DISPENSER CONFIGURATION 4
FINS FOLDED 4A
SCALE: 2/1

Figure 47 - DISPENSER CONFIGURATION 4, FINS FOLDED 4A

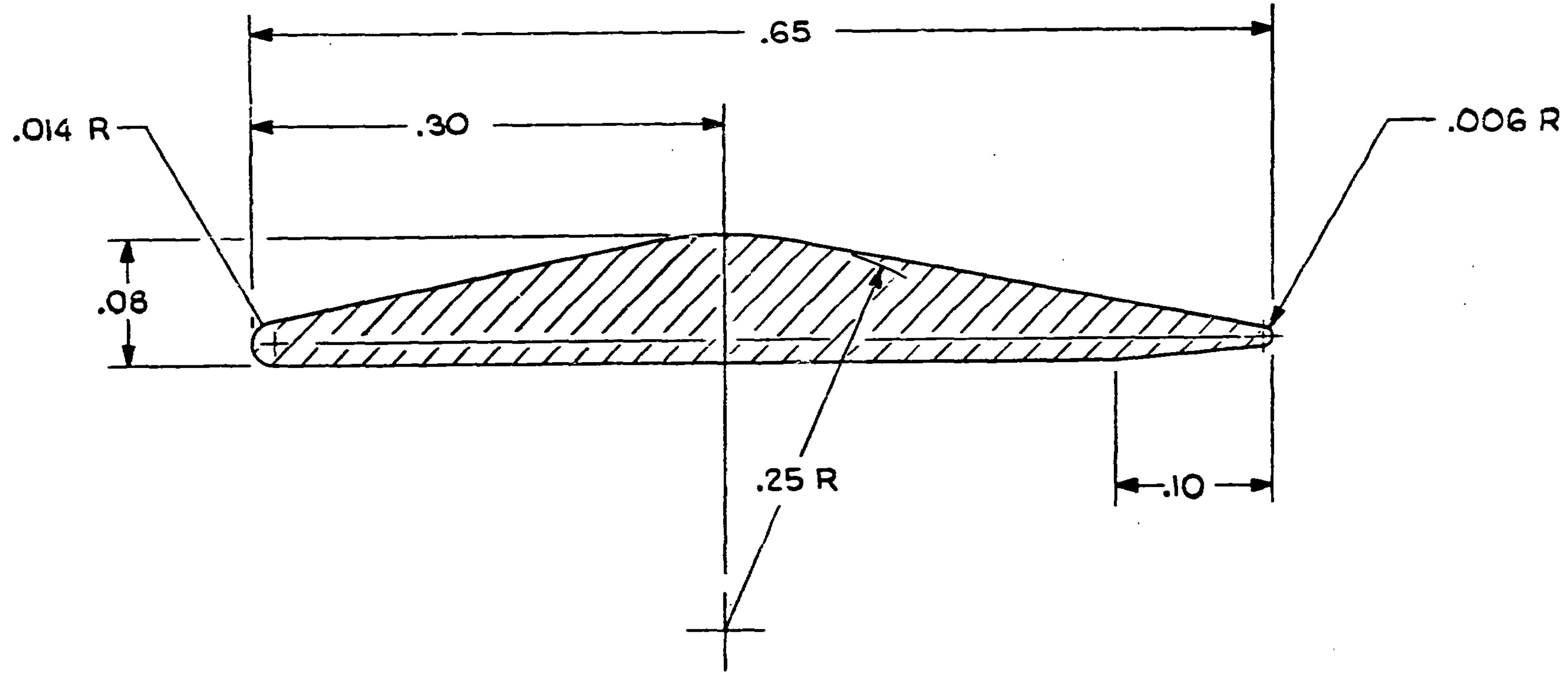


Figure 48 - DISPENSER FIN SECTION, CONFIGURATIONS 3 AND 4

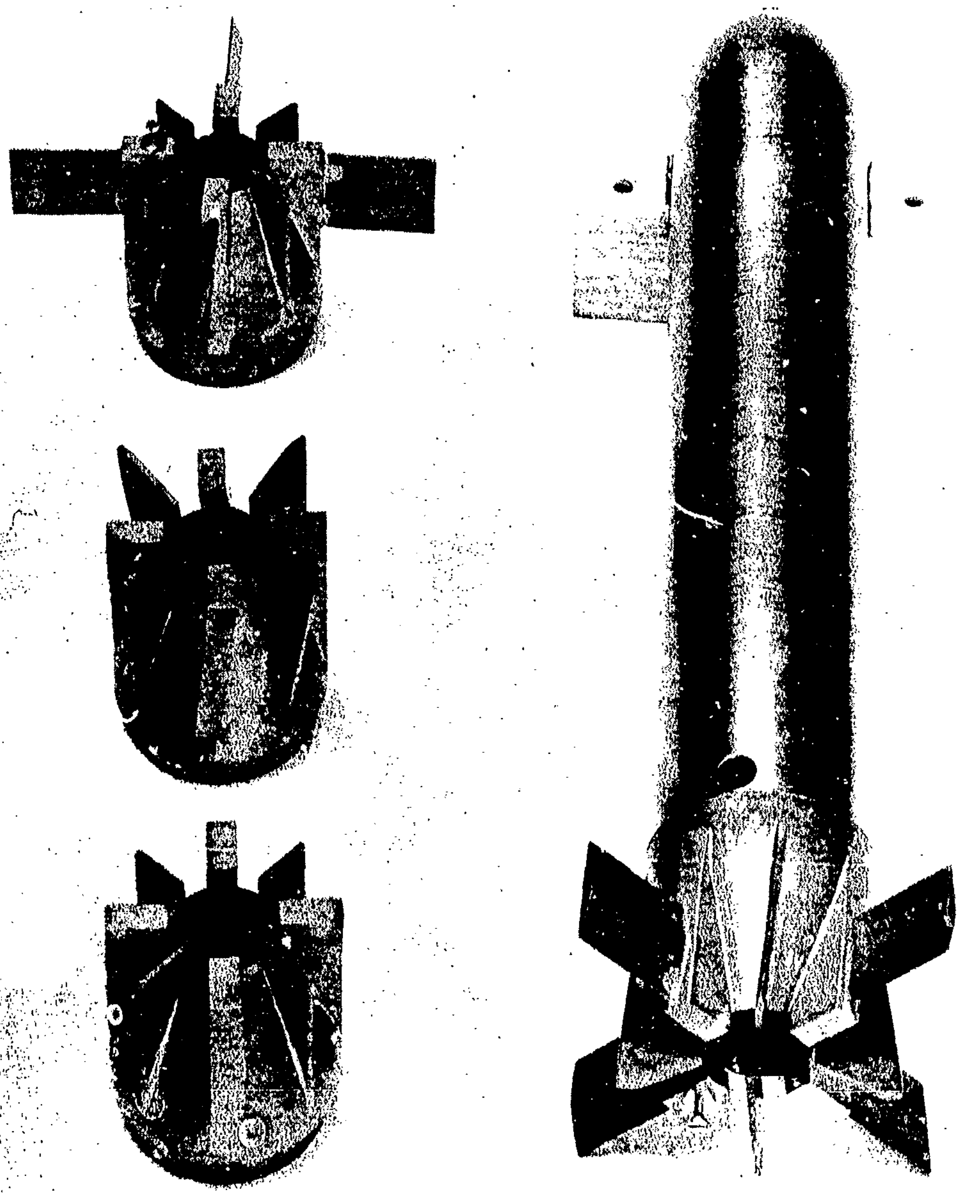


Figure 49 - DISPENSER TAIL CONFIGURATIONS 3, 3A, 4, AND 4A

The span and chord of the revised tail assembly fin were 28.5 inches and 6.5 inches respectively. The fins were cambered to provide additional lift for a given cant angle and to delay the stall angle of attack. Cant angle was established at 9°, a value which, on the basis of the wind tunnel data, would provide sufficient spin at the 1.2 second time of flight (dispenser opening time) to achieve the desired pattern size.

Both the tailcone and the fins were designed for semi-permanent mold aluminum casting. The fins were cored out to reduce the weight and moment of inertia as much as possible.

Redesign of the fins was accompanied by parallel modifications in the release mechanism. The mechanism was relocated to the rear of the tailcone to provide space for the larger fins and to enable use of a simpler and more reliable release mechanism. The release spring was eliminated, the torsion springs on each fin rotating the release device out of engagement upon extraction of the arming wire.

The arming wire conduit was recessed into the intermediate fin roots to provide a larger radius of curvature for easier insertion of the wire. The design of the fin assembly incorporating these modifications can be seen in Figure 50, which shows the cored out, airfoil fins; the arming wire conduit; and the release mechanism.

As the tail section aerodynamic profile was being evolved through studies and analyses, concurrent design modifications were being made to improve fin deployment performance. The results of these efforts are discussed below. The flight test results on the tail section embodying both the aerodynamic and opening improvements are described.

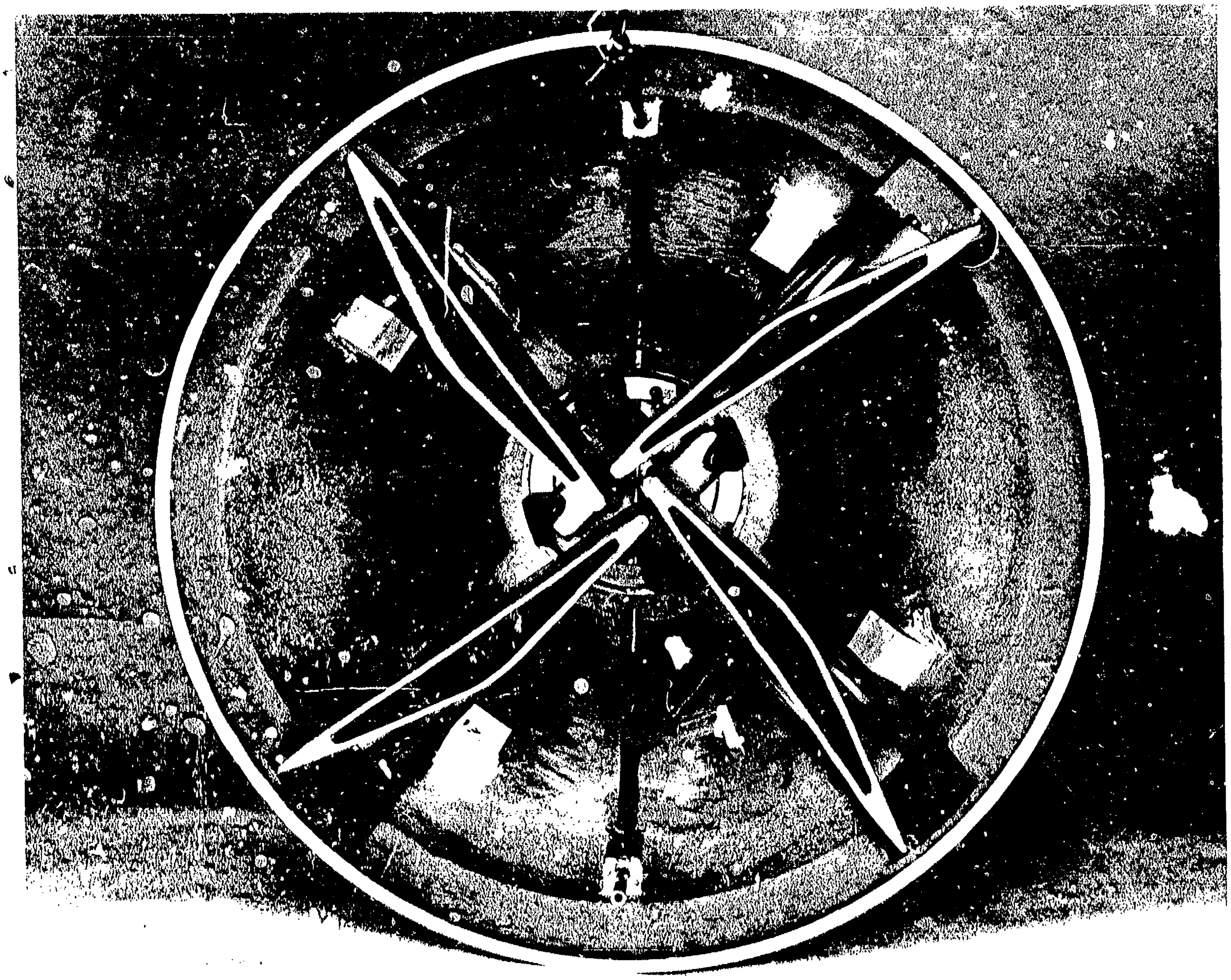


Figure 50 - MODIFIED FIN DESIGN

During the latter phases of the effort on the preliminary fin design, a problem in achieving fin deployment in flight became evident. A tail assembly was tested in captive flight at the Naval Ordnance Test Station, China Lake, on 22 November 1963. The purpose of the test was to determine the deployment characteristics of the fin under high aerodynamic loading conditions. Two tests were conducted (the model modified to permit extension of only one fin) with the tail assembly mounted so as to provide fin angles of attack in the extended position of 9° and 20°. The fins failed to deploy properly in both tests. At the 9° angle of attack, the fin rotated approximately 57° in 60 milliseconds and then stopped. A maximum opening angle of only 47° was attained in the 20° test, the fin requiring approximately 47 milliseconds to reach this position. During functioning tests without air loads conducted at Honeywell, the fin had consistently extended to the fully deployed (90°) position in about 60 milliseconds.

An investigation was conducted to determine the cause(s) of the test failures. Examination of the leading edge and tip of the fin of the flight test model revealed evidence of rubbing against the side of the fin slot in the tailcone. This interface was designed so that all frictional contact between the fin and tailcone would occur on an electrofilmed annular boss around the fin pivot. Inspection of this area showed that the machined boss surfaces were misaligned with the cast fin chord by approximately 1/2°. The reduced clearance resulted in high friction at the fin-slot interface and thus impeded fin deployment.

The aerodynamic loads acting on the fins during deployment were next reviewed. The aerodynamic loads of significance in fin extension are those acting normal to the fin and those acting along or axial to the fin. The normal loads determine the fin deflection and the frictional torque that must be overcome. The axial loads determine the amount of torque resulting from fin drag, which assists in openings.

Reduction of the wind tunnel data revealed that the actual fin normal loads were approximately 30% higher than the values used in the design of the fin deployment mechanism. While the fin was adequate from a strength standpoint for this higher load, the increased deflection further aggravated the fin-to-slot clearance problem and produced higher frictional forces.

It was noted that the wind tunnel fin load data were referenced to the dispenser centerline rather than the fin centerline. Resolving the loads along and perpendicular to the fin then revealed a very significant factor in the fin opening problem. The component of the normal force acting along the fin was of larger magnitude and opposite in direction to the axial or drag component along the fin for fin angles of attack greater than 4°. This meant that, at all but very low fin angles of attack, the airloads tended to close the fins rather than open them. The fin mechanism was designed to utilize the estimated fin drag loads to assist in opening. Since the drag load was more than offset by the normal force component along the fin chord axis, the torsion springs were not strong enough to deploy the fins against this load. This condition, together with the higher than anticipated normal loads and the fin tip rubbing, caused the fin deployment failures in the flight test.

The equations of motion of fin deployment were programmed on a digital computer to evaluate these findings. The fin opening was simulated utilizing the airload data from the wind tunnel program together with the measured frictional coefficient, spring torque, and fin physical properties. The theoretical fin opening history of this simulation showed a close correlation with the flight test data.

The computer program developed for this study was then used to determine the amount of energy required to deploy the fins under maximum loading conditions. It was found that 200 inch-pounds of energy would deploy the fins at the highest flight velocities anticipated, and this value was empirically confirmed in laboratory tests. Consequently, a torsion spring providing this level of energy was incorporated into a model and tested in captive flight (20° fin angle of attack) at China Lake. The fin functioned satisfactorily at an aircraft speed of 350 KIAS but rotated only 64° when activated at 530 KIAS.

The torsion springs used in this testing were about as large as possible considering physical clearance limitations. It was, therefore, decided to reduce the friction at the fin-slot interface rather than try to increase the spring size and torque. Consequently, roller thrust bearings (Torrington #NTA3244 and #TRA3244 races) were substituted for the electrofilmed surfaces at the frictional face between the fin boss and the tailcone slot, a modification that reduced the friction coefficient of the fin-to-slot interface by a factor of at least ten.

The tail assembly incorporating the revised interface is shown in Figure 51 with the associated parts. Two captive tests of this model were conducted at China Lake, again using a 20° fin angle of attack. In both cases the fin opened and locked satisfactorily, rotating to the fully deployed position in approximately 40 milliseconds. Since the test conditions were more rigorous than would be experienced in normal delivery (the velocity of the first run was Mach 0.9 and the altitude was 18,000 feet MSL; the second run was at a speed of 540 KIAS and at an altitude of -100 feet MSL), it was concluded that the revised design provided the required reliability of function.

The modified tail assembly (incorporating the changes described in the foregoing and the canted fin, straight fin root) was first tested under release conditions in September, 1964, at China Lake in Phase I dispenser A-5. Failure of the bomb rack attachment to the fin release arming wire at dispenser ejection, however, prevented fin deployment. In October, 1964, the modified fin assembly was tested under release conditions in weapon A-6; and satisfactory function was demonstrated in fin deployment, dispenser stability, and spin-up.

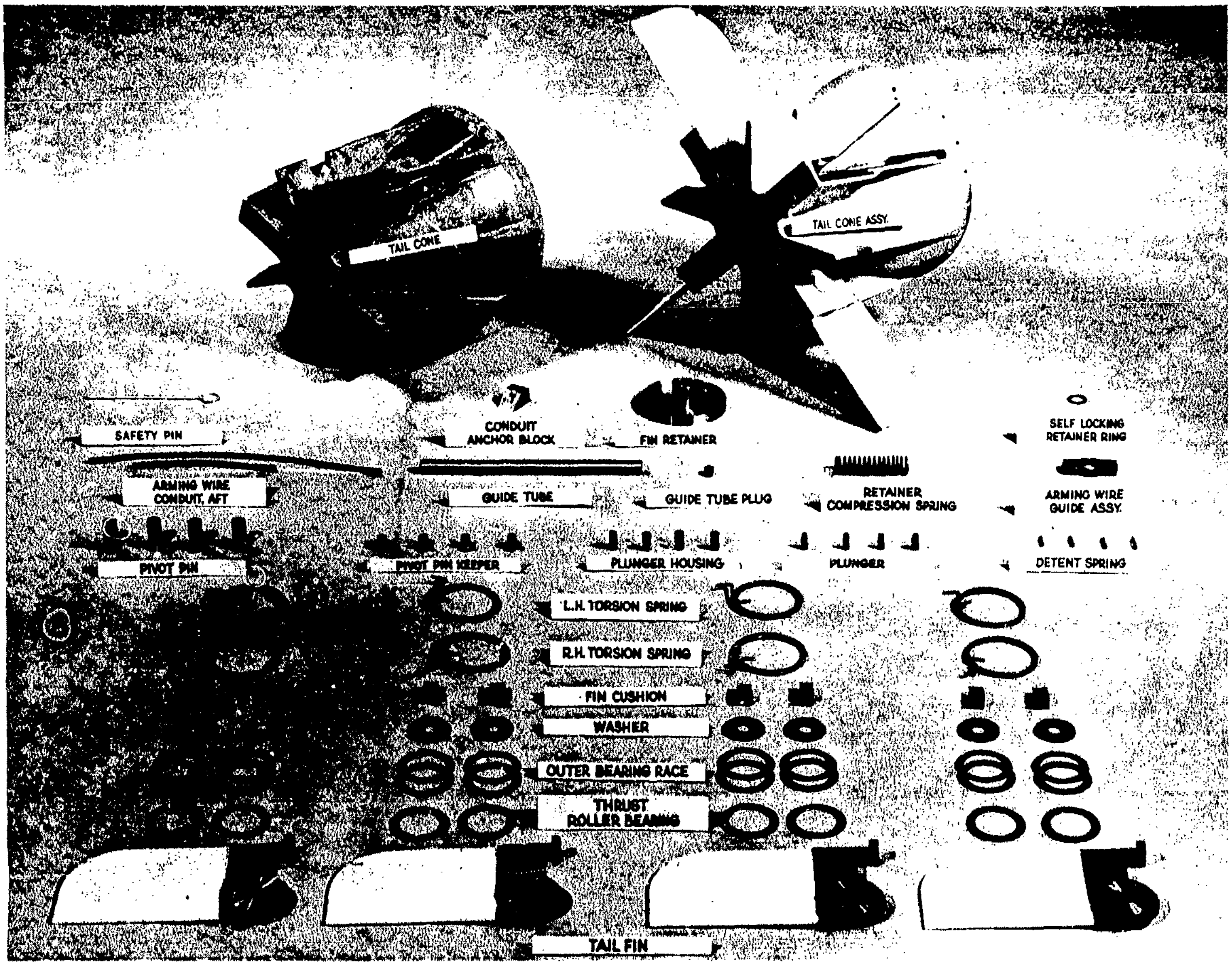


Figure 51 - ROCKEYE II TAILCONE ASSEMBLY AND ASSOCIATED PARTS

Subsequent full flight release tests were made in weapons A-7, A-8, A-9, A-10, and A-11 with satisfactory results. The results of these tests substantively confirmed the adequacy of the design approach, and the tail section configuration remained relatively unchanged throughout the remainder of the program. Minor modifications, however, were made to the design to improve the performance and/or enhance the producibility of the assembly.

The internal fin release mechanism was replaced by an external release band located in a circumferential recess adjacent to the forward edge of the tail-cone. In this approach, the band locking the fins in the depressed position is held in place by the arming wire running through interfacing apertures at the end portions of the band. At release, the arming wire is withdrawn, releasing the band and freeing the fins to deploy.

The design (shown in Figures 52 and 53) enabled use of an external arming wire, thus providing compatibility with a parallel change to an external arming wire for the fuze. In addition the revised approach simplified the functional sequence (concurrently enhancing functional reliability) and reduced the cost of the assembly. The pull force under ambient conditions at the band required to release the fins in this concept was less than 10 pounds.

The external wire/release band design was tested in weapons A-12, A-13, A-14, and A-15 with satisfactory results. There was no tendency for the band to collide with the release aircraft. Although this release configuration slightly increased the time required for fin deployment, no problems in dispenser stability or spin-up resulted. This increase in time for the fins to extend was substantially reduced later when the band was increased in thickness and decreased in width.

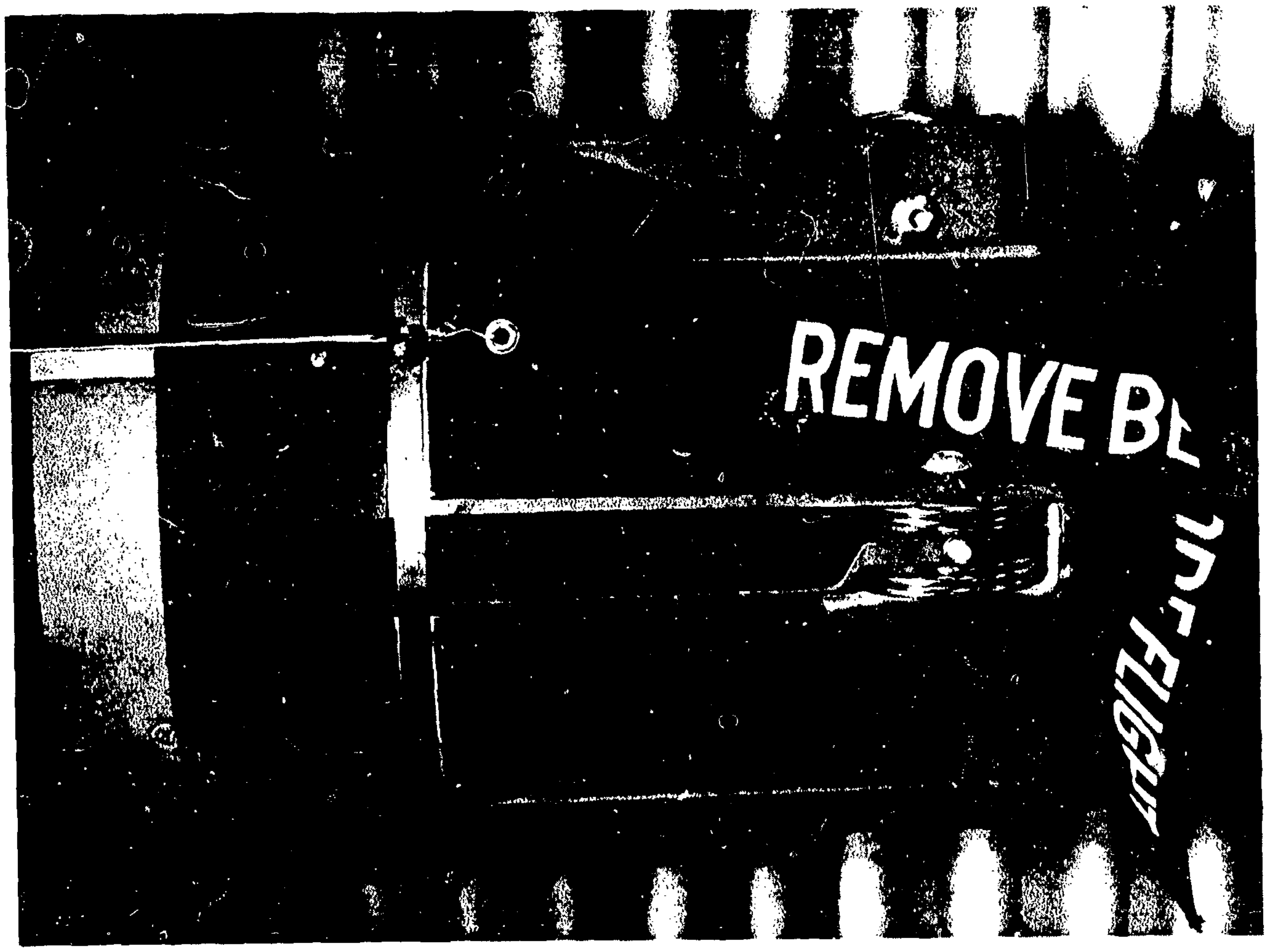


Figure 52 - FIN RELEASE BAND

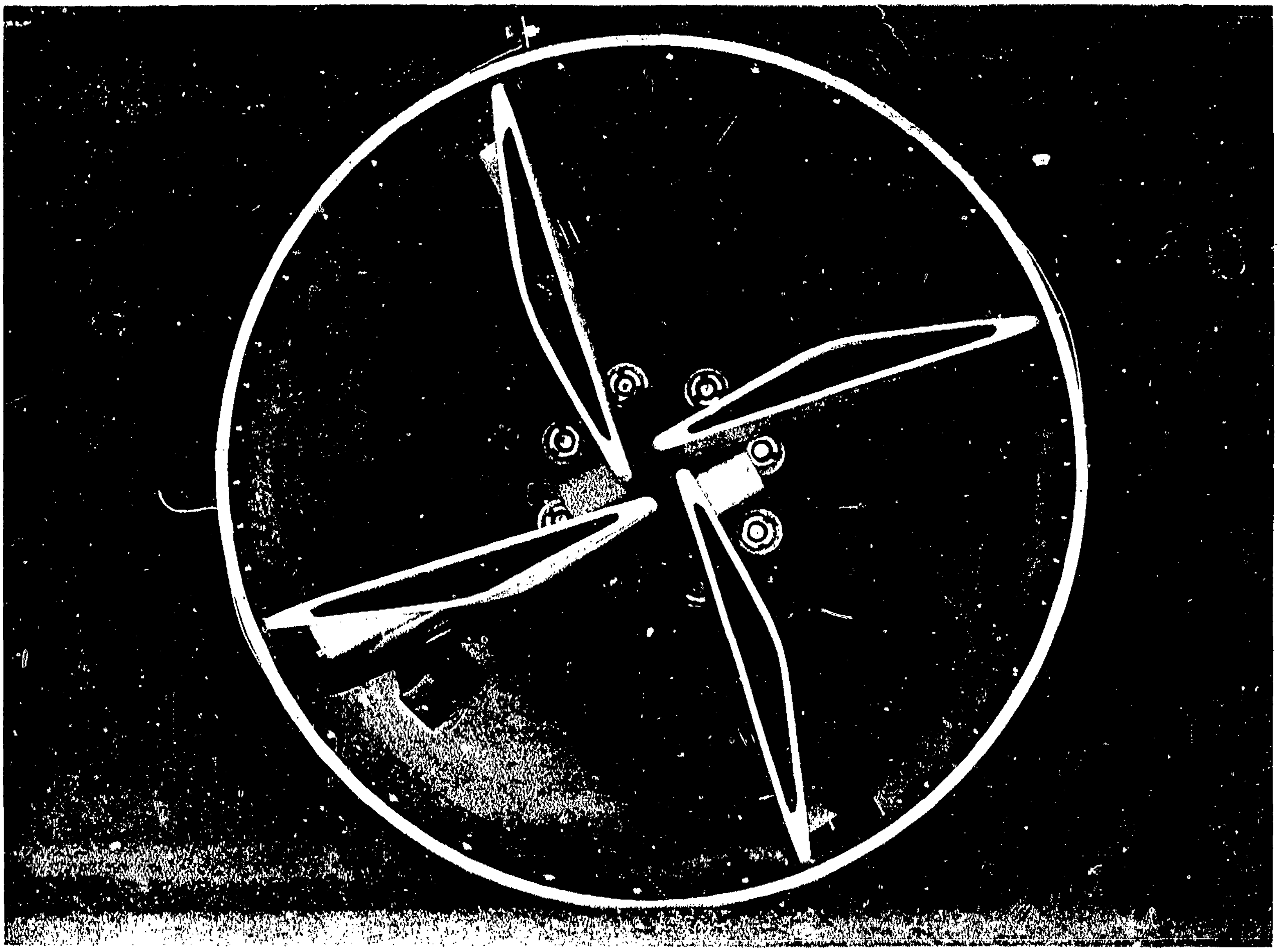


Figure 53 - INTERNAL FIN RELEASE DESIGN

The external arming wire design enabled casting the aft bulkhead as an integral portion of the tailcone since access for installation of an internal mechanism was no longer required. This provided additional savings in the fabrication and assembly of the tail section. Design on this configuration was, therefore, initiated; but the design objective was subsequently modified to parallel a related effort on improving bomblet deployment at dispenser opening. It was felt that a pre-split tailcone with an aluminum plate bolted to the base to act as a hinge would provide dispenser opening characteristics compatible with optimum bomblet release conditions. This modification was tested in weapons B-12 and B-13 and showed decided improvements over previous release techniques.

Consequently, the tailcone for the Phase III dispenser was redesigned as a pre-split unit. This created a problem with respect to structural integrity during handling, loading, and carriage conditions. A new aft bulkhead configuration that incorporated webs re-oriented along and perpendicular to the split plane satisfactorily resolved these problems. The tail section assembly (including bulkheads) reflecting these changes weighed approximately six pounds less than the previous configuration.

During functioning tests conducted on Phase II weapons after exposure to environmental extremes, the following fin opening and locking problems were encountered:

(1) Fin release band sticking to the tailcone paint

(2) Locking detents inoperable because of corrosion and/or metal parts seizure

(3) Fin springs and/or bearings degraded in function because of icing.

The first problem was experienced on weapons B-16 and B-17 after temperature-humidity cycling. Exposure to this environment apparently softened the paint, which then adhered to the band. Assembly specifications were consequently revised to provide that the area of the tailcone under the band be masked during painting. The iridite finish on this surface gives adequate metal protection; no metal deterioration would, therefore, result from a lack of paint. In subsequent tests under identical environmental conditions, consistently successful band release functioning was obtained with units having no paint in this area.

The fin detent failures were traced to a lack of silicone grease in the detent assembly. This grease was inadvertently omitted during the build of Phase II hardware. Icing, salt spray, and 28-day humidity/temperature cycling tests were subsequently completed on properly lubricated detent assemblies with successful functioning demonstrated in every case.

The failure of the fins to deploy properly after the icing environment was unexpected, since proper function had been repeatedly demonstrated in previous tests under the same conditions. The test assembly was disassembled, and all moving parts were sprayed with a Teflon lubricant compound, Emralon 323. This dry-film material isolates the metal surfaces from moisture, thus preventing ice formation. The fin detents were filled with DC-33 silicone grease, and the test was repeated with completely satisfactory fin deployment being achieved.

In the evaluation of the fin openings, an associated problem - galling between the outer bearing race and the mating fin boss - was noted. The condition developed gradually with repeated opening of the fins and resulted, in the more advanced state, in increased fin resistance to the opening torque of the springs. It was felt that this would not constitute a problem with production units, which would not be subjected to repeated fin operation. To preclude any possibility of malfunction in service units, however, engineers evolved an alternate interface configuration between the fin bearing and boss that eliminates galling of these surfaces. The modified interface, consisting of an 0. 005-inch thick mylar plastic shim between the two surfaces, was subsequently tested and found to be wholly satisfactory.

In subsequent requalification tests of the tail assembly DC-33 silicone grease on the roller bearings and pivot pins was substituted for Emralon on the bearing races and pivot pin. This change eliminated problems of application and adherance of the Emralon. Two tailcones with greased surfaces satisfactorily passed all previously troublesome environments including low temperature, salt spray, icing, and humidity. A repeat sand and dust test was conducted to assure no problem introduced by grease, and again completely satisfactory results were obtained.

In salt spray tests, the helical torsion springs showed surface corrosion even when electrofilmed. With an electro-polish finish, however, the springs withstood the environment satisfactorily as may be seen in Figure 54, which shows electropolished and electofilmed units after exposure to salt spray. Electropolish was, consequently, specified as the finish for the helical torsion springs. This surface treatment also eliminates any potential stress corrosion problem with the springs, and thereby avoids any possible spring failure subsequent to long term storage.

No other major modifications were made to the tail section assembly during the course of the development program.

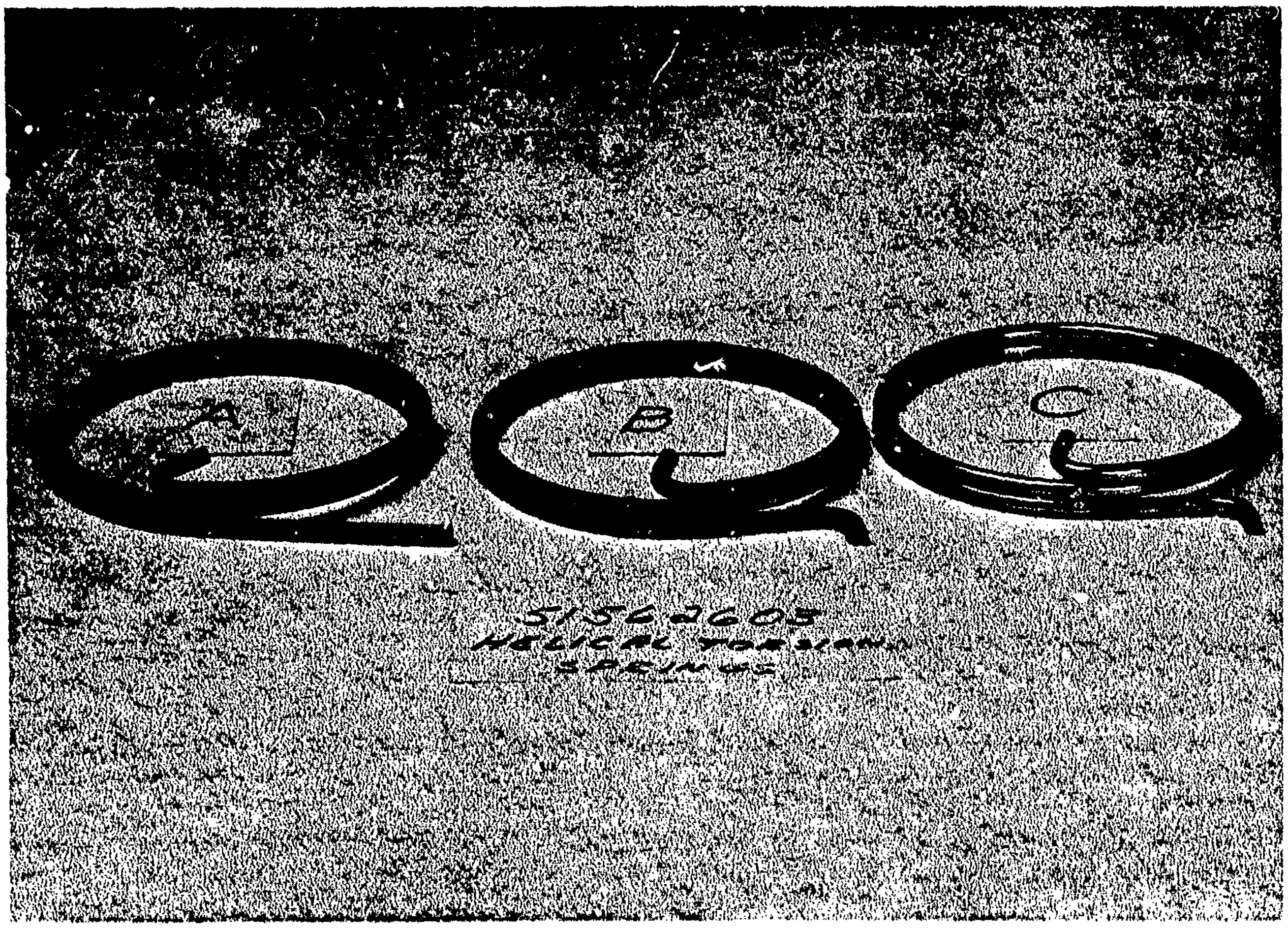


Figure 54 - EFFECTS OF SALT SPRAY ON SURFACE FINISH. ITEM A - HELICAL TORSION SPRING FROM STOCK. ITEM B - SPRING WITH ELECTROFILM FINISH PROPERLY APPLIED. ITEM C - ELECTRO POLISHED SPRING.

3. Description of Final Dispenser Design

a. Functional Description

The Rockeye II dispenser* performs the following basic functions:

- Provides structural support and sealed protective containment for the MK 118 MOD O Anti-Tank Bomb and other cargo loads during shipping, handling, and storage of the weapon.
- Provides a configuration which is geometrically and structurally compatible with nearly all operational Navy and Air Force tactical aircraft and their associated bomb racks.
- Provides the structural capability of the weapon to withstand the inertial and aerodynamic load and vibration environments of captive flight, catapult, and arrested landings.
- Provides an aerodynamically stable vehicle in a normal environment for delivering the cargo bomblets to the desired release point; introduces angular momentum to the bomblets for dispersal; and releases the bomblets into a stable flight mode which produces an effective pattern.

(1) Loading Sequence

The Rockeye II weapon, which is stowed in an "all-up" condition, is attached to the aircraft bomb rack using standard handling equipment. The bomb rack hooks engage standard 1000-lb. class lugs threaded into the dispenser strongback. Two arming wire extractor swivels on the dispenser are attached to the nose and tail arming wire solenoids of the bomb rack.

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* The stress analysis and material selection code covering this design are included as Appendix C and D respectively in Volume I, Part B.

The bomb rack sway braces are tightened against the strongback surface of the dispenser to complete the installation. The safety flags for the nose fuze and the fin release band are pulled and the weapon is ready for use.

(2) Delivery Sequence

When the weapon is released, the forward extractor strips the fuze arming wire from its protective conduit. This removes the end of the wire from the fuze band and jump-up pin on the MK 339 MOD O Fuze mechanical timer, and initiates the fuze enabling and arming functions. At the same time the aft extractor strips out the fin arming wire; as this wire pulls out of a stud, the fin band releases the spring loaded folding fins. The four canted fins rotate open, providing aerodynamic stability and inducing a roll moment to the weapon. The weapon follows a ballistic trajectory during which time it experiences a rapid spin acceleration.

After 1. 2 seconds of dispenser free flight, the fuze initiates a stab detonator. This in turn initiates the explosive network by firing an explosive lead and booster which initiates a strand of aluminum linear shaped charge (AL-LSC). The AL-LSC cuts the cargo section in half longitudinally, and the two sections hinge outward about a plate attached to the base of the pre-split tail cone releasing the bomblets. The centrifugal and aerodynamic forces at dispenser opening cause the bomblets to distribute into an effective random pattern. The pattern is oval in shape with a size dependent on the release altitude and velocity.

(3) Design Features

The Rockeye II dispenser incorporates the following significant design features.

- An "all-up" design concept requiring no maintenance, preparation, or special care.
- A rugged, all-aluminum structural configuration capable of withstanding severe conditions such as Sea Level, Mach 1.2 captive flight; "cordwood" style shipboard stowage; and 40 foot drop onto steel surface concrete without rupture of the cargo section.
- Suitability for other cargo items such as the MK 17, MOD O munition up to a gross weapon weight of 750 lb.
- A highly efficient configuration from both a weight and volume standpoint with a cargo compartment volume approximately 80 percent of the total weapon volume and a cargo weight capacity approximately 85 percent of the gross weapon weight (at 750 lb. gross weapon weight).
- A safe and reliable linear shaped charge skin cutting network.
- An effective cargo compartment seal that has a leak rate of less than 0.018 PSI/HR with a one atmosphere pressure differential. This seal makes it possible for the unprotected MK 1 MOD O bomblet fuzes to pass the MIL-STD 304 Temperature and Humidity Cycling Test and the very severe MIL-STD 305 Vacuum Steam Pressure test.

- High strength, fatigue resistant arming wires that are mechanically protected from damage and inadvertent extraction, are quickly attached to any bomb rack solenoid, and are retained with the weapon after release to prevent whipping damage to the aircraft at high speeds.

- A reliable folding fin design that has been demonstrated to function properly after exposure to all the required natural environments. The folding fins provide several advantages including ease of handling and stowage, maximum aircraft and bomb rack fitment, no interference with catapult bridles, and low captive flight drag.

- Mechanical and explosive compatibility with the MK 339 MOD O Fuze, Mechanical Time, and also the M 908 Fuze (with appropriate adapters).

- An end-loading cargo compartment that enables unitized insertion and removal of the cargo pack.

b. Physical Characteristics

(1) General Description

The Rockeye II Dispenser is 13.2 inches in diameter and 91.3 inches long. The nose is a one caliber tangent ogive, the body is a 65-inch cylinder, and the tail is a one caliber boattail with a 5-inch base diameter. The tail section has four folding fins and four intermediate fixed stub fins. The extended folding fins have a span of 28.5 inches, a chord of 6.5 inches, and cant of 9°.

The dispenser is of all aluminum construction and consists of three basic sections; the nose section, cargo section, and tail section. The nose section is made up of two pre-split ogive fairings, the MK 339 MOD O Fuze, Mechanical Time, and the fuze mounting devices.

The basic components of the cargo section are the skin (with integral ogive section and forward bulkhead), the internal strongback, the linear shaped charge skin cutting network, and the seal plate. Additional components include the arming wire system, the suspension lugs, the MBR standoff pads, and swaybrace chafing discs.

The tail section consists of a cast tailcone with an integral aft bulkhead, four cast folding fins, and a fin release band. Each fin is mounted between needle thrust bearings and powered by helical torsion springs. Spring loaded detents lock the fins in the open position after they deploy.

The metal parts comprising the dispenser are shown in Figure 55.

(2) Weight and Balance Characteristics

The Rockeye II weapon weighs approximately 466 pounds and has a cg at Station 44. 3. The empty dispenser weighs 113 pounds, and the cg is located at Station 50. 3. The weight of each of the major components is indicated in the following:

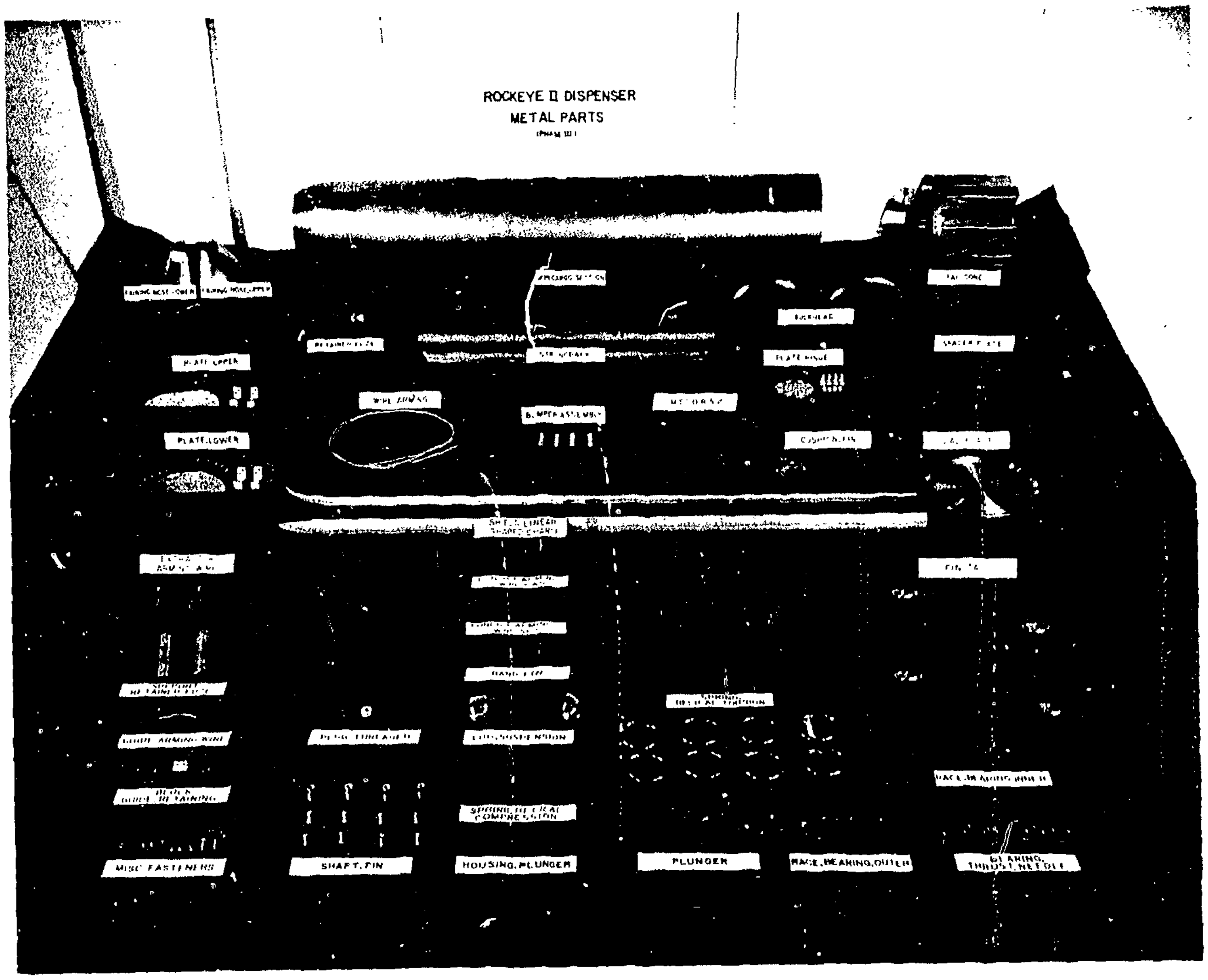

Figure 55 - PARTS LAYOUT, FINAL DISPENSER DESIGN

Item	Weight (Pounds)
Dispenser Only	107.7
Cargo Removal Plates	1.7
MK 339 MOD O Fuze, Mechanical Time	3.8
Packing Spacers	18.6
MK 118 MOD O Anti-Tank Bombs (247)	334.7
Total Weapon	466.5

A summary of weight, balance, and inertia characteristics for the weapon and the empty dispenser is presented in Table VIII. Data are provided for both the fins closed and fins open conditions.

The cargo characteristics of the live Phase III bomblets are reflected in these data. The dispenser characteristics are those of the Phase III design except that the new integral bulkhead tailcone has been substituted for the heavier Phase III unit.

TABLE VIII

ROCKEYE II WEIGHT - BALANCE & INERTIA

		Weight (lb)	$\bar{X}$ (in)	$\bar{Z}$ (in)	I_{XX}	I_{YY}	I_{ZZ}
Mk 7 Mod O Universal Dispenser (Empty)	Fins Open	113.2	50.3	1.32	.70	19.3	19.2
	Fins Closed	113.2	50.3	1.32	.65	19.5	19.4
Mk 20 Mod O Cluster Bomb	Fins Open	466.5	44.3	0.13	1.88	47.0	46.9
	Fins Closed	466.5	44.3	0.13	1.95	47.2	47.2

c. Design Details

The design details of the Rockeye II Dispenser are discussed in the following paragraphs.

(1) Nose Section

The nose section consists of two pre-split ogive fairings, the MK 339 MOD O Fuze, and the fuze mounting devices (Figure 56).

The nose fairings are made of 0.125-inch thick 6061-T6 aluminum alloy, and are pre-split to avoid the need to extend the explosive cutting network into this area. A transparent polycarbonate window which provides a convenient means to visually check the safe or armed condition of the MK 339 Mod O Fuze, Mechanical Time, is mounted in the upper fairings. Both fairings are secured to the forward bulkhead area of the cargo skin with AN 509 screws.

A 2024-T6 aluminum alloy fuze retainer is cantilever mounted by means of cap screws to the lower half of the cargo skin (Figure 56). A face mounted O-ring provides the seal between the fuze retainer and the cargo skin, and the fuze is secured in the retainer by three set screws. A formed tube attached to the front bulkhead guides and positions the arming wire for proper alignment with the fuze.

(2) Cargo Section

The basic components of the cargo section are the skin (with integral ogive section and forward bulkhead), the internally mounted strongback, the linear shaped charge skin cutting network, and the arming wire system (Figures 57 and 58). Other components include the suspension lugs, the MBR standoff pads and swaybrace chafing discs, and the aft seal plate. These components are discussed in detail in the following sections.

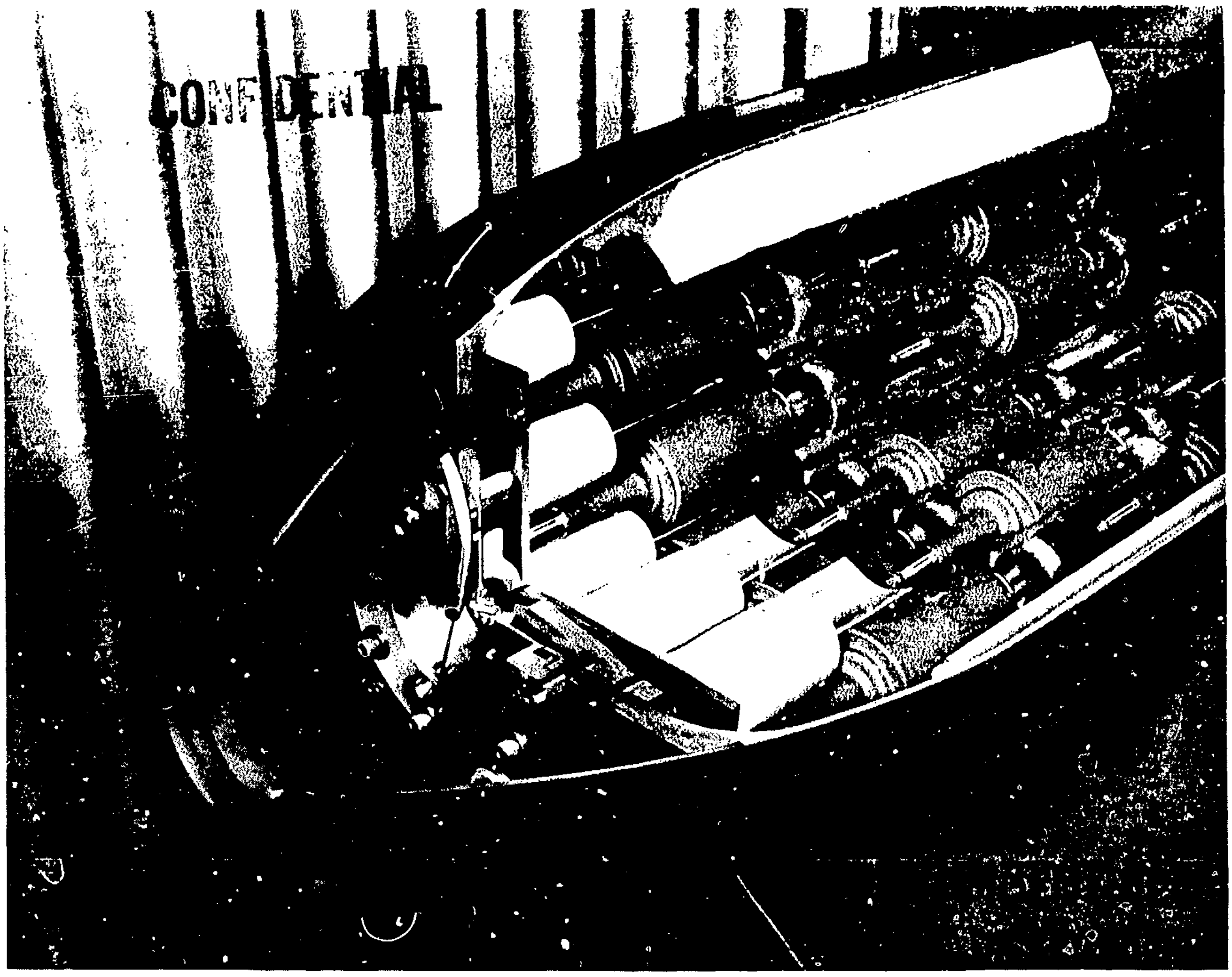

Figure 56 - DISPENSER NOSE SECTION

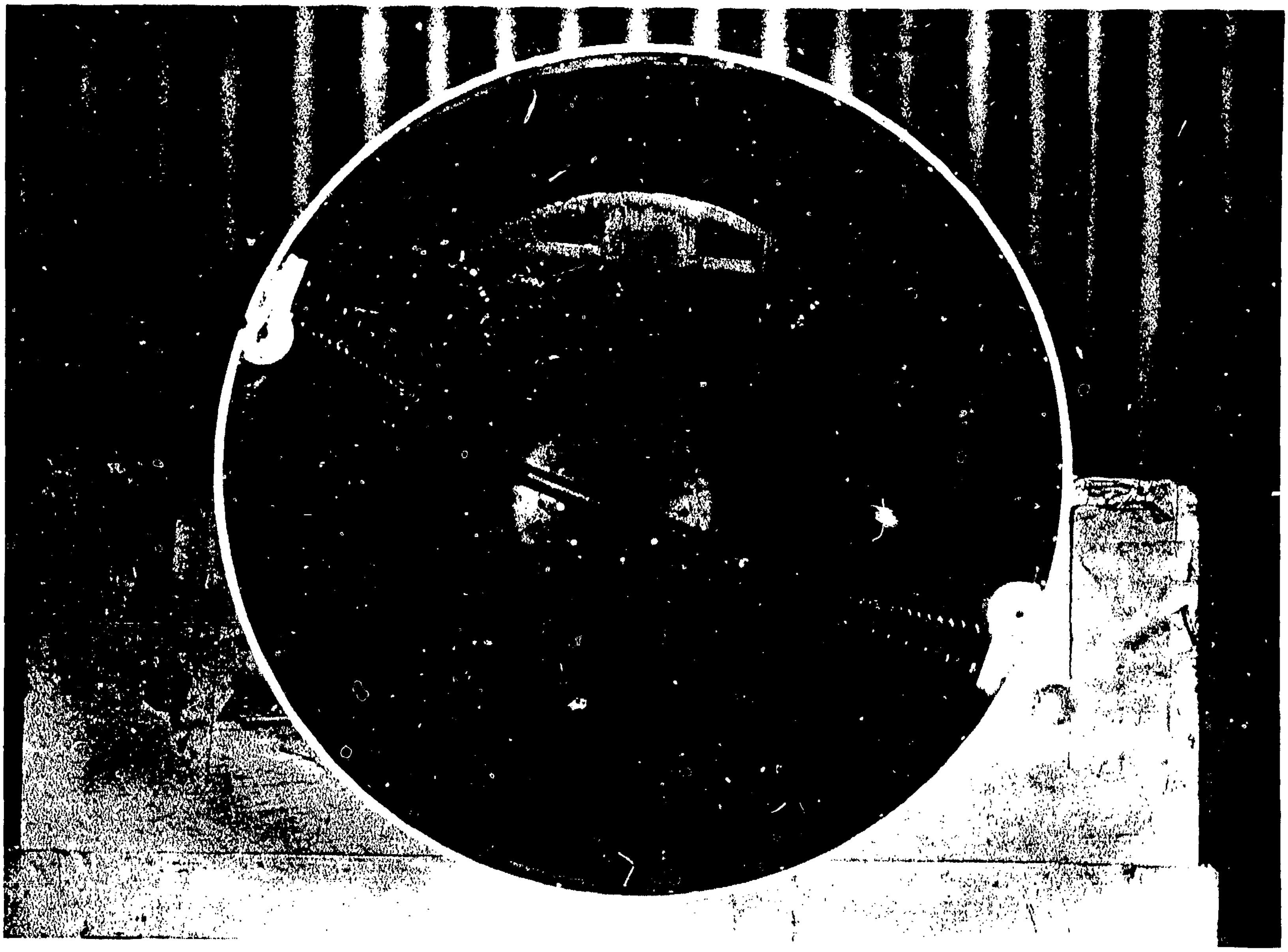

Figure 57 - CARGO SECTION INTERIOR

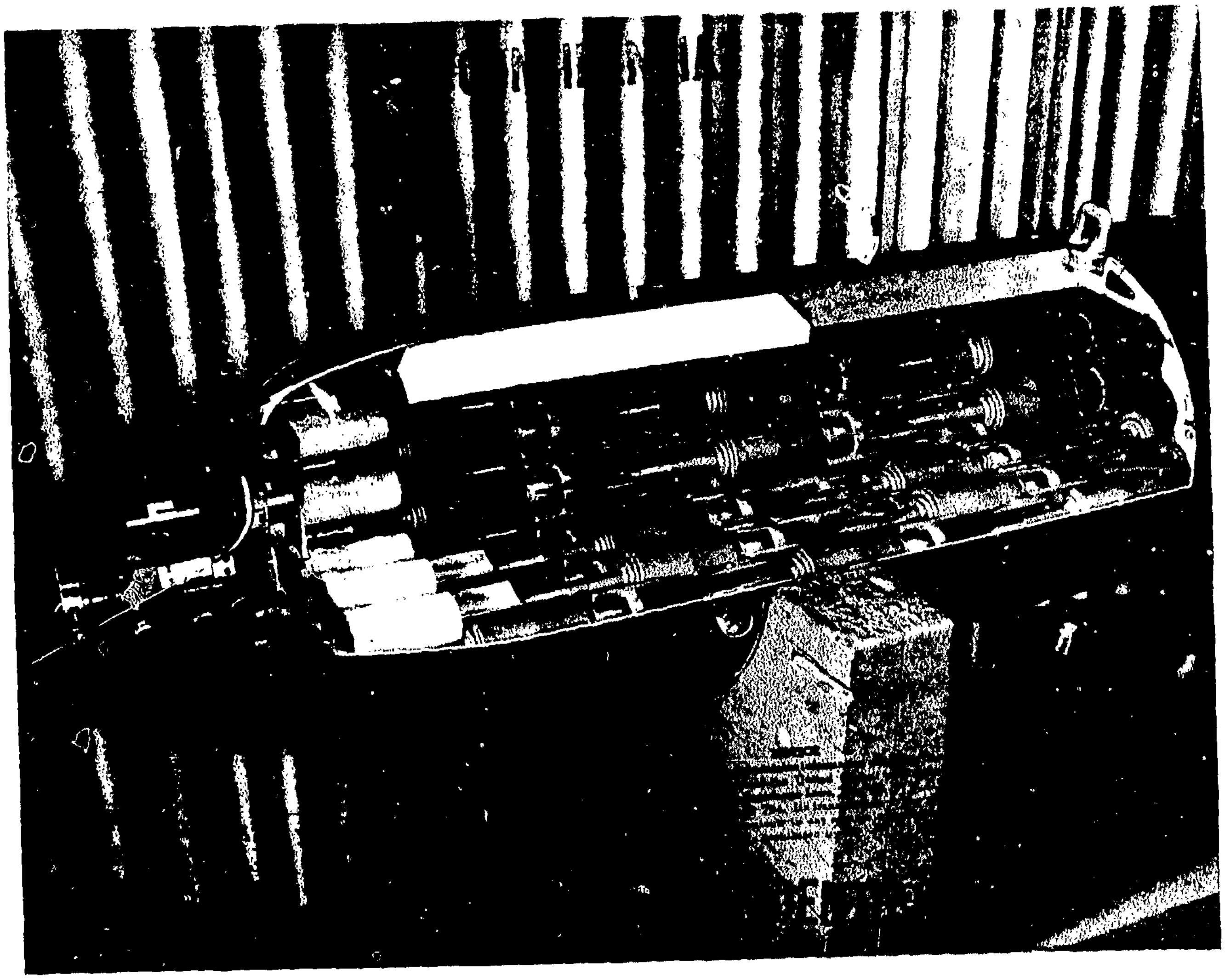

Figure 58 - CARGO SECTION AND FUZE ARMING WIRE

(a) Structural Configuration - The cargo section comprises the primary dispenser structure; it consists essentially of the skin and strongback. The skin is a 1/8-inch thick 6061-T6 aluminum alloy cylindrical section with an integral ogive and 1/2-inch thick forward bulkhead. The skin is fabricated by means of shear forming (flow turning) or cold extruding.

The strongback is a 6061-T6 extrusion approximately 39 inches long, 9 inches wide, and 1.4 inches deep at the center. The cross section has two lightening holes to reduce weight and four grooves along the bottom surface to provide clearance for the MK 118 MOD O Anti-Tank Bomb fins. The ends are cut at a 45° angle to facilitate cargo installation or removal and to provide a structural transition area to reduce stress concentrations in the skin at the strongback corners.

The strongback is mounted internal to the skin and attached by means of No. 10-32, 100° flathead O-ring seal screws. The captive flight inertial and aerodynamic loads acting on the weapon are reacted by the bomb rack hooks and sway braces. The strongback provides the structural interface with the bomb rack. Standard 1000 lb. class 14" spaced suspension lugs (MK 6 MOD O), which thread into the strongback, attach to the bomb rack hooks. The sway braces contact the skin surface in an area supported by the strongback flanges, which extend the full length of the strongback to provide support for virtually all existingbomb rack sway bracing arrangements. The strongback also serves to support and stiffen the skin longitudinally for counteracting bomb rack ejection loads.

The cargo section contains no rings or intermediate bulkheads to stiffen the skin (see Figures 57 and 58). The relatively unconventional design approach was dictated by the end-loading feature together with the need to maximize the cargo compartment volume. The result is a clean, unobstructed cargo compartment cross section which exceeds 90% of the total weapon cross section. Instead of utilizing rings, the cargo itself is used to stiffen the skin. Under a side load condition, such as would be experienced in a rolling-pullout maneuver, the skin is loaded in bending along the juncture with the strongback. Bending stresses in this area increase with loads up to the point where the cargo "bottoms-out", and starts to pick up load. The skin stresses then increase at a much slower rate with load. Loads transferred to the individual cargo items are quite small, even at maximum loading conditions.

The cargo stiffening effect and the point where it starts to occur depend on how tightly the cargo fits the dispenser. Tests conducted with a relatively loose fitting cargo of MK 118 MOD O Anti-Tank Bombs confirmed that skin stresses can be kept below yield conditions even at 185% of limit load. Other tighter fitting cargo items would provide even greater support.

Cargo support for fore and aft loads such as those experienced during catapult, arrested landing, shipping, and handling are provided by the forward bulkhead (integral with the skin) and aft bulkhead (integral with the tailcone). These bulkheads are designed for 25-g limit load factors.

The structural configuration of the dispenser combines extreme simplicity and associated cost savings with ruggedness, light weight, and a very efficient cargo compartment volume.

(b) Cargo Packaging

A cargo adaption kit is utilized to provide an efficient packaging of the MK 118 Anti-Tank Bombs. This kit consists of six rigid polyurethane foam spacers, 43 molded nylon spacers, hardboard shims, and a pre-split cargo removal plate.

The urethane foam spacers fill the radial voids between the cargo and the skin, provide structural support for the cargo (and skin) in a radial direction, provide thermal insulation for the bomblets, and protect the bomblet fins from backblast effects of the linear shaped charge cutting network. Four of these spacers extend the length of the cargo compartment. The other two are located ahead of and behind the strongback and are adhesively bonded in place prior to insertion of the cargo (see Figure 59). The lower two full length foam spacers serve as supports for stacking the bomblet package. They are placed in the loading fixture (see Figure 60), and the bomblet package is built up in them. The upper two full length spacers are then placed in position and the entire package is inserted into the dispenser by means of the loading fixture (Figure 61).

The molded nylon spacers are used to introduce fore and aft loads from the bomblets into the bulkheads. The spacers used ahead of the first wafer of bomblets carry the loads from the front shoulder of the Mk 118 bomblets in the first wafer to the face of the cargo removal plate. The bomblet nose fuze sensing element is thus protected (Figure 62).

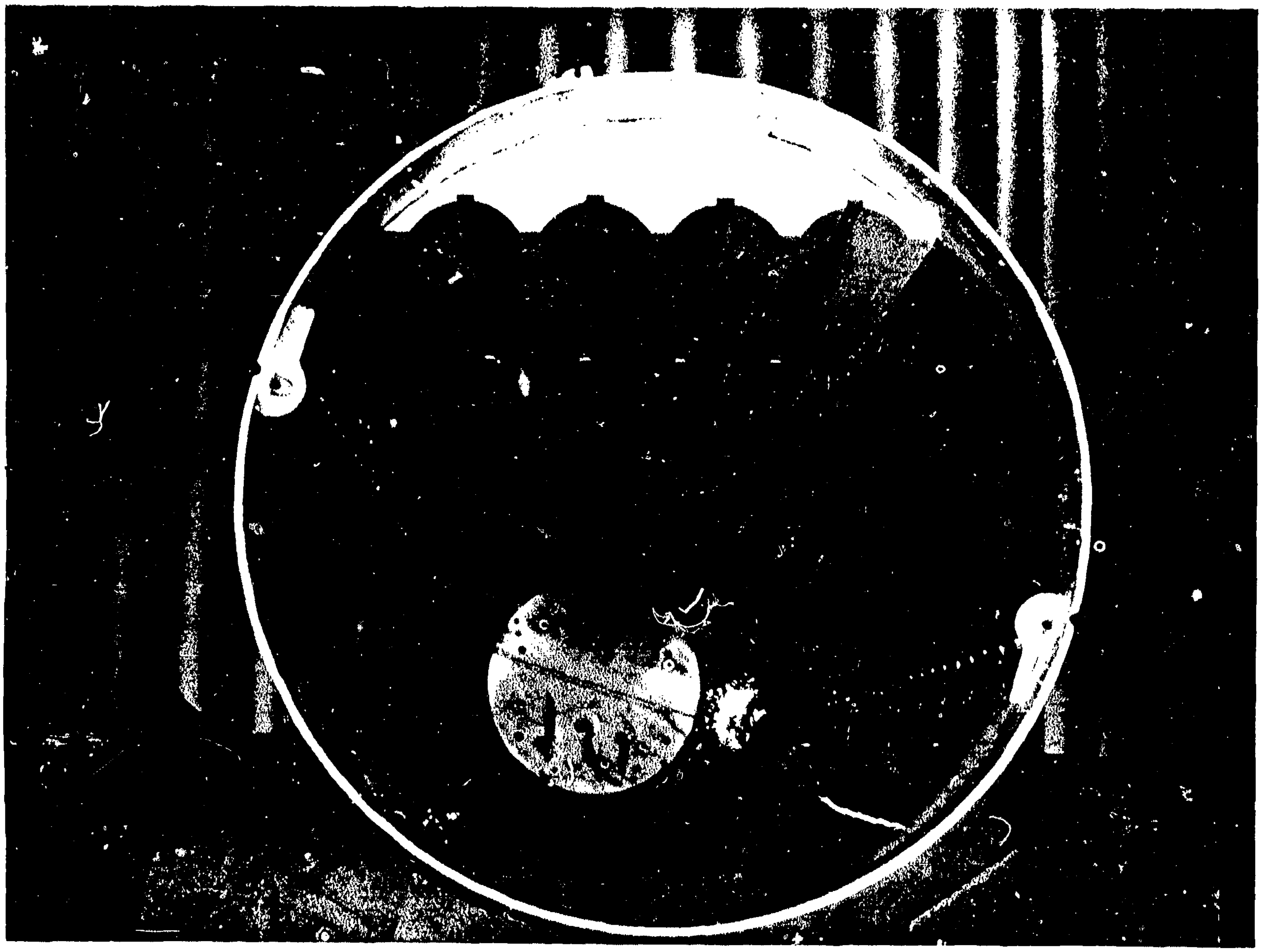

Figure 59 - SPACERS ADAPTED TO STRONGBACK

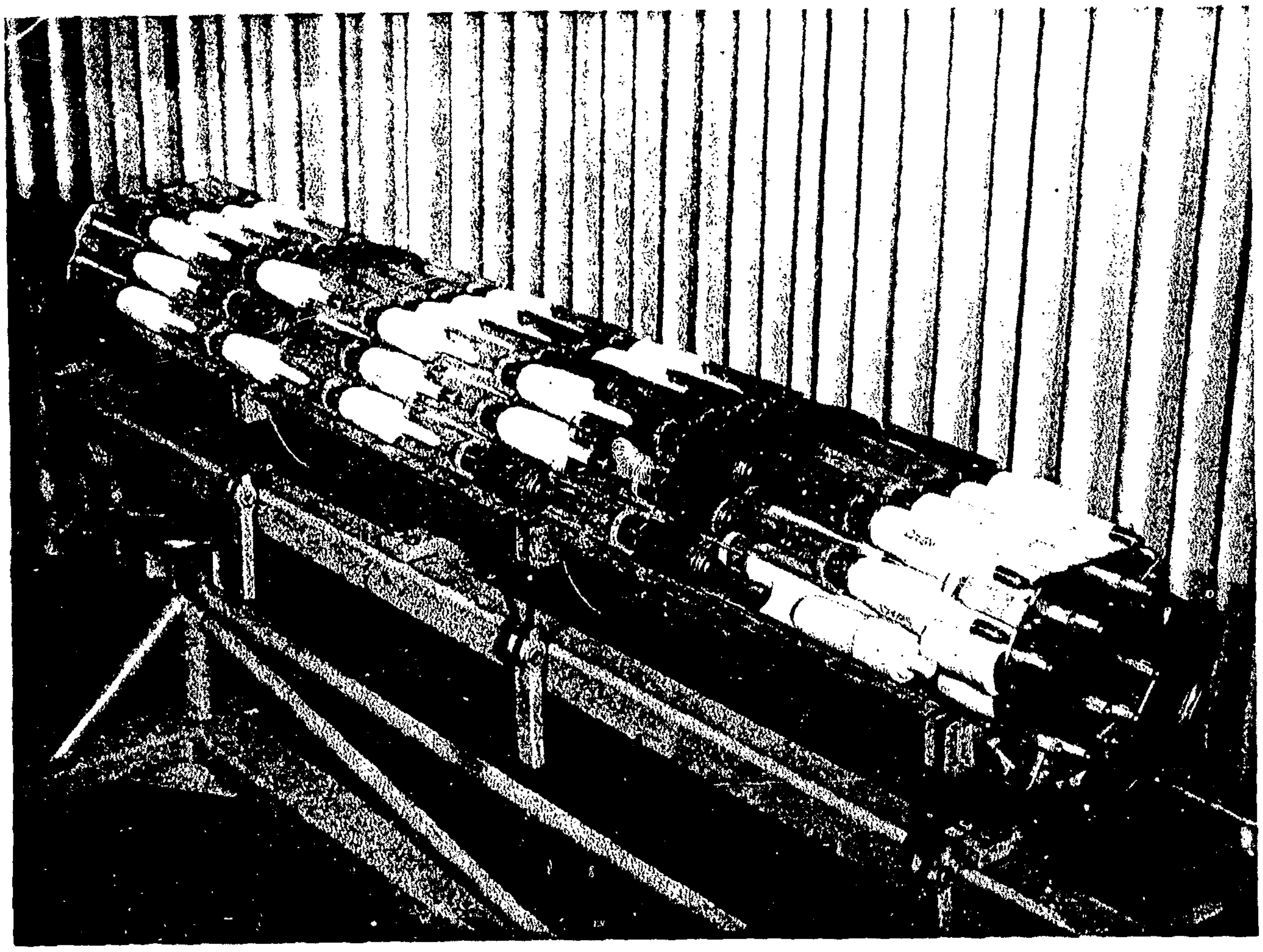

Figure 60 - LOWER CARGO SPACERS

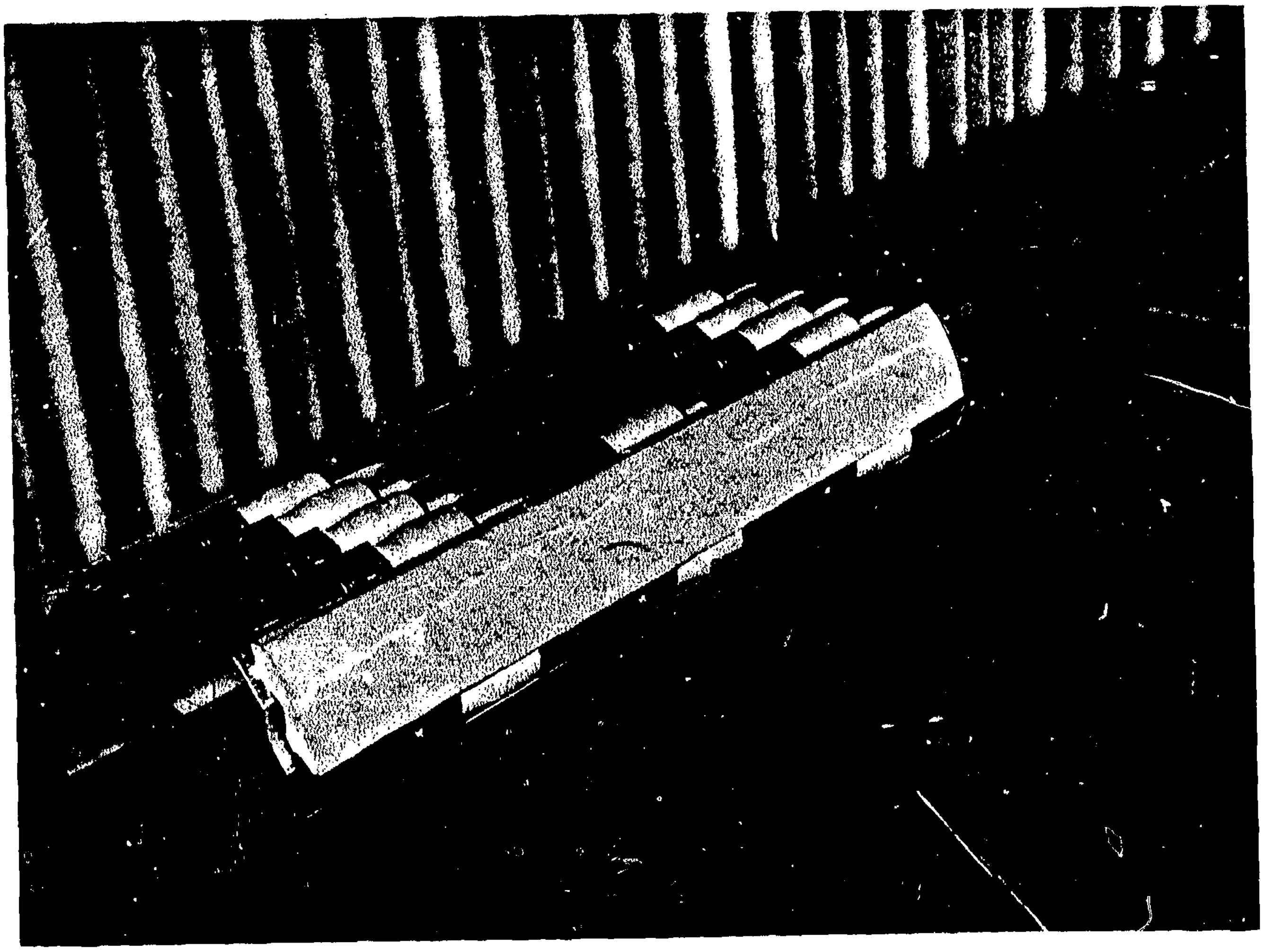

Figure 61 - LOADING BOMBLETS INTO DISPENSER

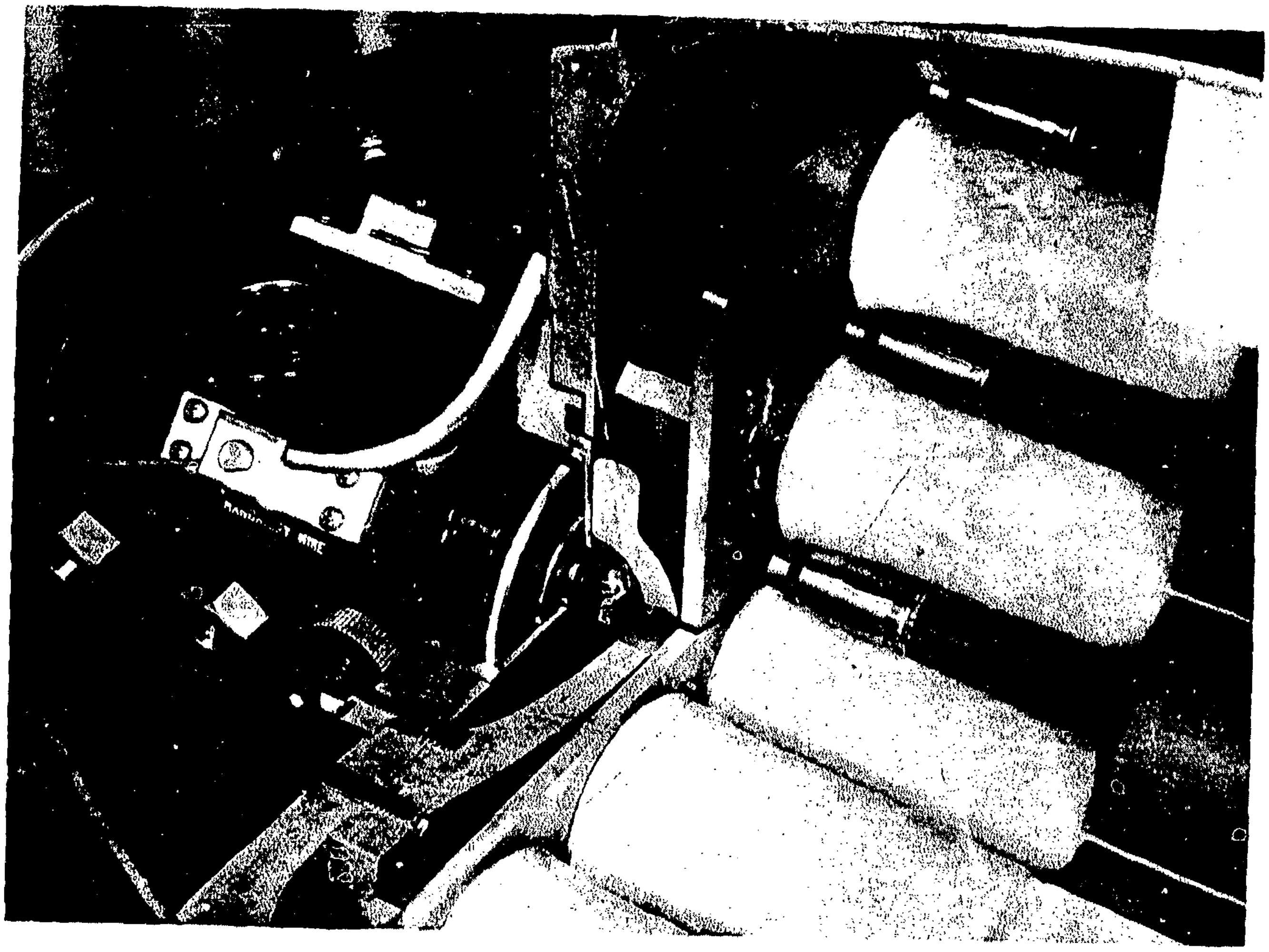

Figure 62 - FORWARD CARGO SPACERS

The spacers used behind the last wafer of bomblets carry loads from the fuze arming vane shroud to the packing shims, to the seal plate, and finally into the aft bulkhead. These spacers thus protect the fins of the bomblets in the last row (Figure 63).

The cargo removal plate is installed into the dispenser along with the cargo (Figure 60).

It is positioned ahead of the front row of nylon spacers by means of four 3/16" diameter rods. These rods are inserted through voids which extend the entire length of the bomblet package and threaded into the cargo removal plates. The cargo is then inserted into the dispenser, and the cargo removal plates are secured to the front bulkhead by means of seal screws installed through holes in the front bulkhead.

The rods are unscrewed from the plates and withdrawn to complete the cargo installation. The cargo can easily be removed at any time by re-inserting the rods, removing the seal screws from the front bulkhead, and pulling out the cargo with the rods.

The cargo removal plates have several standoff supports to carry loads from the plates across the gap required for the explosive network installation to the front bulkhead. These supports are internally threaded and two on each half of the plate are used to attach the assembly to the front bulkhead.

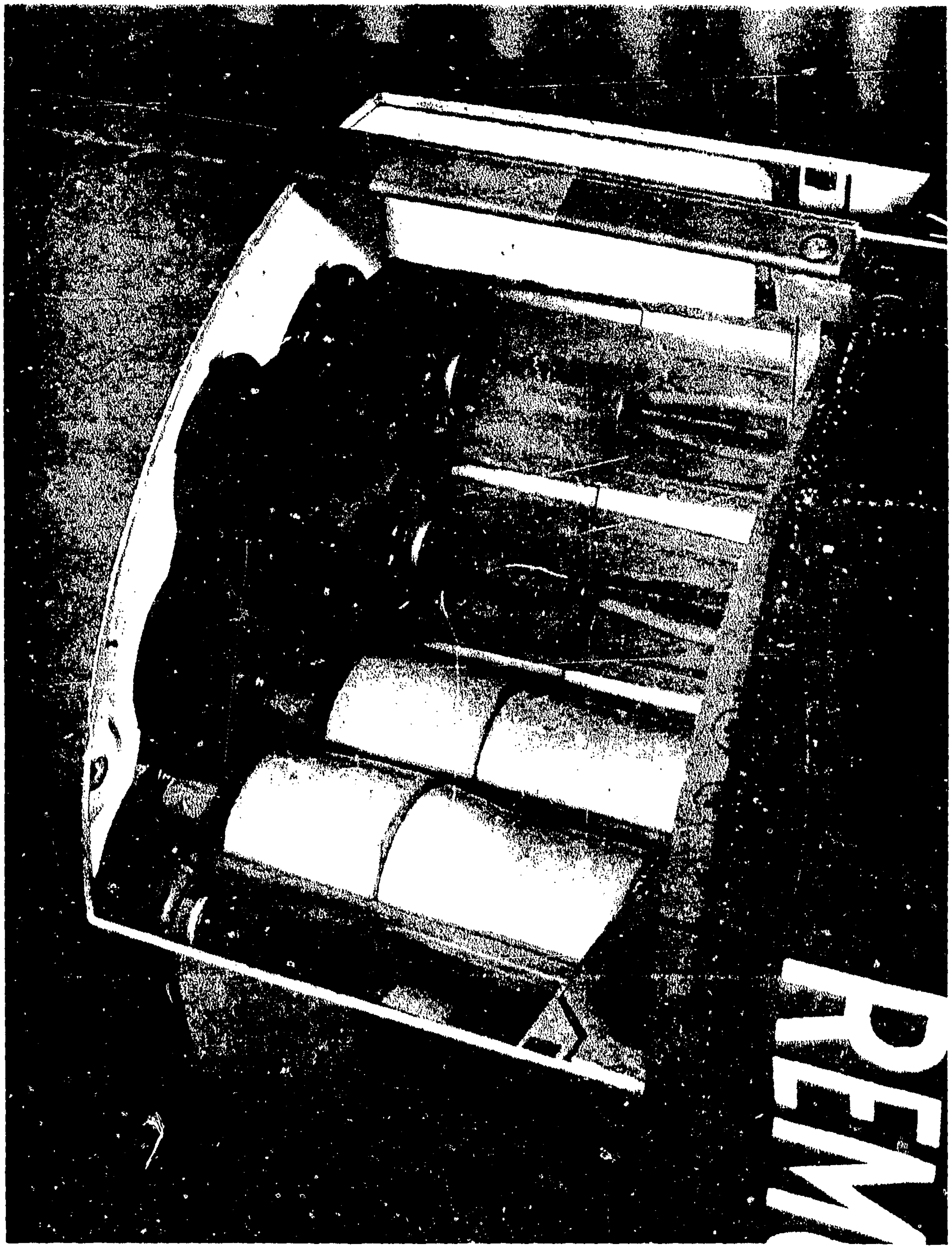

Figure 63 - REAR BULKHEAD CARGO SPACERS

(c) Explosive Network - The cargo compartment is cut in half longitudinally to release cargo at event by a "V" shaped strand of aluminum linear shaped charge (AL-LSC). The remaining sections of the dispenser (the nose firing and tail section) are pre-split, and the forward bulkhead area of the skin is partially cut through. The thickness of the bulkhead and ogive is reduced to that of the remaining skin (1/8 inch) in this area to facilitate cutting. The strand of AL-LSC extends the length of the cargo compartment, around the 2-inch inside radius at the front bulkhead, across the front bulkhead, around the 2-inch radius on the opposite side, and down the other side of the cargo compartment.

The explosive skin cutting network consists of five major components: lead, booster, Al-LSC, mounting strip, and shield. The lead is a column of composition CH-6 which is approximately 0. 17-inch in diameter x 0. 93 inches long pressed in several increments at a pressure of 10, 000 PSI and is contained in a thin walled (0. 008-inch) aluminum can which is crimped and sealed at the end. The can is mounted in a stainless steel housing and is retained by epoxy cement which also serves to provide a seal between these two components. The housing threads into the base of MK 339 MOD O, Mechanical Time, Fuze in such a manner that it positions the initiation surface of the lead in intimate contact with the foil seal in the base of the fuze. The MK 43 detonator in the fuze is located directly behind this foil seal when the fuze is armed.

The next component in the explosive train is the [illegible]oster, which is similar to the lead except in length and diameter. It [illegible]0. 25-inch diameter, 0. 75 inch long column of CH-6. The booster is positioned directly against the open "V" face of the AL-LSC and is thus perpendicular to and bisected by the output end of the lead (See Figure 62). The purpose of the booster is to initiate the AL-LSC.

The AL-LSC is 20-grain/ft, CH-6, AL-LSC, Configuration IV. This material has a chevron shaped cross section with an AA 1080-0 or 1090-0 aluminum sheath and a 20-grain/ft. core of RDX composition CH-6. This material will cleanly and reliably sever a 0. 156-inch thick 6061-T6 aluminum alloy sheet at the standoff provided by the mounting strip (0. 10 inch). The AL-LSC was chosen over the more common lead sheathed FLSC because it was found to do a cleaner cutting job with considerably less backblast. AL-LSC has the further advantage of a greater optimum standoff distance than FLSC (. 25 inch vs. 0. 06 inch). In the Rockeye application, the holding strip locates the AL-LSC a minimum of 0. 10 inch from the skin. All tolerances, gaps, and mismatches of the shield relative to the skin increase the standoff toward its more optimum cutting performance point and thus improve rather than degrade performance. With FLSC, tighter controls of tolerances would be necessary.

The holding strip is an irradiated extrusion of low density polyethylene L-P-390, Type II, Grade I, with an internal shape corresponding to the external shape of the AL-LSC. It holds the AL-LSC at a minimum standoff distance of 0. 10 inch from the skin. The external surface is "U" shaped to match the mounting groove in the shield (Figure 64). The plastic strip protectes the AL-LSC from damage in installation, facilitates installation into the assembled dispenser, and controls the minimum standoff. The low density polyethyelene is used for its low cost and good extruding characteristics, and irradiation of the material considerably increases its temperature resistance.

The shields, two of which are used, are 6061-T6 aluminum extrusions trimmed and formed at the end to conform to the ogive and front bulkhead contours. They are located approximately 17° counter clockwise from the 90° and 270° position when viewed from the nose section, these positions causing least interference with the cargo load. The primary functions of the shields are to hold the AL-LSC against the skin and to protect the bomblets from damage.

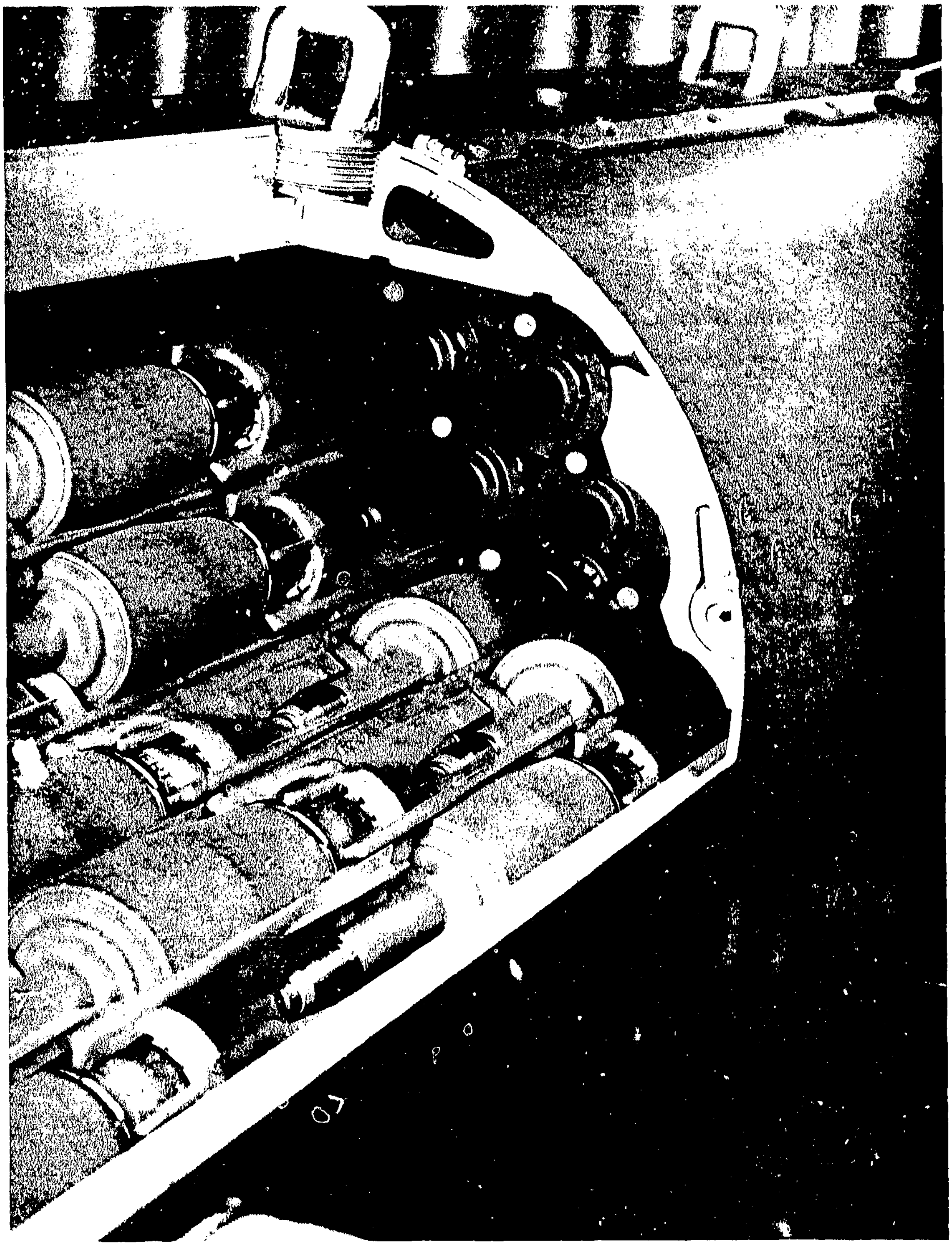

Figure 64 - LSC AND SHIELD

The shields are cantilever-mounted to the skin by No. 10-32 seal screws that retain the shields with the skins after cutting. The shields also serve to stiffen the skin halves and minimize buckling of the skins during opening. Support of the shields at the front bulkhead is provided by aluminum extrusions attached to the bulkhead and by the cargo removal plate.

The groove in the shields is sized to allow installation of the AL-LSC after the shields are attached to the skin. This allows loading plant installation of the explosive network. The strand of AL-LSC and plastic strip is pulled into position using a wire hooked to the plastic and cranked with a small winch-like fixture. It is necessary to lubricate the plastic strip with a silicone lubricant or Teflon spray to pull the strand around corners of the front bulkhead. Installation of an individual strand more than one time is not recommended because of the hardening and cracking effects on the AL-LSC. After the strand is in place, the ends are trimmed flush with the ends of the shields and sealed with an explosive epoxy such as "Metagrip 303". The seal is not critical in that it is used simply to prevent any tendency of the explosive to "flake out" of the ends of the strand.

(d) Arming Wire System - Two arming wires are used on the Rockeye dispenser: one to initiate the MK 339 Fuze, Mechanical Time, and one to release the folding fins. Both wires are routed through protective conduits located on the top surface of the cargo section (Figure 65). The fuze conduit extends from just ahead of the aft lug to the front bulkhead, and is offset from the lug centerline by approximately 1.5 inches (to starboard). The tail fin conduit extends from aft of the forward lug to the tailcone and is offset to the port side.

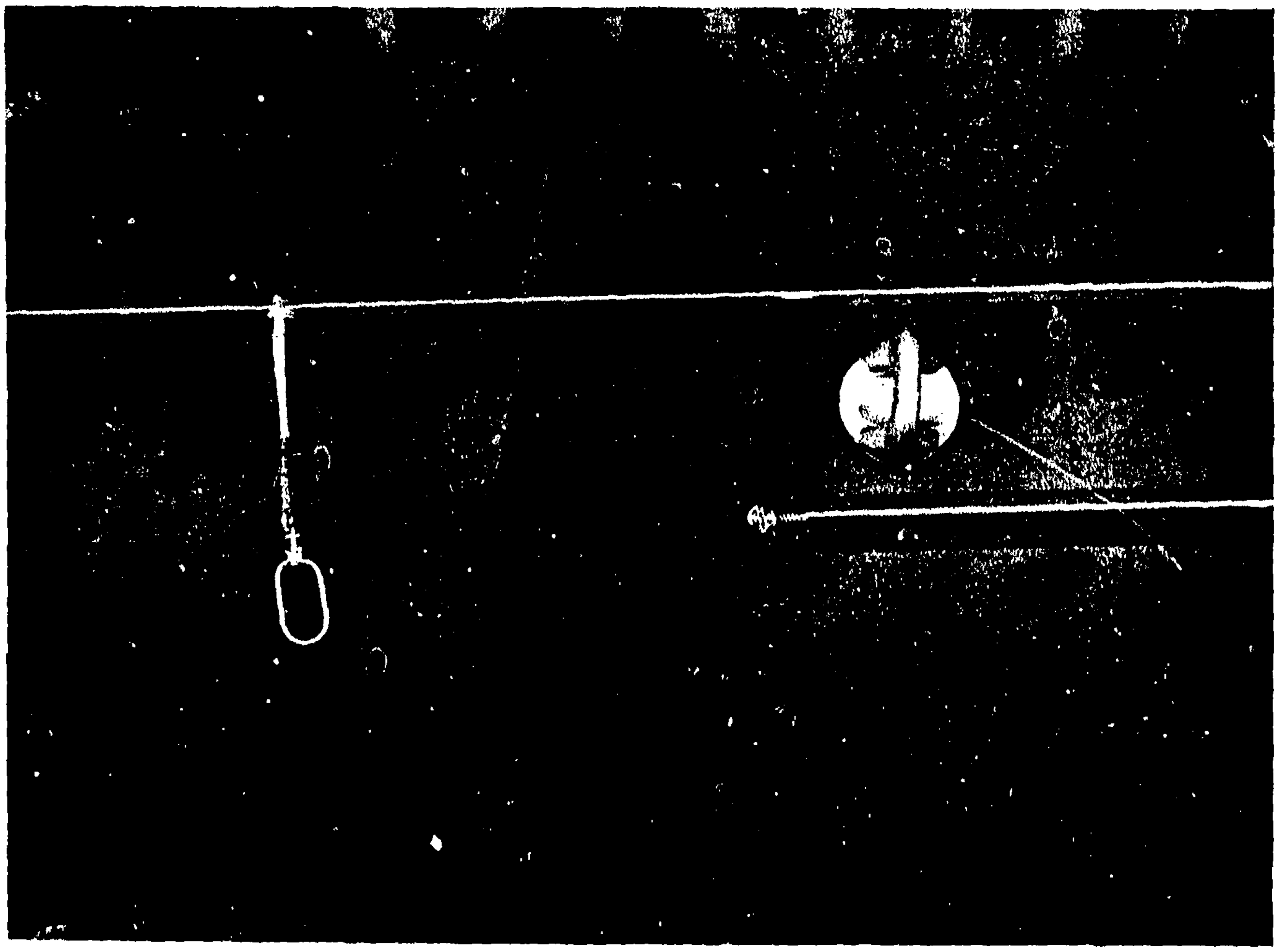

Figure 65 - ARMING WIRE CONDUITS

The conduits are 6061-T6 aluminum extrusions approximately 0.75 inch wide and 0.25 inch high. A groove opening to the upper surface contains the wire which is encased in the Teflon tubing. This groove has a reduced width near the surface.

The Teflon tubing is larger in diameter than the reduced opening of the groove. This retains the wire in the groove where it is protected from inadvertent extraction.

Notches are milled across the groove at several locations, allowing an extractor to be "tied" to the wire and attached to the bomb rack arming wire solenoid. The particular notch used depends upon the bomb rack to be employed. The extractor is a conventional arming wire swivel crimped to a short loop of braided cable. The cable is encased in Teflon tubing.

The aft end of the fuze wire and the forward end of the tail fin wire are anchored to the strongback. As the weapon is released from the aircraft, the extractors strip the wires out of the protective conduit by deforming the Teflon tubing. Approximately 25-pound force on the extractor is required to strip out the wire. As this force is applied, the wires disengage the fuze and the fin release band. They then continue to slip through the extractor loop until they are completely free of the extractor.

The wires remain attached to the weapon and the extractors are the only thing left with the aircraft. This prevents damage to the aircraft by the whipping of the wires.

The arming wires are A1S1 302 stainless steel, spring temper. This material was chosen over the conventional brass arming wires because of its much higher shear and fatigue properties, important in reducing the possibility of accidental fuze functioning during captive flight because of arming wire failure.

The conduits have milled cutouts (Figure 65) to provide clearance for the sway-braces of the MBR, MER, TER, and AERO 15C bomb racks. Attachment of the conduits to the skin is accomplished with an epoxy adhesive and screws.

(e) Bomb Rack Compatibility

The strongback area of the cargo section provides the interface with the various bomb racks. The fourteen-inch spaced MK 6 MOD O suspension lugs and the swaybrace bearing surfaces are mounted in the strongback area. Special features incorporated for bomb rack compatibility include swaybrace chafing discs and standoff pads for the multiple Bombrack (MBR), and arming wire conduit cutouts for MBR, MER, TER, and AERO 15C bomb rack sway brace clearance.

The MBR chafing discs are hardened steel pads that mate with the small diameter surfaces of the MBR sway braces. These discs are required to withstand the very high bearing loads produced because of the small diameter and small reaction angle of the MBR sway braces.

The standoff pads are required on weapons installed on the shoulder stations of the MBR. They cant the weapon sufficiently to prevent interference with the mounting bolt. These pads do, however, interfere with the sway braces of other bombracks and are therefore removable.

The arming wire conduits contain several cutouts which allow removal and relocation of the arming wire extractor so that all bombrack solenoid locations can be accommodated.

The ejector piston of some bombracks (such as the AERO 7A) contacts and overlaps the arming wire conduits. This condition produces no apparent problems as evidenced by the many successful flight tests.

(3) Tail Assembly

The tail assembly consists of a presplit, integral bulkhead tail cone with four spring loaded cleaver type folding fins; a fin release band; and a hinge plate. The roller bearing mounted fins are snubbed at opening by silicone rubber pads and locked open by spring loaded detents.

The tailcone is an approximately one-caliber conical boattail with a five-inch diameter base. It contains four one-caliber span stub-fins in a cruciform configuration equally spaced between four folding-fin root fairings. The extended fins have a 28.5-inch span, a 6.5-inch chord, and a 9° cant angle.

The tail assembly provides several important functions. The stub finned boattail configuration serves to minimize both the aerodynamic drag experienced in captive flight and the instability of the weapon prior to fin opening. With the canted fins deployed, the tail assembly stabilizes the weapon in normal free flight and imparts spin for the purpose of cargo dispersal.

The integral bulkhead provides structural support of the cargo for shipping, handling, and catapult launching. The hinge plate, which attaches the pre-split tailcone section together at the base, provides the dispenser with a clam shell-like opening characteristic. The hinge also serves to counteract the tendency of the halves to skew relative to each other during the dispenser opening.

The tailcone is the primary component of the assembly. It is an A356 aluminum alloy permanent mold casting made initially in one piece. The casting is machined with the appropriate diameters of the cargo section and fin band interfaces prior to the saw cut operation which splits the tailcone in half. The saw cut is made at a 17° angle from the horizontal to correspond with the plane of the linear shaped charge cutting network. Other finishing operations of the tailcone include drilling out mounting holes for the hinge plate, fin-pivot pins, and other component structure; and milling surfaces in the fin fairings for interface with the bearing races. A reinforcing ring is installed inside the base of the tailcone for distributing opening loads from the hinge plate.

The integral aft bulkhead is structurally strengthened by webs oriented parallel and perpendicular to the pre-split plane. It should be noted that the integral bulkhead design was not used in the Phase III weapons.

The folding fins are centrifugal permanent mold castings of A-356 aluminum alloy. The fins have a cambered airfoil to maximize lift and stall angle of attack. The fins are hollowed out to minimize weight and moment of inertia, and each fin has machined bosses for accommodating roller bearings and races. An integrally cast lug snubs the fin on opening by engaging the silicone rubber snubbing pads mounted to the inside surface of the tailcone.

The fins are attached to the tailcone by means of pivot pins, which also control roller bearing-to-fin clearance and structurally support the sides of the fin root fairings against fin side airload reactions. The pivot pins are coated with DC 33 silicone grease to prevent any corrosion or icing problems that might prevent proper fin opening.

Roller thrust bearings with stainless steel needles and an electroless nickel plated cage are sandwiched between electroless nickel plated steel races on both sides of each fin. The bearings are required to assure proper fin deployment under such high airloads as are associated with high speed weapon release. The bearings and races are quite economical and actually cost less than the application of solid film lubricant ("electrofilm") used in the first design approach for this interface. The bearings are also coated with DC 33 grease to prevent icing and corrosion problems. An 0.005-inch thick mylar shim is located between the inside diameter of the outer bearing race and the mating outside diameter of the fin boss to eliminate a galling problem between these two surfaces created by the relatively high radial torsion spring loads forcing these surfaces together.

The torsion springs used for fin deployment (two per fin) are made of 17-7 PH stainless steel wire heat treated to the CH 900 condition. This material was selected because of its excellent combination of strength and stress corrosion resistance. The latter characteristic is very important to assure long term storage reliability of the stored energy springs. To further enhance this characteristic and to eliminate icing, galling, and salt spray corrosion, the springs are electropolished. This treatment has proven its worth in helping solve fin opening problems experienced after exposure to adverse test environments.

Spring loaded stainless steel detent pin assemblies are press fitted into the back surface of the fins near the pivot pins. These pins engage holes in the aft surface of the tailcone to lock the fins open. The pin assemblies are filled with DC 33 grease for corrosion and icing protection.

The hinge plate is five-inch diameter, 0. 180 inch thick, 4130 steel with cadmium plating and a chromate dip. The plate is attached to the two tailcone halves with eight 5/16-inch diameter button lead cap screws. The hinge size and material was determined on the basis of performance data obtained in flight tests.

The fin release band is made of 0. 5-inch wide, 0. 040 thick type 301 stainless steel, 1/4 hard. The ends of the band are connected together by a stud held in engagement by the tail arming wire and the tail safety wire. Release of these wires frees the band, which is then hurled down and clear of the aircraft by the spring energy of the band and the fin torsion springs.

The aerodynamic analysis considerations pertinent to the design of the tail assembly are discussed in Appendix E of Part 2, Volume I.

C. DEVELOPMENT ACHIEVEMENTS VERSUS PROGRAM GOALS

As of this writing,final environmental testing has not been completed. However, testing results thus far have provided sufficient evaluation data to confirm that normal development goals were attained, and in some cases exceeded, in many important areas.

The dispenser is generally compatible with tactical aircraft (though not yet tested on each of the aircraft cited) and with the specified delivery conditions. Aircraft compatibility has been extensively demonstrated in an array of aircraft under normal, and in some cases (A-9) extreme, flight conditions. In repeated delivery tests under high Mach (up to 0.9), low altitude release conditions, the dispenser has released well from primary racks and provided optimum conditions for bomblet dispersion.

The desired cargo quantity was exceeded by 23 bomblets, or approximately 10%. This was achieved, at least in part, by development of a cargo packing structure representing a high volumetric efficiency and a slight decrease in bomblet penetration. The cargo structure design also permitted assembly of the cargo as a unit package that would be inserted in the dispenser in one simple operation, thus simplifying the loading process and facilitating production.

Functionally the dispenser has met every requirement. The fin mechanism is simple in concept and reliable in normal performance, and the aerodynamic configuration of the fins provides both the stability and the spin-up required for accurate placement of an effective bomblet pattern. The explosive skin separation network severs the dispenser cleanly and reliably without damage to the cargo munitions. The final opening configuration, which included the pre-split tail section with the steel hinge plate at the base, has proved effective in enabling release of the bomblets with minimal damage.

Throughout the development, there was a continuing and intensive concentration on reducing hardware and functional complexity to enhance unit reliability and reduce the production cost. Significant achievements were made in design simplification, achievements which are particularly evident in the fin release and deployment mechanism, the dispenser body structure, and explosive skin separation network and shielding. As the design was simplified and hardware items were combined, there was a continuing reduction in the quantity of parts required for a complete assembly. The net result is evident in Figures 66 and 67 which show layouts of parts for the original (A-1) configuration and for the final (Phase III) design.

In terms of total objectives, Rockeye II development on the dispenser must be adjudged as completely successful. The evaluation data obtained thus far confirm that the dispenser meets structural storage, and operational requirements satisfactorily. The final configuration represents an ordnance item fully developed to the production stage and capable of providing the type of on-target effectiveness desired.

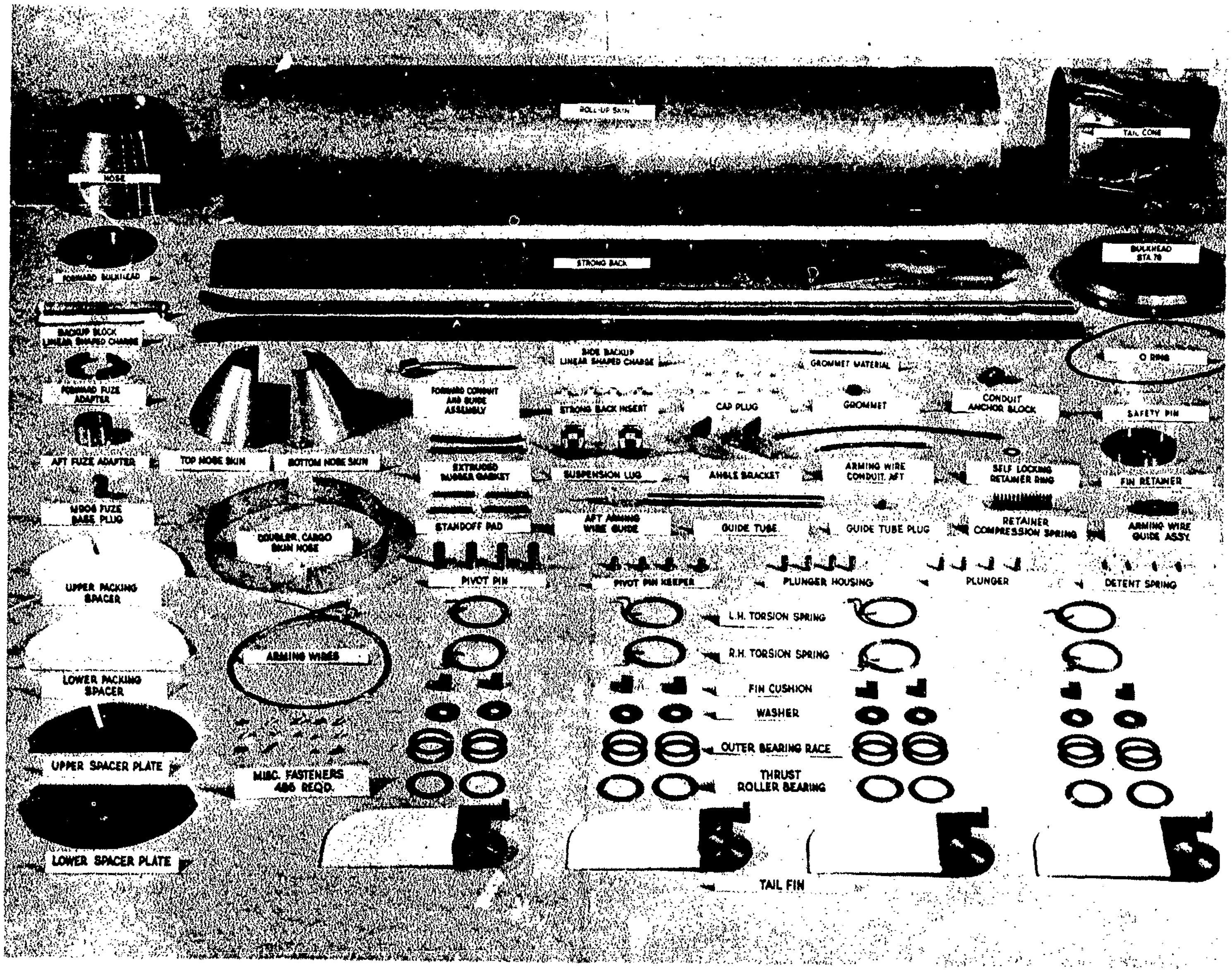

Figure 66 - PARTS LAYOUT, ORIGINAL DISPENSER CONFIGURATION

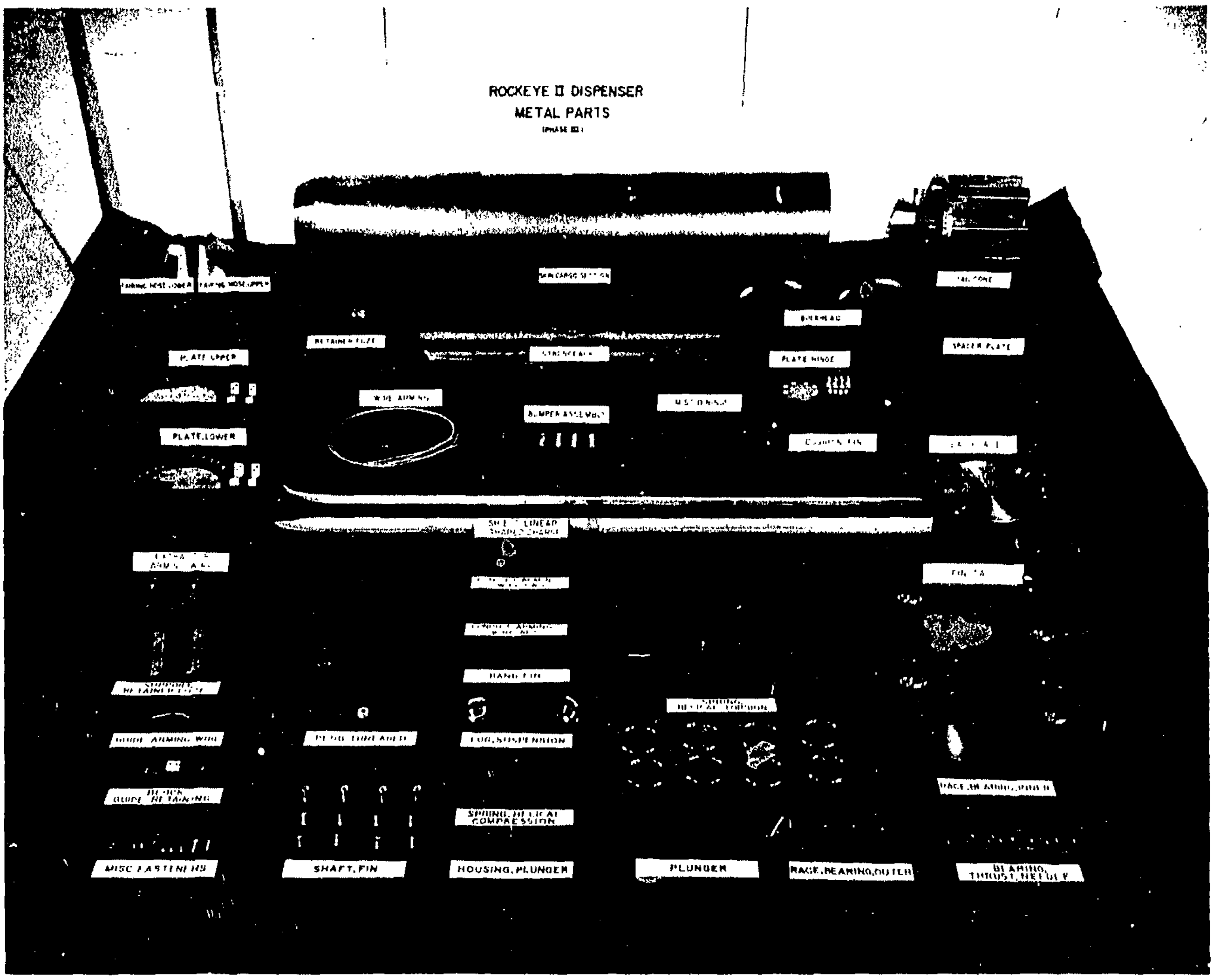

Figure 67 - PARTS LAYOUT, FINAL DISPENSER DESIGN

IV. DESIGN AND DEVELOPMENT

ROCKEYE II BOMBLET

The design and development of the Rockeye II bomblet is described in this section of the report. The performance and structural requirements cited in the contract are reviewed first; and then the design approach to these requirements is discussed including the evolutionary changes and modifications in the design. Finally, the program objectives are compared to the developmental achievements to illustrate the degree of success attained in the program.

A. DESIGN REQUIREMENTS

The following requirements were specified in the contract or established, as noted in some cases, as modifications of the original requirements:

1. Physical Requirements

The bomblet shall not be larger than 2.2 inches in diameter.

2. Functioning and Reliability

The bomblet shall be capable of penetrating materials ranging from armor to mild steel and shall generate fragments which will be lethal to enemy personnel.

The bomblet shaped charge shall be capable of penetrating at least 8.5 inches of rolled homogeneous armor plate of 450 Brinell hardness dynamically at Mach 0.9 and will provide a sufficient hole profile to offer an exit opening of 1/4 inch (the exit hole requirement was reduced to 1/8 inch to meet achieved results in R & D tests).

The bomblet shall have a fragmentation capability such that the effectiveness against personnel is as great as possible.

The bomblet shall have an operational functioning reliability of at least 0.96 (later revised to 0.87 to fit achieved results in R & D tests).

3. Fitment

The bomblet shall be of such configuration that the maximum number are packaged within the available volume of the dispenser without affecting weapon performance function and reliability.

4. Aerodynamics and Ballistics

The bomblet shape and stabilizing and/or drag surfaces shall be such that terminal velocity is between 200 and 300 feet per second.

The bomblet shall be statically and dynamically stable so that proper arming and initiation of the fuze occurs, and so that the fuze and the warhead may function properly on the target.

5. Loads

The bomblet shall be capable of withstanding any of the loads transmitted to it by the container in normal usage.

The bomblet shall retain structural integrity and functioning reliability after separation from the dispenser under all possible release conditions.

6. Environment

The bomblet assembled into the weapon shall be able to withstand the vibration environments encountered during flights, catapult takeoffs, arrested landings, taxiing, or ground landing, and takeoffs of all aircraft with which the dispenser is required to be compatible.

The bomblet, either assembled into the weapon or unassembled shall not be affected functionally by any normal handling encountered during transportation from point of origin to any end use activity, or by storage or normal handling encountered during transportation from point of origin to any end use activity, or by storage or normal handling.

The bomblet as assembled into the weapon shall not be affected functionally by temperatures ranging from -65° F to +165° F, wind, fungus, snow, ice, rain, or salt spray when in storage or fixed to parked or flying aircraft.

7. Safety

The bomblet shall have safety features such that the probability of accidental detonation is 10^{-6} or less during transportation, handling, weapon assembly, or attachment of weapon to the aircraft.

The bomblet and bomblet fuze shall be safe where exposed to the electromagnetic radiations of ship and shore communications and radar equipment.

8. Other Considerations

The bomblet shall be capable of passing through light foliage and camouflage material without detonating.

The bomblet shall be capable of deeply penetrating sand bags or soft earthen barriers before detonating without damaging the warhead or hindering its function.

The bomblet shall have a storage life when contained in the MK 7 MOD 0 Dispenser of 10 years without requiring rework during that period.

The bomblet construction shall be such that use of critical or strategic materials are minimized.

B. HISTORICAL DESIGN EVOLUTION

The design approach to the foregoing requirements as reflected in the Honeywell proposal document is a convenient initial design fix from which the developmental evolution of the bomblet configuration may be traced. Consequently, the proposal design is described first, and then the changes and modifications to this design as a result of the development effort are discussed. The final configuration is then described to provide a complete picture of the end product of the development program.

1. Original Bomblet Design

The bomblet configuration originally proposed is shown in Figure 68. The kill mechanism consisted of a shaped charge with a 42° sintered powdered copper liner. From calculations it was estimated that this charge would penetrate 8.5 inches of armor plate and provide an exit hole of 1/4 inch. The shell of the bomblet was internally scored to ensure uniform fragment formation, and it was estimated that the resulting anti-personnel lethal area was 400 to 450 square feet (prone troops; bomblet impact angle, 15° from vertical).

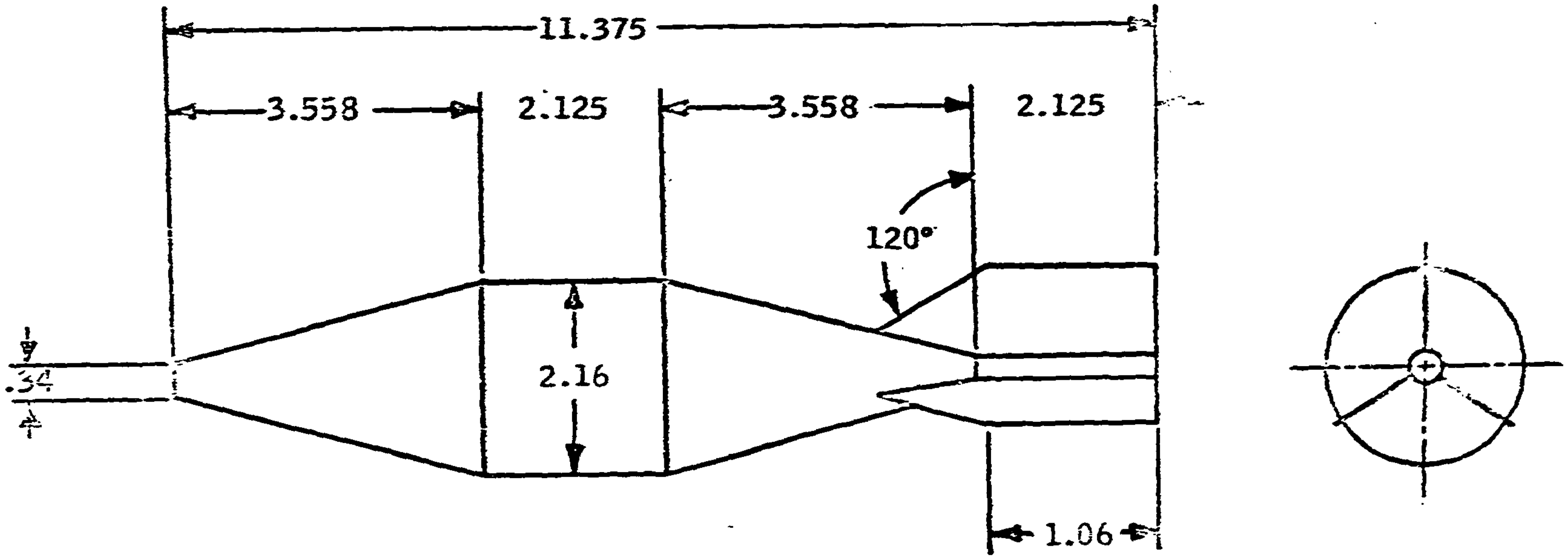

Figure 68 - PROPOSED BOMBLET CONFIGURATION

Aerodynamic stability and bomblet orientation were provided by fins. A sliding outer fin section interfaced with a delay arming assembly maintained the fuze in a safe condition in the cargo pack. When the fin was freed to move aft at bomblet release, it disengaged the delay escapement permitting the fuze to arm.

The bomblet had a maximum diameter of 2.20 inches and an estimated weight of 1.5 pounds maximum.

2. Developmental Evolution, Bomblet Design

In this section, successive changes and modifications to the design as a result of the development effort are traced in chronological order. The section is subdivided to correspond with the three primary areas of concentration - aerodynamic configuration, shaped charge, and structural functional parts.

a. Aerodynamic Configuration

The aerodynamic considerations inherent in the design evolution of the external profile of the Rockeye II Bomblet are discussed in this section of the report. Factors other than aerodynamics (adequate shaped charge standoff, packing efficiency, fuze arming requirements) decidedly influenced the design; but since these factors are covered in detail in other sections of the report, they are discussed here only where required to indicate design change made on the basis of considerations other than aerodynamics.

(1) Phase I Design (Experimental Phase) - The original design approach (refer back to Figure 68), upon analysis, was found deficient in that it would not provide the terminal velocity required, and that it represented an inefficient packing configuration. The first modification to this approach consisted of

proving cutouts in the ogive of the nose, as shown in Figure 69, to increase drag and concurrently evolve a configuration having a high nose-to-tail-fin packing compatibility. The tail fin was modified at this time. This change was effected to provide a shroud (See Figure 70) to ensure ram air activation of the fuze arming vane.*

The tail fins in this design extended beyond the maximum diameter of the bomblet and thus degraded packing efficiency. Consequently, the fins were redesigned as shown in Figure 71 to provide a span corresponding to the maximum diameter of the bomblet. Since this change effectively reduced the stabilizing moment exerted by the fins, it was necessary to modify the nose to reduce its destabilizing effect; the changes reflected in Figure 72 were therefore made.

Ultimately a spike nose configuration (shown in Figure 73) - which potentially provided the drag, foliage and camouflage penetration, and the packing efficiency desired - was evolved. A model reflecting two variations of this design approach was fabricated, and then evaluated with models of the hollow cut-out nose and of the solid cut-out nose in the Rosemount (University of Minnesota) wind tunnel. The three basic nose configurations (shown in Figure 74) employed the same design tail fin.

Upon completion of the wind tunnel tests, the data obtained were compared to determine the comparative performance of each nose configuration model. Performance data on the hollow cut-out nose configuration previously tested at the Naval Ordnance

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* In the original approach, it was planned to arm the fuze through an escapement mechanism activated by a sliding fin. However, a vane assembly was established by NOL/WO as the preferred arming technique in the fuze program, necessitating the above modification in the fin assembly.

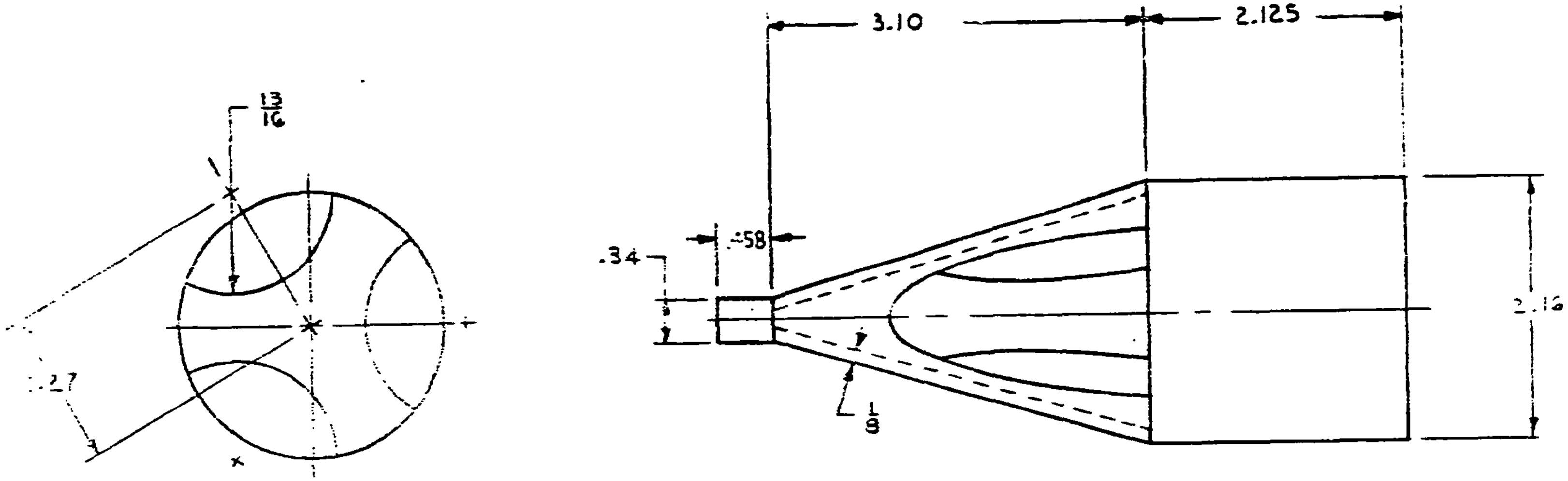

Figure 69 - BOMBLET NOSE, MODIFICATION 1

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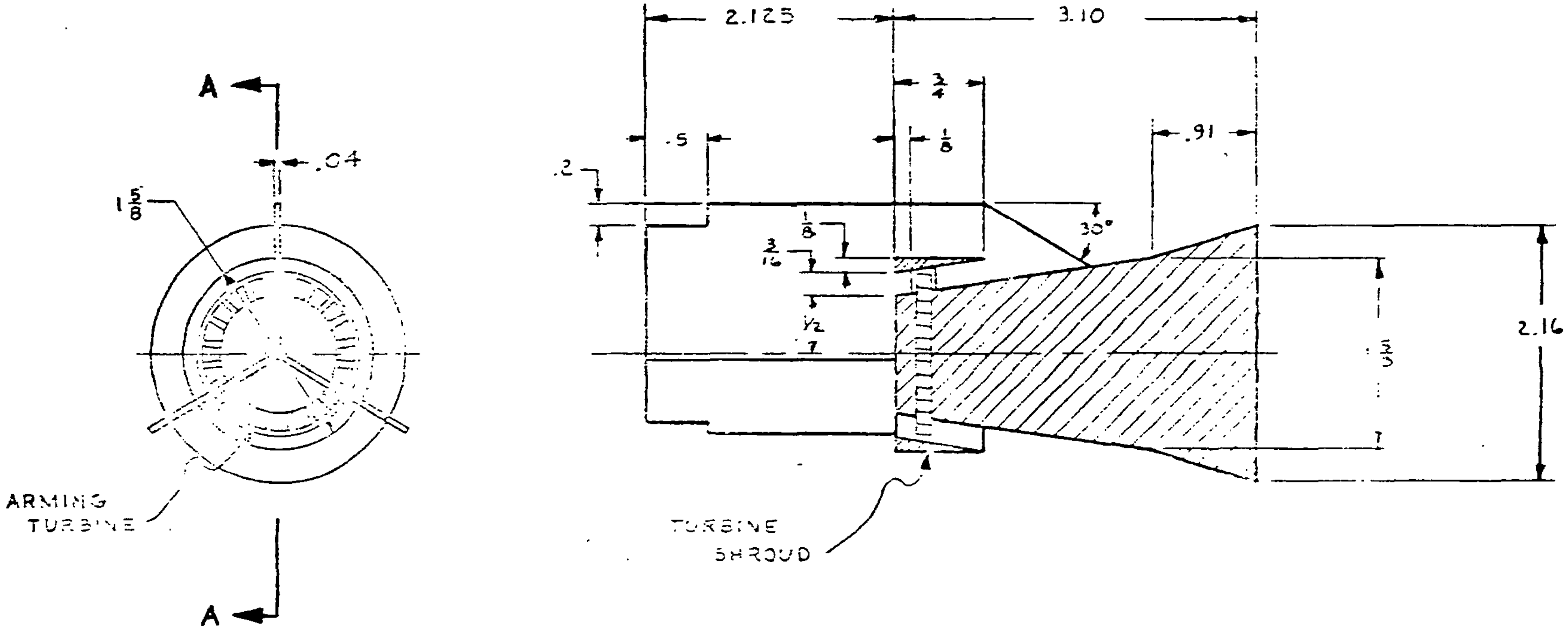

Figure 70 - BOMBLET TAIL, MODIFICATION 1

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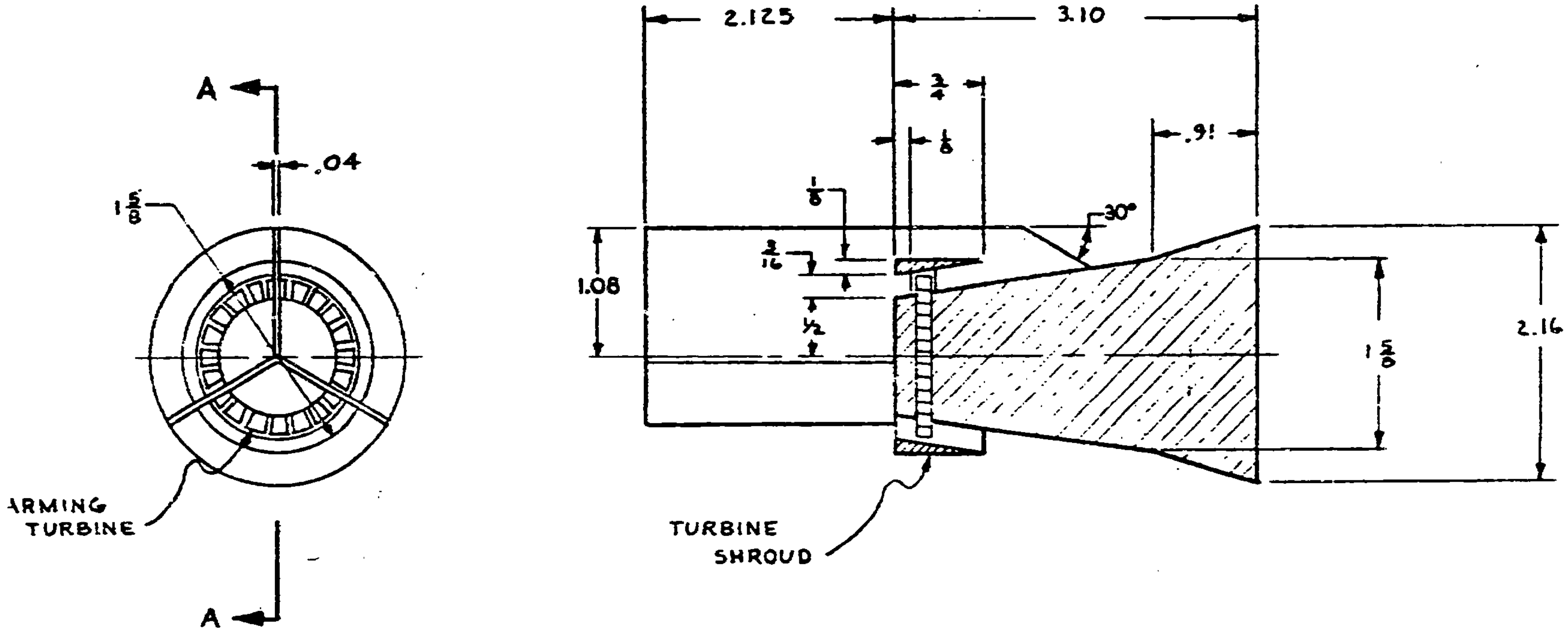


Figure 71 - BOMBLET TAIL, MODIFICATION 2

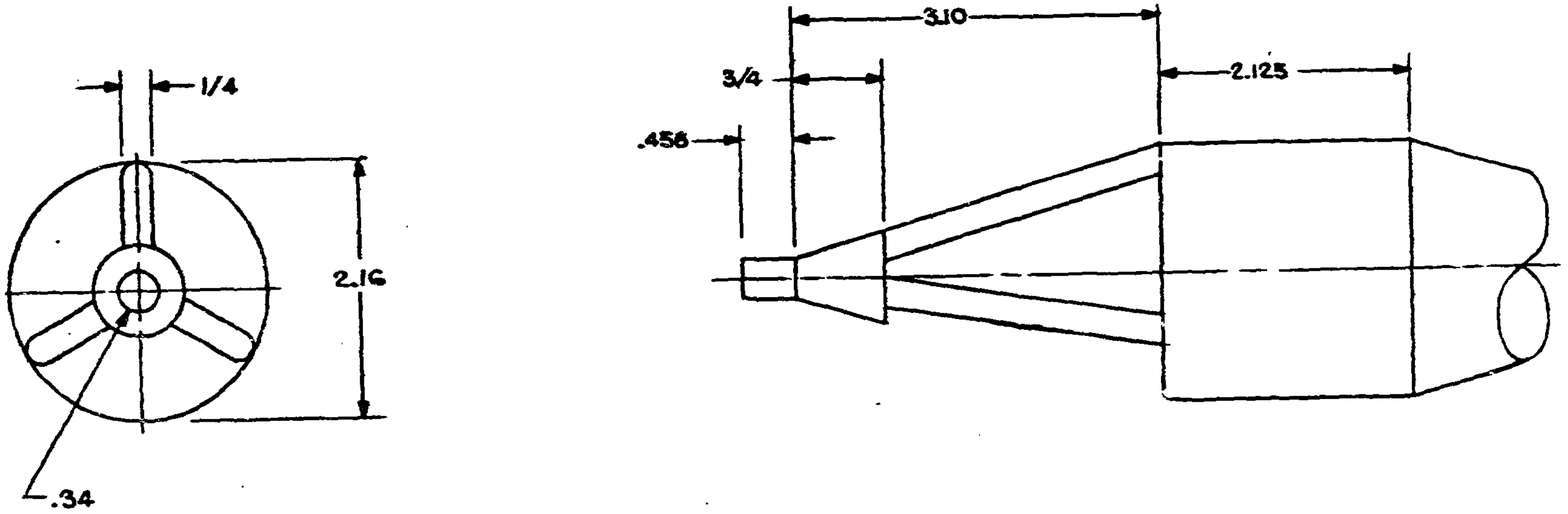


Figure 72 - BOMBLET NOSE, MODIFICATION 2

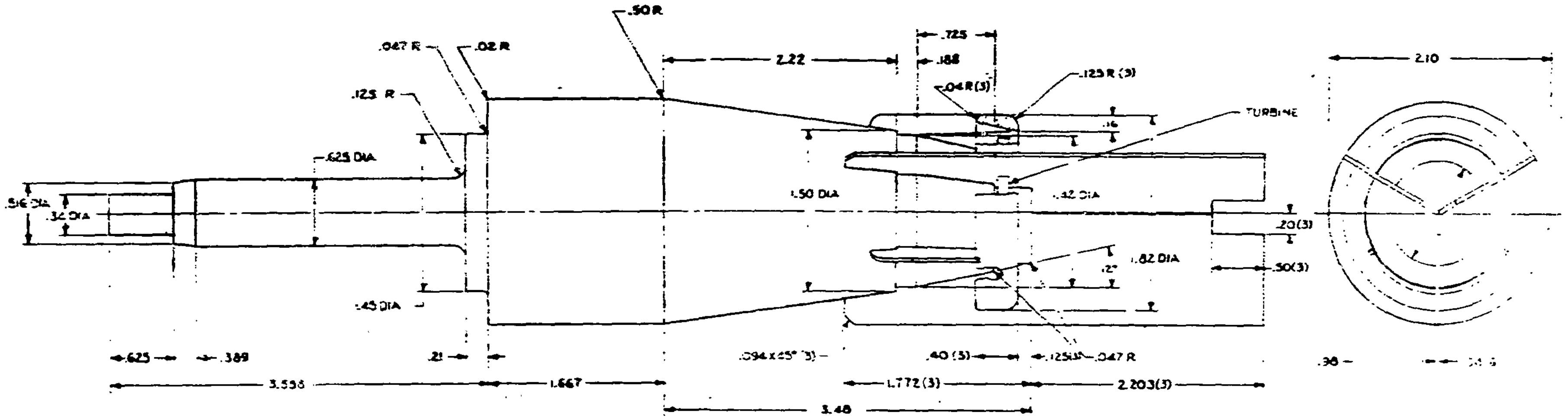


Figure 73 - BOMBLET CONFIGURATION SHOWING ORIGINAL SPIKE NOSE DESIGN

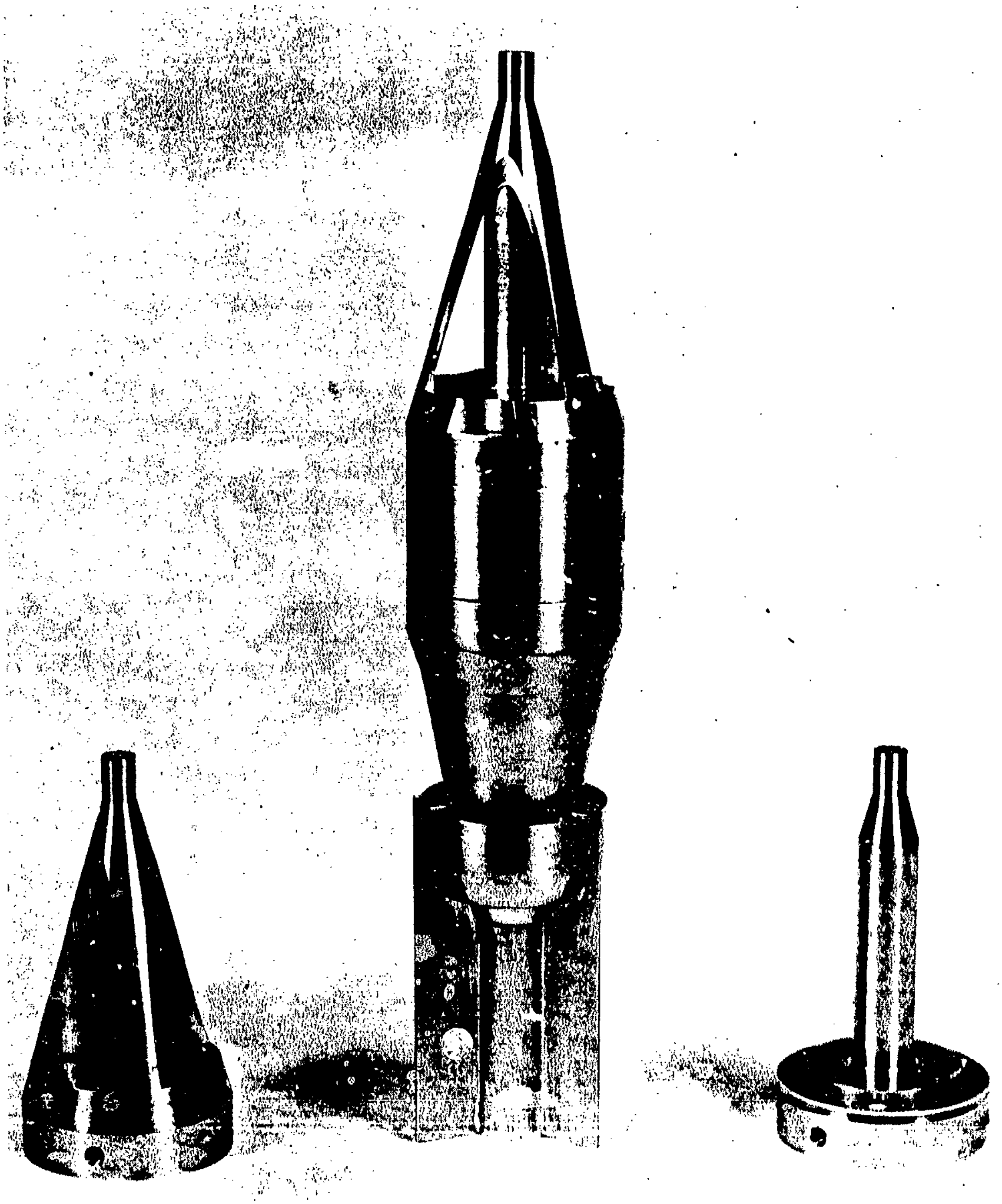


Figure 74 - ROCKEYE II BOMBLET WIND TUNNEL MODELS, CONFIGURATIONS 2-1, 2, 4

Laboratory, White Oak, Maryland, were included in this comparison to ensure consideration of all designs thus far evaluated. The drag characteristics determined for the various models are shown in Figure 75. It can be seen from these data that the spike nose model (sharp corner design no. 2-3) exhibited the highest drag and, consequently, had the lowest terminal velocity. The drag demonstrated by the other models was, however, considered satisfactory. The unit tested at NOL (No. 2-4) showed the highest stability. Bomblet instability was in some cases attributed to choking of the air flow in the turbine shroud. In all other respects, the basic fin configuration performed satisfactorily.

Because of its higher drag and the advantages in packing it provided, the spike nose design with the sharp corner step was selected for further development. The most immediate requirement following this selection was to establish a shroud design that provided the flow of air necessary to activate the vane arming device and still maintain stability. Three tail fin shroud designs were generated for evaluation and were subsequently subjected to static aerodynamic testing in the Rosemount wind tunnel (the three approaches are shown in Figures 76, 77, and 78).

The results of the tests are shown in Figures 79 through 86. The curves of the normal force and pitching moment coefficients in these figures were smoothed at the small angles to remove data scatter, which was generally less than 0.05 in both parameters.

These results indicated that the configuration shown in Figure 77 was the most stable of the three designs and it was, therefore, selected as the primary design approach. Detailed wind tunnel data is given in Appendix F, Part B of Volume I.

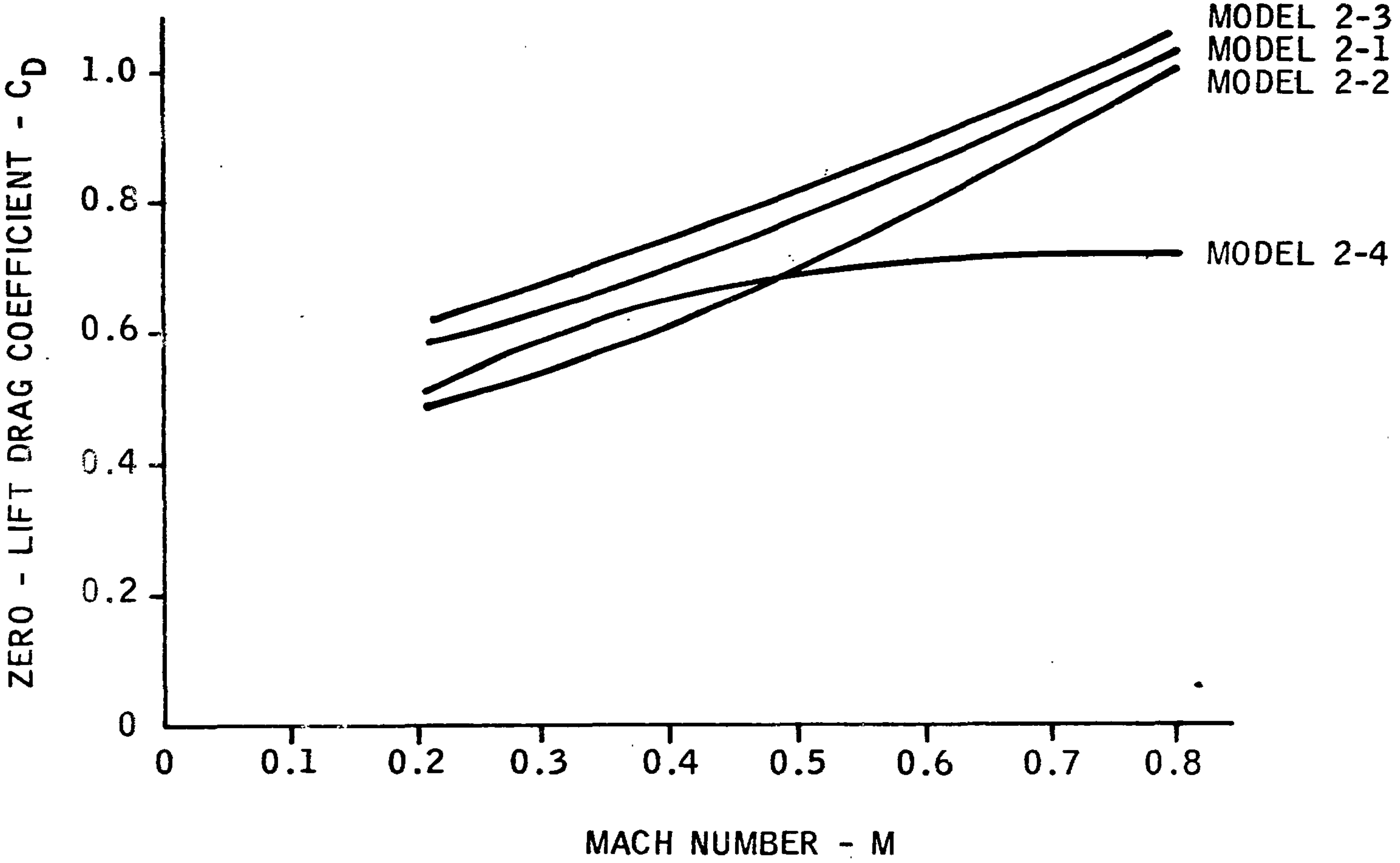


Figure 75 - COMPARISON OF DRAG COEFFICIENTS FROM WIND TUNNEL DATA OF VARIOUS BOMBLET CONFIGURATIONS

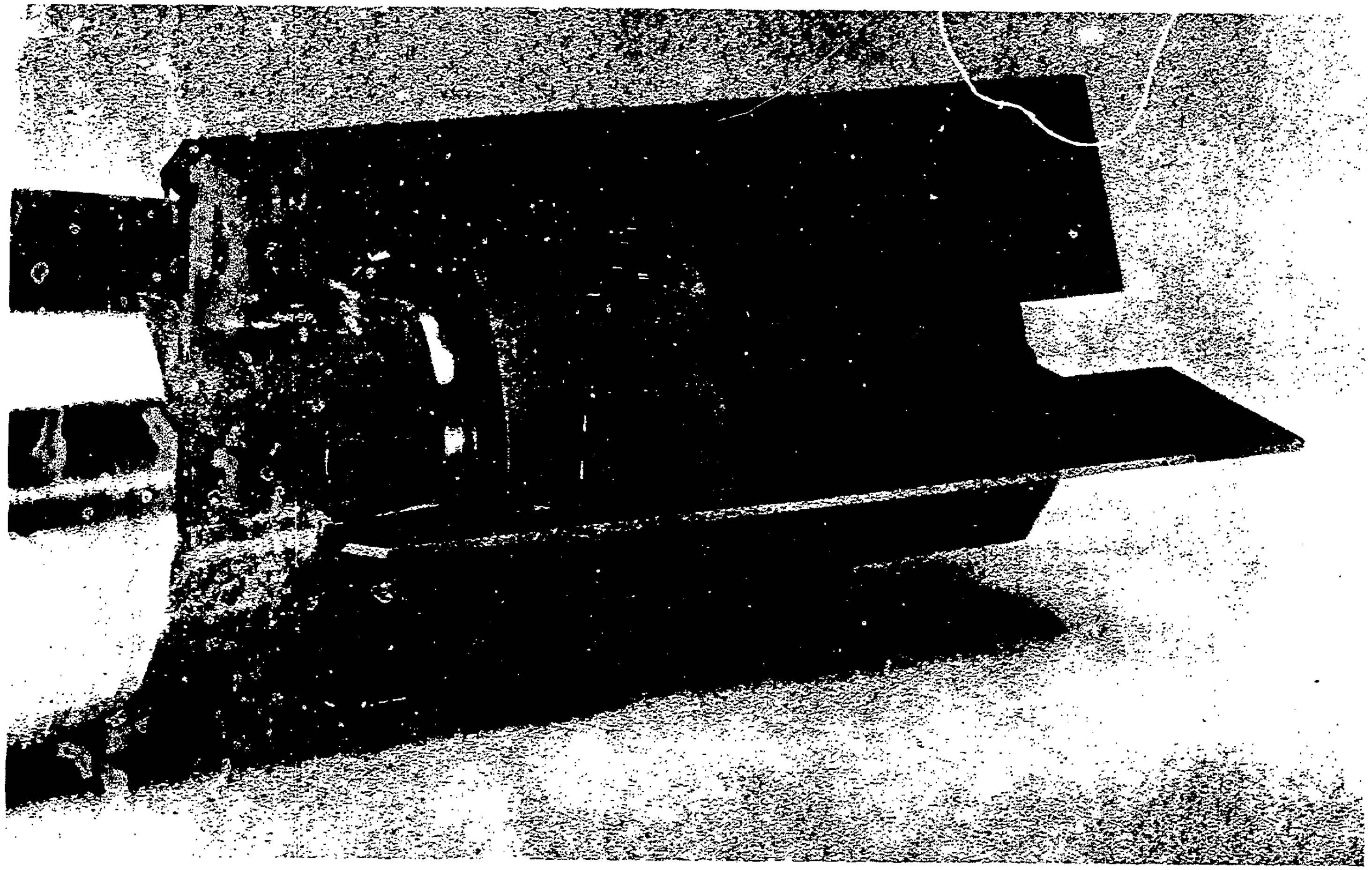


Figure 76 - BOMBLET TAIL CONFIGURATION 3-5A

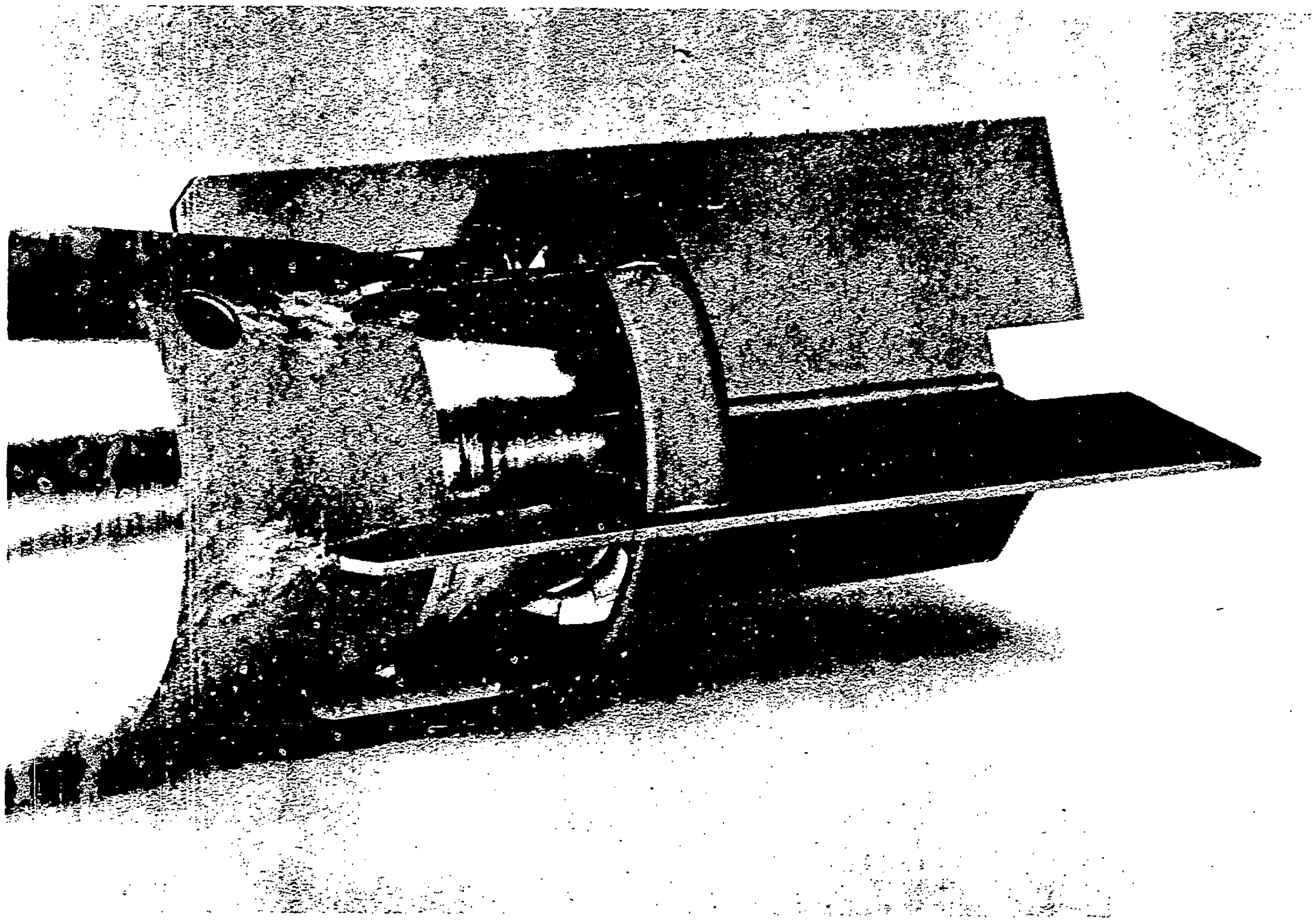


Figure 77 - BOMBLET TAIL CONFIGURATION 3-5B

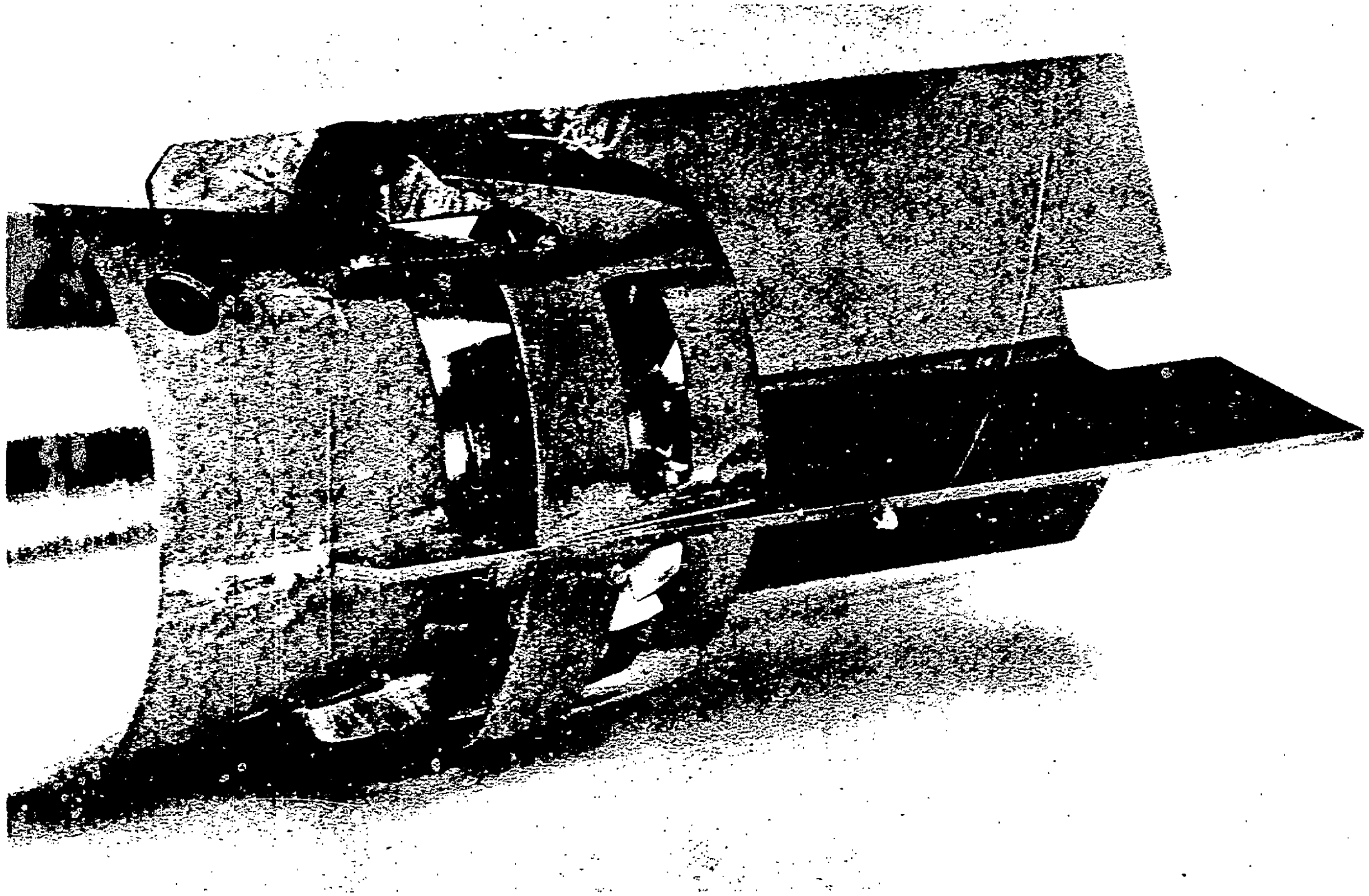


Figure 78 - BOMBLET TAIL CONFIGURATION 3-5C

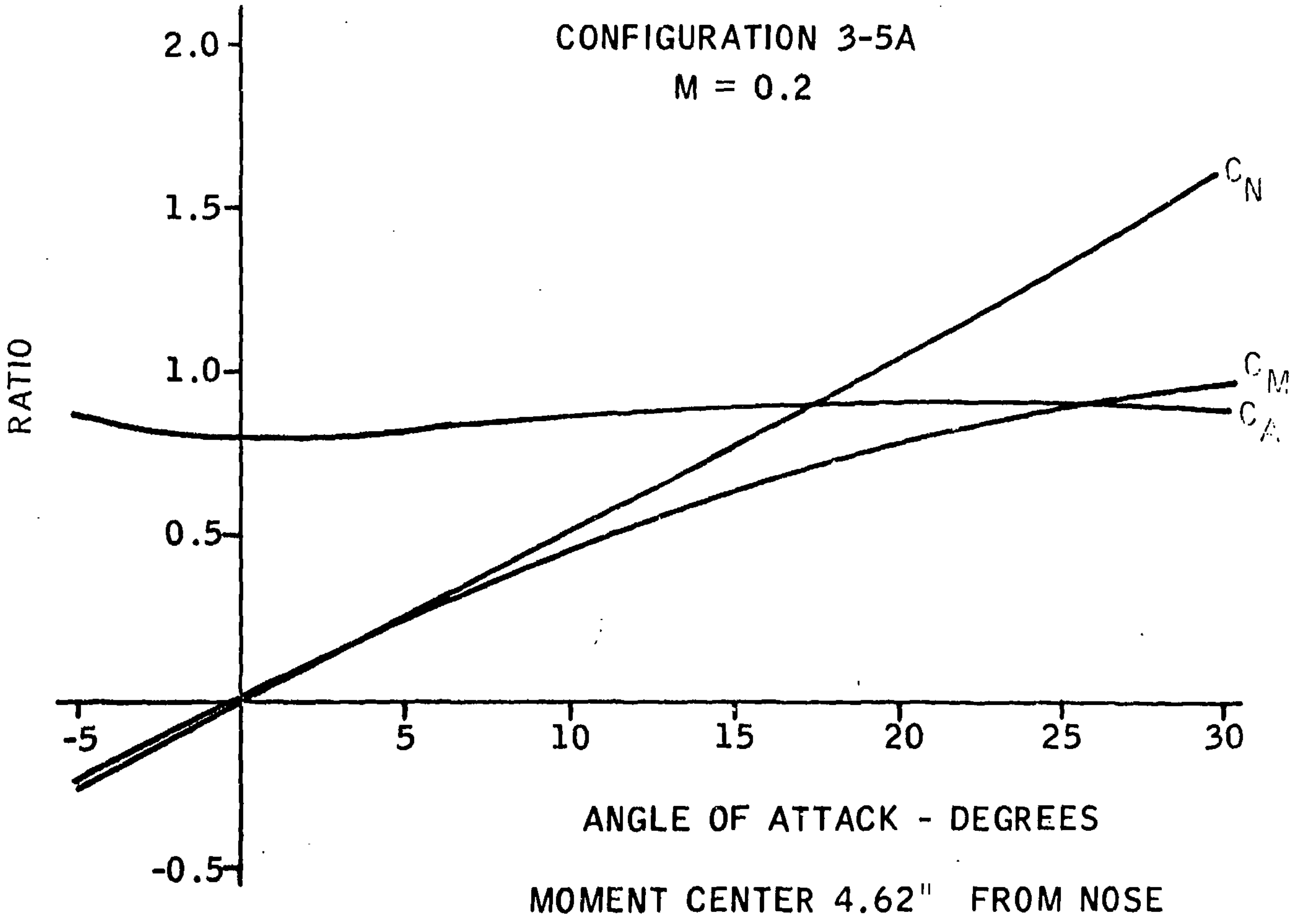


Figure 79 - BOMBLET AERODYNAMIC CHARACTERISTICS, TAIL CONFIGURATION 3-5A (See illustration, Figure 76)

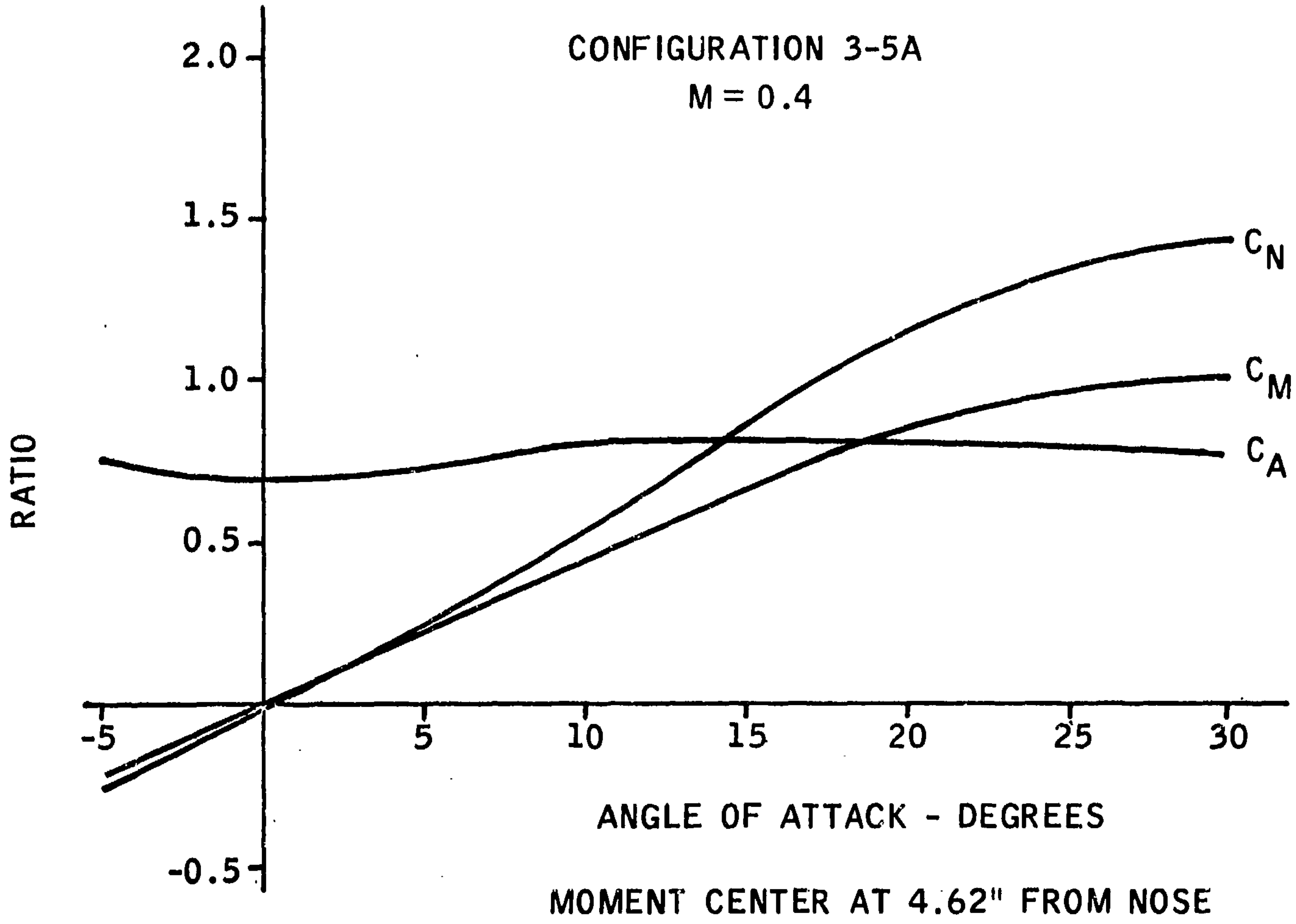


Figure 80 - BOMBLET AERODYNAMIC CHARACTERISTICS, CONFIGURATION 3-5A, M = 0.4

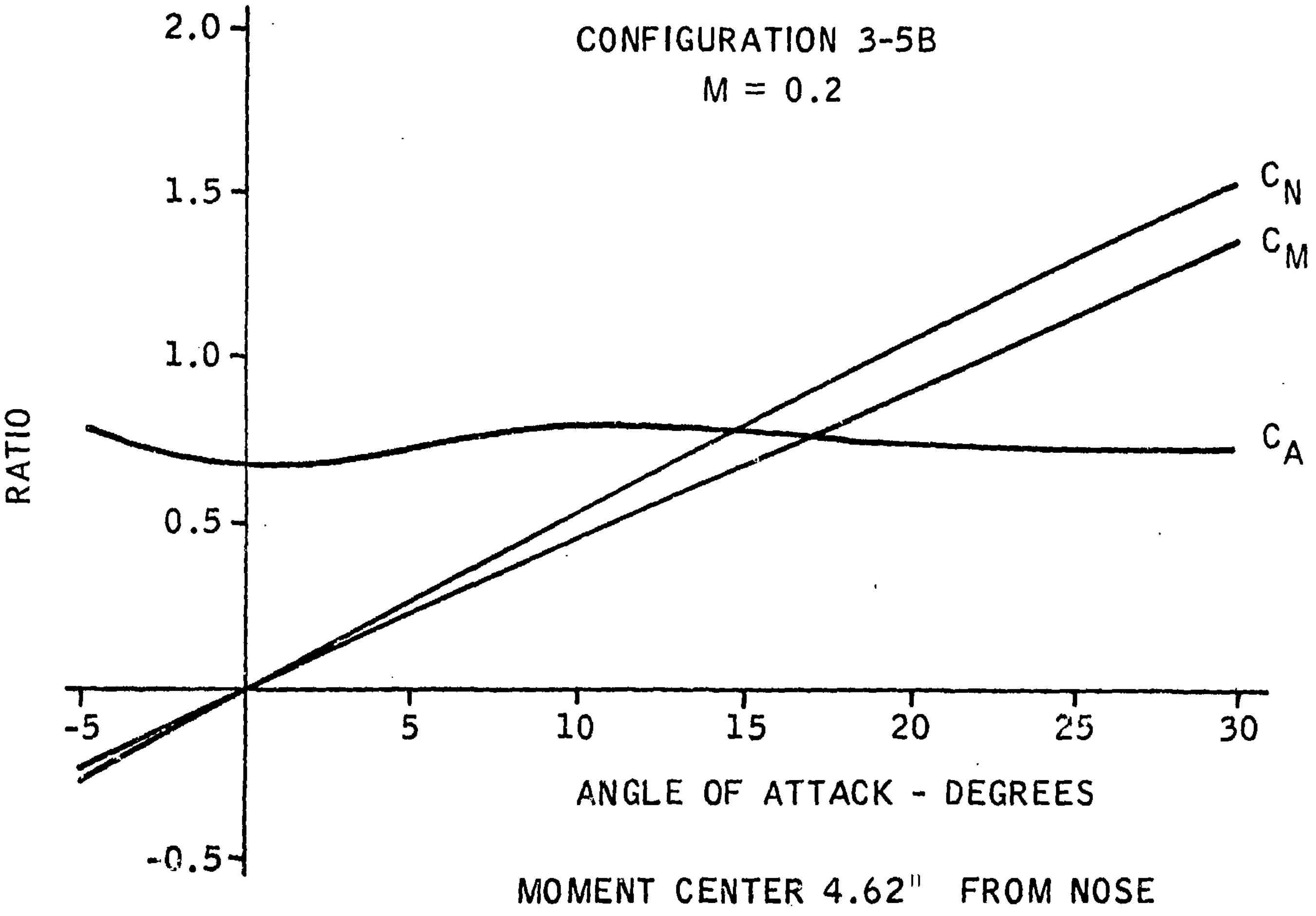


Figure 31 - BOMBLET AERODYNAMIC CHARACTERISTICS, CONFIGURATION 3-5B, M = 0.2

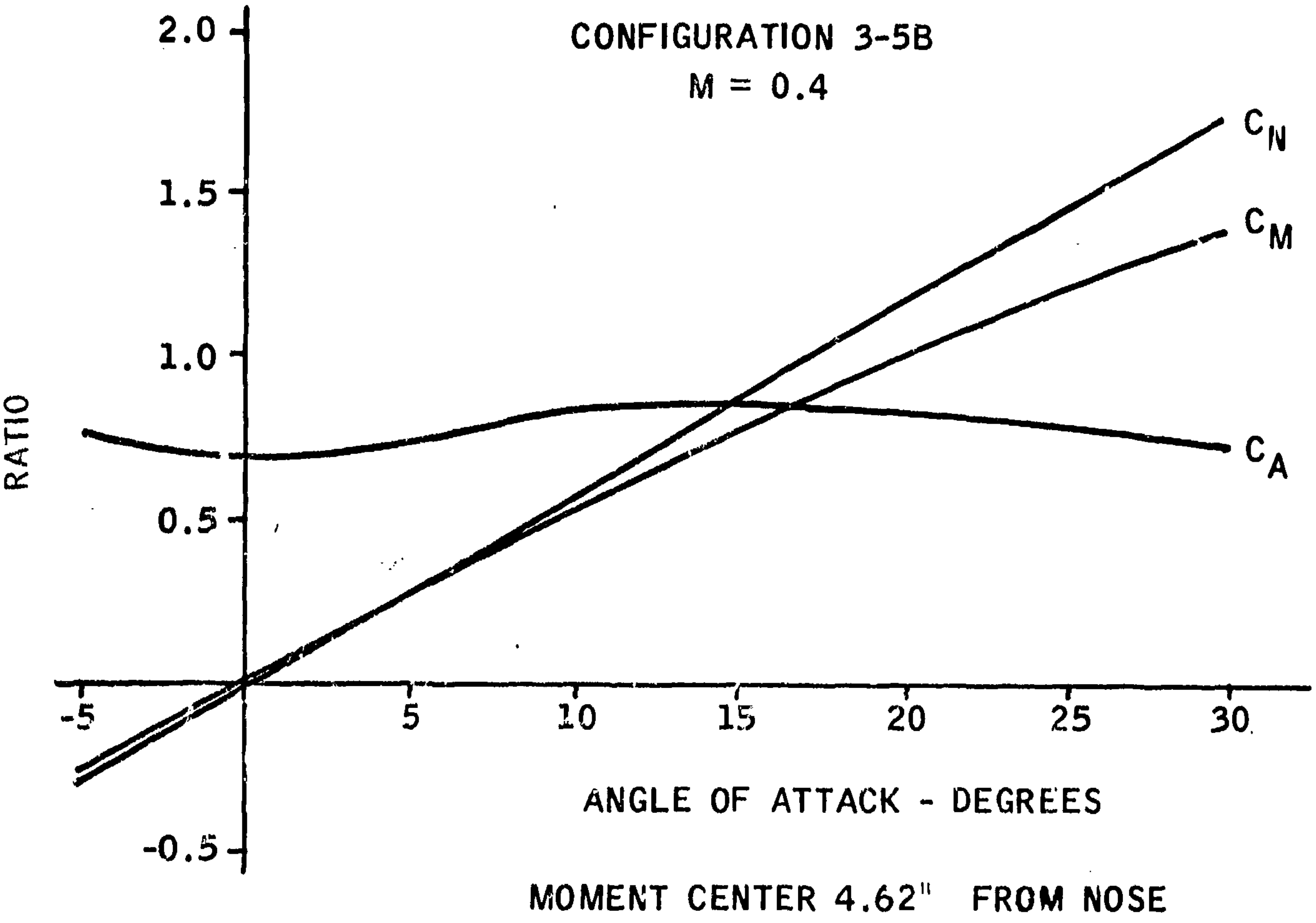


Figure 82 - BOMBLET AERODYNAMIC CHARACTERISTICS

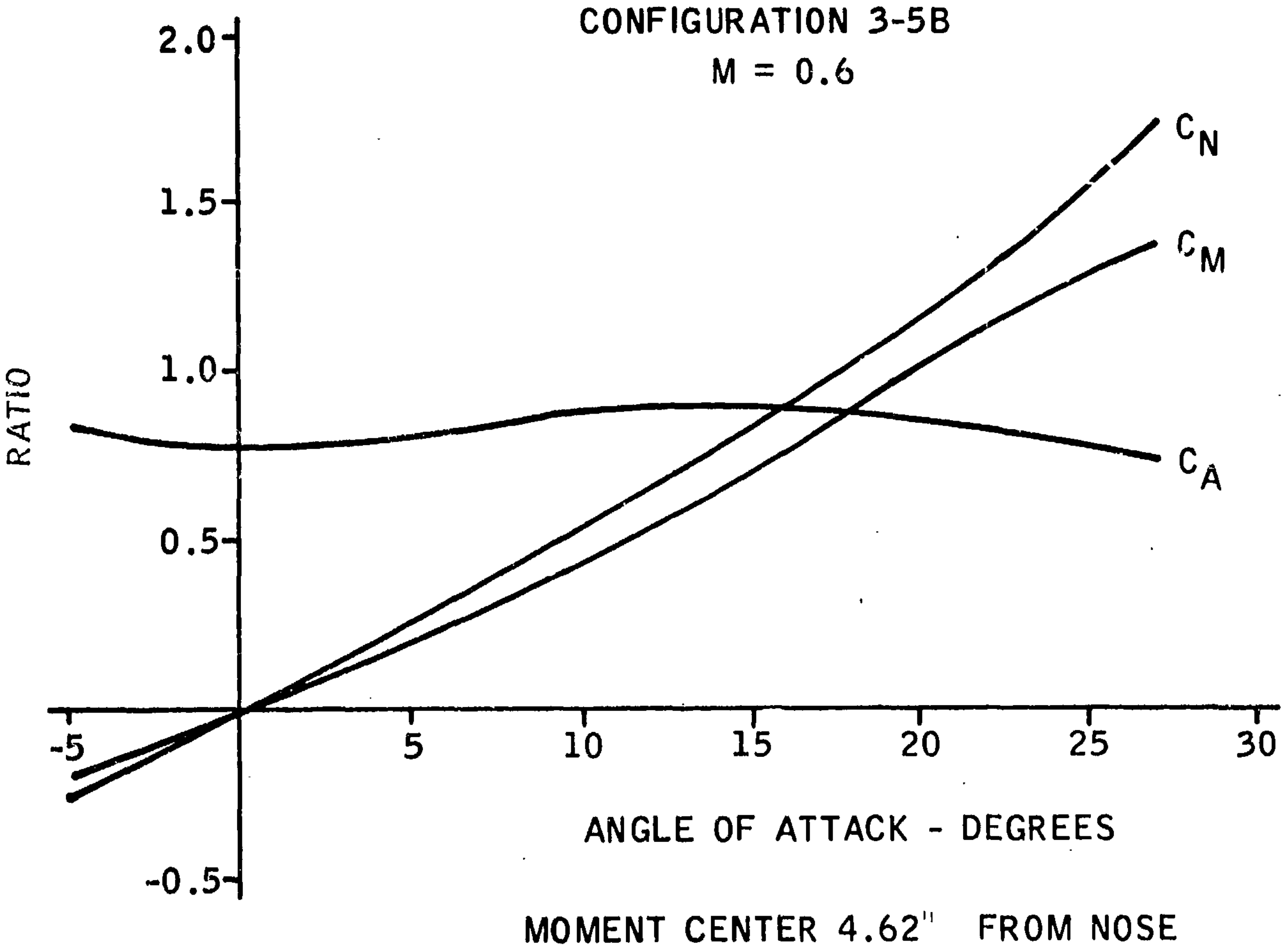


Figure 83 - BOMBLET AERODYNAMIC CHARACTERISTICS, CONFIGURATION 3-5B, M = 0.6

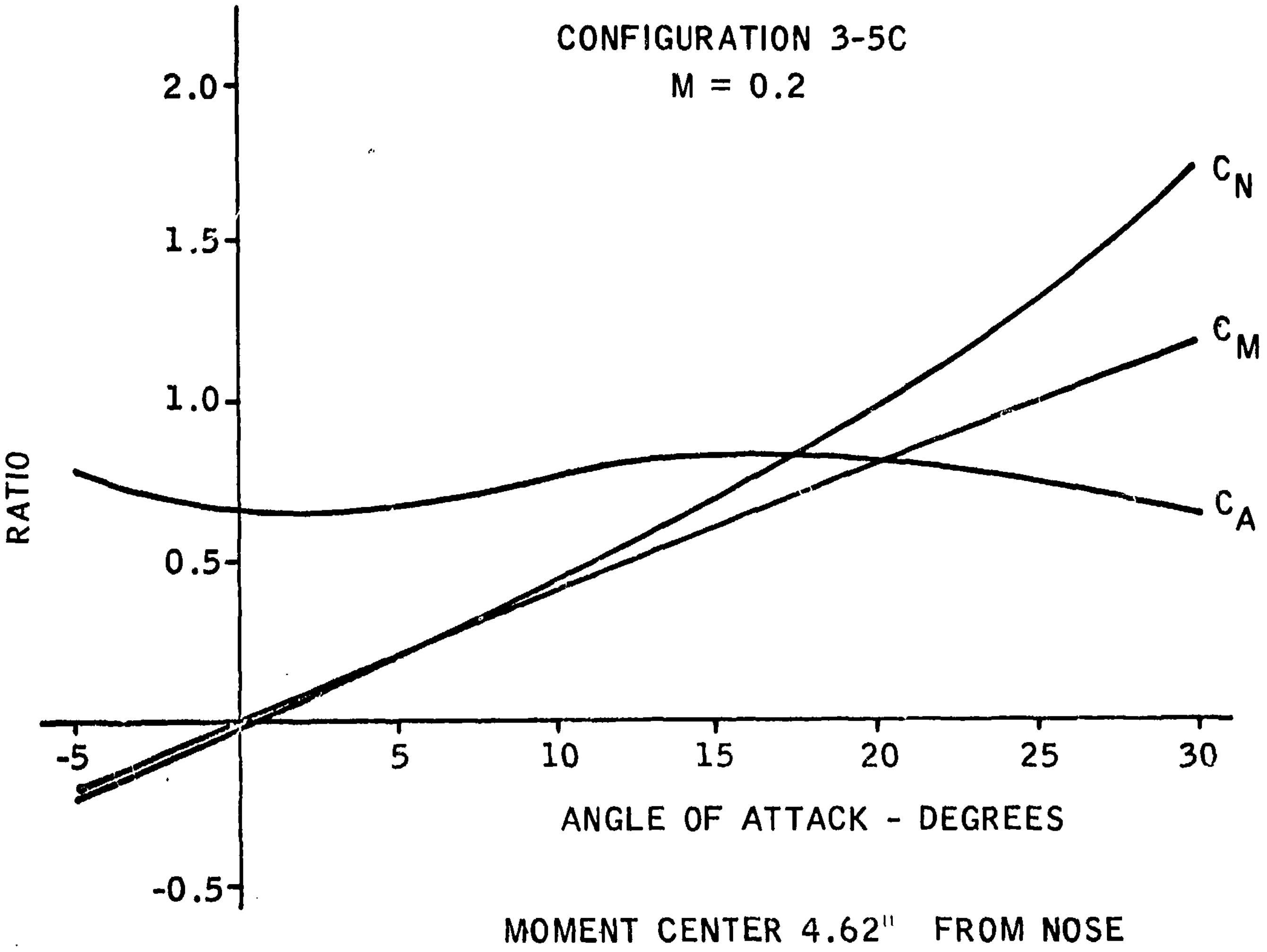


Figure 84 - BOMBLET AERODYNAMIC CHARACTERISTICS, CONFIGURATION 3-5C, M = 0.2

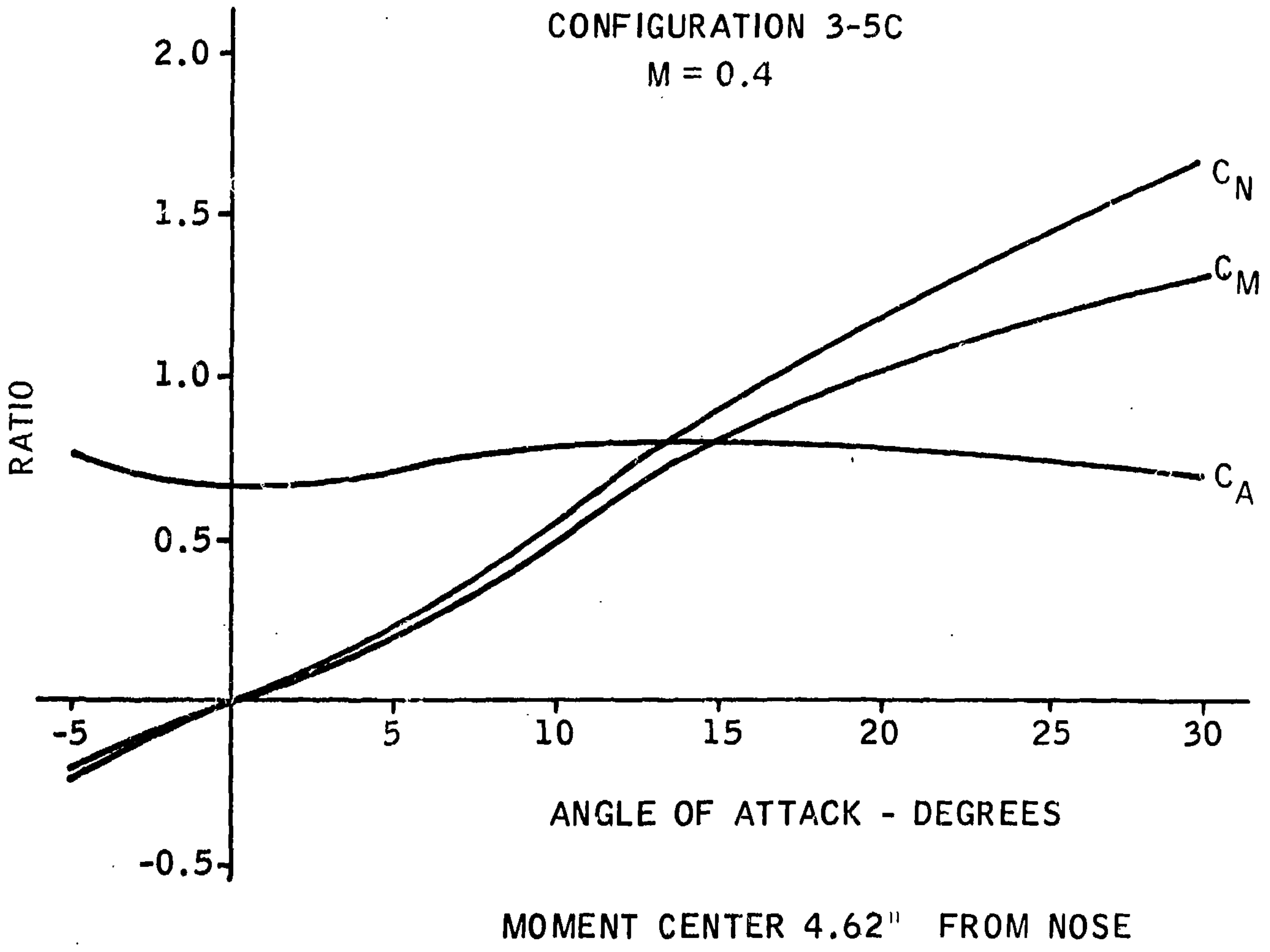


Figure 85 - BOMBLET AERODYNAMIC CHARACTERISTICS, CONFIGURATION 3-5C, M = 0.4

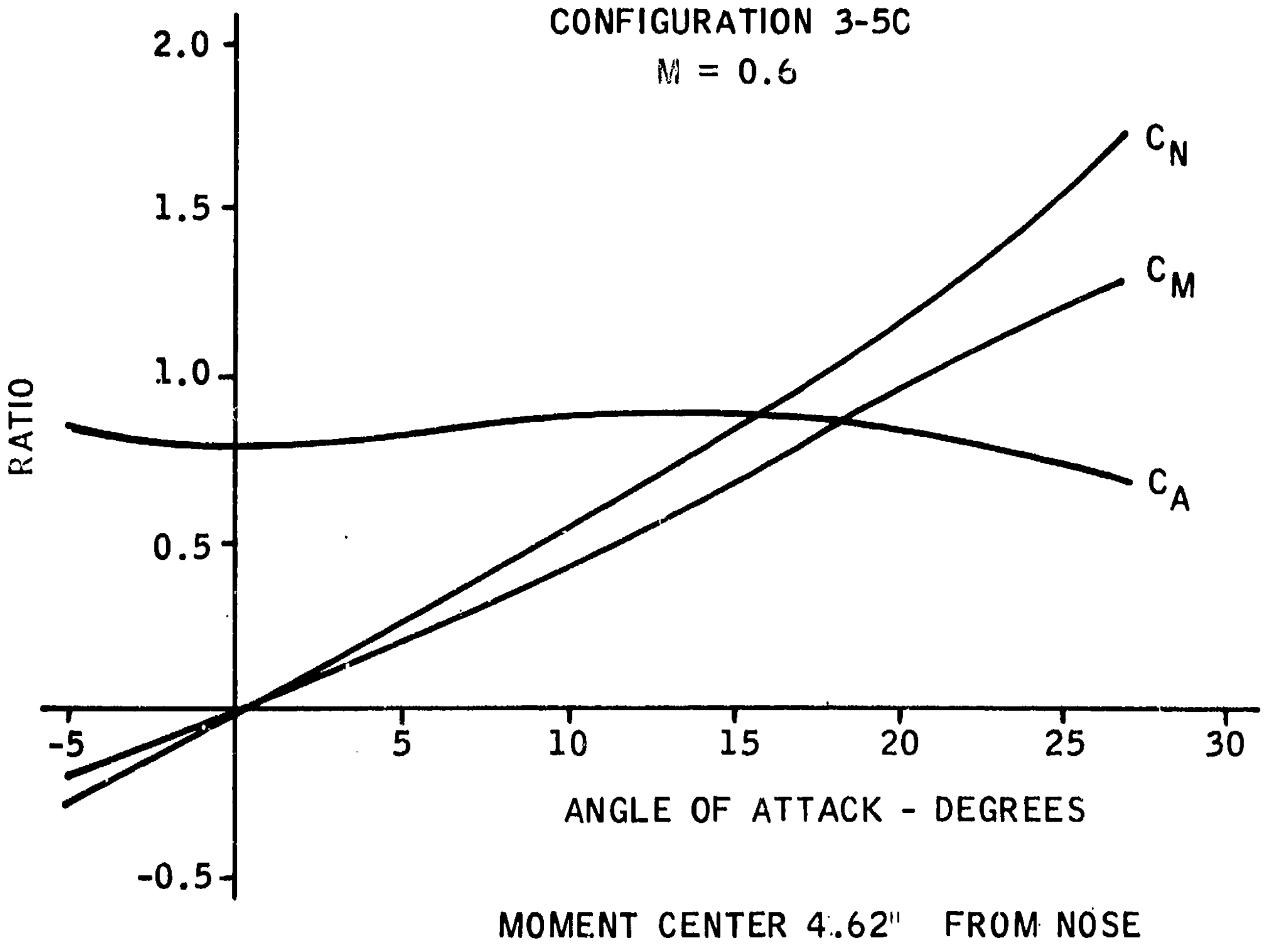


Figure 86 - BOMBLET AERODYNAMIC CHARACTERISTICS,
CONFIGURATION 3-5C, M = 0.6

Field tests at NOTS as well as estimated damping derivatives based on the static aerodynamic data revealed that pitch damping of this configuration would not be adequate at low speed (Mach 0. 3), low altitude (100 feet) deliveries. A 1-inch extension was added to the trailing edge of the fins, as shown in Figure 87, in an attempt to improve low velocity damping performance. Subsequent wind tunnel tests indicated that the desired improvement in low velocity damping was provided. Therefore, the design shown in Figure 8 was established as the basic approach.

A model of this design was tested at Mach. 0. 3, 0. 5, 0. 6, and 0. 7 at angles of attack of -40° to +40°. With the entire fin assembly removed, additional testing was conducted to obtain isolated effects contributed by this unit. The aerodynamic data obtained are shown in Figures 88 through 91. These data indicate terminal velocity of the bomblet when weighing 1. 22 pounds to be 265 ft/sec. The desired terminal velocity previously noted was between 200 and 300 ft/sec.

The normal force and pitching moment contributions of the fins in the static model are shown in Figure 92. If the cg location was maintained, these data show pitch damping to possibly be inadequate. Additional testing was made in a dynamic environment with the complete model at Mach 0. 15, 0. 20, and 0. 25 to evaluate pitch damping further. These tests, the model was mounted in the wind tunnel on a pivot with the fins in the "Y" orientation. It was yawed to 180° and released, and the subsequent yaw oscillations were recorded. The damping coefficients obtained for yaw, shown in Figures 93, 94 and 95, indicate greater damping capability than that reflected in the static data.

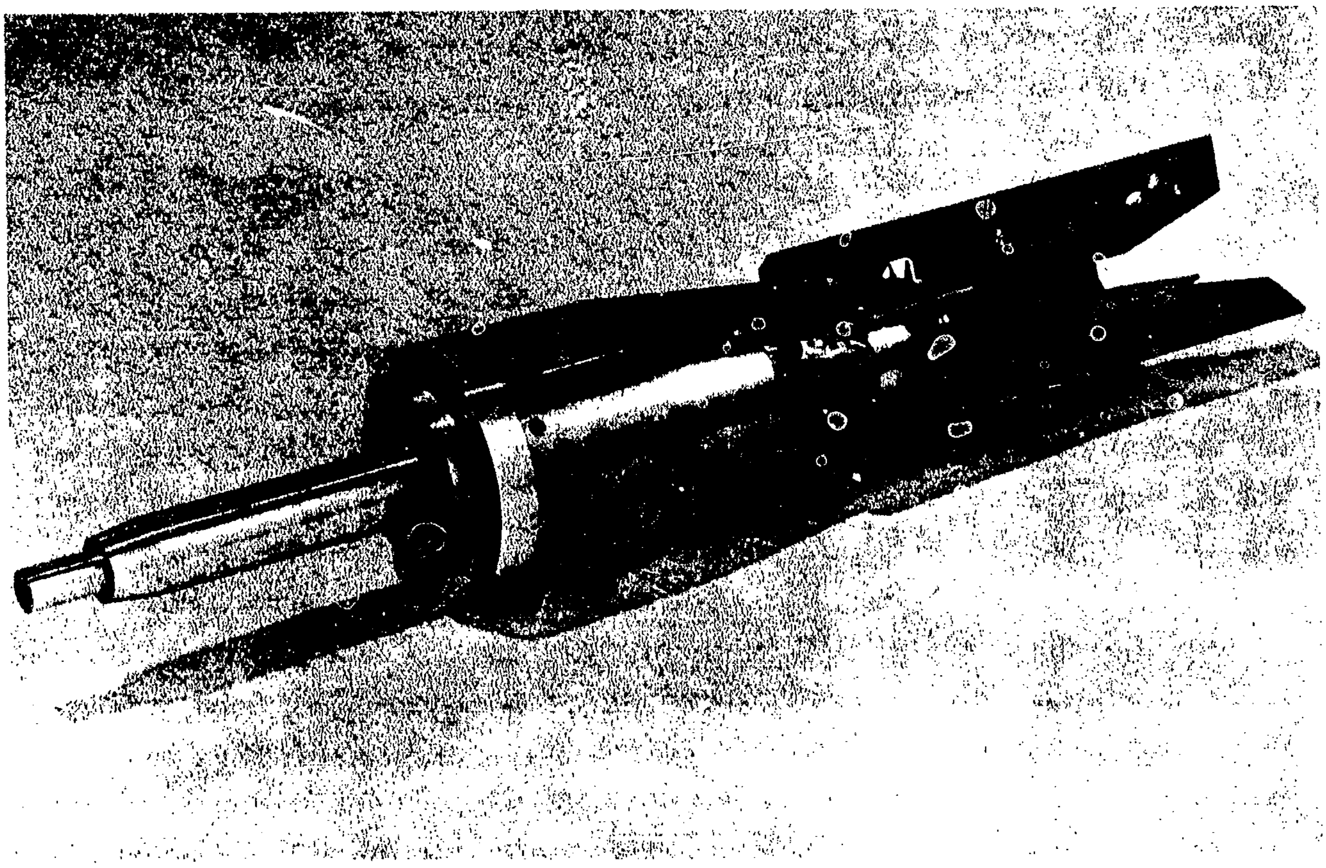
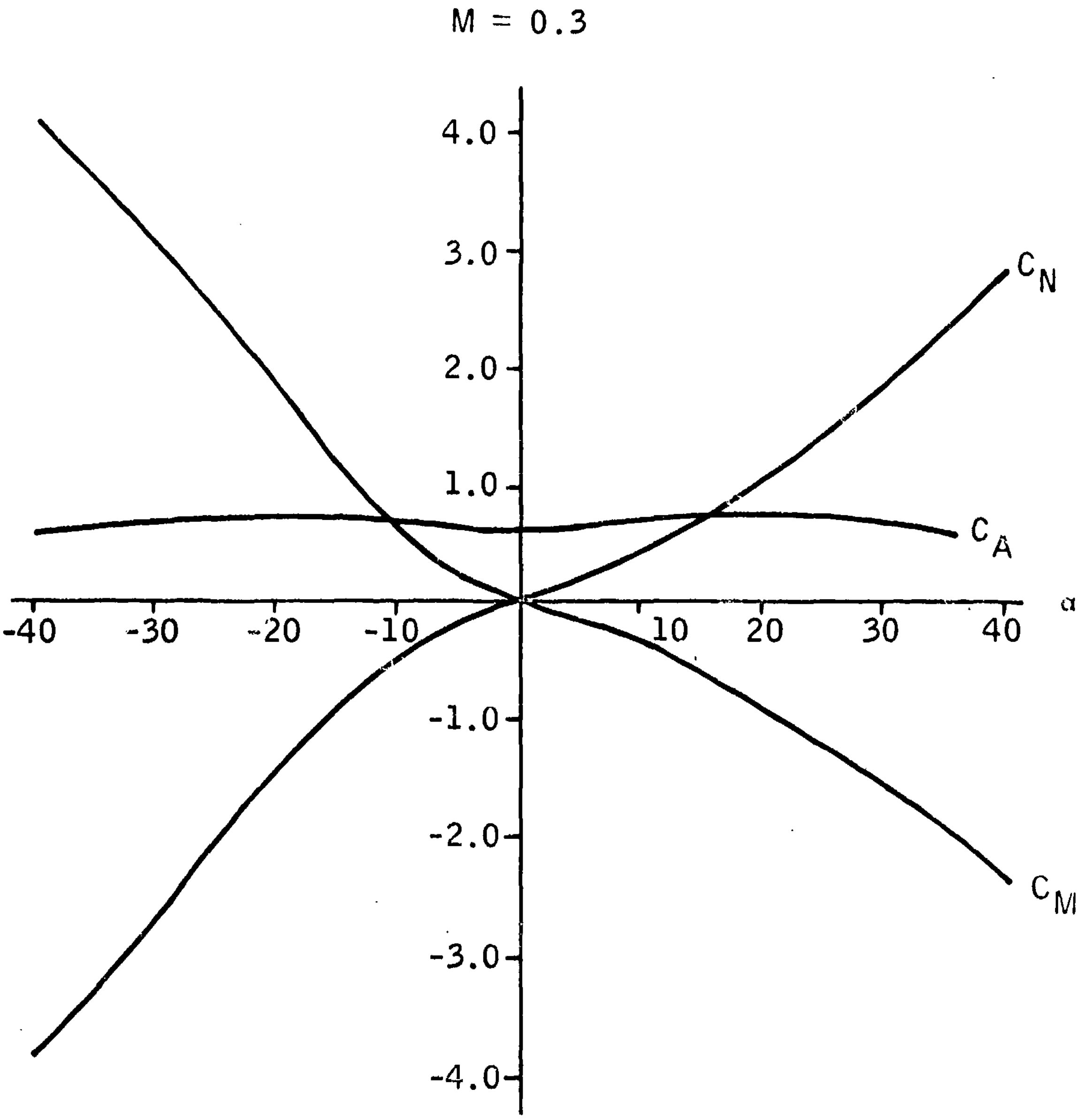
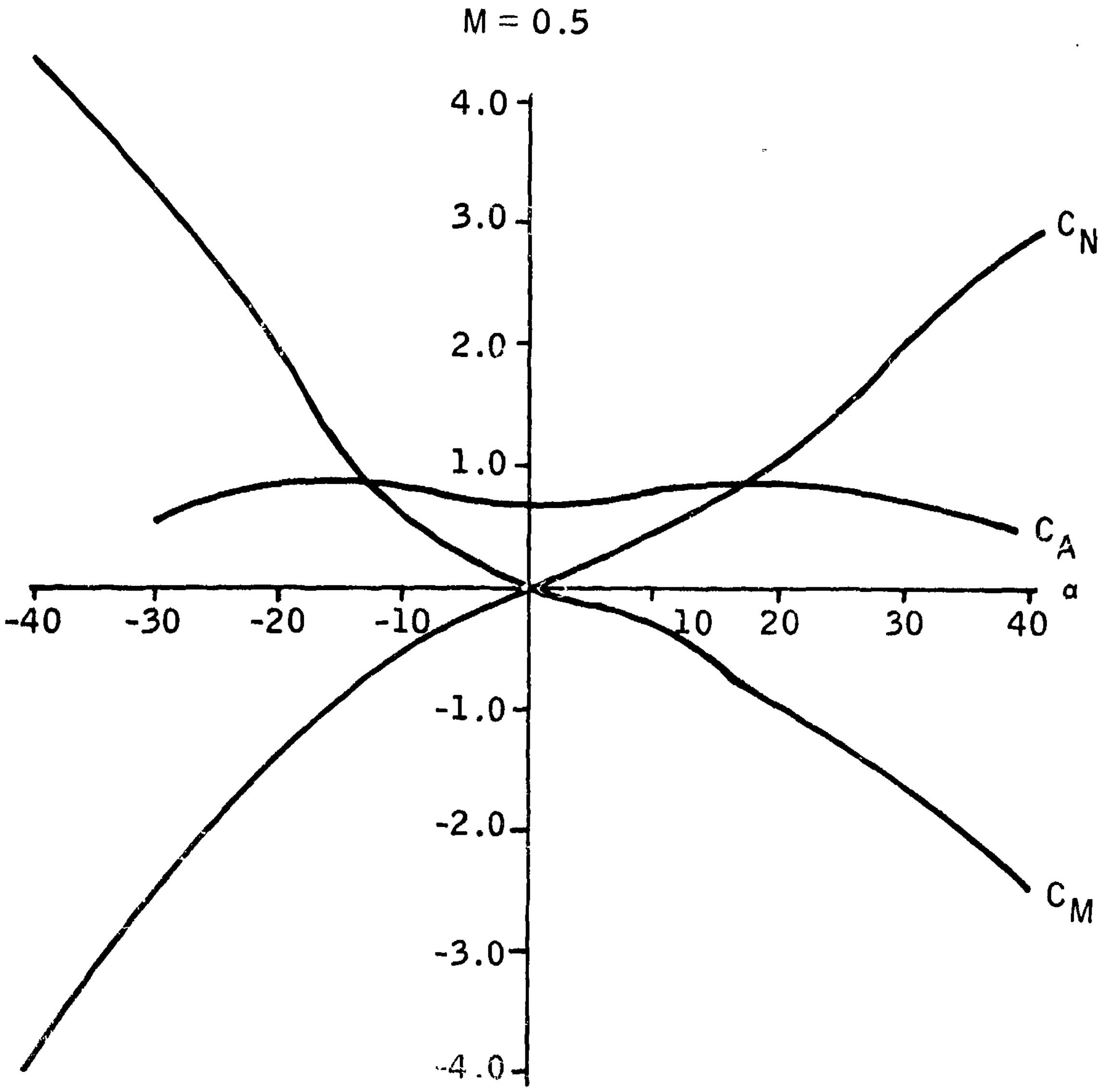


Figure 87 - BOMBLET CONFIGURATION 3-5B MOD 1



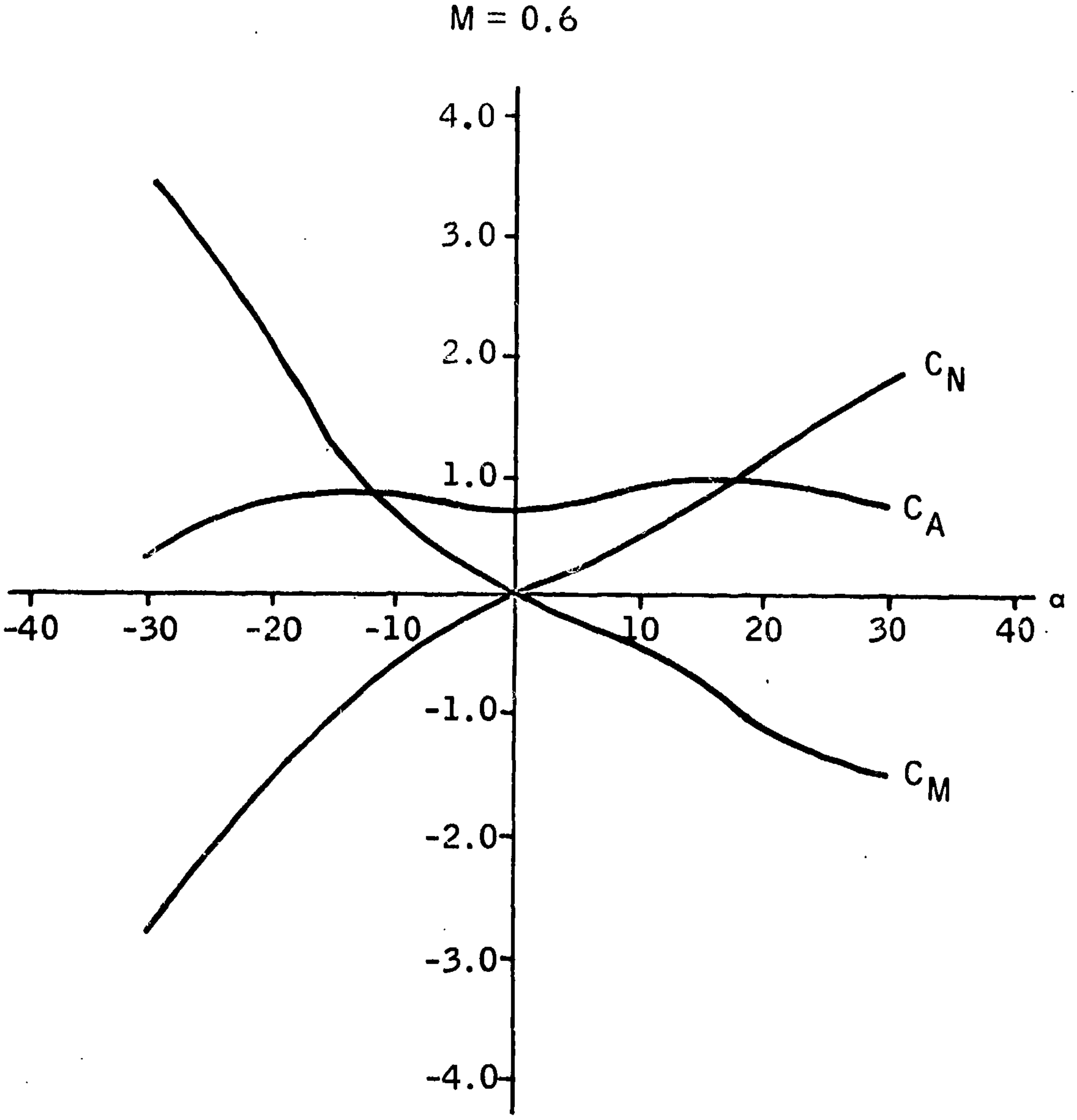
MOMENT CENTER 4.62" FROM NOSE

Figure 88 - BOMBLET AERODYNAMIC CHARACTERISTICS, CONFIGURATION 3-5B, MOD 1, M = 0.3



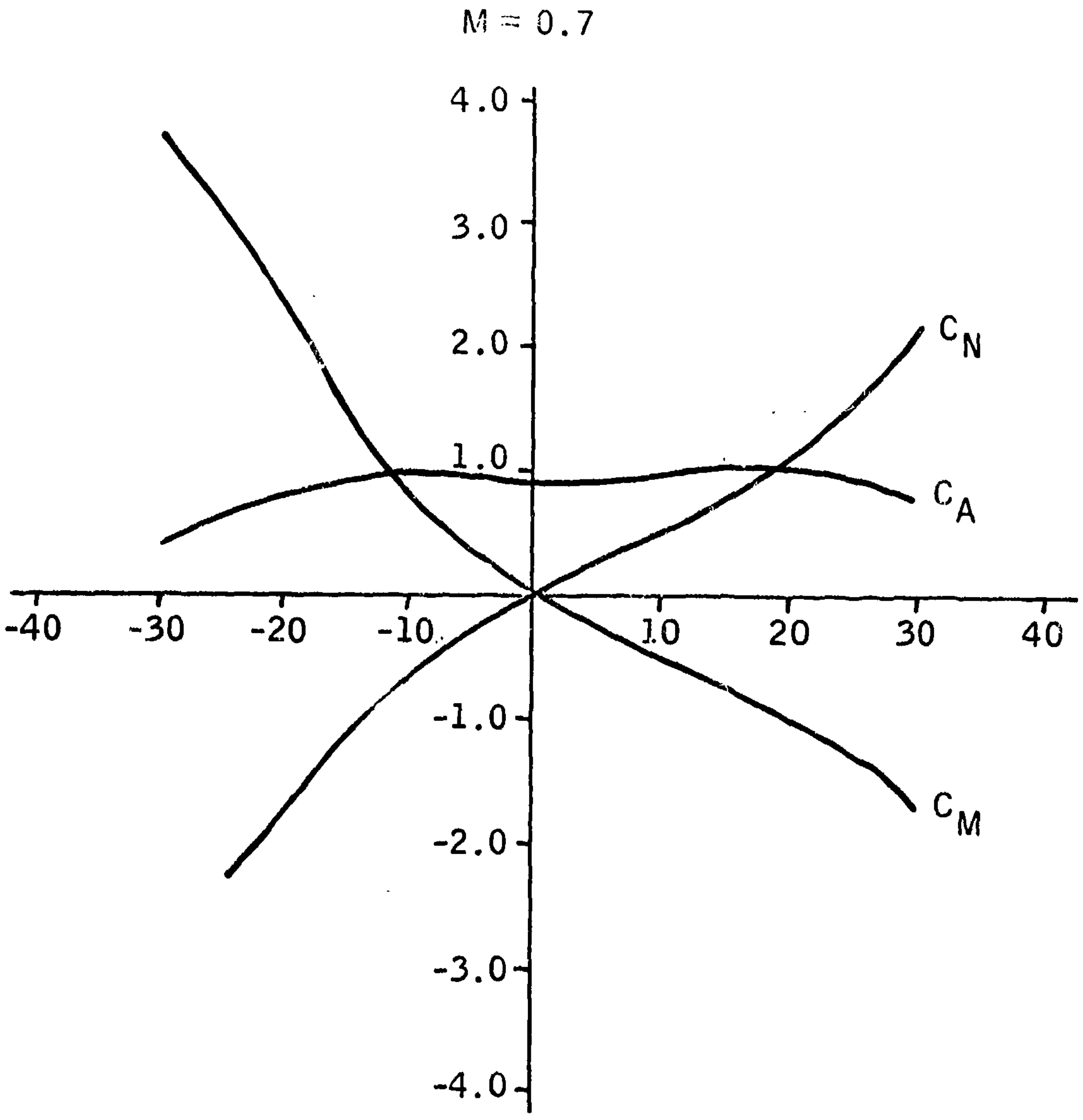
MOMENT CENTER AT 4.62" FROM NOSE

Figure 89 - BOMBLET AERODYNAMIC CHARACTERISTICS, CONFIGURATION 3-5B, MOD 1, M = 0.5



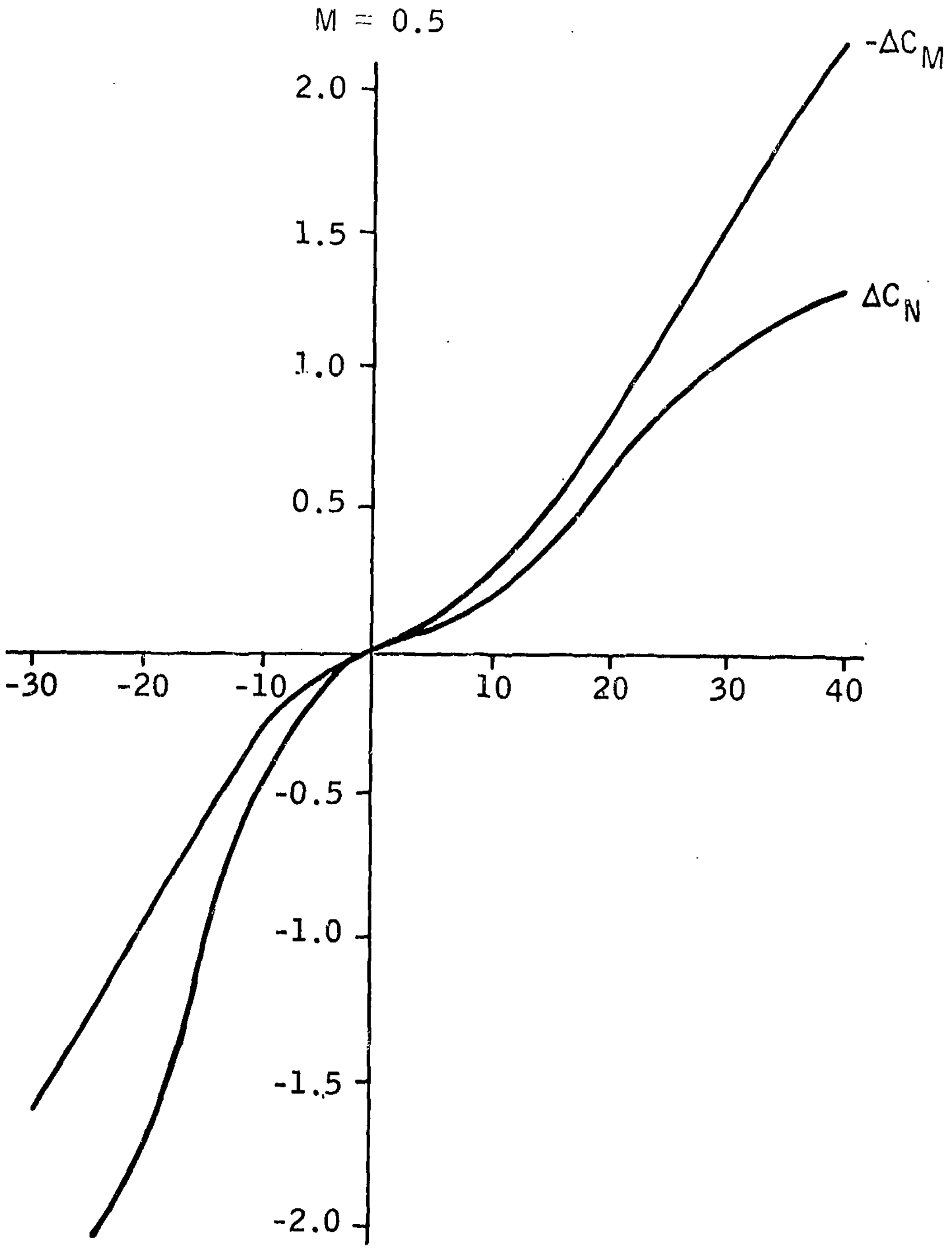
MOMENT CENTER AT 4.62" FROM NOSE

Figure 90 - BOMBLET AERODYNAMIC CHARACTERISTICS, CONFIGURATION 3-5B, MOD 1, M = 0.6



MOMENT CENTER AT 4.60" FROM NOSE

Figure 91 - BOMBLET AERODYNAMIC CHARACTERISTICS, CONFIGURATION 3-5B, MOD 1, M · 0.7



MOMENT CENTER 4.62" FROM NOSE

Figure 92 - BOMBLET TAIL CONTRIBUTION, CONFIGURATION 3-5B, MOD 1
M = 0.5

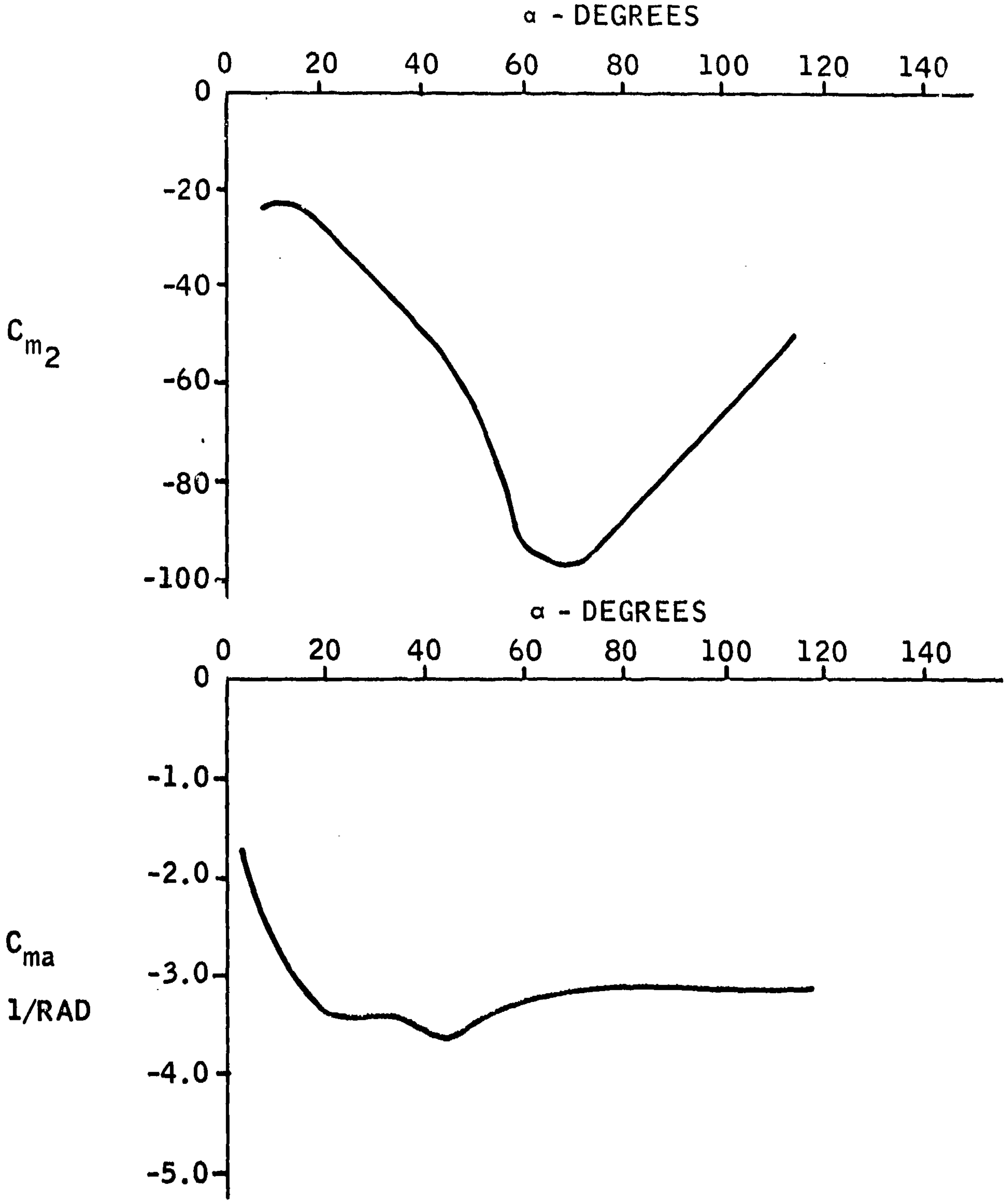


Figure 93 - BOMBLET DYNAMIC STABILITY TEST RESULTS, $M = 0.151$, MODEL 3-5B, MOD 1

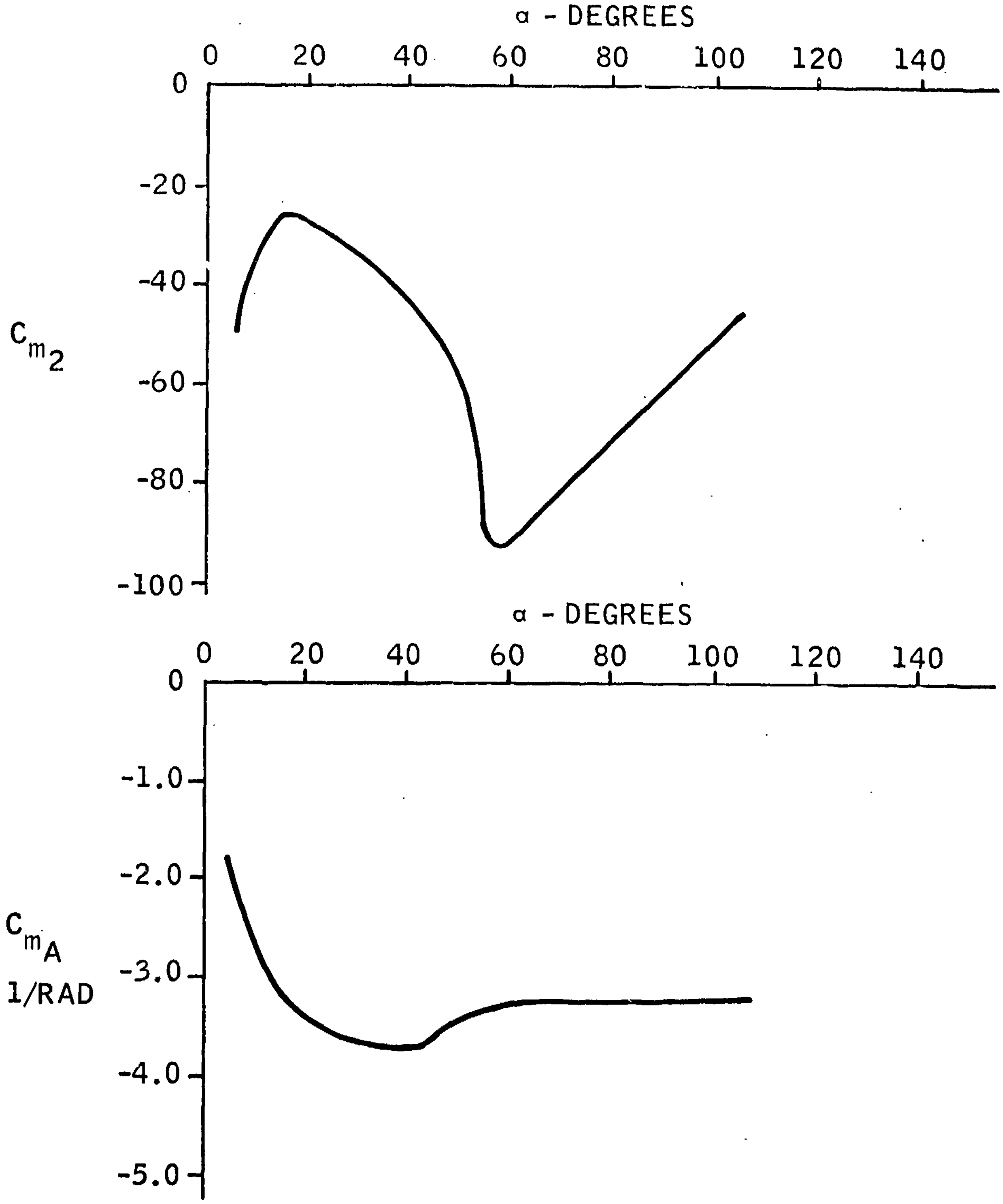


Figure 94 - BOMBLET DYNAMIC STABILITY TEST RESULTS, M = 0.204, MODEL 3-5B, MOD 1

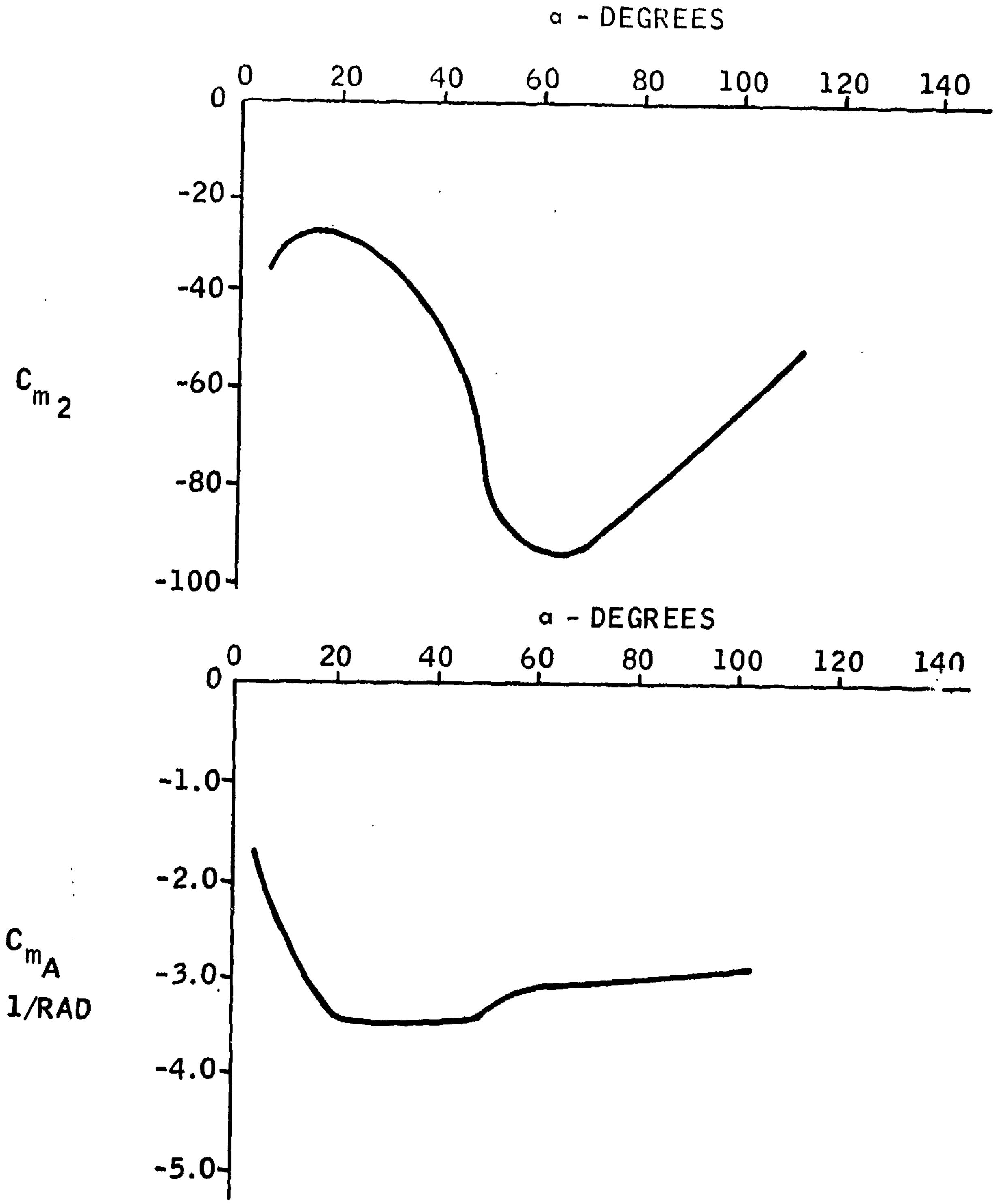


Figure 95 - BOMBLET DYNAMIC STABILITY TEST RESULTS, M = 0.256, MODEL 3-5B MOD 1

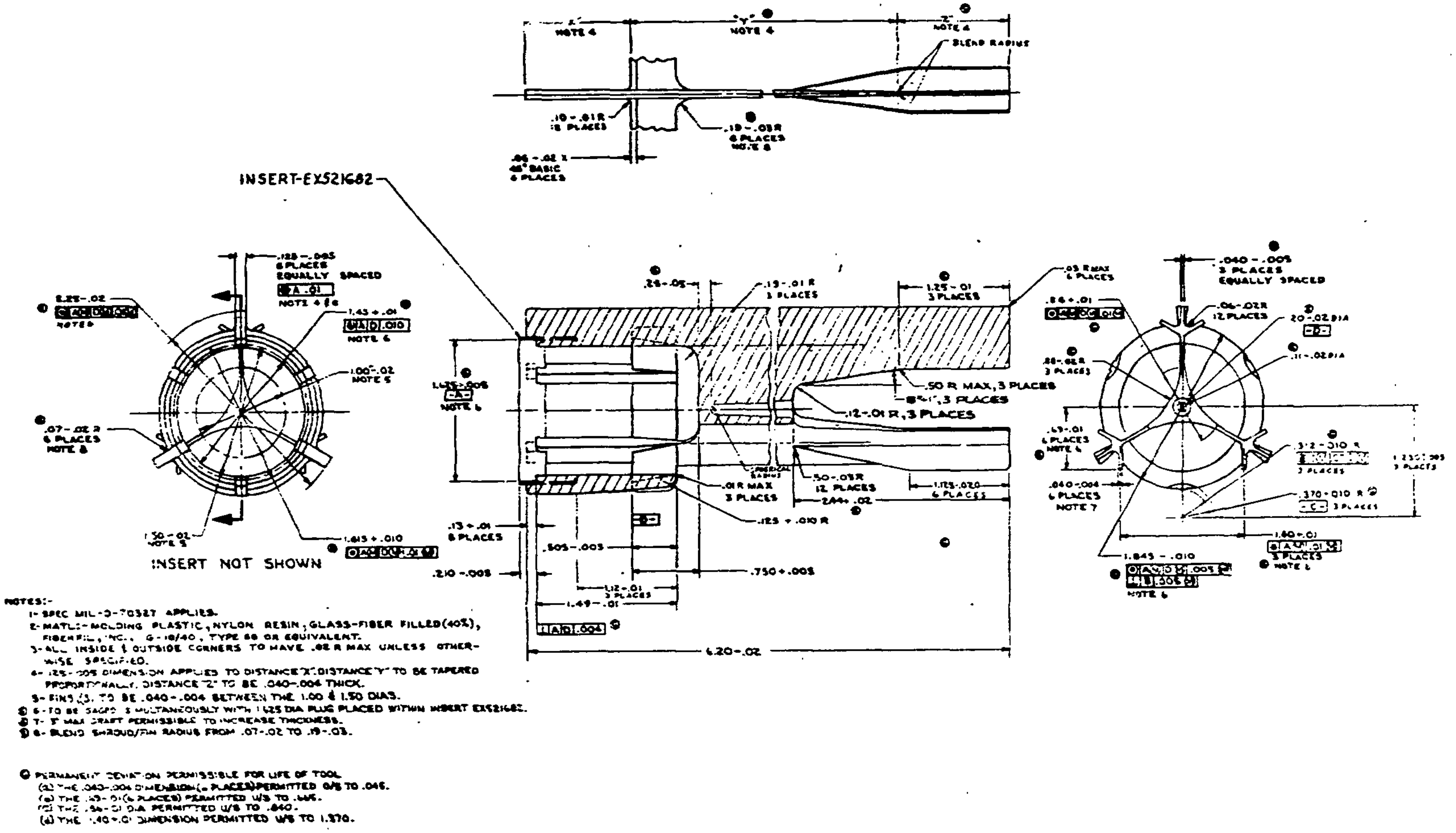
On the basis of these results, it was concluded that the Phase I design was statically and dynamically stable within the specified Mach range. The terminal velocity met performance objectives, and the damping capability was adequate. A summary of the wind tunnel testing on all the aerodynamic configurations evaluated up to this time is contained in Appendix F, Part B, Volume I.

(2) Subsequent Design Modifications - As noted previously, the basic Phase I configuration (spike nose, cylindrical body with the aft taper, 3-radial fin and shroud tail assembly) remained the design approach for the remainder of the development program. However, minor modifications were made subsequent to the establishment of this design, and these later changes are discussed in this section of the report.

During the parametric investigation of the shaped charge design, it was determined that the desired penetration capability could be provided by increasing the amount of the explosive load. A design change was, therefore, effected which necessitated a corresponding increase in the length of the body. The body and the nose sections were each increased by 0.345 inch and the fins were increased in length by 1.25 inches to provide stability for the revised body configuration. The extended length fin and especially the finlet section, shown in Figure 96, were added to alleviate a pitch-roll instability that was found to occur during flight conditions in the original length bomblet. The fragile, sharp radius construction was changed to a stout 40% glass filled Nylon construction. Due to the increased bomblet body length, the number of rows of bomblets in the dispenser were reduced from 12 to 11.

The resulting bomblet configuration is shown in Figure 97. A test model of this configuration was fabricated and evaluated in a wind tunnel at Mach 0.3, 0.6, and 0.9 and the unit was found to be compatible with all stability and terminal velocity requirements. One other change, the addition of a reinforcing section to the forward ribs of the fins as shown in Figure 98, was made to this design. This modification was incorporated to enhance structural integrity and had no appreciable effect on the aerodynamic characteristics of the bomblet.

Material and structural details of the final aerodynamic configuration are discussed in Section IV. B. 3.



NOTES:-

1- SPEC MIL-D-70327 APPLIES.
2- MATL:- MOLDING PLASTIC, NYLON RESIN, GLASS-FIBER FILLED(40%), FIBERFIL, INC., G-10/40, TYPE 66 OR EQUIVALENT.
3- ALL INSIDE & OUTSIDE CORNERS TO HAVE .02 R MAX UNLESS OTHERWISE SPECIFIED.
4- .125-.005 DIMENSION APPLIES TO DISTANCE "X". DISTANCE "Y" TO BE TAPERED PROPORTIONALLY. DISTANCE "Z" TO BE .040-.004 THICK.
5- FINS (3) TO BE .040-.004 BETWEEN THE 1.00 & 1.50 DIAS.
6- TO BE GAGED SIMULTANEOUSLY WITH 1.625 DIA PLUG PLACED WITHIN INSERT EX521682.
7- 3° MAX DRAFT PERMISSIBLE TO INCREASE THICKNESS.
8- BLEND SHROUD/FIN RADIUS FROM .07-.02 TO .19-.03.

PERMANENT DEVIATION PERMISSIBLE FOR LIFE OF TOOL
(a) THE .040-.004 DIMENSION (6 PLACES) PERMITTED O/S TO .045.
(b) THE .69-.01 (6 PLACES) PERMITTED U/S TO .665.
(c) THE .84-.01 DIA PERMITTED U/S TO .840.
(d) THE 1.40-.01 DIMENSION PERMITTED U/S TO 1.370.

Figure 96 - ROCKEYE II FIN ASSEMBLY REVISION

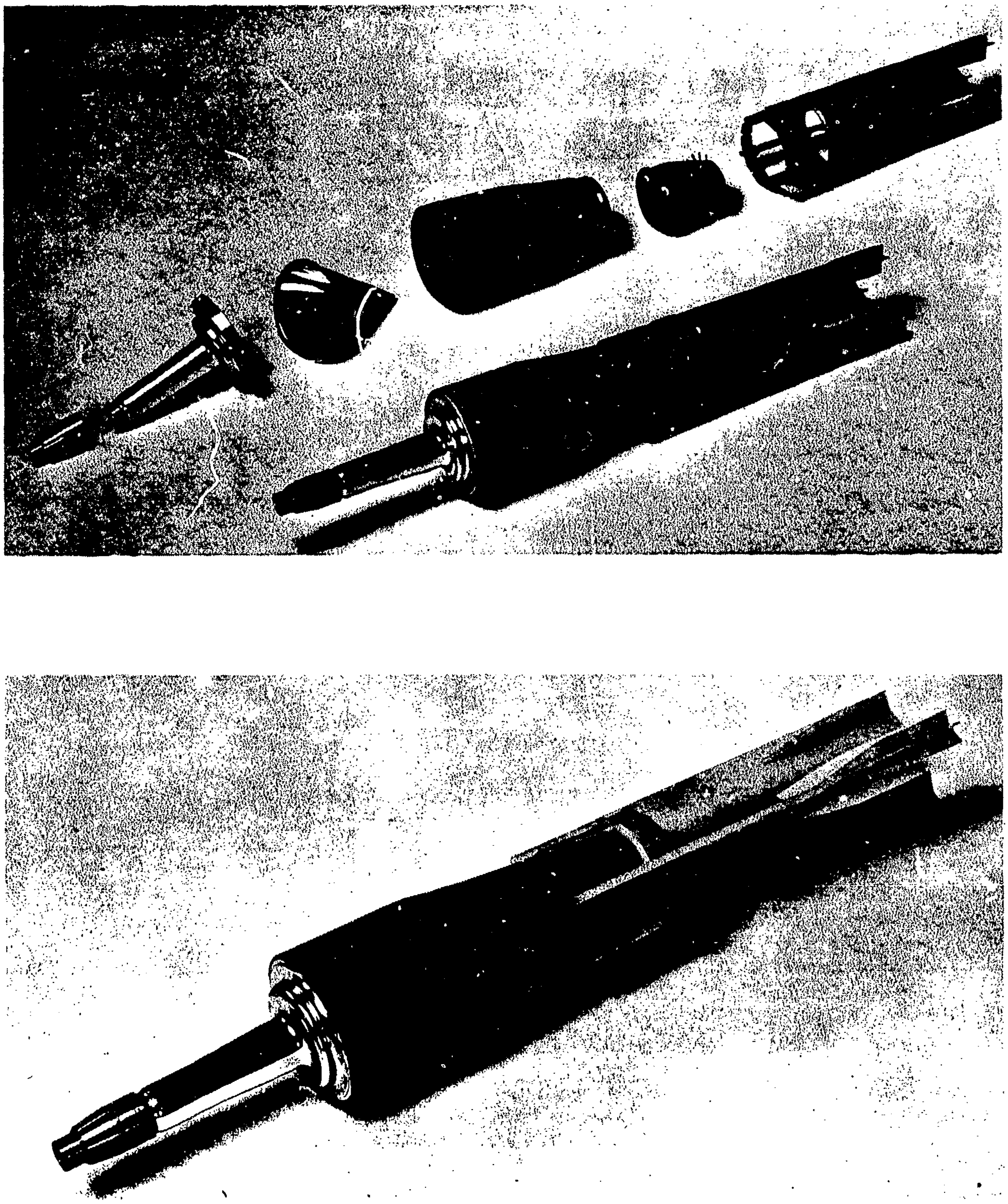


Figure 97 - ROCKEYE II BOMBLET CONFIGURATION; DISASSEMBLED AND ASSEMBLED

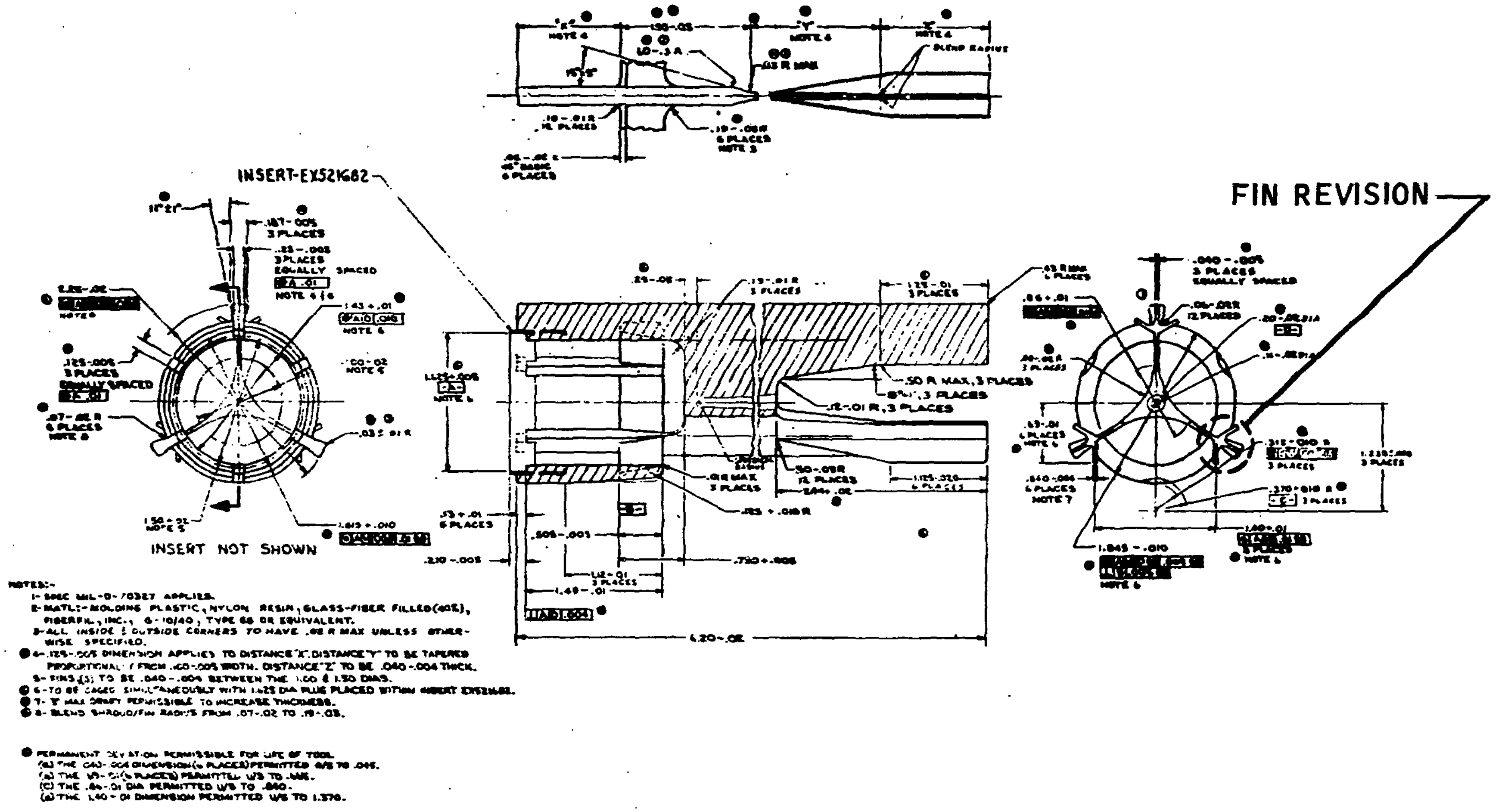


Figure 98 - MODIFIED FIN

b. Shaped Charge Design and Development

The kill mechanism of the Rockeye II bomblet for armored vehicles is a shaped charge, and its developmental evolution during the program is described in this section of the report. The section is divided to coincide with the major factors considered during development - anti-tank capability, anti-personnel capability, and explosive loading and sealing.

(1) Anti-tank Capability - Program effort with respect to the anti-tank capability of the shaped charge covered two basic developmental investigations - (a) definition of a shaped charge design providing the desired penetration performance and (b) determination of the cause of a degradation in performance noted in Phase II evaluation units. Consequently,the report on development of the shaped charge with respect to the anti-tank capability is organized to reflect this division of effort.

(a) Definition of Design - In the design requirements, it was specified that the Rockeye II bomblet be capable of penetrating 8. 5 inches of armor plate having a hardness of R_c45. In an early study on cargo packing, a diameter of 2. 1 inches was established as optimum for bomblet packing efficiency, and this value, consequently, was accepted as the diameter constraint on the shaped charge. It was decided to proceed from this fixed value and conduct a parametric trade off study of the other factors involved in shaped charge design to evolve an optimum configuration. The other parameters to be included in this investigation were:

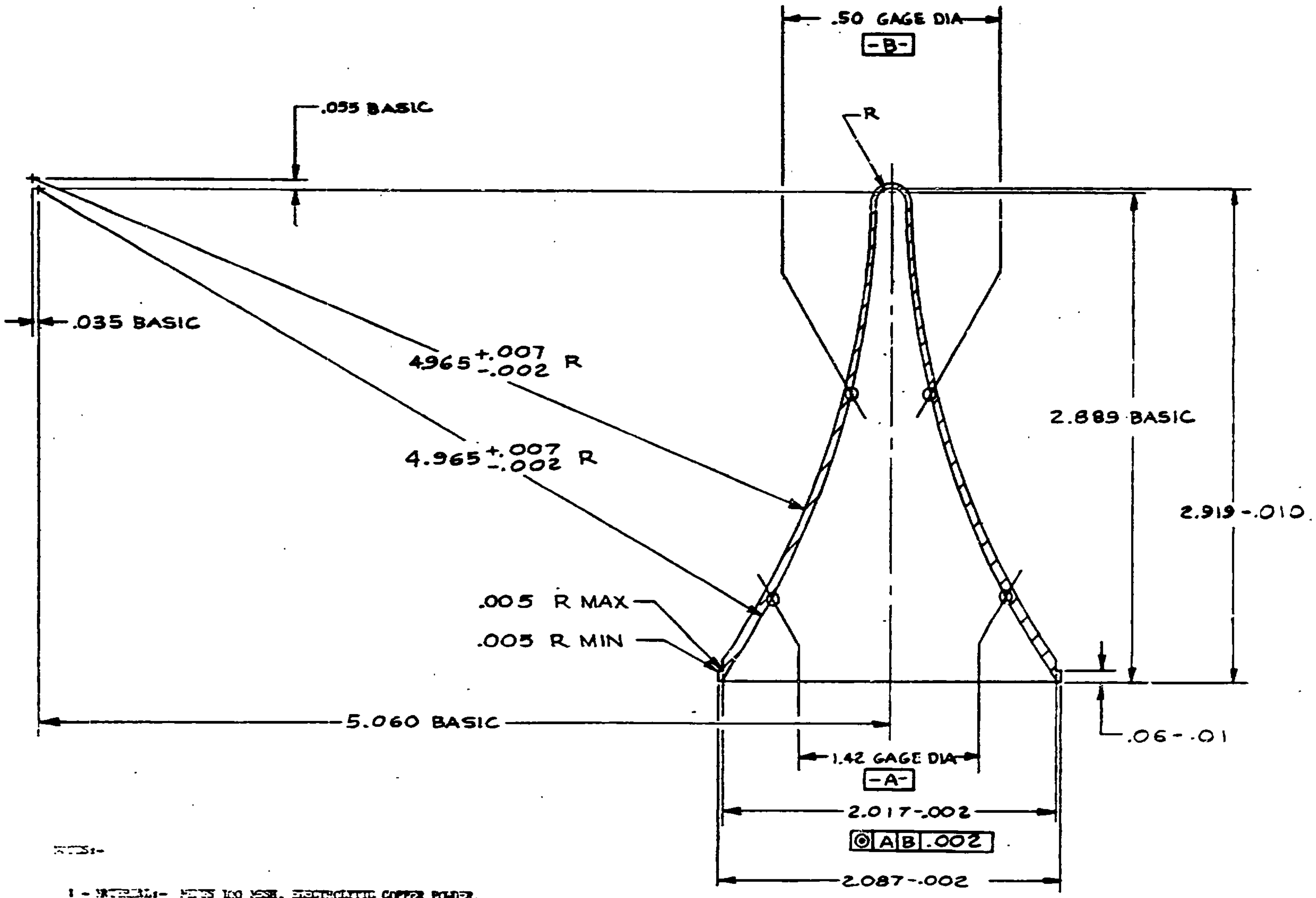
(a) Liner shape and thickness
(b) Explosive heads
(c) Type of explosive
(d) Standoff
(e) Wave shaper
(f) Confinement

A standard bomblet, shown in Figure 68, had been defined at this time to establish an initial point for development. Two liner configurations compatible with this standard were posited for investigation - a conventional 42° cone; and a trumpet, or concave, cone as shown in Figure 99. Test models of the two line configurations were fabricated with the following physical characteristics:

	Conventional 42° liner	Trumpet liner
Explosive Load	220 grams Comp B	167 Grams Comp B
Confinement	.050-inch thick steel wall	Same
Standoff	3.5 inch	Same
Liner Material	.060-inch thick powdered metal process	Same
Nose Confinement or Structure	None	None

These units were test fired using a #6 electric blasting cap for initiation and a CH6 booster for propagating to the main charge. Shot into mild steel, the conventional liner units penetrated an average of 10.46 inches; and the trumpet liner assemblies penetrated an average of 9.96 inches. When shot into target blocks of R_C45 armor, average penetrations of 6.9 and 5.45 inches were obtained for the conventional and the trumpet liners, respectively.

Subsequently, a series of test shots was made of both these basic configurations with selective variation of critical parameters. The results in terms of effect on penetration are shown in Table IX, which also describes parametric modifications made. In view of these results, the following conclusions were made:



NOTES:-

1 - MATERIAL:- MINUS 100 MESH, ELECTROLYTIC COPPER POWDER, 99% MINIMUM PURITY.
2 - PART MUST BE FREE OF PARTING LINES, BURRS, ROUGH EDGES, PIN MARKS AND GATES.
3 - OPTIMUM DENSITY AND MICRO STRUCTURE UNIFORMITY IN ALL PLANES PERPENDICULAR TO AXIS IS IMPERATIVE FOR END USE.
4 - FINISH ALL OVER 63/ .
5 - ALL EXTERNAL SURFACES OF PART SHALL BE WITHIN .002 TIR WHEN ROTATED ABOUT AXIS AS DETERMINED BY CONCENTRIC GAGE DIAMETERS A & B.
6 - WALL THICKNESS VARIATION IN ANY PLANE PERPENDICULAR TO AXIS BETWEEN GAGE DIA A & B SHALL NOT EXCEED ± .0005.

Figure 99 - TRUMPET LINER

TABLE IX

TEST SERIES "A" RESULTS

SUB SERIES	VARIATIONS FROM STANDARD	AVERAGE PENETRATION (INCHES) MILD STEEL	CHANGE FROM STANDARD (INCHES)	NO. OF UNITS TESTED
CONVENTIONAL 42° LINER				
1	STANDARD ROUND*	10.46	---	3
2	WAVE SHAPER-LOCATION 1	8.69	- 1.77	3
3	WAVE SHAPER-LOCATION 2	8.79	- 1.67	3
4	130 GRAM EXPLOSIVE LOAD	9.71	- .75	3
5	310 GRAM EXPLOSIVE LOAD	10.31	- .15	3
6	.090 INCH THICK LINERS	7.90	- 2.56	3
7	.120 INCH THICK LINERS	9.21	- 1.25	3
8	2 INCH STANDOFF	8.73	- 1.73	3
9	5 INCH STANDOFF	8.79	- .67	3
10	MACHINED LINER	10.67	+ .21	3
11	WITH NOSE STRUCTURE	8.83	- 1.63	3
12	WITH EXTENDED NOSE STRUCTURE	9.04	- 1.02	3
13	R_C45 ARMOR	6.9	- 3.56	3
TRUMPET LINER				
1	STANDARD ROUND**	9.96	---	3
2	25% GREATER EXPLOSIVE LOAD	10.29	+ .33	3
3	50% GREATER EXPLOSIVE LOAD	12.33	+ 2.36	3
4	2.0 INCH STANDOFF	9.69	- .27	3
5	5.0 INCH STANDOFF	9.15	- .81	3
6	WITH NOSE STRUCTURE	8.75	- 1.21	3
7	WITH EXTENDED NOSE STRUCTURE	7.83	- 2.13	3
8	R_C45 ARMOR	5.4	- 4.56	6

* 220 GRAMS COMP. B, 0.050 INCH THICK STEEL WALL, 3.5 INCH STANDOFF, LINER OF 0.060 INCH THICK POWDERED METAL PROCESS MATERIAL NO NOSE CONFINEMENT.

** 167 GRAMS COMP. B, ALL OTHER ITEMS SAME AS CONVENTIONAL ITEM EXCEPT SHAPE OF LINER.

(a) The conventional cavity liner generally provided deeper penetrations than the trumpet liner, although with some explosive loads this is not true.

(b) The addition of wave shapers at the location tested degrades penetration performance.

(c) Penetration increases as the amount of the explosive load increases (within the limits of 167 grams and 310 grams).

(d) Penetration decreases with wall thickness in excess of 0.06 inch (although a sufficient range of variations to develop the relationship were not tried).

(e) A standoff of 3.5 inches is probably near optimum for this shaped charge configuration.

(f) Performances of machined liners and powdered metal liners were essentially the same.

(g) The nose structure confinement used in these tests degraded penetration capability. Data obtained on the extended nose structure were inconclusive.

(h) The degradation that occurred when fired into hard targets was significant.

On the basis of conclusion (a) above, developmental consideration was focused on the conventional 42° liner configuration. The other conclusions indicated the necessity for further effort - particularly in the areas of explosive load body confinement, and nose confinement structure - in order to establish the optimum design configuration. Consequently, a basic shaped charge design was established and tested under conditions enabling controlled changes of the component structure relating to these areas. The significant characteristics of the basic design were:

- 150 to 155 grams of Comp B
- 0. 050-inch thick body confinement
- 3. 5-inch standoff
- 0. 050-inch liner wall thickness
- Powdered metal liner (42°)
- No nose confinement

This design was tested first to establish a base line of performance with which the results achieved through parametric variation might be compared (the initiation explosives were the same as those used for the previous tests). Then modified units were test fired and the results, as shown in Table X, were evaluated. It was concluded that (a) none of the configurations provided the penetration desired; (b) machined liners and powdered metal liners were essentially equal in performance; (c) drawn 0. 040-inch liners do not give as much penetration as powdered metal liners with 0. 050-inch thick walls; (d) the use of a tetryl lead between the #6 blasting cap and the main charge does not improve penetration; (e) a smaller (0. 25 inch thick as

TABLE X

TEST SERIES "B" RESULTS

SUB SERIES	VARIATIONS FROM STANDARD	AVERAGE PENETRATION (INCHES)	CHANGE FROM STANDARD (INCHES)	NO. OF UNITS TESTED
1	STANDARD*	6.50	---	3
2	R_C30 TARGET HARDNESS	7.63	+ 1.63	3
3	MILD STEEL TARGET	8.75	+ 2.25	3
4	MACHINED LINERS	6.75	+ .25	3
5	#6 BLASTING CAP & TETRYL LEAD INITIATION	6.35	- .15	3
6	.250 INCH THICK BOOSTER	5.83	- .67	3
7	NOSE CONFINEMENT & PROPOSED NOSE ELEMENT	3.29	- 3.21	3
8	OCTOL (75/25) EXPLOSIVE	7.38	+ .88	3
9	LINERS SINTERED IN CRACKED GAS ATOMOSPHERE	6.88	+ .38	3
10	.060 INCH WALL THICKNESS	5.75	- .75	3
11	DRAWN LINERS - .040 WALL THICKNESS	5.56	- .94	3

* 150 ± 5 GRAMS COMP. B, 0.050 INCH THICK STEEL WALL, 3.5 INCH STANDOFF, 0.050 INCH LINER WALL THICKNESS, POWDERED METAL LINER (42°), NO NOSE CONFINEMENT.

compared to the previously used 0.4-inch size unit) booster reduces penetration capability; (f) the proposed nose element decidedly degrades penetration capability; (g) use of 75/25 Octol substantially (13%) increases penetration over Comp B; (h) employing liners sintered in a cracked gas atmosphere does not affect penetration capability.

Generally, the most critical problem revealed in this test series was the effect of the nose structure/sensing element on penetration. Consequently, another test series was scheduled to enable detailed evaluation of this effect. In the first tests, the nose structure was used without the sensing element and the shaped charge design was identical to the basic configuration tested in the prior series except that 75/25 Octol replaced Comp B. The results of this testing are shown in Table XI.

The results of these tests* indicated that a 5/8-inch bore nose structure will not appreciably degrade penetration performance. Further, an extended space clear of structure in front of the liner was determined to be unnecessary. The test series was then extended to encompass the impact sensing element (two versions being included) with tapered and straight bore nose structures. A concomitant objective for this testing was to evaluate the effects of varying the liner and increasing the explosive load on penetration. Because of some difficulty in obtaining consistently good loads with 75/25 Octol, Comp B was used as the explosive. The basic configuration for these tests included:

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* These findings were further validated through analysis of nose section hardware of units tested at NWL, Dahlgren, Virginia for dynamic penetration.

TABLE XI

TEST SERIES "C" RESULTS

TEST	DEVIATION FROM STANDARD	AVERAGE PENETRATION (INCHES)	CHANGE FROM STANDARD (INCHES)	NO. OF UNITS TESTED
1	NO NOSE STRUCTURE, 42° CONICAL LINER	6.46	---	3
2	1/2" BORE NOSE TUBE, 42° CONICAL LINER	4.08	*	3
3	5/8" BORE NOSE TUBE, 42° CONICAL LINER	6.88	+ 0.42	3
4	1/2 EXTENDED SPACE IN FRONT OF LINER, 1/2" DIA. NOSE, 42° CONICAL LINER	4.46	**	3

* 150 + 5 GRAMS 75/25 OCTOL, 0.050 INCH THICK STEEL WALL, 3.5 INCH STANDOFF, 0.050 INCH LINER THICKNESS, POWDERED METAL LINER (42°), NO NOSE CONFINEMENT.

** DEFECTIVE EXPLOSIVE LOADS - DATA RESULTS NOT COMPLETE.

(a) Comp B Charge.

(b) CH_6 Booster 0.80-inch in diameter and 0.40-inch thick.

(c) 42° conical liner with 0.05-inch wall.

(d) Booster initiation by the base fuze explosive train and base fuze initiation by the nose element where included.

(e) 3.5-inch standoff.

The parameters varied and the test results are listed in Table XII. From these data, the following was concluded:

(a) Penetration is approximately the same for both the straight (spike) 5/8-inch nose bore and the 5/8-inch to 1/2-inch tapered nose bore.

(b) Increasing the size of the explosive head substantially increases penetration capability.

(c) Decreasing the radius of the liner apex improves penetration.

(d) The nose element decreases penetration by approximately 1 to 1.5 inches (compared to about 3.5 inches in the original design).

At this time the results of this and previous tests were reviewed to determine the most potentially productive areas for further investigation. First it was determined that Octol, wherever conditions were such as to permit direct comparisons, had demonstrated a greater penetration capability in this

TABLE XII

TEST SERIES "D" RESULTS

SUB SERIAL NO.	VARIATIONS FROM STANDARD* ROUND DEFINITION	AVERAGE PENETRATION (INCHES)	NO. OF UNITS TESTED
1	NO NOSE STRUCTURE OR CAVITY WIRE	7.71	3
2	NO NOSE STRUCTURE BUT WITH WIRE	7.375	3
3	NO IMPACT SENSING ELEMENT, BUT WITH 5/8 INCH BORE NOSE SPIKE	6.650	5
4	5/8 INCH TO 1/2 INCH TAPERED NOSE SPIKE, NO IMPACT SENSING ELEMENT	7.250	5
5	ORIGINAL (LARGE MASS) IMPACT SENSING ELEMENT**	4.67	3
6	REDESIGNED (REDUCED MASS) IMPACT SENSING ELEMENT**	4.00	3
7	LIKE (5) BUT WITH ALUMINUM SPIT BACK TUBE IN THE LINER APEX**	4.79	3
8	LIKE (6) BUT WITH ALUMINUM SPIT BACK TUBE IN THE LINER APEX**	5.79	3
9	LIKE (6) BUT WITH 42° CONICAL LINER CONTAINING A .070 INSIDE RADIUS LINER APEX**	5.33	3
10	1 INCH ADDED EXPLOSIVE HEAD, 4-1/2 INCH STANDOFF REDESIGN NOSE ELEMENT**	6.06	2
11	LIKE (10) WITH .11 RADIUS APEX LINER**	6.92	3
12	SAME AS (2) BUT .040 INCH LINER WALL**	7.83	3
13	SAME AS (1) BUT .030 INCH LINER WALL**	6.60	5

* COMP. B CHARGE, CH_6 BOOSTER (0.80 INCH DIAMETER AND 0.40 INCH THICK), 0.05 INCH LINER WALL (42°), 3.5 INCH STANDOFF.

** 5/8" STRAIGHT BORE NOSE SPIKE.

particular application than Comp B. It was also evident that further increasing the size of the explosive head might well provide the penetration capability desired. Consequently, a series of tests using Octol and varying the size of the explosive head was scheduled. As a preliminary to this testing, however, it was decided to first determine the effect of varying body confinement, a parameter not as yet investigated in detail.

Nine test units were assembled, three each having a wall thickness of 0. 050, 0. 100, and 0. 150 inch. The outside diameter was maintained at the previously established 2. 10 inches; therefore, each increase in wall thickness was accompanied by a related decrease in body explosive. The units were fired into mild steel with the following results:

Wall thickness (inch)	Average Penetration (inches)
0. 050	11. 29
0. 100	10. 38
0. 150	9. 04

These data indicated that the 0. 050-inch body wall thickness gave the best penetration and fragmentation (this latter is discussed in the following section of the report under anti-personnel lethality). Consequently, 0. 050 inch was specified as the standard body thickness.

The test series on increasing the size of the explosive head using Octol was then conducted. Trumpet shaped and double angle liners were included in the test units since no previous performance data had been obtained on Octol in these configurations. In addition, the liner wall thickness and, in some cases, the standoff, were to be varied to determine the influence of these parameters on penetration. To obtain the flexibility necessary to vary the parameters within the limits required for investigation purposes, the liners were machined from 99% purity, electrolytic tough pitch copper in the dead soft condition (ASTM B133). The basic configuration for this test series consisted of:

(a) 75/25 Octol.

(b) CH_6 Booster (0.800 inch OD x 0.400 inch thick).

(c) 5/8 to 1/2inch tapered nose spike.

(d) Base fuze explosive train initiation.

(e) 5.5 inch standoff.

(f) Nose element used to initiate base fuze where applicable.

The results of this testing are shown in Table XIII which also lists the variations in primary parameters for each sub-series. The performance of the various design configurations in this test led to the following conclusions:

(a) The desired penetration of 8.5 inches in R_c 45 steel is achievable by increasing the size of the explosive head.

(b) There appears to be limits beyond which increasing the explosive head will not yield increased penetration.

(c) When compared to the 42° conventional liner on the basis of penetration capability, the trumpet liner is manifestly inferior while the double angle liner is slightly superior.*

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* Not, however, sufficiently superior to justify the additional expense entailed in use of this liner.

TABLE XIII

TEST SERIES "E" RESULTS

SUB-SERIES NUMBER	LINER DETAILS	OTHER DESCRIPTIVE DETAILS*	AVERAGE PENETRATION (R_C 45 ARMOR)	NO. OF UNITS TESTED
1	42° CONICAL .045 WALL	.95" ADDED EXPLOSIVE HEAD AND STANDOFF	7.95	5
2	42° CONICAL .040 WALL	.95" ADDED EXPLOSIVE HEAD AND STANDOFF	8.58	5
3	42° CONICAL .040 WALL	.95" ADDED EXPLOSIVE HEAD AND STANDOFF	5.56	5
4	TRUMPET .045-.065 WALL	.95" ADDED EXPLOSIVE HEAD AND STANDOFF	6.37	3
5	TRUMPET .035-.055 WALL	.95" ADDED EXPLOSIVE HEAD AND STANDOFF	6.58	4
6	25° TO 61° DOUBLE ANGLE .035 TO .055 WALL	.95" ADDED EXPLOSIVE HEAD AND STANDOFF	8.75	5
7	42° CONICAL .040 WALL	.43" ADDED EXPLOSIVE HEAD AND STANDOFF	8.33	3
8	42° CONIC 040 WALL	STANDARD UNIT**	4.46	5
9	42° CONICAL 0 WALL	.95" ADDED EXPLOSIVE HEAD AND STANDOFF, NO IMPACT SENSING ELEMENT	8.19	5
10	42° CONICAL .040 WALL	.43" ADDED EXPLOSIVE HEAD AND STANDOFF, NO IMPACT SENSING ELEMENT	8.59	5
11	42° CONICAL .040 WALL	TOROIDAL IMPACT SENSING ELEMENT	7.95	2

* NOSE ELEMENT EXCEPT WHERE NOTED.

** 75/25 OCTOL CHARGE, CH_6 BOOSTER (0.80 INCH OD X 0.40 INCH THICK), 5/8 TO 1/2 INCH TAPERED NOSE SPIKE, BASE FUZE EXPLOSIVE TRAIN INITIATION, 5.5 INCH STANDOFF.

(d) The toroidal impact sensing element gave significantly better penetration than the standard element (compare results Sub series 11, this test, and the results of test series D, Table XII). However, with the added explosive head the standard impact sensing element had little or no effect on penetration (compare sub-series 2 with 9 and 7 with 10).

On the basis of the results of Test Series E, it had been planned to lengthen the explosive head by 0.43 inch and to reduce the number of rows of bomblets in the dispenser from twelve to eleven. But with these modifications, the maximum load of bomblets could be accommodated only if one inch was left off the tail sections of the bomblets in the last row. Since this would result in non-identical parts that would require selective assembly, it was decided to reduce the 0.43-inch dimension to 0.345 inch, thus distributing the one-inch difference over the eleven rows of bomblets.

As of this time sufficient emperical data had been established to enable definition of a Rockeye II shaped charge capable of penetrating 8.5 inches of R_c45 armor. However, this capability had not been demonstrated with liners fabricated using powder metallurgy. Consequently, a test series was scheduled on parts containing powder metallurgy liners and production run metal parts.

Twenty-five test units incorporating these modifications were assembled for evaluation. Ten of the bomblets were tested for penetration at Honeywell, and were fired at NWL Dahlgren, to determine impact element obliquity sensitivity and dynamic penetration. The Dahlgren tests gave an average penetration of 8.42 inches, and the results of the units tested at Honeywell showed an average penetration of 8.26 inches (penetration for each shot is shown in Table XIV).

TABLE XIX

DAHLGREN TEST SERIES RESULTS

UNIT NO.	PENETRATION (R_C 45 ARMOR)
1	*
2	7.5
3	8.0
4	8.5
5	8.3
6	8.0
7	8.6
8	8.5
9	8.4
10	8.5
AVG.	8.26

* TEST INITIATION FAILURE

On the basis of these results, it was concluded that the design at this time substantially met the penetration requirement, and had been optimized in terms of producibility and cargo packing efficiency. This configuration was used in Phase II and Phase III. The following principal design modifications were made in the transition from the original approach to its final configurations:

(a) Nose structure changed to include a tapered bore 1/2 inch to 5/8 inch.

(b) Body increased 0.345 inch in length to accommodate larger explosive head.

(c) Booster thickness increased from 0.25 to 0.40 inch.

(d) Explosive changed from Comp B to Octol 75/25.

(e) Body wall thickness stabilized at 0.050 inch.

(f) Liners wall thickness stabilized at .040 inch.

(b) Evaluation of Design - Upon establishment of a shaped charge design compatible with program objectives, 120 powdered metal liners were submitted to the Naval Ordnance Test Station, China Lake, for evaluation using the flash X-ray technique.* The jets in these units broke up in an average time of 67.6 inches/microsecond and had an average tip velocity of 8500 meters/second. Penetration tests at NOTS on identical liners gave an average penetration of 8.25 inches in R_C45 armor.

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* Flash X-ray enables evaluation of shaped charge effectiveness as a function of jet breakup time and velocity. The jet is X-rayed at discrete time intervals after initiation.

Subsequent Phase II units evaluated at NOTS demonstrated a marked reduction in penetration capability. The average penetration for Phase II assemblies was 6.8 inches, while NOL tests on Phase II hardware showed an average penetration of 6.62 inches. The performance degradation was confirmed by tests at Honeywell during which the penetration achieved averaged 6.45 inches. In addition, the flash X-ray analyses at NOTS, of these later units showed that the average breakup time had dropped to 50.7 inches/microsecond.

Examination of the X-rays revealed that the jets were badly disrupted. The jet particles were irregular and rounded rather than elongated and needle shaped. Particle distribution in the jet was poor, some areas being characterized by a spray of minute pieces instead of well formed and distinct particles.

On the basis of an evaluation of the test data, it was concluded that the liner was the major factor in the decreased penetration. Consequently, an investigative program was initiated to determine the changes introduced in the liner during fabrication to cause the degradation in performance. Three changes made subsequent to the achievement of satisfactory penetration were to be studied to determine their effect on liner performance. These changes were:

(a) Change in source of copper powder.

Originally the powder had been procured from Metal Disintegrating Company (Type MD 151) but later was obtained from American Metals Climax, Inc. (Type Special B). The two powders gave identical results when inspected according to the requirements for sieve analysis, flow rate, and apparent density.

(b) Change in sintering processor.

While the quantities of units being fabricated remained small, it was possible to sinter the liners in the Honeywell Metallurgical Laboratory. However, it was necessary to engage a vendor, Flame Industries, when the quantity required exceeded the laboratory capability. The sintering process used by Honeywell was specified for Flame Industries.

(c) Change in briquette tooling.

The briquette tooling had been changed to compensate for the shrinkage rate of the briquette after tooling. Shrinkage had caused a problem in the final coining operation.

Prototype liners representing all of the possible combinations encompassed by three changes were fabricated for testing (fabrications parameters for each type of liner are listed in Table XV. Twenty-five units of each type were produced with the following manufacturing conditions applicable to all types:

Briquette Pressure

25 ± 1 psig air pressure indicated on impact press.

Sintering

1750° ± 20° F for one hour ± 5 minutes in a dry hydrogen (-60° min. dew point) atmosphere.

Coining pressure

35 ± 1 psig indicated on impact press

TABLE XV
LINER PARAMETRIC TEST PROGRAM PLAN

TEST SERIES	POWDER		TOOLING		SINTERING	
	MD151	AMAX-B	ORIGINAL	MODIFIED	HONEYWELL	FLAME
1	X		X		X	
2	X			X	X	
3	X			X		X
4		X	X			X
5		X		X		X
6		X		X	X	
7	X		X			X
8		X	X		X	
9	X		X		X	
10	X		X		X	

Each series of liners was to be evaluated for physical characteristics and penetration capability. A minimum of three liners would be assembled into bomblets and sent to NOTS for explosive loading and flash x-ray analysis. Additional liners would be used for penetration testing at Honeywell.

The physical properties to be determined were:

- Density of the flange and of the lower, middle, and upper regions of the cone, both after briquetting and after coining.
- The microstructure after briquetting and coining at 100x magnification.
- Tensile strength and percent elongation after coining operation.

During fabrication, excessive shrinkage was encountered on Series 1, 4, 7, and 8, and these liners could not be coined to the required dimensions. In all of these cases the flange cracked or came off the conical portion of the liner. Consequently these liners, which were all made using the original briquette tools, could not be evaluated. Two additional liner series were then added to the evaluation program to enable including the effect of the original tooling. Changing the briquetting pressure for these series (referred to as 9 and 10 in the table) from 25 psig to 35 psig permitted the use of the original briquette tooling and reduced the shrinkage in sinter to permit the liner to be coined to the proper dimensions. Fifty-two grams of copper powder were used in the Series 9 liners and 50 grams were used in Series 10 units. The change was made to reduce liner wall thickness (0.044 inch) of Series 9 units to 0.041 inch for Series 10 liners, this latter value being closer to the nominal specified thickness.

The physical properties determined for the liners are listed in Table XVI. Three units from each of Series 3, 5, 9 and 10 and four units from Series 2 and 6 were sent to NOTS for Flash X-ray testing, and the results of these tests are shown in Table XVII. Upon evaluation of these data, the following conclusions were made:

a) The sintering process is quite critical and sintering variations may have contributed to the degraded performance in Phase II type liners.

b) Series 2 units gave the best performance based on flash X-ray followed by series 10, 6, 5, and 13. However data on Series 10 is only for a single unit.

c) None of the liners tested exhibited the badly disrupted jet of Phase II hardware.

d) The physical properties determined did not show any specific variation that could be correlated with the results of the flash X-ray analysis.

The problem that occurred in Phase II may have been present to varying degrees in earlier experimental hardware, and contributed to the sometimes erratic warhead performance.

Concurrently with flash X-ray testing, three bomblet assemblies using liners from Series 2 were fired into R_c45 target blocks to determine penetration capability. The description of the test bomblets is as follows:

TABLE XVI

LINER PARAMETRIC TEST PROGRAM PHYSICAL PROPERTIES

SERIES & LINER	TENSILE STRENGTH AVERAGE PSI	ELONGATION % AVERAGE	SERIES & LINER	DENSITY			HARDNESS (AVERAGE) ROCKWELL F SCALE		
				LOWER	MIDDLE	UPPER	LOWER	MIDDLE	UPPER
2-49	37,800	10.5	2-29	96.3	96.9	94.8	77.3	79.1	75.6
2-40	37,250	9.5	2-50	98.0	97.5	98.2	82.3	83.2	79.4
2-47	39,450	11.0	2-28	97.0	97.2	96.4	77.7	78.6	75.8
2-35	35,400	11.0	2-31	97.6	98.4	98.5	80.5	80.8	82.4
3-70	34,315	12.5	3-64	97.2	98.3	97.3	76.8	77.6	75.2
3-53	41,300	11.5	3-57	99.3	97.3	97.6	78.0	78.4	75.5
			3-68	96.4	97.0	97.4	75.8	76.3	79.5
5-116	34,110	24.5	5-101	97.3	98.7	98.9	76.6	79.5	83.9
5-105	37,450	10.5	5-107	97.0	97.2	98.0	74.1	75.5	76.6
5-111	36.600	11.0	5-125	97.5	98.0	98.0	79.2	78.2	76.2
5-112	32,850	19.0							
6-136	37,200	10.0	6-128	96.7	97.2	97.0	78.5	80.5	77.5
6-142	38,400	10.0	6-141	95.5	96.5	96.0	76.8	77.9	79.5
6-139	35,700	4.0	6-150	96.1	97.4	97.1	75.5	77.6	77.9
6-145	35,400	15.0							
9-201	34,295	22.0	9-208	96.1	96.7	98.2	78.0	73.7	77.3
10-226	37,940	18.0	10-225	96.9	95.3	96.1	77.7	73.3	73.6

TABLE XVII

LINER PARAMETRIC TEST PROGRAM FLASH X-RAY ANALYSIS

SERIES NUMBER	TIP VELOCITY		BREAKUP TIME	
	AVERAGE	RANGE	AVERAGE	RANGE
2	8220 M/SEC	7660 TO 8930	70.8 μSEC	67.9 TO 77.2
3	8500 M/SEC	8100 TO 8800	55.8 μSEC	49.8 TO 61.2
5	8820 M/SEC	8830 TO 8860	58.2 μSEC	56.4 TO 60.0
6	8670 M/SEC	8100 TO 8800	64.9 μSEC	60.1 TO 68.1
9	NO DATA	NO DATA	NO DATA	NO DATA
10	8130 M/SEC*	----	69.4 μSEC*	----

* DATA OBTAINED ONLY ON ONE UNIT

a) The units were initiated with a #6 blasting cap.

b) The units were tested without the impact sensing element but did have the ferrule of the impact sensing element for proper standoff.

c) No sealant was used in the explosive cavity.

d) The standard booster with the foil wrap removed from the sides and bottom was used.

The three bomblets gave penetrations of 7.0, 7.25, and 8.5 + (went through target block) inches for an average penetration of 7.58 inches. The disparity in penetration was presumed to have resulted from some inconsistency in the shaped charge rather than any marginal performance of the blasting cap. This was confirmed by the shape of the hole -- now symmetrical with a typical ricochet ledge-- for units with reduced penetration.

Additional penetration testing was performed on liners from some of the other series after the flash X-ray testing had been completed. Three units were tested from Series 6, one from Series 3, and one from Series 5. The number of units tested was limited by the availability of test blocks. The units, which did not incorporate impact sensing elements, were initiated with a #6 blasting cap. With these exceptions the assemblies were made as prescribed by the drawings. The results of the test are shown in Table XVIII.

In view of the results of the flash X-ray and penetration testing of this liner series, it was decided that all liners in Phase III which would be used in shaped charge performance testing would be manufactured identically with the process and conditions used for Series 2 liners. Approximately 1000 liners were manufactured to fulfill this requirement. A sample of forty liners was selected during the course of the build and checked for physical properties. Liners were checked in both the after-sintering and after-coining conditions with results as listed in Table XIX.

TABLE XVIII

LINER PARAMETRIC TEST PROGRAM - PENETRATION TESTING

LINER SERIES	PENETRATION (R_C 45 ARMOR)
3	8.44
5	7.38
6	8.25 8.56+* 7.13
AVG.	7.95

* SHAPED CHARGE JET PASSED THROUGH TEST BLOCK.

TABLE XIX

PENETRATION LINER BUILD PHYSICAL PROPERTIES SUMMARY

PROPERTY	CONDITION	AVERAGE	RANGE
DENSITY %			
FLANGE	SINTERED	86.5	78.9 - 91.0
	COINED	93.9	91.2 - 97.1
LOWER	SINTERED	85.5	72.0 - 91.0
	COINED	97.3	95.6 - 98.2
MIDDLE	SINTERED	87.0	84.0 - 89.7
	COINED	96.8	95.1 - 97.7
UPPER	SINTERED	87.2	83.0 - 90.5
	COINED	97.3	95.0 - 99.5
HARDNESS (F SCALE)			
LOWER	COINED	81.0	72.2 - 86.0
MIDDLE	COINED	80.5	72.8 - 87.0
UPPER	COINED	81.1	70.4 - 86.0
TENSILE STRENGTH	SINTERED	16,050	11,300 TO 19,800
	COINED	38,300	35,500 TO 41,300
% ELONGATION	SINTERED	10.4	6 TO 16
	COINED	8.3	5 TO 14

Three liners were selected from those manufactured, and assembled into bomblets for penetration testing. The units were initiated with a #6 blasting cap and were without the impact sensing elements. The penetration of the three bomblets in inches was 6.19, 7.88, and 8.56 + (completely through the target block) for an average of 7.54 inches. This compares with the average penetration of 7.58 inches previously obtained during Series 2 test. Examination of the liner data, explosive load X-rays, and bomblet assembly inspection data gave no indication why the range of values of penetration were encountered.

(2) Anti-Personnel Capability

While the armor defeating capability of the Rockeye II bomblet was a cardinal consideration in the design of the kill mechanism, it was specified that anti-personnel effectiveness would be a major development objective. The original approach as reflected in the proposal document was to utilize fragmentation from the body case against personnel, scoring the case interior to ensure uniformly effective fragments. During the shaped charge development, fragmentation tests were conducted to determine the desirability of this approach.

Both scored (1/4 inch square pattern) and unscored units were tested in the evaluation. The two types of units were identical in every respect (except for the scoring), consisting of a 0.049-inch thick cold drawn steel case; a 0.06-inch thick, 42° conical liner; and a high explosive load of Comp B. All of the test assemblies were initiated with a #6 blasting cap.

The fragmentation achieved with the scored and unscored bodies is shown in Figures 100 through 103. About 60% of these fragments passed through a 1/8-inch diameter sieve, and the remaining 40% passed through a 1/4-inch sieve. The scored case units did, as anticipated, rupture primarily along the pattern lines, about 80% of the fragment being complete 1/4 squares of the casing material. Fifteen percent of the recovered fragments were in the form of small squares or broken parts of the full size squares.

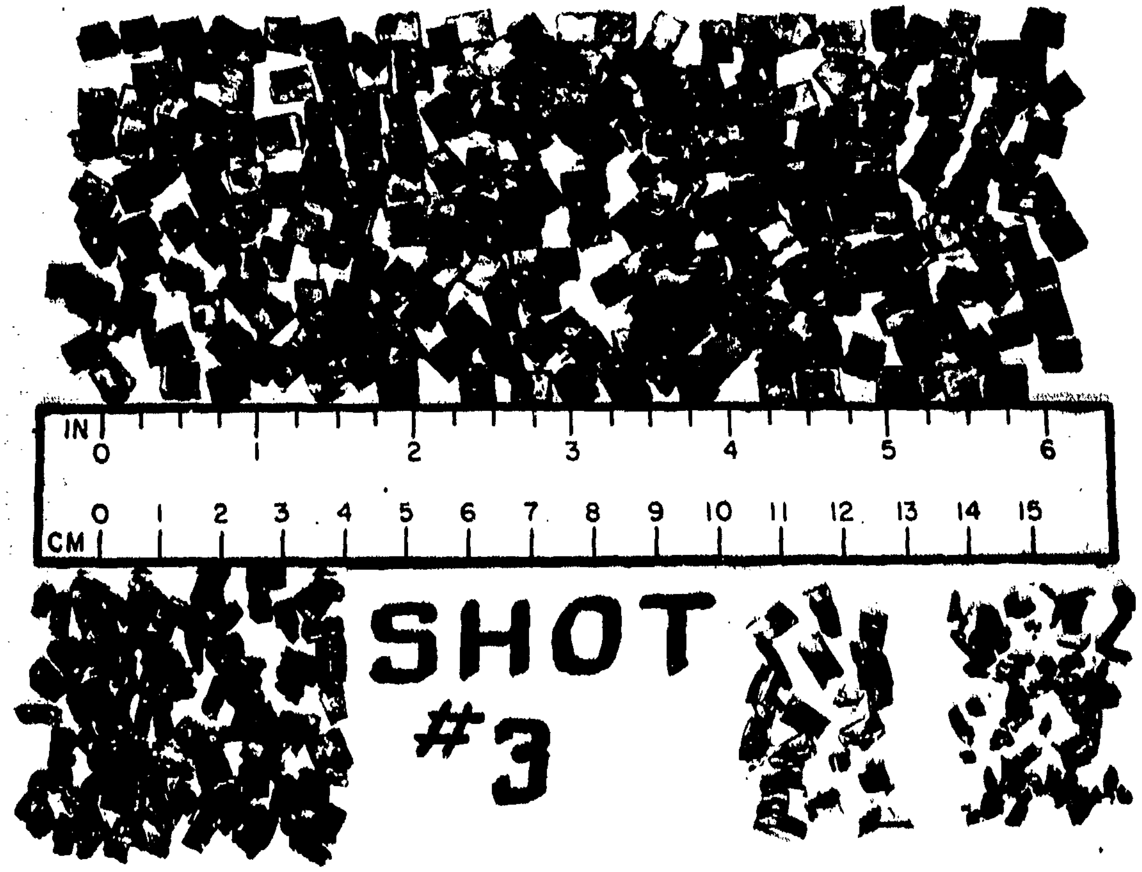


Figure 100 – FRAGMENTATION PHOTO, SHOT #3, SCORED BODY CASE

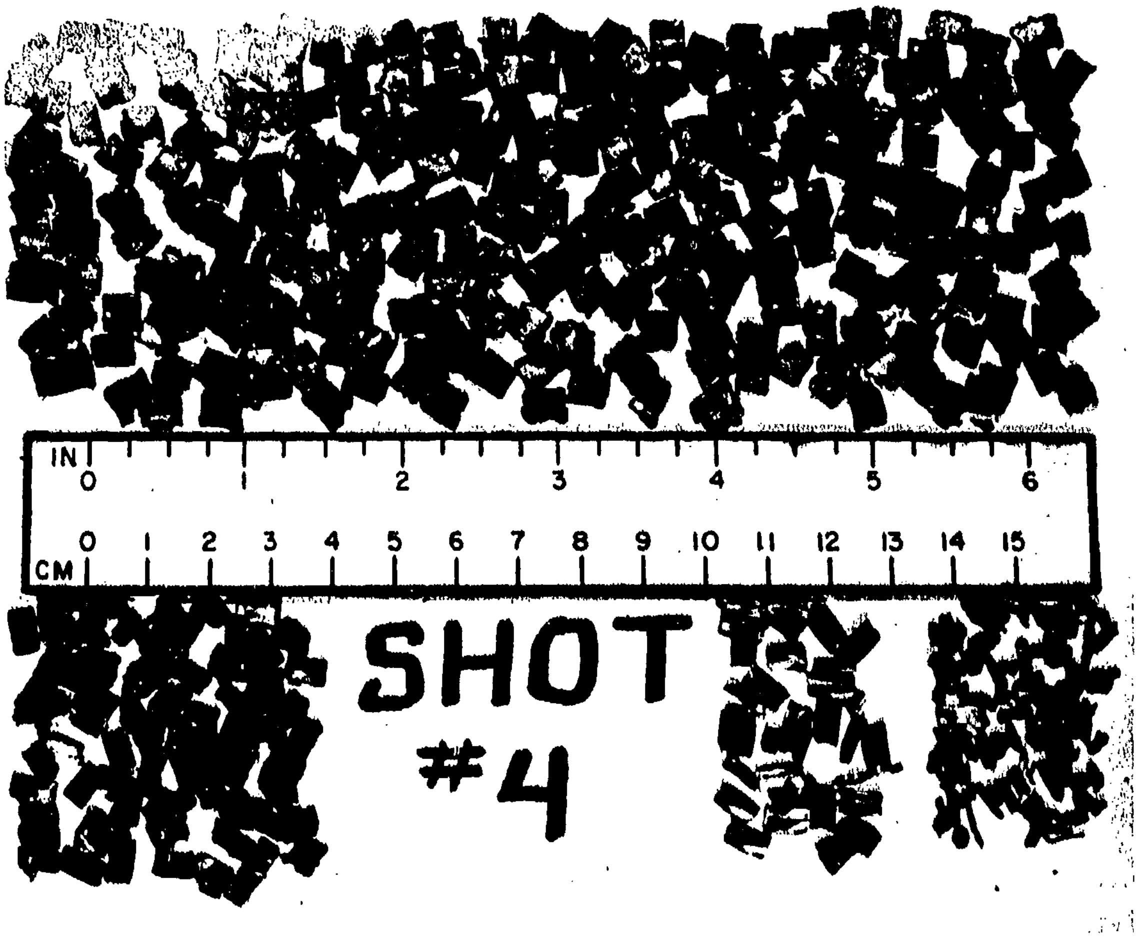


Figure 101 - FRAGMENTATION PHOTO, SHOT #4, SCORED BODY CASE

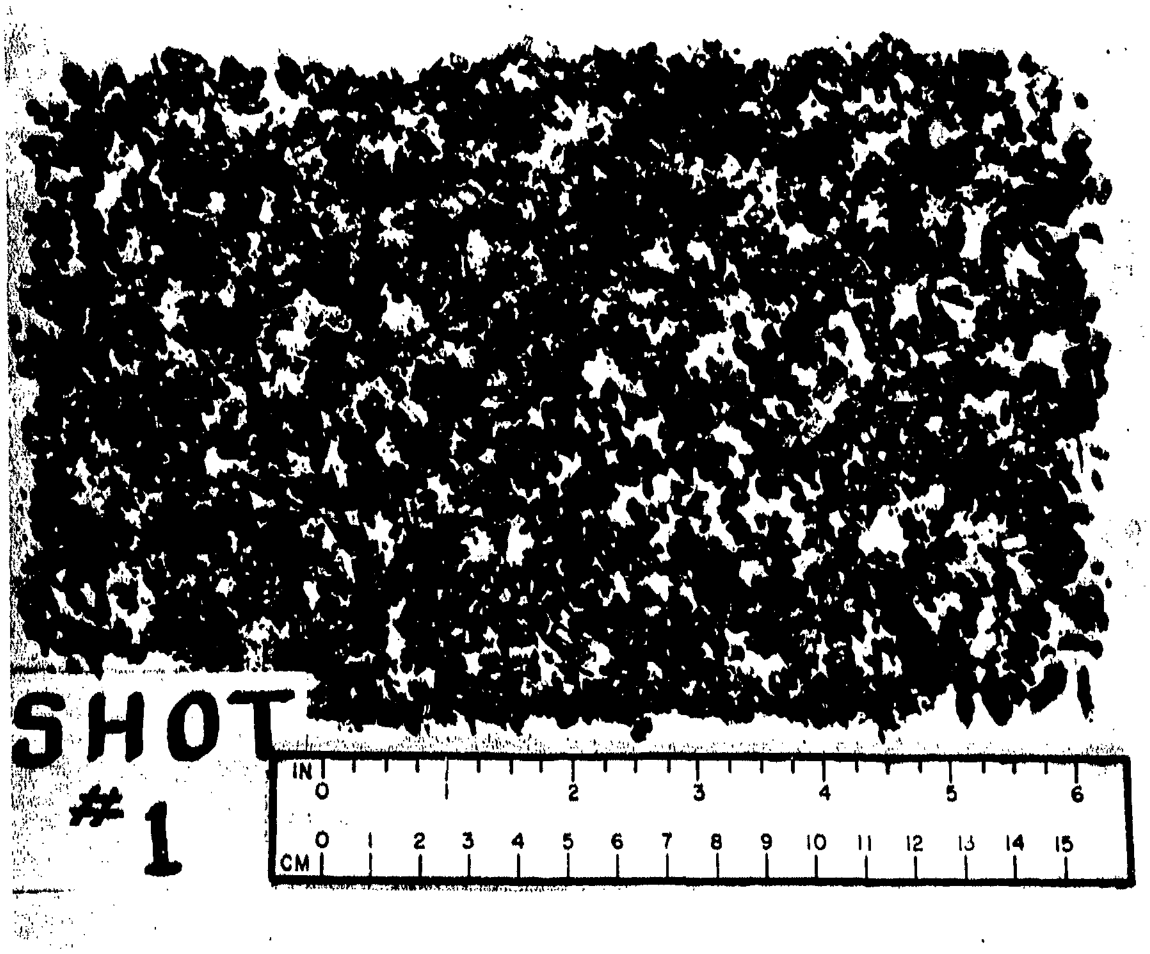


Figure 102 - FRAGMENTATION PHOTO, SHOT #1, UNSCORED BODY CASE

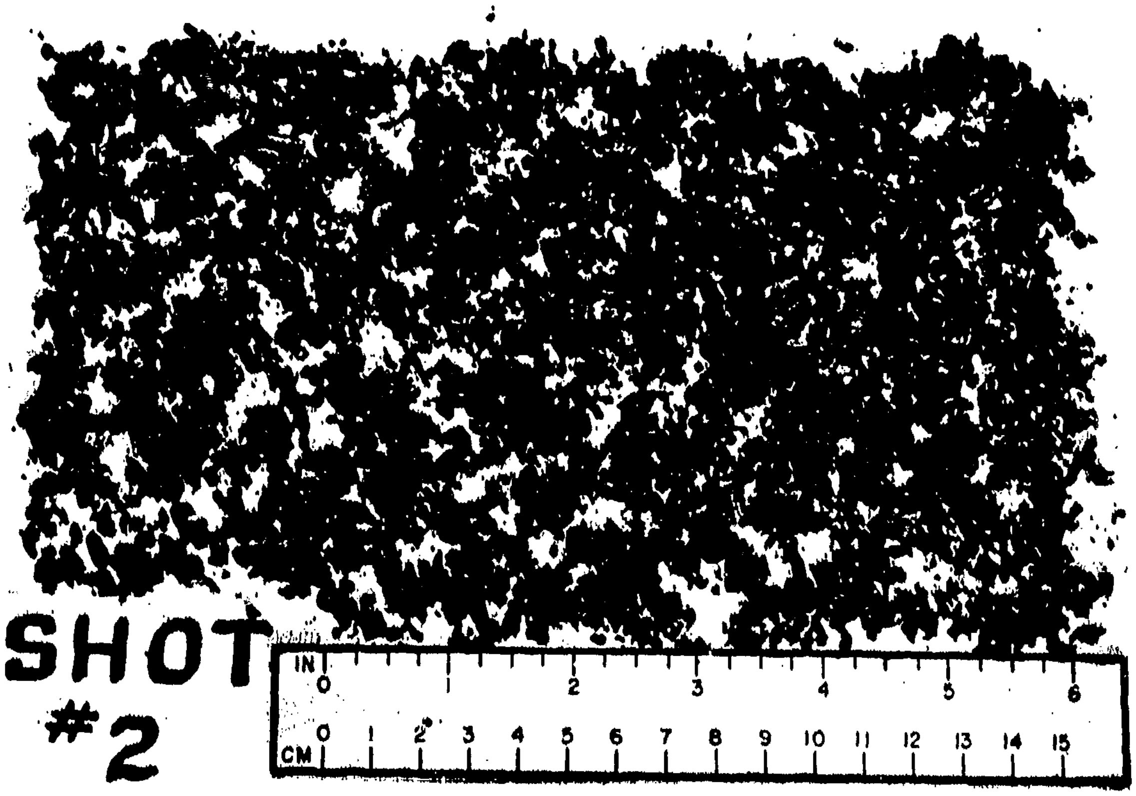


Figure 103 - FRAGMENTATION PHOTO, SHOT #2,
UNSCORED BODY CASE

Upon evaluation of the test results, it was concluded that the fragments obtained from the unscored units were more desirable because their asymmetrical mass would inflict greater body damage. An additional factor favoring the smaller size fragments was the potential hazard to aircraft which could be caused by the 1/4-inch squares should a bomblet be prematurely initiated as a result of inter-munition collision at dispenser event. Consequently, the unscored body was specified as the standard configuration.

During shaped charge testing to determine optimum body wall thickness for confinement, as described in the preceding sub-section of the report, fragmentation as a function of wall thickness was an additional parameter to be evaluated. It was determined that as wall size increased, fragmentation size also increased. Fragments from 0. 15-inch thick bodies averaged 0. 20 x 0. 50 inch, while those from 0. 05 inch bodies averaged 0. 125 inch. The smaller fragments were considered more desirable from the standpoint of personnel lethality. There were no fragment velocity measurements in these tests. Since the 0. 05-inch thick body was also the most compatible with shaped charge performance of the three body sizes evaluated, it was specified for the bomblet design.

No other modifications were made in the kill mechanism with respect to anti-personnel lethality.

(3) Explosive Loading and Sealing

(a) Explosive Loading

Two types of explosives, Composition B and 75/25 Octol, were used during the course of the Rockeye II bomblet development program. Both explosives can be melted and cast in place. During loading with Comp. B, the explosive initially used, it was found that simply pouring the explosive into the bomblet cavity and riser resulted in large voids between the booster and liner apex. The voids resulted from shrinkage of the explosive as it hardened. The problem was resolved by use of steam probe equipment as shown in Figures 104 and 105. The probe was inserted into the riser, and the steam kept the explosive molten so that it could flow into the bomblet cavity as the explosive hardened and shrank. This method was used for all subsequent Comp. B loading operations and resulted in no faulty units.

The problem recurred when 75/25 Octol was used in the first experimental bomblets. Since molten Octol is more viscous than Comp. B, it appeared that the Octol might be trapping air. However, a group of identical bomblets poured with Comp. B also exhibited identical load defects around the flange of the liner. Investigation showed that the sealant between the liner and body expelled gas when in contact with the molten explosives and formed bubbles observed on the X-rays of the explosive load. This sealant had been changed from epoxy to RTV, SE/02, which was the difference between the units used. The loading procedure was revised to include preheating the bomblet to a temperature greater than the molten explosive. Addition of the cooler explosive then would not produce any further gassing of the sealant. This procedure in conjunction with use of the steam probe improved the problem considerably. However, as more groups of bomblets were loaded it became apparent that the procedure was producing too much variation from group to group. This was particularly evident in Octol loading operations. Since Octol had a significantly increased shaped charge performance, it was chosen as the explosive for the Rockeye II bomblet, and this necessitated an improvement in the loading procedure. An investigation showed that vibrating the units while pouring the explosive achieved considerable improvement in the load quality; consequently, an air unit was used to vibrate the bomblets at

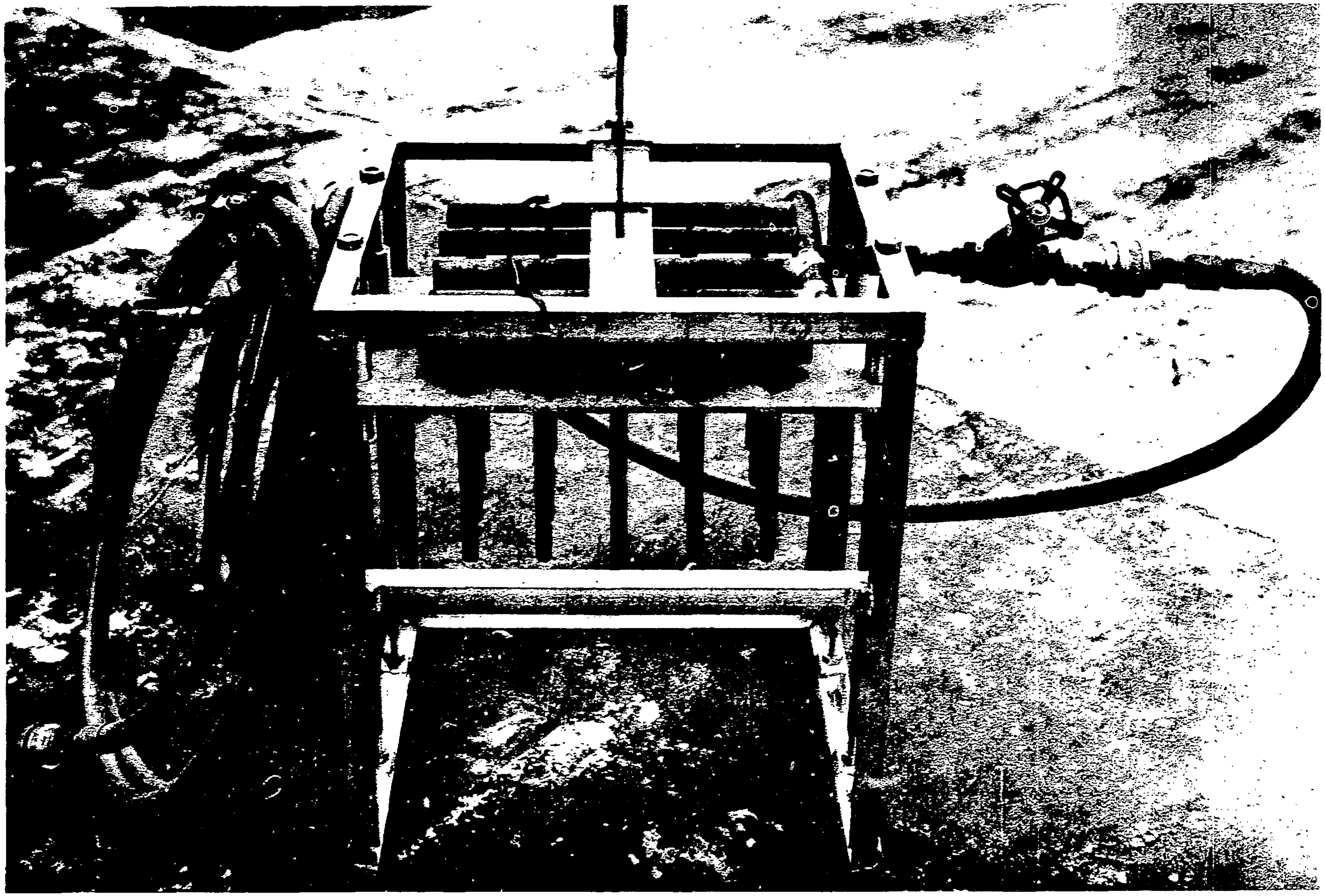


Figure 104 - STEAM PROBE USED IN POURING THE COMP B

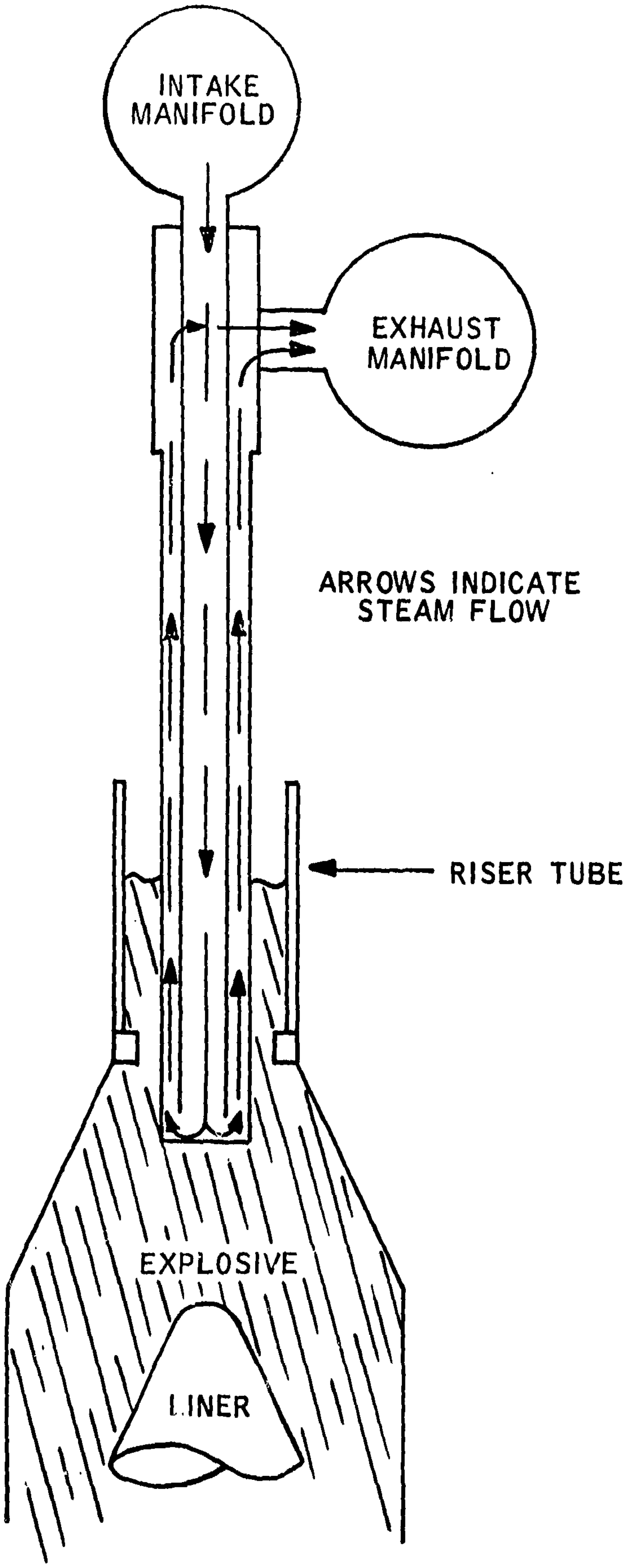


Figure 105 - STEAM MANIFOLD CONFIGURATION

approximately 200 cps for 5 minutes during the loading operation. The equipment had a capacity of twenty warheads and is shown in Figure 106. Further evaluation indicated it was not necessary to use the steam probe to get good quality loads, but it was still necessary to preheat the bomblets to 225° F before pouring. Vibration could be stopped after the 5-minute interval, even though the explosive in the riser had not solidified, without any harmful effects.

The use of X-ray analysis for acceptance of the explosive loads required that a criteria be established for bomblet acceptance or rejection. This was done by dividing the explosive cavity into three zones on the basis of criticality with respect to shaped charge performance as shown in Figure 107. Zone C is considered the most critical, and Zone A is considered the least critical. The criteria for the load defects for each zone are as follows:

Zone A: Voids and/or cracks are permissible in this area.

Zone B: Void 1/16 diameter or smaller are permissible providing center-to-center distances are greater than 1/4 inch.

Zone C: A maximum of three voids ranging from 1/16 to 1/8 inch in diameter are permissible. Small cracks and voids below 1/16 inch in diameter are permissible providing they are not closely grouped.

(b) <u>Explosive Cavity Sealing</u>

The Rockeye II Bomblet explosive cavity has the following possible leak points:

- Liner/Body Interface
- Adapter/Body Interface
- Liner/Leadwire Interface
- Electrical Connector/Adapter Interfaces
- Booster/Adapter Interface

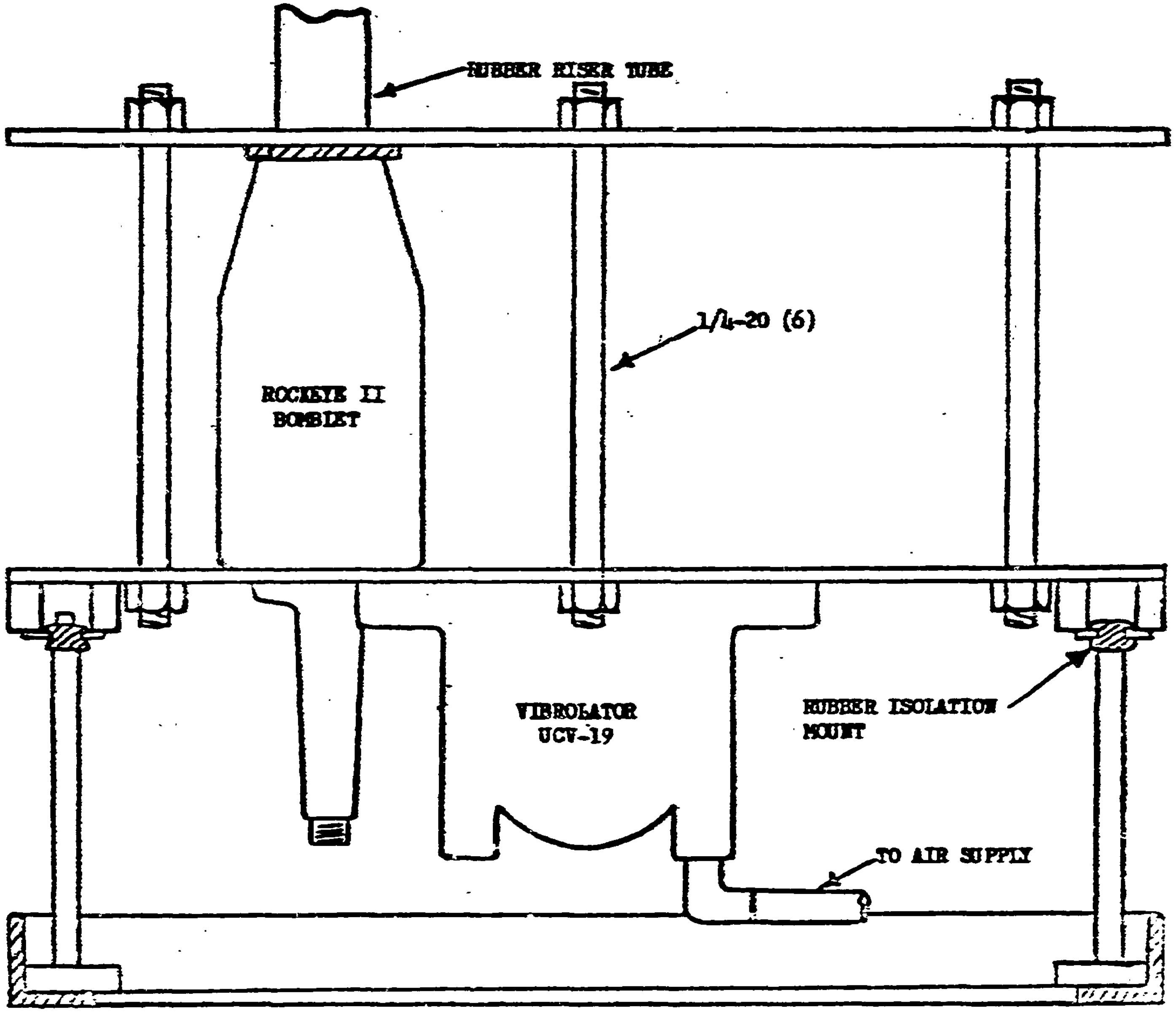
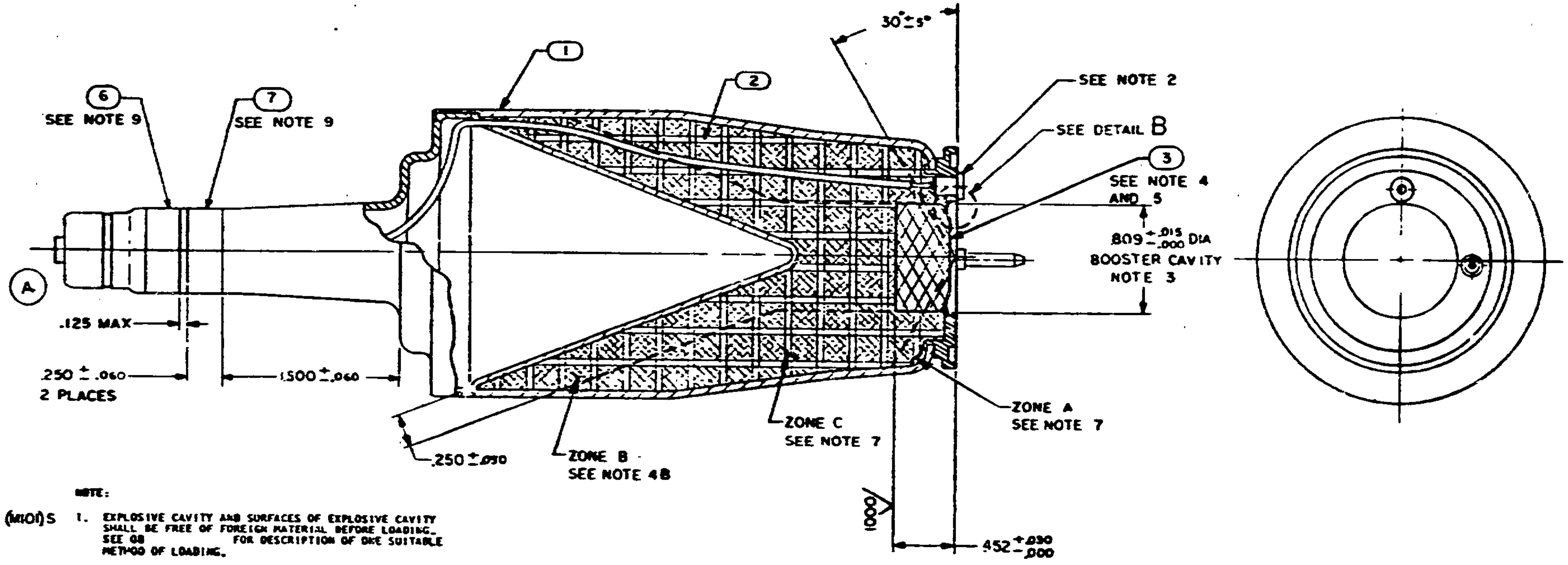


Figure 106 - EXPLOSIVE LOADING VIBRATION TEST FIXTURE



NOTE:

(M101)S 1. EXPLOSIVE CAVITY AND SURFACES OF EXPLOSIVE CAVITY SHALL BE FREE OF FOREIGN MATERIAL BEFORE LOADING. SEE OD FOR DESCRIPTION OF ONE SUITABLE METHOD OF LOADING.

(C1) 2. NO EXPLOSIVE PERMITTED, IN AREA INDICATED OR ON ANY OTHER EXTERIOR SURFACES.

3. DRAFT IN BOOSTER CAVITY PERMITTED WITHIN PRESCRIBED TOLERANCE.

4. ITEM 3 SHALL BE FREE OF FOREIGN MATERIAL AND RIPS, TEARS, HOLES OR OTHER DISCONTINUITIES.

(M102) 5. ITEM 3 SHALL BE FULLY SEATED IN 0.809 BOOSTER CAVITY.

(M103) 6. SEAL WITH ITEM 4 OR ITEM 5. SEAL FILLET SHALL BE CONTINUOUS WITHOUT VOIDS AND FLUSH OR BELOW SURFACE Z.

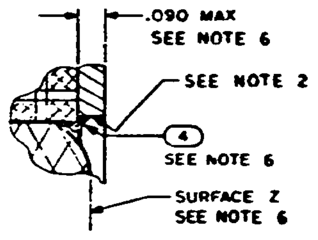
(M104) 7. ASSEMBLY SHALL MEET RADIOGRAPHIC INSPECTION REQUIREMENTS OF MS 7123.

8. SUMMARY OF ANNOTATED CLASSIFICATION OF CHARACTERISTICS ON THIS DRAWING TO BE VERIFIED IN ACCORDANCE WITH MIL-STD-105 UNLESS OTHERWISE SPECIFIED:

CRITICAL	(C1)	THRU	(C2)
MAJOR	(M101)	THRU	(M104)
MINOR	( )	THRU	( )

UNLESS OTHERWISE SPECIFIED UNLISTED CHARACTERISTICS AND CHARACTERISTICS WITH THE SUFFIX S (SPECIAL) SHALL BE VERIFIED TO THE SATISFACTION OF THE GOVERNMENT REPRESENTATIVE.

(C2) 9. APPLY COLOR CODE BANDS AT POSITION SHOWN USING ITEM 6 AND ITEM 7.



DETAIL B
SCALE 4/1

Figure 107 - BOMBLET EXPLOSIVE CAVITY

One of the objectives of the design effort was eliminating any leakage during the explosive loading operation. In the warhead design, a metal to metal seal was used at the liner/body interface, and the copper liner was compressed between the body and the nose to form this seal. In addition, the slot in the flange for the leadwire was sealed with a polyester sealant.

The booster cavity was machined, and the booster was inserted and sealed around its diameter with RTV 371. This design did not provide a consistent seal since it was dependent on the quality of the surface finish and on the hardness of the liner flange. Occasionally, bomblets leaked around the flange allowing explosive to seep into the small clearance area between the body and the liner and nose. This presented a potential safety hazard in handling since a thin section of explosive could detonate under a hard shock.

During Phase II the sealing method around the flange of the liner was changed to use a room temperature vulcanizing silicone rubber (RTV). The sealant was applied to the flange of the liner in a thin layer (0.003 inch) by thinning the RTV with hexane solvent and dipping the liner in the sealant to cover the flange. The excess was wiped from the inner surface of the liner and the bottom of the flange, and the sealant was allowed to cure. The RTV served as gasket when the liner was installed in the assembly.

The leadwire was fed through a hole approximately 1/4 inch up from the flange. The wire diameter was controlled to 0.039 + 0.003 inch, and the hole in the liner was controlled to 0.040 + 0.002 inch. This permitted a maximum interference of 0.002 inch to a maximum clearance of 0.003 inch. Tests showed that no leakage occurred with a 0.003 inch clearance. This seal proved adequate during explosive pouring, but it did have a disadvantage in that the sealant on the liner was vulnerable to dirt and damage during storage and handling.

During Phase II environmental testing, it was found that some explosive exudate leaked between the body/adapter interface and up through the electrical connector in the adapter during high temperature conditioning.

A study was conducted to determine what methods of sealing might be applicable to the explosive cavity. The factors which were to be considered in the selection of a sealing method were:

- Effect on Performance - The sealing method must not degrade the performance of bomblet in any way.
- Cost - The cost of material, equipment, and application must reflect achievement of a high cost/effectiveness in manufacturing.
- Compatibility - The materials used must be compatible with both the explosive and other materials.
- Seal Test - An inspection operation should be capable of indicating the adequacy of the seal.
- Electrical Continuity - The seal will not interfere with the hardware ground circuit.
- Reliability - The seal has to withstand the effects of explosive loading and all the environmental conditions.

The results of the study in the form of a summary of the sealing techniques available are shown in Table **XX**. The methods considered to be most promising when evaluated on the basis of the previous criteria were sealants and non-wetting coatings. Consequently, four evaluation units (two with "Vydax", a dispersion of Teflon in freon, and two with Hysol 4368) were assembled and

TABLE XX

SEALING TECHNIQUES

MODE OF CONTROL	SPECIFIC TYPE	COMMENTS
MECHANICAL GASKET	1. SEPARATE PIECE PART	FRAGILE PARTS ARE DIFFICULT TO HANDLE - ROLLED TUBE TYPE WASHER SIMILAR TO SPARK PLUG GASKET COULD IMPROVE HANDLING. ONLY SUITABLE FOR LINER/BODY INTERFACE.
	2. RESILIENT FILM APPLIED TO ONE OF PIECE PARTS	TYPE OF SEAL PRESENTLY IN USE. ONLY SUITABLE FOR LINER/BODY INTERFACE.
SEALANTS	1. CAVITY PAINT	THESE ARE DEPENDENT ON PROCESS CONTROL TO A LARGE DEGREE TO INSURE THAT SEALING IS COMPLETE AND EXCESSIVE BUILDUP DOES NOT OCCUR.
	2. LAMINAC	
	3. POLYESTER ADHESIVE	MUST BE APPLIED AT ASSEMBLY. SHORT POT LIFE
	4. DAPON 2575/IMPREX	THESE MATERIALS ARE LIQUIDS WHICH CONVERT TO SOLIDS UPON CURING. MATERIAL COST IS FAIRLY HIGH BUT PROCESSING METHODS ARE STRAIGHTFORWARD AND THICKNESS IS WELL UNDER 1 MIL. SOME CONCERN EXISTS ON MAINTENANCE OF A HARDWARE CIRCUIT DUE TO THE ABILITY OF THIS MATERIAL TO PENETRATE ALL CRACKS.
NON-WETTING COATINGS	1. FLUOROCARBON DISPERSION 2. POLYETHYLENE DISPERSION 3. SILICONES 4. STEARATES 5. WAXES (DAMAR)	APPROPRIATE FOR ALL LEAK POINTS. COATING THICKNESS IS VERY LITTLE AND CONTROL PROBLEMS SHOULD BE MINOR. THE ADHERENCE OF THE FILM TO THE PIECE PARTS MAY BE A PROBLEM IN THE CASE OF POLYETHYLENE. IT WILL BE NECESSARY TO HEAT THE ASSEMBLY FOLLOWING APPLICATION IN ANY EVENT AND THIS MAY RESULT IN SUFFICIENT ADHERENCE.
FUSED OR BONDED INTERFACES	1. INDUCTION SOLDERING	NOT APPROPRIATE FOR LEAD HOLE IN LINER.
METAL-TO-METAL	1. SEALING BEAD	CONSIDERED FOR LINER/BODY INTERFACE WHERE A SMALL BEAD COULD BE COINED IN LINER OR MACHINED ON BODY. WOULD RELY UPON DISPLACEMENT OF LINER MATERIAL TO CONFORM TO BODY MICRO-CONTOUR. ABILITY TO WITHSTAND TEMPERATURE CYCLING IS QUESTIONABLE.
	2. SWAGED	APPLICABLE TO ADAPTER/BODY INTERFACE
SPECIAL TYPES	1. INTEGRAL BODY/ADAPTER	UNDER CONSIDERATION. SOLVES THIS INTERFACE BY ELIMINATION
	2. COPPER FOIL/INSULATING FILM SANDWICH GASKET	THIS SPECIAL TYPE IS BEING CONSIDERED AS HAVING ADVANTAGES IN PROVIDING A MORE PRODUCIBLE SOLUTION TO PROVIDING THE HOT CIRCUIT PAST THE LINER. IT WOULD ELIMINATE THE NEED FOR A LEAD HOLE AND CONSEQUENTLY THE LEAK INTERFACE. IT WOULD INTRODUCE ADDITIONAL ASSEMBLY TOLERANCE THAT COULD AFFECT PERFORMANCE.

loaded using the non-wetting type sealant approach. Temperature testing of these units produced some exudation at 170°, a result indicating a very small margin of safety since the maximum temperature is 165°. On the basis of this result and in consideration of the fact that a pressure check was not a valid test for this type of seal, this approach was discarded.

The sealing technique eventually adopted was a combination of various methods depending on the interface location as described below:

Adapter/Body - The change in the adapter material from aluminum to steel and the change in the adapter finish from the relatively hard electroless nickel to the soft electrodeposited reflowed tin improved the quality of the crimp between the body and adapter to such an extent that the seal was adequate. Varying expansion rates was no longer a problem because of identical mating materials and the fact that the soft tin finish tended to serve as a gasket to close up any surface irregularities. Pressure and soap film tests verified the quality of the seal.

Ground Pin/Adapter - The riveting of the ground pin into the adapter produced an adequate seal at this interface for the same reasons cited above for the body/adapter assembly.

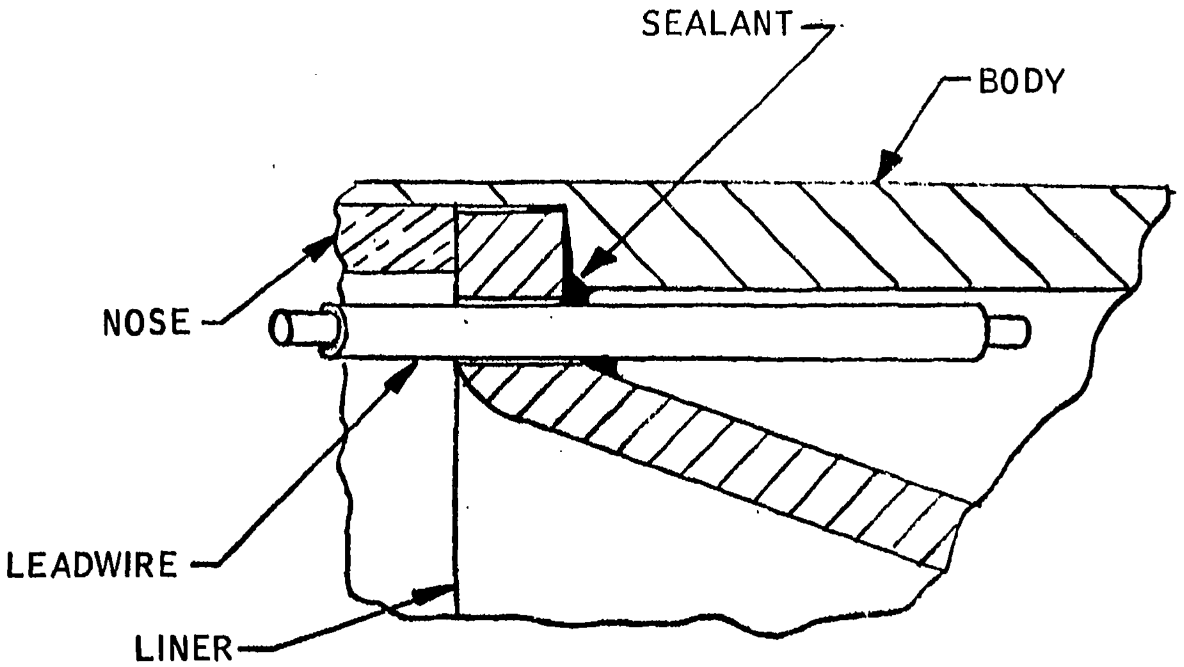
Electrical Connector/Adapter - The primary source of leakage through this interface occurred around the floating contact in the connector. The connector was changed to one with the contact molded into the Teflon body. This connector, while not being perfectly sealed, had a leakage rate of only 0.005 psi in 10 seconds. This rate would not result in any exudation.

Liner/Body - This interface was sealed by using RTV sealant. The sealant was thinned in hexane (5 parts RTV to 1 hexane) and metered into the cavity after unit assembly. Approximately 20 drops of sealant was required to effect an adequate seal.

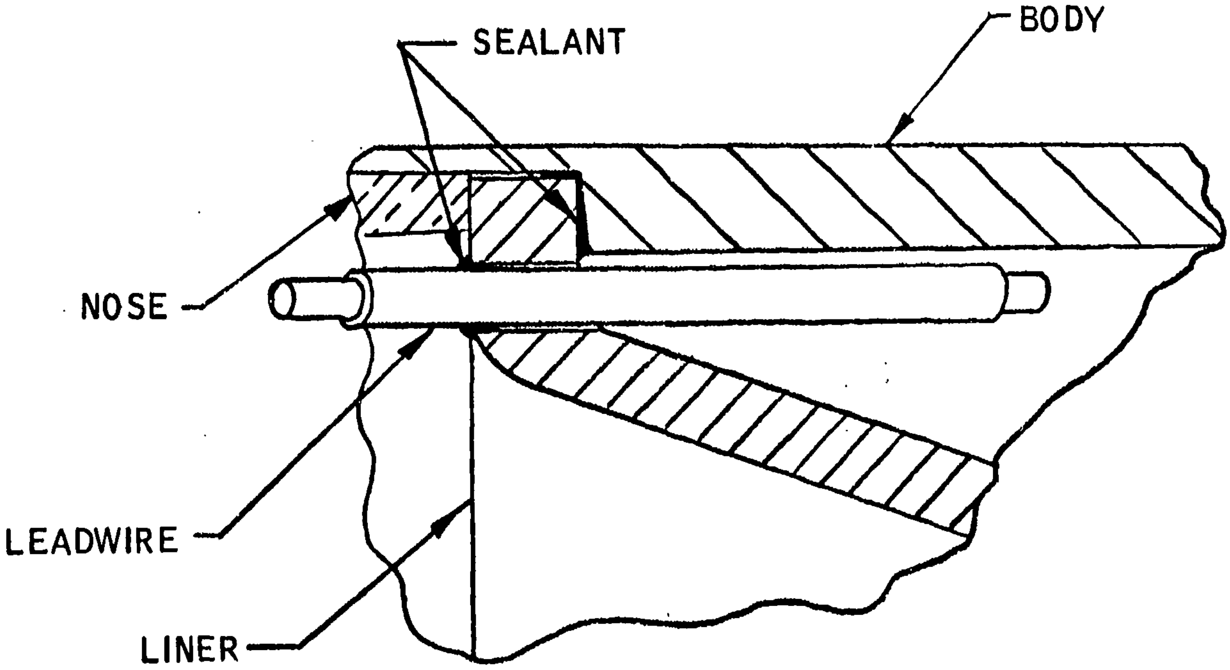
Liner/Leadwire - The leadwire sealant was relocated from the cone of the liner to the flange as shown in Figure 108, permitting the sealant (which is applied to the body/liner interface) to flow around the leadwire and seal it.

The leakage rate permitted in the explosive cavity is specified as 0.25 psi maximum in 10 seconds with a pressure differential of 2 psi. The pressure is applied through the booster hole in the adapter and thus checks all the interfaces except the booster cavity interface.

The sealing technique was modified slightly for Phase III units. The addition of the sealant around the liner after the bomblet was assembled resulted in some sealant being deposited on the wall of the liner or body, and, because of the inaccessible location, salvage was not possible. It was considered desirable from an assembly and functional point of view to minimize the amount of sealant within the explosive cavity. Therefore, the sealant technique was changed as follows. The same sealant previously used was applied to the counterbore step in the body, and any excess was wiped from the inside surface. This left a small fillet of material on the counterbore. The leadwire was threaded through the liner, and the liner was seated against the counterbore. A drop of sealant was applied on the leadwire at liner/leadwire interface on the outside of the explosive cavity. The nose was then crimped in place and the sealant allowed to cure. This method produced the required seal and yet minimized the amount of sealant within the explosive cavity. This completed the explosive cavity seal development.



OLD DESIGN



NEW DESIGN

Figure 108 - LINER-LEADWIRE REDESIGN

c. Structural/Functional Parts

The development of the structural and/or functional parts of the Rockeye II bomblet is summarized in this section of the report. The design evolution of some of these parts was previously described in terms of the aerodynamic configuration or the kill mechanism. To avoid redundancy, we have, in so far as possible, limited the discussion on these parts, in this section, to developmental considerations other than those concerning aerodynamics or lethality.

The parts covered in this section consist of the nose section, the body, the adapter, the tail fin, and the electrical circuit.

(1) Nose Section - A primary objective in the design of the Phase I nose was to evolve a configuration that interfaced closely with the bomblet tail fin, thus providing maximum packing efficiency between adjacent munitions in the longitudinal axis. Such efficiency was not inherent in the initial approach, as may be seen by referring back to the original configuration (Figure 68). Attainment of this design objective in the Phase I nose is fully evidenced by the fact that, although the complete bomblet assembly was approximately 11.5 inches in length, each bomblet required only 5 inches of space in the primary axis of the dispenser (except of course, bomblets in the first and twelfth rows). With this design a total of 270 bomblets constituted a full dispenser load in a packing arrangement as shown in Figure 109. The contours of the nose provided a second function which made the nose the energy absorbing media to permit the impact sensing element to discriminate between a hard target (1/16" thick mild steel) and a soft target (1/4" thick plywood). (This nose configuration has a spring rate of 48,000 lb/in.) The impact sensing element was fastened to the nose by means of a threaded adapter which was crimped into the nose. The shaped charge investigation indicated that the bore of the Phase I nose was producing a detrimental effect on the performance of the shaped charge jet.

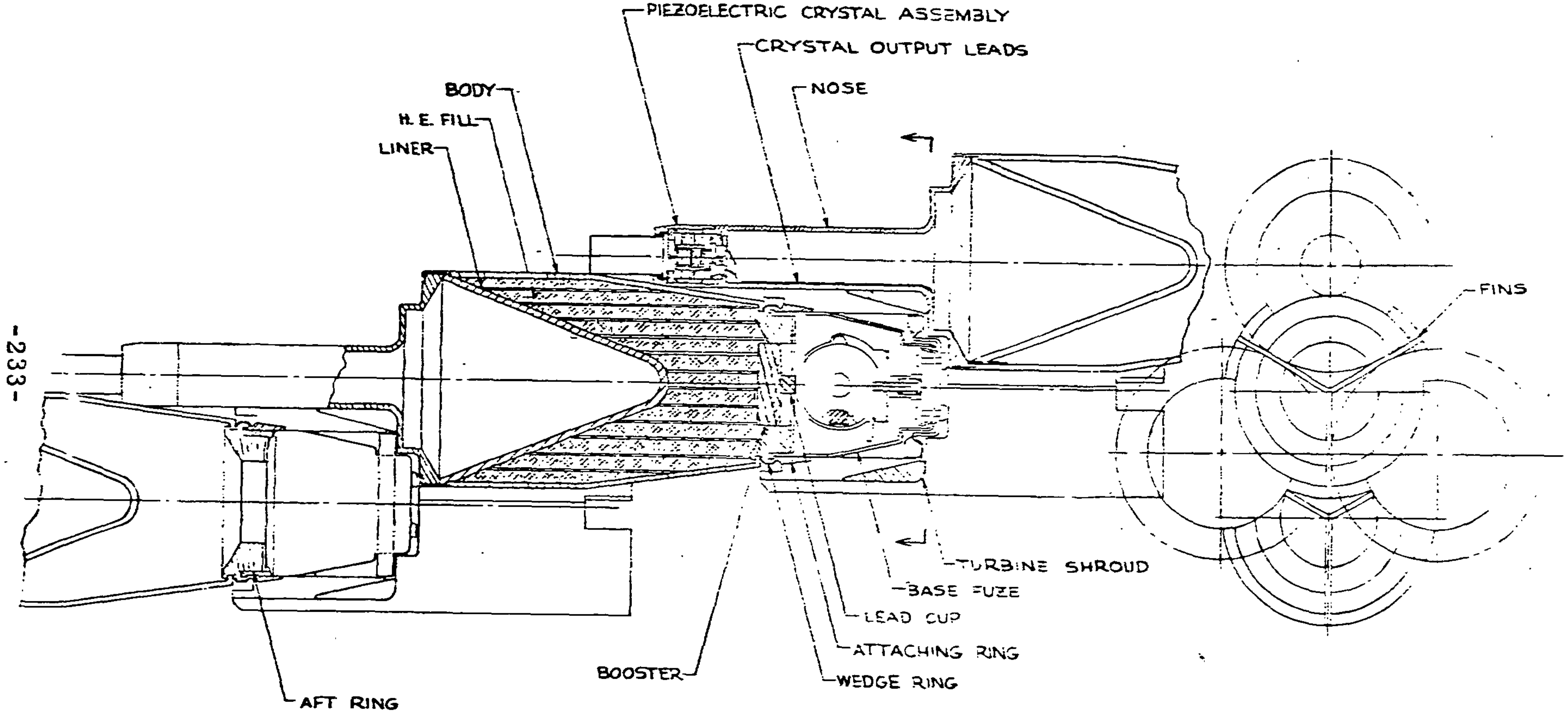


Figure 109 - BOMBLET LAYOUT

The inside diameter of the Phase I nose was 0.5 inch. Investigation showed that if this was increased to 0.625 inch, little or no detrimental effect was produced on the jet. Further investigation indicated that the additional diameter was required only where the contours of the nose blended into the nose spike. The nose was, therefore, redesigned to include a tapered section as shown in Figure 110.

Concurrent with the penetration findings on the nose structure (both diameter and standoff), the shaped charge investigation also showed that increasing the explosive load by 0.345 inch resulted in an improved penetration. The change made on the nose at this time was the elimination of the separate threaded adapter for attaching the impact sensing element by machining the threads into the nose after forming. This nose configuration was used during Phase II and part of Phase III.

The last major change made on the nose concerned the attachment of the impact sensing element. A problem area was uncovered with the threaded attachment. On high angle obliquity hits, the last thread on the nose piece was fracturing before the impact sensing element functioned, resulting in a dudded bomblet. The nose was changed by eliminating the threads and replacing them with a reduced diameter and a groove. The impact sensing element ferrule was also changed to eliminate the threads, and assembly of the parts was accomplished by crimping the ferrule into the groove of the nose. This completed the development of the bomblet nose.

(2) Body - The Phase I bomblet body configuration provided the required aerodynamic features to permit the airflow to enter the fin shroud for arming the base fuze. The body had a wall thickness of 0.056 inch, a value determined by test as producing the best fragment size for aircraft safety and anti-personnel effectiveness, and providing adequate

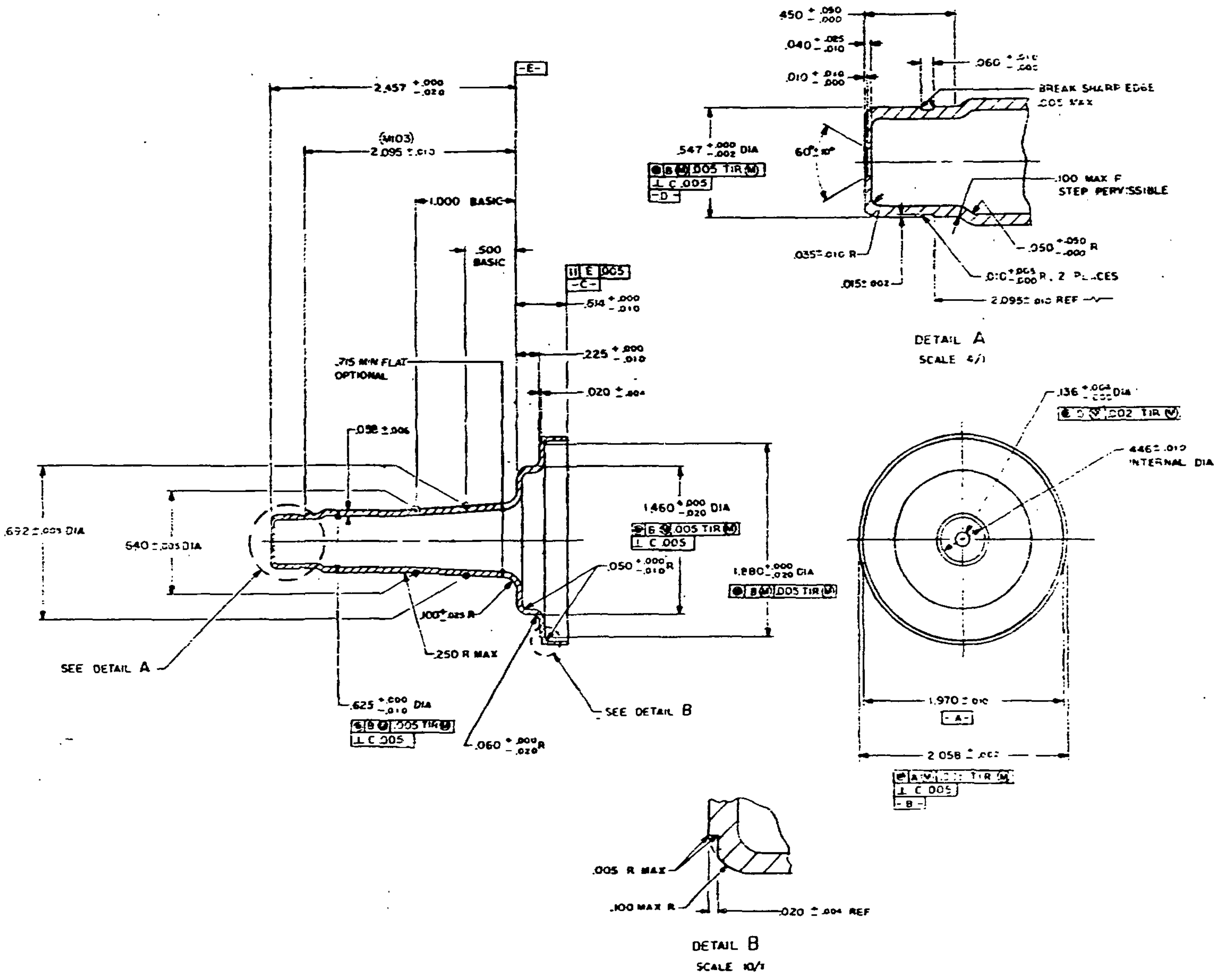


Figure 110 - REDESIGNED NOSE SECTION

confinement for the shaped charge. The results of these tests are discussed in the shaped charge development section of this report. The only major change to the Phase I design occurred when the shaped charge investigation showed that the explosive head should be increased by 0.345 inch. The body was increased by this amount and the tapered section was changed from a single angle to a double angle. This was necessary to maintain the maximum amount of explosive without affecting the stacking arrangement. This revised body design is shown in Figure 111.

(3) Adapter - The Phase I adapter was an aluminum ring with the outside threaded to accept the fin. The adapter, which was fastened to the body by six rivets, located the electrical connectors which mated with the base fuze assembly. In Phase II, the adapter was modified as shown in Figure 112 to permit the part to be crimped onto the body. The threads were also eliminated at this time since the fin attachment was changed from screw threads to a crimp.

In the next modification the material was changed from aluminum to steel and the plating was changed from irridite to reflowed tin plate. This was done to allow the use of a hardware ground circuit and to affect a metal to metal seal between the body and adapter to eliminate explosive leakage. Since the body was steel, the use of a steel adapter would eliminate the possibility of galvanic corrosion at the interface. A lightening groove was added to the adapter to reduce the weight increase caused by the material change, thus minimizing the effect on the center of gravity of the bomblet.

(4) Tail Fin - The development of the bomblet fin assembly in terms of type of material strength and producibility considerations is described in this section of the report. The design evolution as a result of aerodynamic analyses and evaluations is covered in the section entitled Aerodynamic Configuration.

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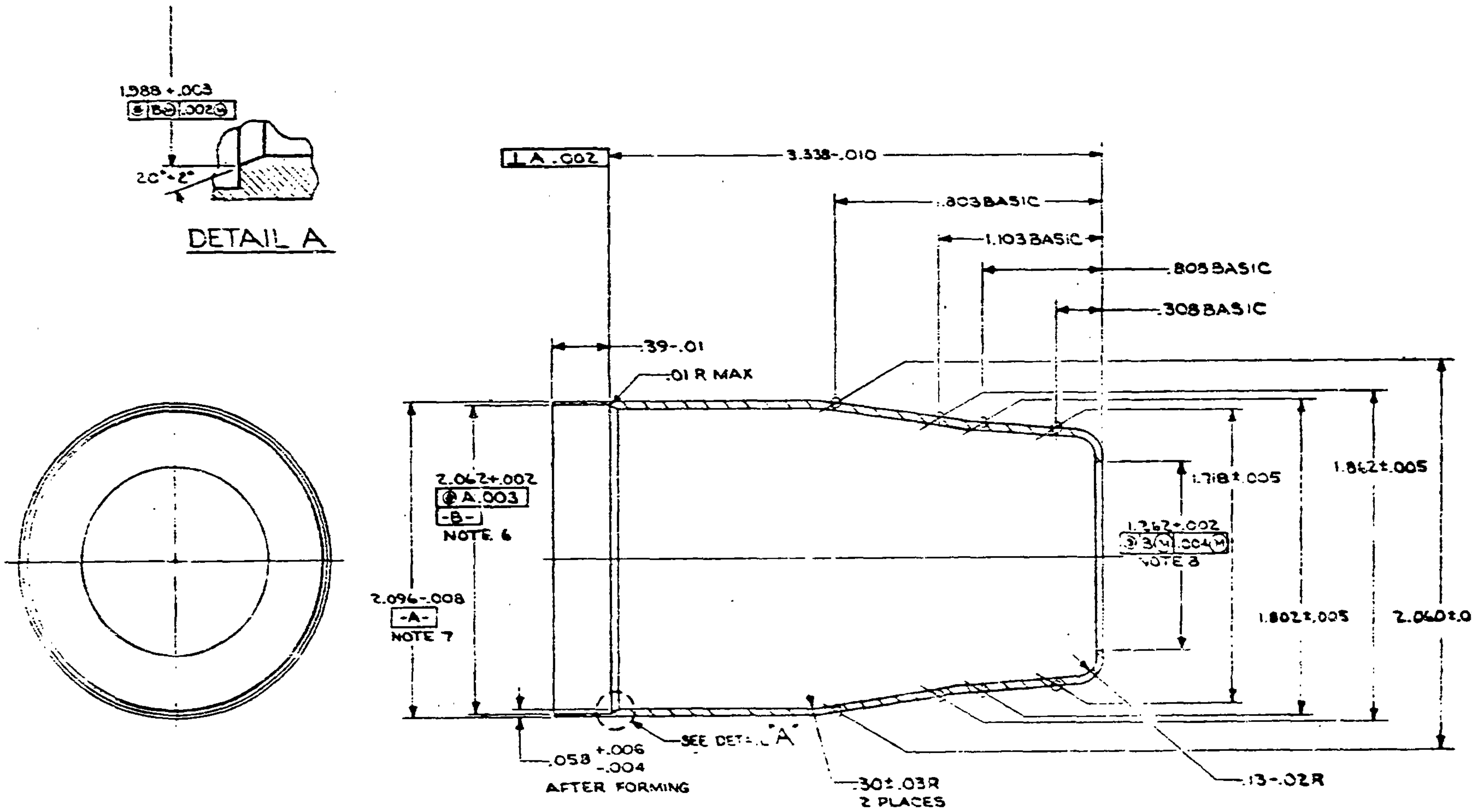


7-THE 1.262+.002 DIMENSION TO BE 1.260 MIN AFTER PRIMING.
6-THE 2.096-.008 DIMENSION TO BE 2.098 MAX AFTER PRIMING.
5-THE 2.062+.002 DIMENSION TO BE 2.060 MIN AFTER PRIMING.
4-DIMENSIONS APPLY BEFORE PAINTING.
3-PART MAY BE RESTRICTED FOR GAGING PURPOSES.
2-PAINT USING PRIMER PER MIL-P-22332A.
1-MATERIAL:- STEEL, LOW CARBON, SHEET, COLD ROLLED, #4 TEMPER
DRAWING QUALITY, (CRDQ), SPEC QQ-S-698

Figure 111 - ROCKEYE II BODY

CONFIDENTIAL

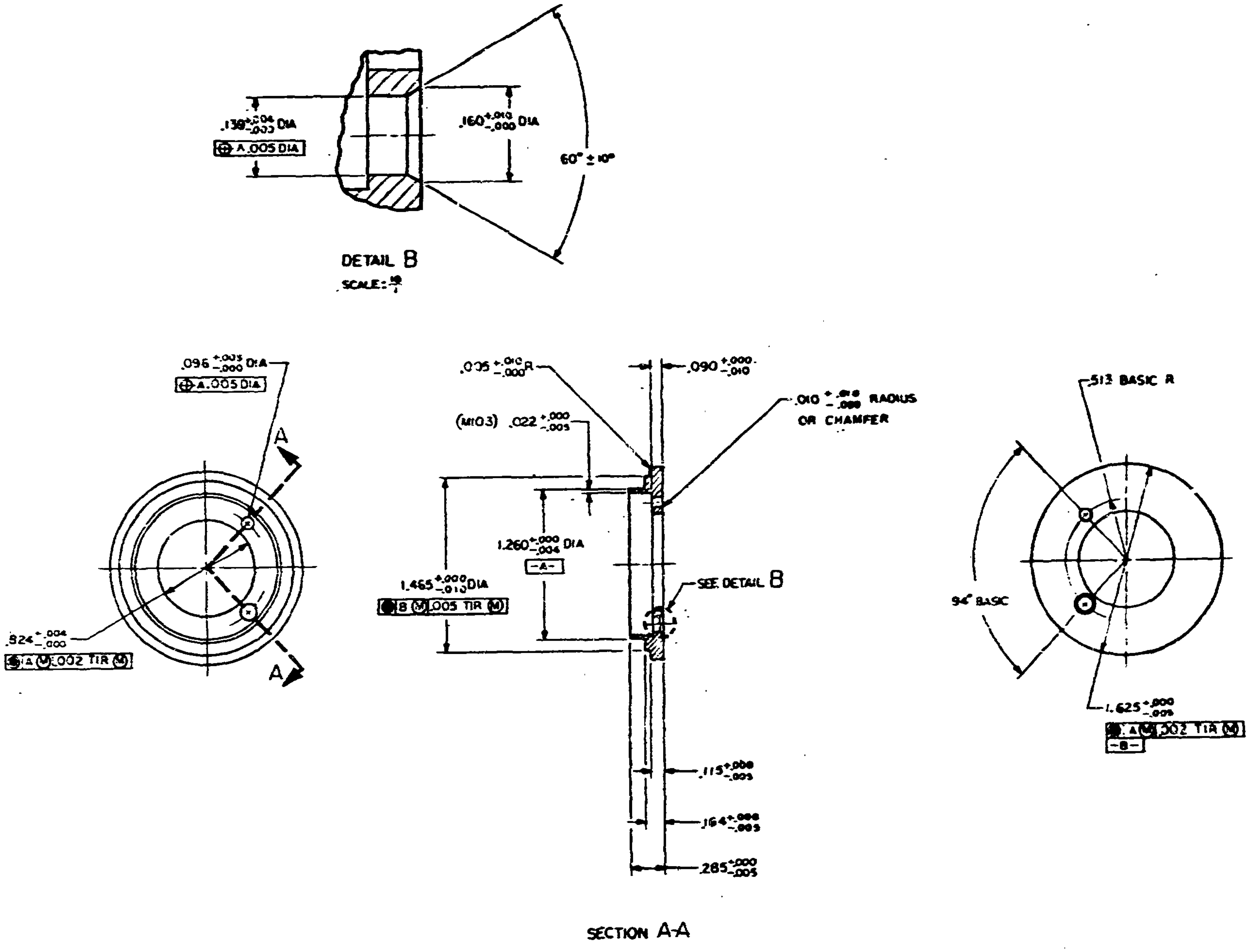
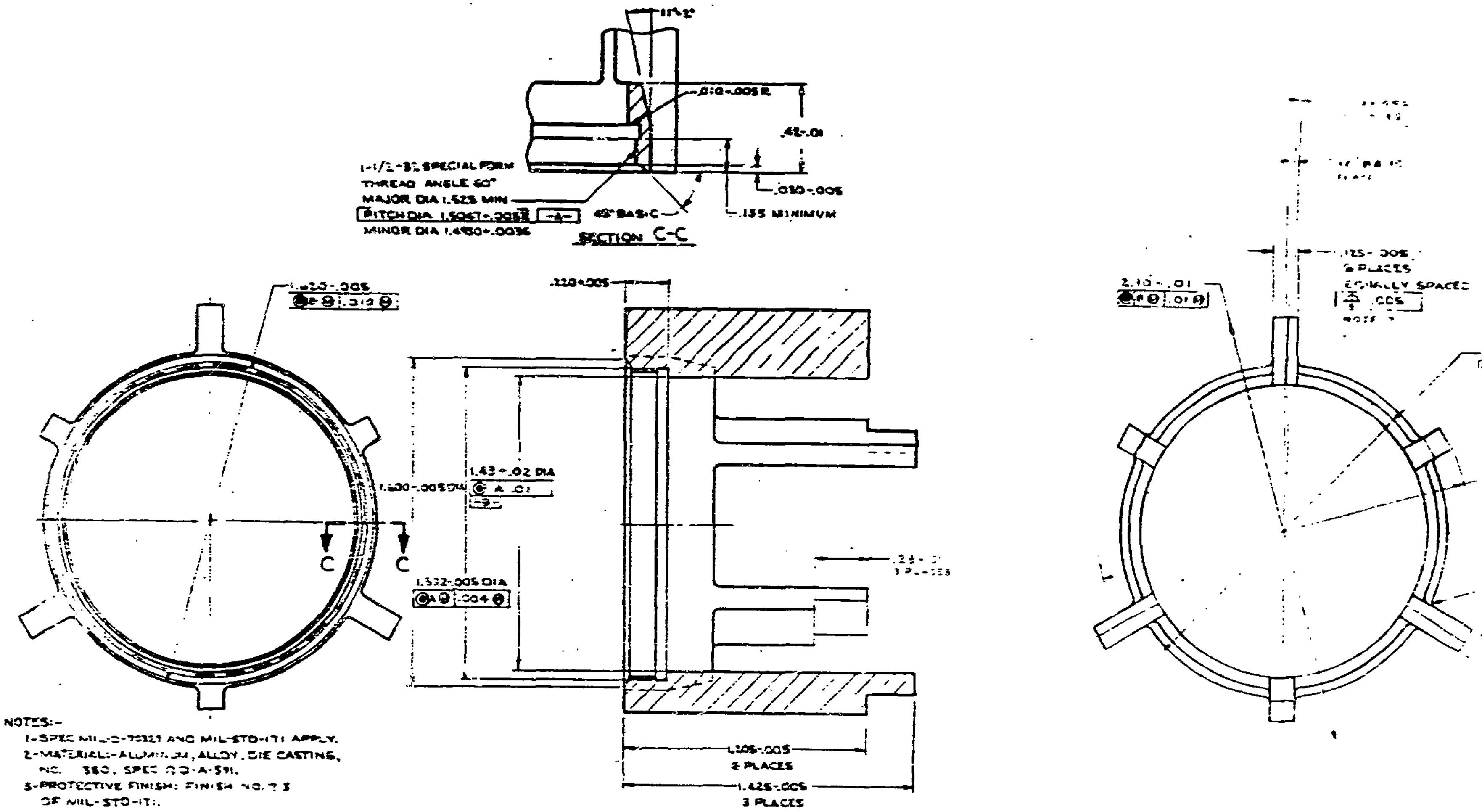


Figure 112 - BOMBLET ADAPTER

The Phase I fin consisted of two parts (as shown in Figures 113 and 114) riveted together to form the complete fin assembly. The fin material was 40% glass filled nylon, selected because of its ability to absorb impact energy without deformation (its yield strength is approximately identical to its ultimate strength). Deformation of the fin would be undesirable because of its effect on bomblet stability.

Phase I weapon drops showed a very high rate of fin breakage. In some drop tests, approximately 30% of the bomblets suffered fin damage, primarily in the area behind the shroud. Consequently, the fin was redesigned (as shown in Figure 115) to incorporate a stainless steel insert molded into the fin. The fin material selected was glass filled nylon. This design eliminated the threads used previously for attaching the base fuze to the bomblet, using the insert for this purpose by crimping it over the adapter and base fuze cover flange. Additional strength was obtained aft of the shroud by tapering the fin edge uniformly from 0. 125 to 0. 040 inch. This fin design was never produced because a change in the fin configuration was needed to improve the bomblet stability. This need arose partly because the bomblet body and nose length was increased, and also to correct a pitch roll instability apparent in weapon flight tests. The design was modified to that shown in Figure 116. Since it was necessary to remove one bomblet wafer in order to increase the nose and body length, it became practical to compromise the increased body length slightly in order to increase the fin length to 1. 25 inches. This would serve to increase the bomblet stability. Wind tunnel testing showed that further stability was obtained with the addition of the secondary fins as shown in the figure. In this design, radii and material were used to provide maximum section strength and a minimum of stress concentration points. Two materials selected for initial evaluation were both glass reinforced Zytel 101 Nylon (Nylon type 66), but the glass fill content was 30% for one and 40% for the other. The 40% glass was capable of absorbing more impact energy, and the 30% glass fill material could deflect more before fracturing.



NOTES:-

1-SPEC MIL-C-75321 AND MIL-STD-171 APPLY.
2-MATERIAL:-ALUMINUM, ALLOY, DIE CASTING, NO. 380, SPEC QQ-A-591.
3-PROTECTIVE FINISH: FINISH NO. 7.3 OF MIL-STD-171.
4-DRAFT PERMITTED WITHIN PRESCRIBED TOLERANCES EXCEPT AS NOTED.
5-ALL OUTSIDE EDGES MAY HAVE .02 MAX CORNER BREAKS EXCEPT WHERE OTHERWISE NOTED.
6-ALL INSIDE CORNERS MAY HAVE .02 MAX RADIUS EXCEPT WHERE OTHERWISE NOTED.
7-1° DRAFT PER SIDE TO INCREASE DIMENSION.

Figure 113 - RING, ATTACHING

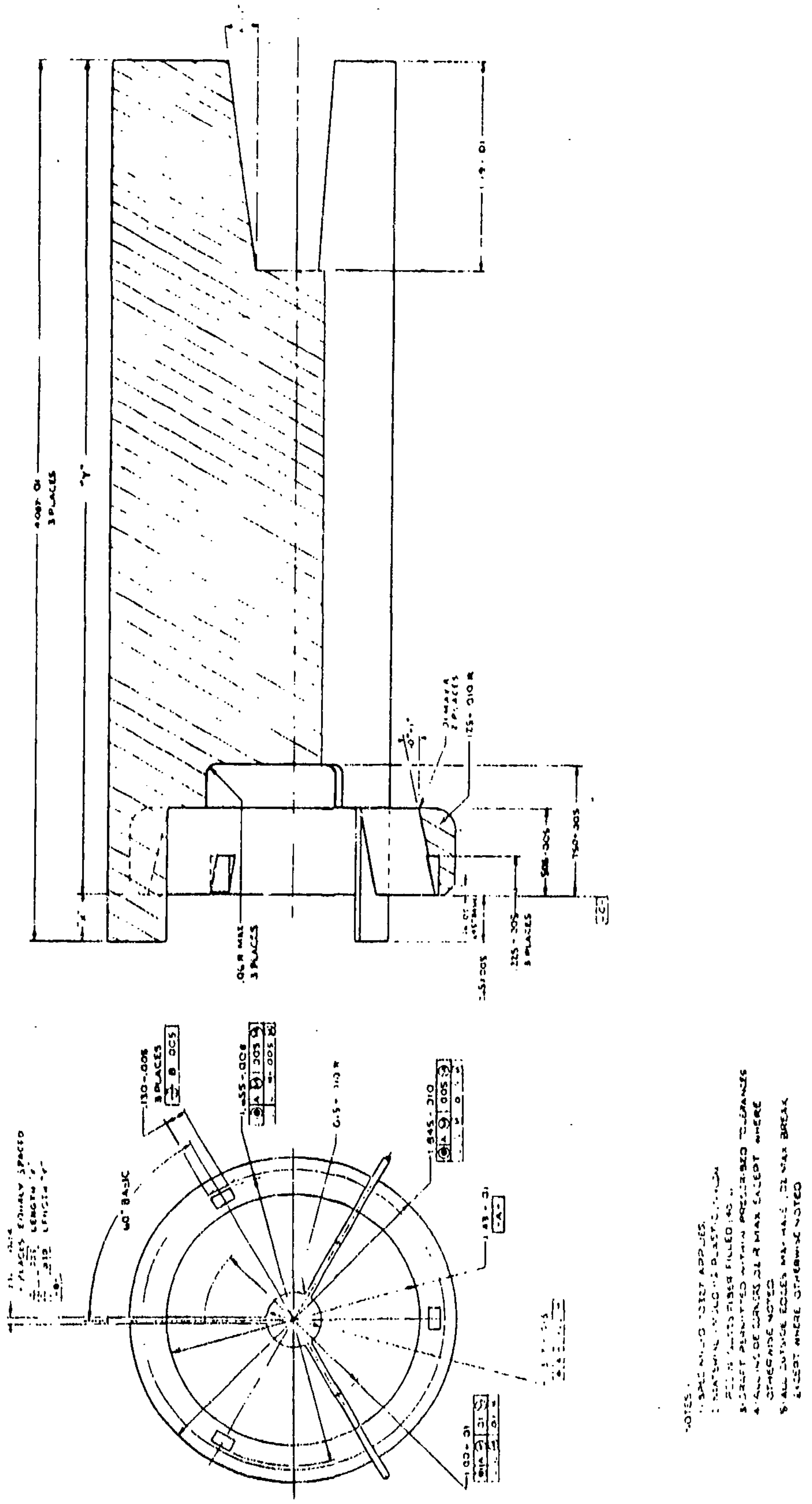
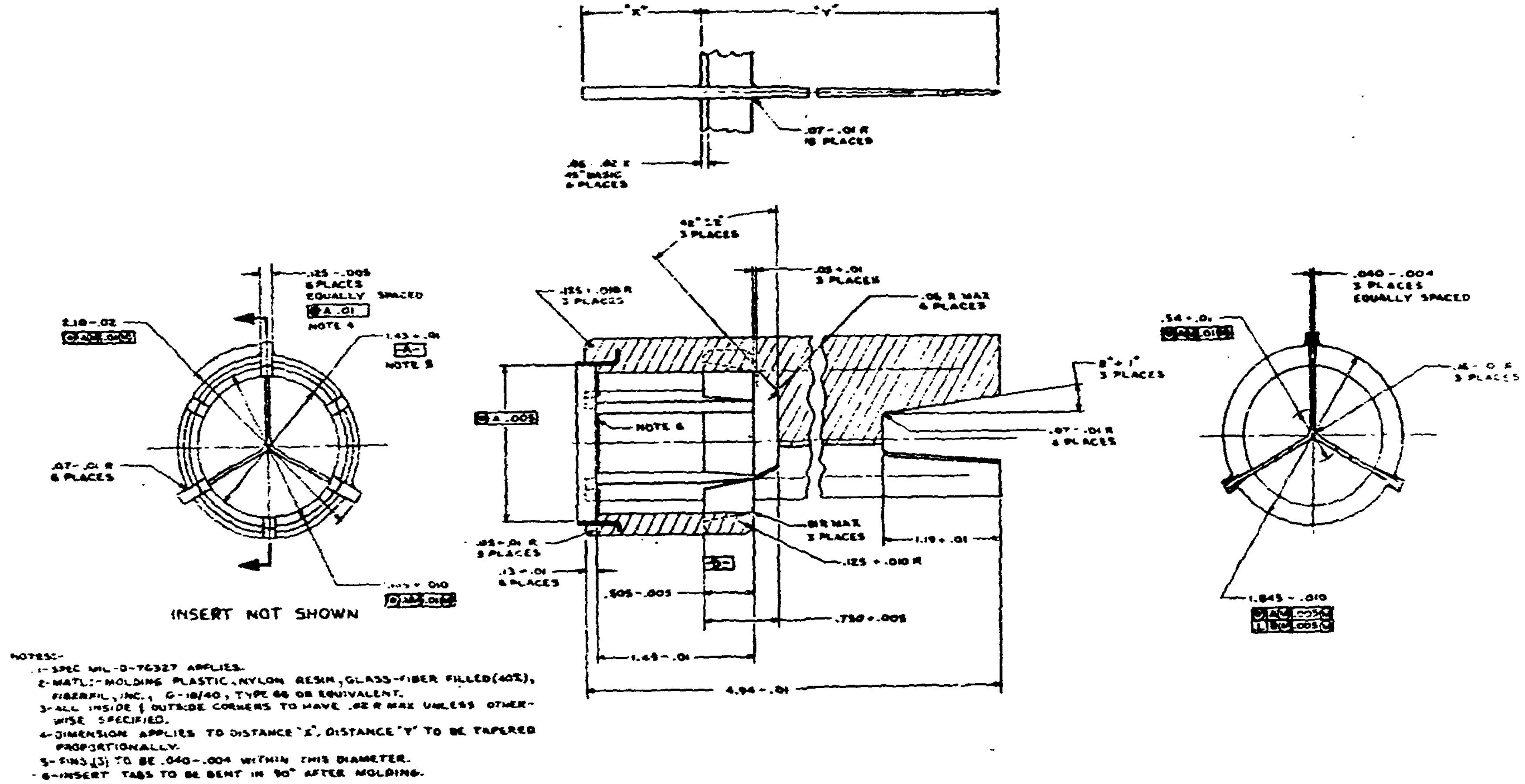


Figure 114 - BOMBLET FIN



NOTES:-
1-SPEC MIL-D-76327 APPLIES.
2-MATL:-MOLDING PLASTIC, NYLON RESIN, GLASS-FIBER FILLED(40%), FIBERFIL, INC., G-10/40, TYPE 66 OR EQUIVALENT.
3-ALL INSIDE & OUTSIDE CORNERS TO HAVE .02 R MAX UNLESS OTHERWISE SPECIFIED.
4-DIMENSION APPLIES TO DISTANCE "X". DISTANCE "Y" TO BE TAPERED PROPORTIONALLY.
5-FINS (3) TO BE .040-.004 WITHIN THIS DIAMETER.
6-INSERT TABS TO BE BENT IN 90° AFTER MOLDING.

Figure 115 MODIFIED BOMBLET FIN

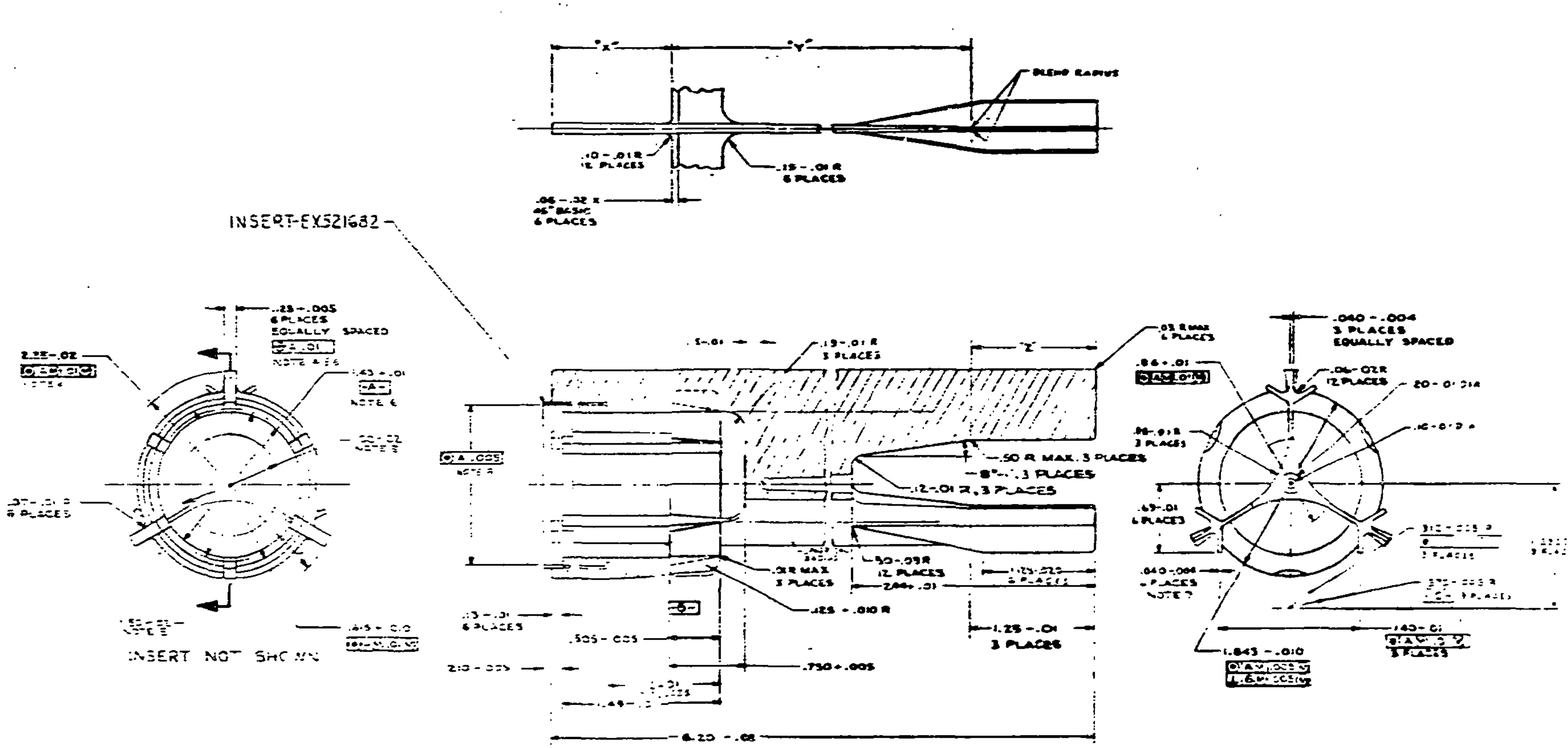


Figure 116 - REDESIGNED BOMBLET FIN

Two weapon drop tests were conducted with mixed loads of the 30% and 40% glass filled material. The 30% material results indicated fin breakage on approximately 27% of the bomblets whereas the 40% material showed breakage on 8.5% of the bomblets. On the basis of these tests the 40% glass filled Zytel 101 nylon was concluded to be the better material, but the breakage was still felt to be unacceptable. The test also indicated a need to further strengthen the section just aft of the shroud. The design was then modified to include a thickened section from the front to one inch aft of the shroud as shown in Figure 117.

An investigation was conducted at this time to determine if there was a material which had better impact energy absorption than those which had previously been tested. A study of various materials was made and the following were selected for test:

1) Zytel 101 nylon (type 66 nylon) with 30% glass fill by weight (previously used material).

2) Zytel 101 nylon (type 66 nylon) with 40% glass fill (previously used material).

3) Plaskon nylon with 40% glass fill (type 6 nylon).

4) Zytel 31 nylon with 40% glass (type 6-10 nylon).

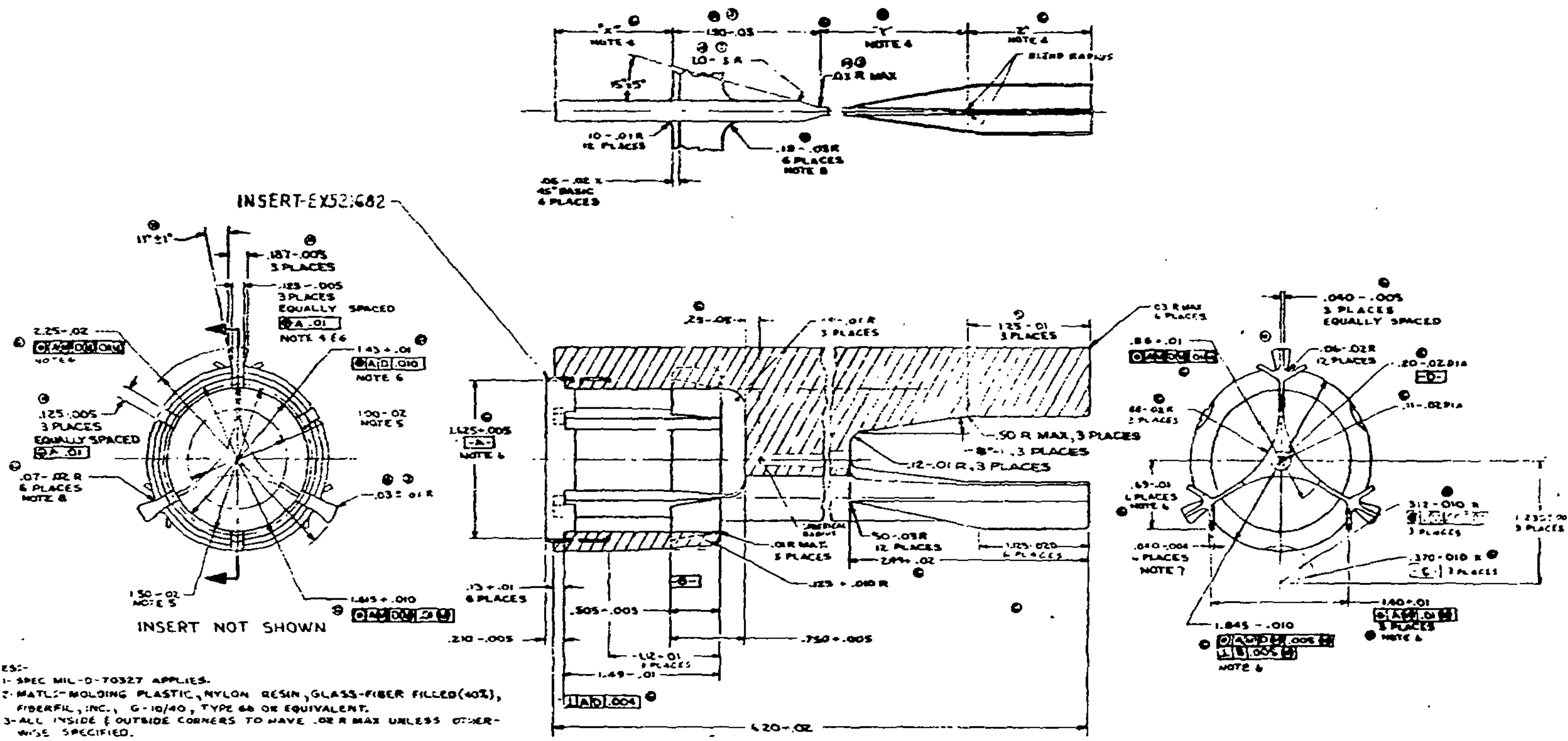
5) Lexan 101 (polycarbonate).

6) Lexan with 40% glass.

7) Hi-density polyethylene with 40% glass.

8) Cyclolac LL.

9) 2024-T4 aluminum (2 shapes).



NOTES:-

1- SPEC MIL-D-70327 APPLIES.
2- MATL:- MOLDING PLASTIC, NYLON RESIN, GLASS-FIBER FILLED (40%), FIBERFIL, INC., G-10/40, TYPE 66 OR EQUIVALENT.
3- ALL INSIDE & OUTSIDE CORNERS TO HAVE .02 R MAX UNLESS OTHERWISE SPECIFIED.
4- .125-.005 DIMENSION APPLIES TO DISTANCE "X". DISTANCE "Y" TO BE TAPERED PROPORTIONALLY FROM .100-.005 WIDTH. DISTANCE "Z" TO BE .040-.004 THICK.
5- FINS (3) TO BE .040-.004 BETWEEN THE 1.00 & 1.50 DIAS.
6- TO BE GAGED SIMULTANEOUSLY WITH 1.125 DIA PLUG PLACED WITHIN INSERT EX521682.
7- 3° MAX DRAFT PERMISSIBLE TO INCREASE THICKNESS.
8- BLEND SHROUD/FIN RADIUS FROM .07-.02 TO .19-.03.

PERMANENT DEVIATION PERMISSIBLE FOR LIFE OF TOOL
(a) THE .040-.004 DIMENSION (6 PLACES) PERMITTED O/S TO .045.
(b) THE .49-.01 (6 PLACES) PERMITTED U/S TO .445.
(c) THE .86-.01 DIA PERMITTED U/S TO .840.
(d) THE 1.40+.01 DIMENSION PERMITTED U/S TO 1.370.

Figure 117 - FINAL DESIGN, BOMBLET FIN

The material listed in 1) through 8) were molded while the aluminum fin was fabricated as shown in Figure 118. The units were tested by dropping a known weight onto the fin in three locations. The weight was dropped at an increasing height until fracture occurred or a displacement of 0. 100 inch took place.

The results of the test are as indicated in Table XXI. The three nylon, 40% glass filled materials performed the best. Lexan 101 fins took a slight set but did not fracture. Since the results of this test were qualitative, a mixture of the four types of materials were flight tested in two dispensers.

The results of the two tests were analyzed on the basis of the type of damage exhibited by the fins. Major damage, classified as that which produced instability in the bomblet, consisted of two or three fin broken tips or the entire fin aft of the shroud being broken off. Minor damage, which would not produce instability in all cases, consisted of minor cracks, fins bent to . 25 inch, or one tip broken off. None of these fins had the thickened section aft of the shroud previously described. The results of the flight tests are shown in Table XXII. The performance of Lexan 101 and Zytel 31 was the best, but the margin of difference between the two was not significant. Another weapon drop test was conducted using only these two materials for the fins. Results of this test were still inconclusive with neither material exhibiting superiority over the other. Total combined breakage for both materials was only 3%. However, further testing of the Lexan fin showed that under cold temperature and vibration, stress cracks developed where the insert was molded into the fin. In addition,the compatability of Lexan with explosive vapors was questionable. On this basis Lexan was eliminated from further evaluation.

Concurrently with the material investigation, a change that reduced fin breakage was incorporated in the dispenser. This modification provided for the use of a hinged tailcone that minimized the dispenser halves from colliding with the bomblets during dispenser opening (further details on this change can be found in the dispenser section of this report).

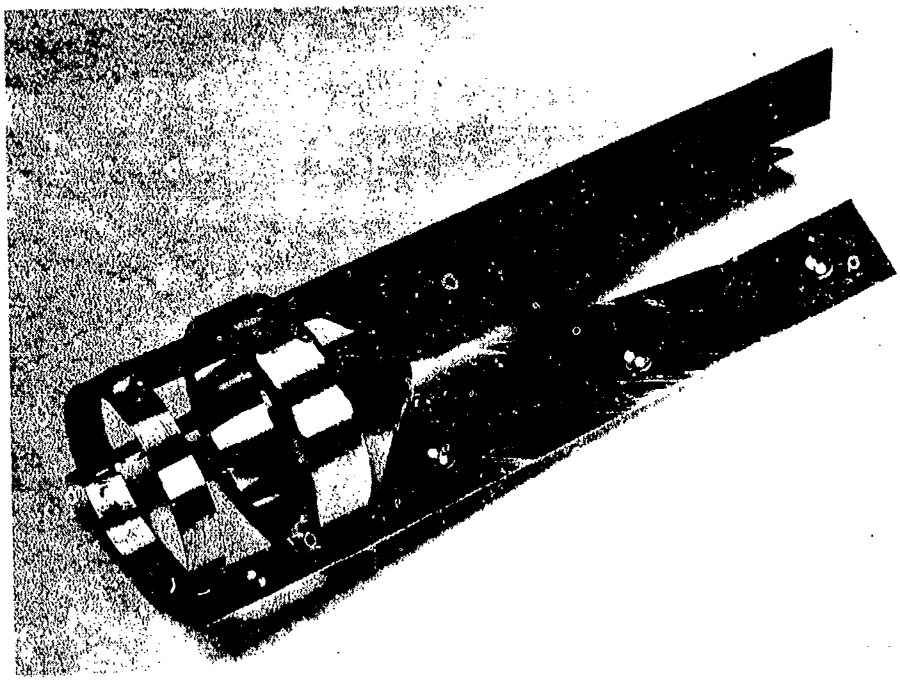


Figure 118 - METAL FIN, STRAIGHT SECTION

TABLE XXI

FIN MATERIAL ENERGY TEST

MATERIAL	AVERAGE ENERGY ABSORBED (IN-LBS)		
	TEST 1	TEST 2	TEST 3
ZYTEL 101, 30% GLASS (TYPE 66 NYLON)	2.0	11.0	14.0
ZYTEL 101, 40% GLASS (TYPE 66 NYLON)	4.7	19.3	26.0
PLASKON NYLON, 40$ GLASS (TYPE 6 NYLON)	5.5	21.0	22.7
ZYTEL 31, 40% GLASS (TYPE 6-10 NYLON)	5.8	19.0	31.3
LEXAN 101 (POLYCARBONATE)	3.2[1]	15.3[2]	15.7[2]
LEXAN, 40% GLASS (POLYCARBONATE)	2.7	13.0	15.7
POLYETHYLENE, 40% GLASS	1.2	4.8	7.3
CYCLOLAC LL	0.5	10.8	9.7
2024-T4 (STRAIGHT FIN) [2]	2.0	5.0	6.5
2024-T4 (FLANGED FIN) [2]	3.0	7.0	9.5

[1] UNIT DID NOT FAIL BUT WEIGHT PASSED BY WITHOUT DAMAGING FIN.

[2] FIN DID NOT FRACTURE BUT TOOK A SET

TABLE XXII (Continued)

FIN MATERIAL EVALUATION - FLIGHT TEST

FIN MATERIAL		DAMAGE (% OF FINS)	
TRADE NAME	BASIC POLYMER	MINOR	MAJOR
LEXAN 101	POLYCARBONATE	3.0	8.3
ZYTEL 101 (10/40)	TYPE 66 NYLON	5.5	28.9
PLASKON (13/40)	TYPE 6 NYLON	9.0	22.0
ZYTEL 31 (12/40)	TYPE 6-10 NYLON	1.25	23.2

The final changes made to the molded portion of the fin assembly were:

a) The internal diameter of the shroud was increased from 1.43 to 1.46 inch, and the chamfer on the leading edge of the shroud was reduced to 0.02 inch.

b) The leading edge of the struts were radiused.

Change a) was made to increase the airflow through the shroud, thus permitting the base fuze to have its all arm point at 200 knots. Change b) was effected to eliminate a flash problem which occurred at the insert and mold interface.

This completed the development of the fin assembly. Flight tests of weapons containing all the modifications indicate the fin breakage to be an acceptable 2 to 3 percent.

The crimping surfaces of the insert underwent a number of modifications to resolve problems associated with the crimping operation. Crimping of the initial insert caused the intermediate struts to deflect outward beyond their limits and resulted in a stacking interference. Consequently, the design was changed to the configuration shown in Figure 119. This insert, when crimped, did not affect the position of the intermediate struts, but the reduced length of the crimped section at the forward edge of the insert proved to be of marginal strength during flight tests. Some fins were knocked off during inter-bomblet collision while a number of others were loosened. The insert was therefore changed to a configuration in Figure 120, which is generally similar to that of the previous design except that the cutouts on the forward edge were reduced in width from 0.125 to 0.060 inch and the depth was reduced from 0.075 to 0.035 inch. This increased the length of the crimped section and also provides a gusset at each end of the section when crimped since the depth of the cutouts is less than the length of material being crimped. This insert proved to be satisfactory during flight tests.

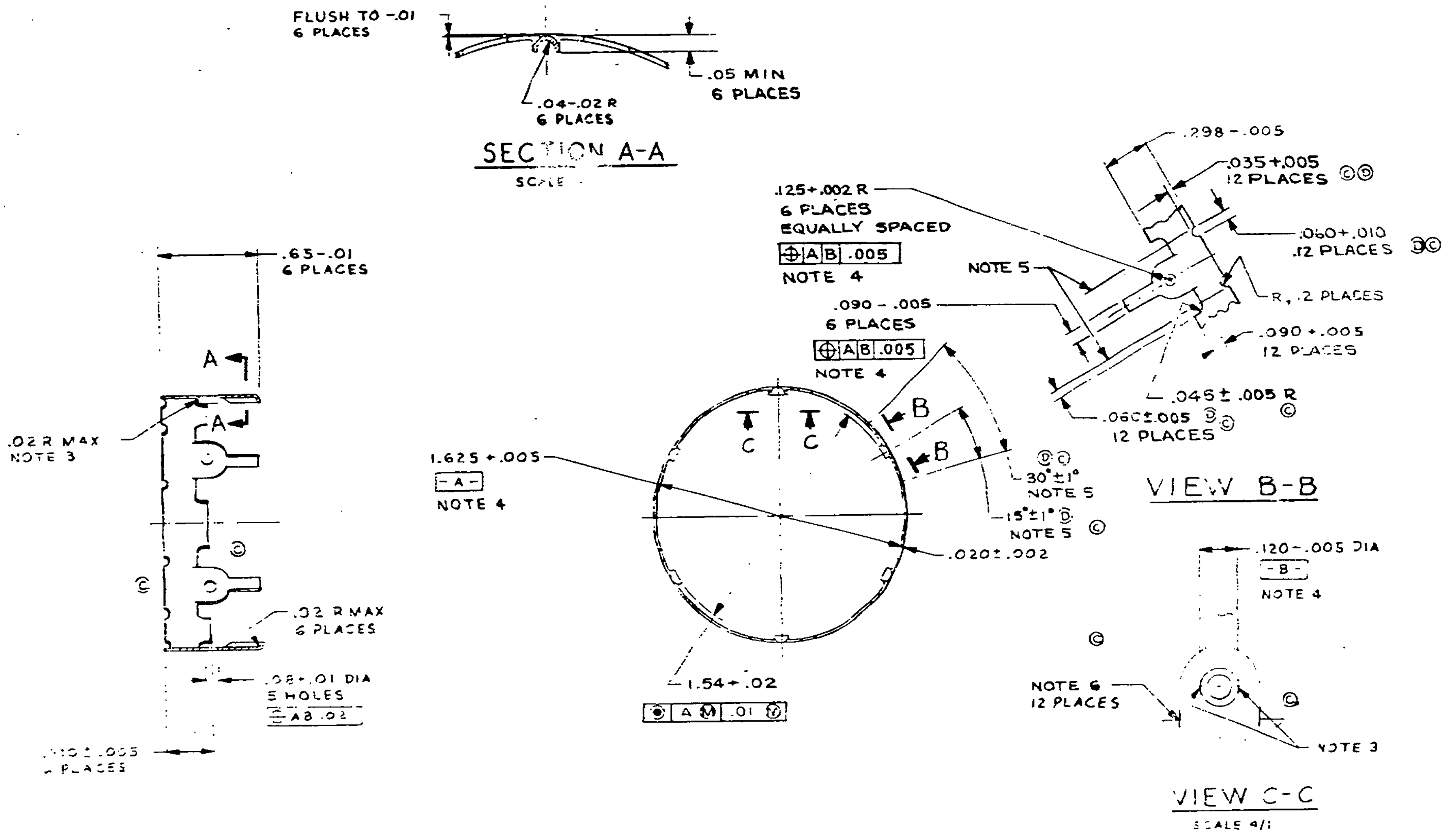
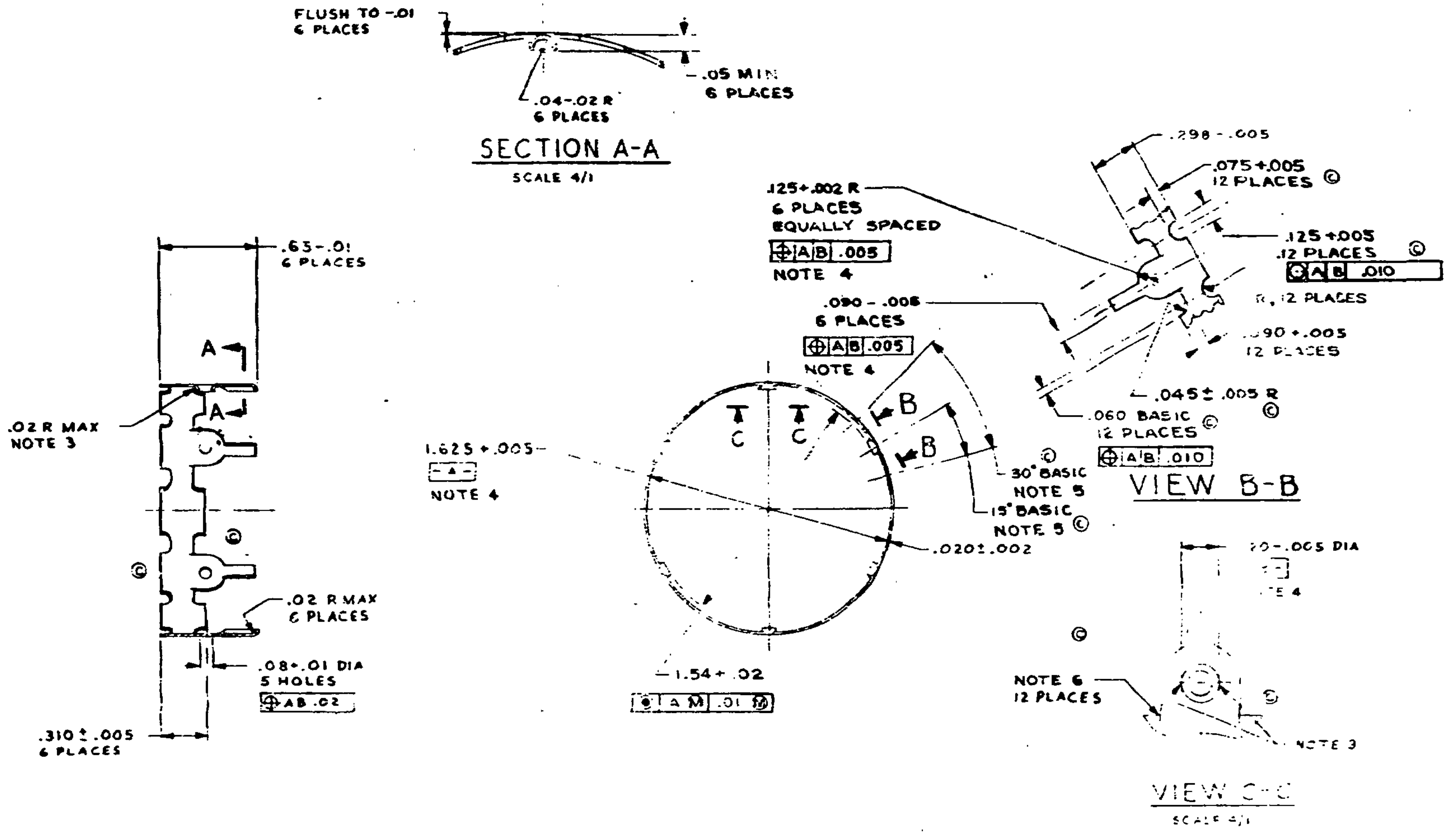


Figure 119 - INSERT



NOTES:-

1- MATERIAL:- STEEL, CORROSION RESISTING, STRIP, TYPE 301, 302 OR 310, ANNEALED, ASTM A167.
2- PROTECTIVE FINISH:- FINISH NO. 5.4.2 OF MIL-STD-171.
3- AREA INDICATED TO HAVE A .005 MAX RADIUS
4- TO BE GAGED SIMUTANEOUSLY.
© 5- DIMENSION APPLIES TO NOTCHES ON OPPOSITE SIDE OF PART.
© 6- LANCE LINE 1/32 LONG PERMISSIBLE.

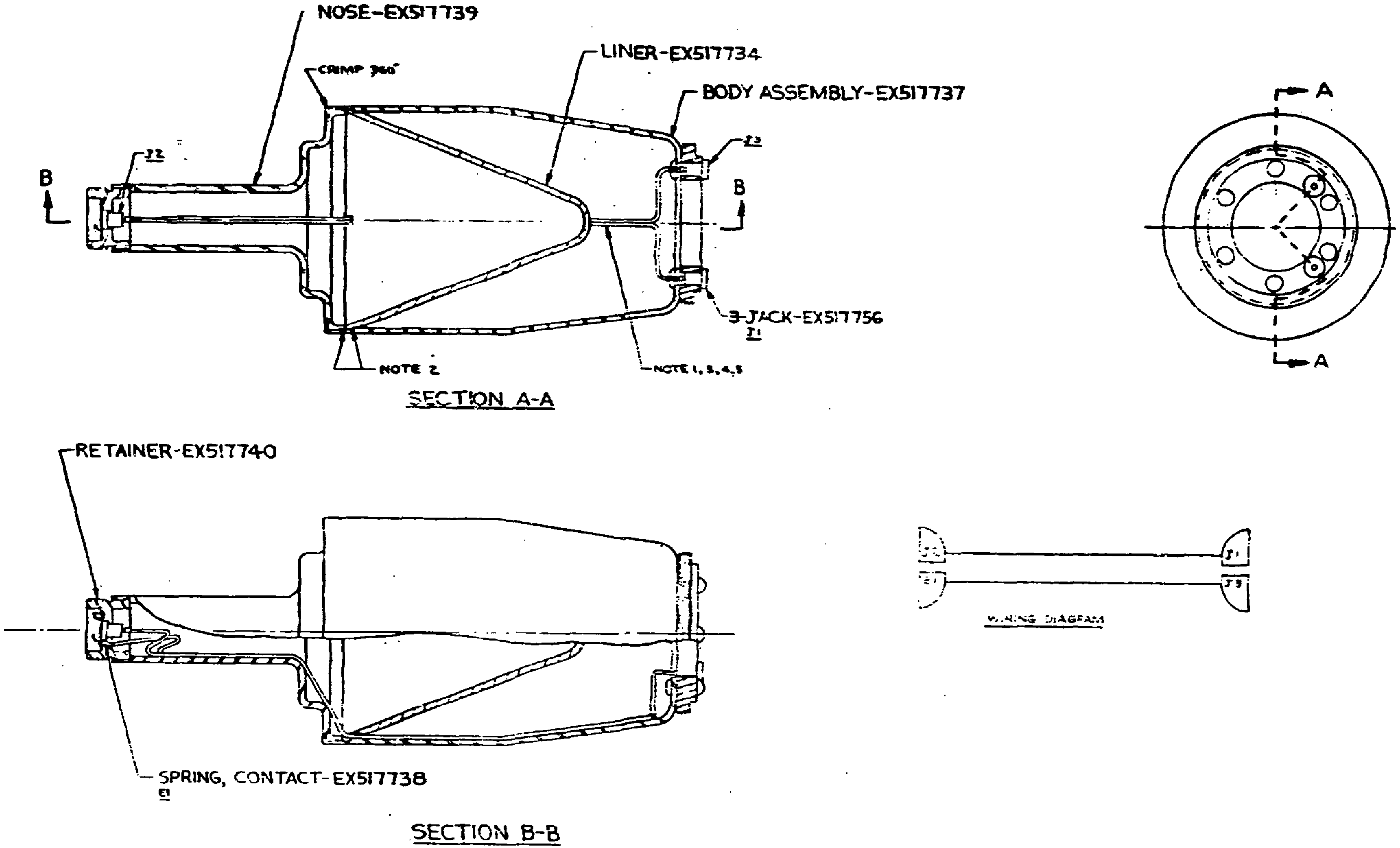
Figure 120 - REDESIGN OF ROCKEYE II FIN INSERT

(5) Electrical Circuit - As noted in the Introduction, the bomblet fuze was not within the scope of the N123(60530)33998A contract, although bomblet and fuze development were continually coordinated to ensure a compatible interface. However, the electrical connector between the impact sensing element and the base fuze was a developmental item within the scope of this program and the design and development of the conductor is discussed in this section of the report.

Two current paths are required to complete the circuit between the impact sensing element, which is located in the spiked nose of the bomblet, and the base fuze aft of and adjacent to the explosive head. The superquick initiating signal is passed through this circuit from the impact sensing element to the electric detonator in the base fuze.

In the Phase I design, a molded Teflon insulated wire containing two parallel conductors was attached and routed as shown in Figure 121.

Three of the four conductor contact leads were soldered to electrical connectors while the fourth was soldered to a spring clip that rested against the impact sensing element after it was assembled. The connectors used in this design had floating contacts so that alignment with the mating fuze connectors would not be a problem. The connectors were installed with a press fit; and the Teflon body, after installation, cold flows out over the mating part, locking the connector in place. The wire passed through a slot in the liner flange, and it was necessary to seal this slot with polyester adhesive to prevent explosive leakage during loading. The wire was held against the body and nose walls with aluminum tape.



1-ATTACH LEADS TO BODY AND NOSE WITH 3/8" WIDE ALUMINUM FOIL TAPE, PRESSURE SENSITIVE, SPEC MIL-T-11291 (MH SPEC 2005IP)
2-SEAL WITH G.E. RTV 102, OR SILASTIC 732, PRODUCT OF DOW CORNING CORP.
3-SOLDER ALL LEADS USING SOLDER, COMPOSITION Sn 60-63, SPEC QQ-S-571.
4-ALL LEADWIRE TO BE #26 AWG AND MUST CONFORM TO SPEC MIL-W-16878. (LENGTH AS REQUIRED)
5-INSULATE CONNECTOR LEADS USING INSULATION TUBING, ELECTRICAL, POLYTETRAFLUOROETHYLENE RESIN, NON RIGID, SIZE 17 AWG, SPEC MIL-I-22129.

Figure 121 - BOMBLET METAL PARTS ASSEMBLY

During Phase II the circuit was modified to eliminate the need for two electrically isolated leads by using the bomblet metal parts as a ground path. This required some modification to the metal parts. The finish on the nose and body was changed to reflowed electrodeposited tin, which provides a combination of good corrosion resistance and excellent conductivity. The finish on the aluminum adapter was changed to electroless nickel for better electrical conductivity. A stainless steel ground pin was riveted into the adapter. This pin was inserted into a socket connection in the base fuze and also served to index the fuze during assembly.

The electrically insulated circuit path was modified only slightly. The single wire was fed through a hole in the liner (approximately 0.250 inch up the cone) rather than through the notch in the flange. The wire diameter was controlled to 0.003 inch so that it would pass through the hole in the liner with a minimum of clearance, thus reducing the leak potential at this point.

The electrical connector mounted in the adapter flange was also changed. It was found that, under high temperature storage conditions, explosive exudate leaked out of the floating type connector. The connector was changed to a non-floating type, which is a structurally sealed assembly. Since the interfacing connector in the base fuze was of the floating type, satisfactory mating compatibility was assured. The non-floating connector was installed in the same manner as the one previously used. The contact spring was modified to eliminate the tang to which the second wire had been soldered, and its center hole was reduced in size so that it would be captured and retained in place by the flange of the insulated connector.

The final modifications made to the bomblet circuit were:

1. The adapter material was changed from aluminum to steel and the finish was changed from electroless nickel to electrodeposited reflowed tin.

2. The position of the feedthrough hole for the leadwire was moved from the cone of the liner to the flange.

The first change (1) eliminated the possibility of galvanic corrosion, which could affect circuit resistance, at the interface of the body and adapter. Substituting steel for aluminum also improved the crimp between the adapter and body. The increase in weight resulting from this substitution did not affect the stability of the bomblet. Change (2) facilitated threading the wire through the liner hole and permitted the RTV sealant, which was applied around the flange of the liner, to seal the wire at the same time. A sketch of the wire location is shown in Figure 122.

During the development program an investigation was conducted to determine if there were other methods that could be used to transmit the fuzing signal from the impact sensing element to the base fuze. The objective of the study was to define a circuit that was more economical and more compatible with high volume production than the one using wire routed through the liner. The following two circuit concepts were evolved and evaluated consequent to this investigation.

(a) Ribbon Conductor - This concept, shown in Figure 123, utilized a preformed ribbon conductor consisting of a 1/4-inch wide by 0.003-inch thick nickel strip coated with 0 002-inch Mylar film. The ribbon conductor was to be first cut, stripped, and formed, and then assembled in the following sequence:

1. Electrical connector installed in the nose.

2. Ribbon connector inserted into the nose and attached to the connector (the figure shows a welded connection although a mechanical connection could be used). An optional cellulose acetate liner on the inside of the nose is shown. This is used to eliminate the possibility of a short circuit if vibration should chafe away the insulation of the conductor.

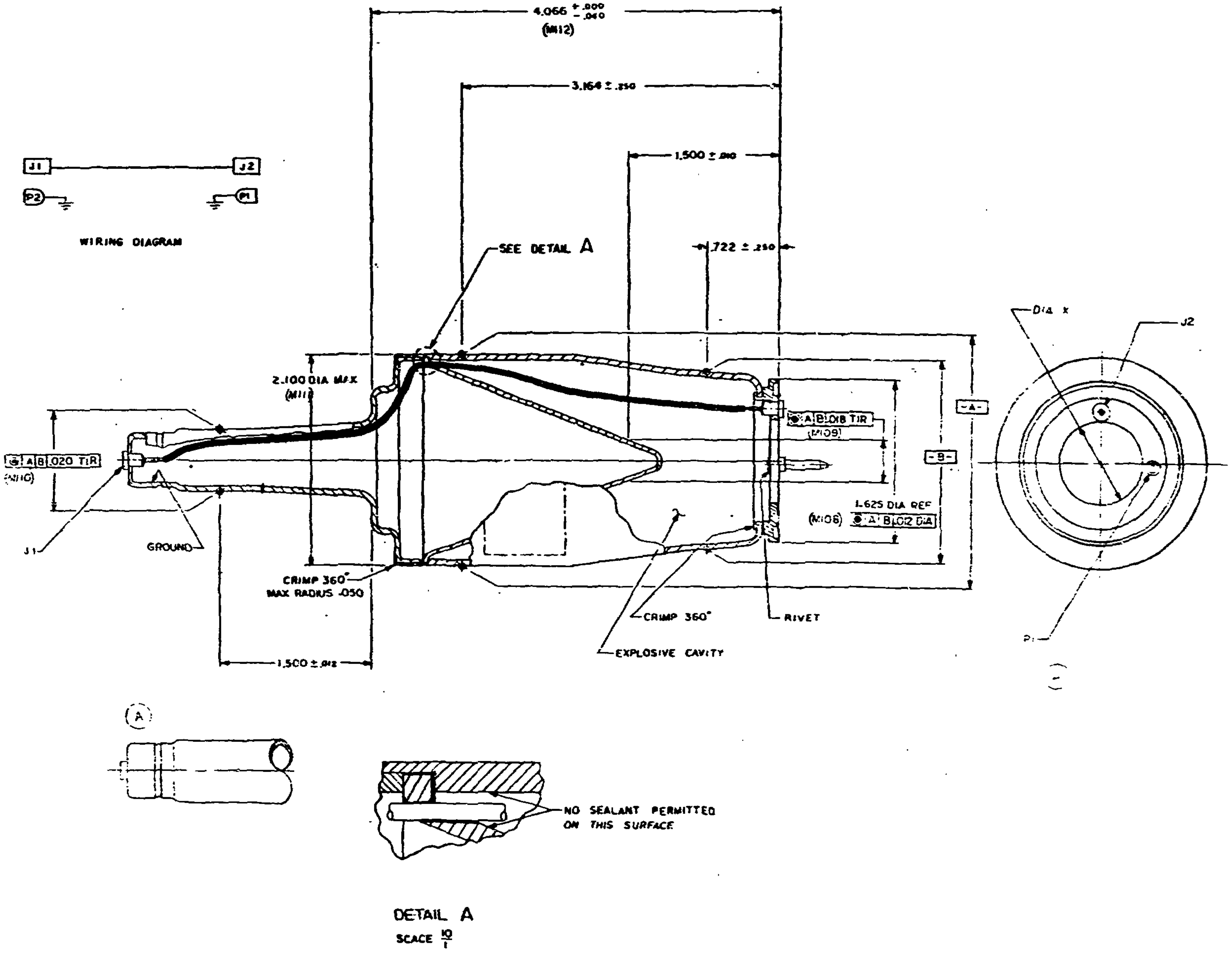


Figure 122 - LEADWIRE LOCATION

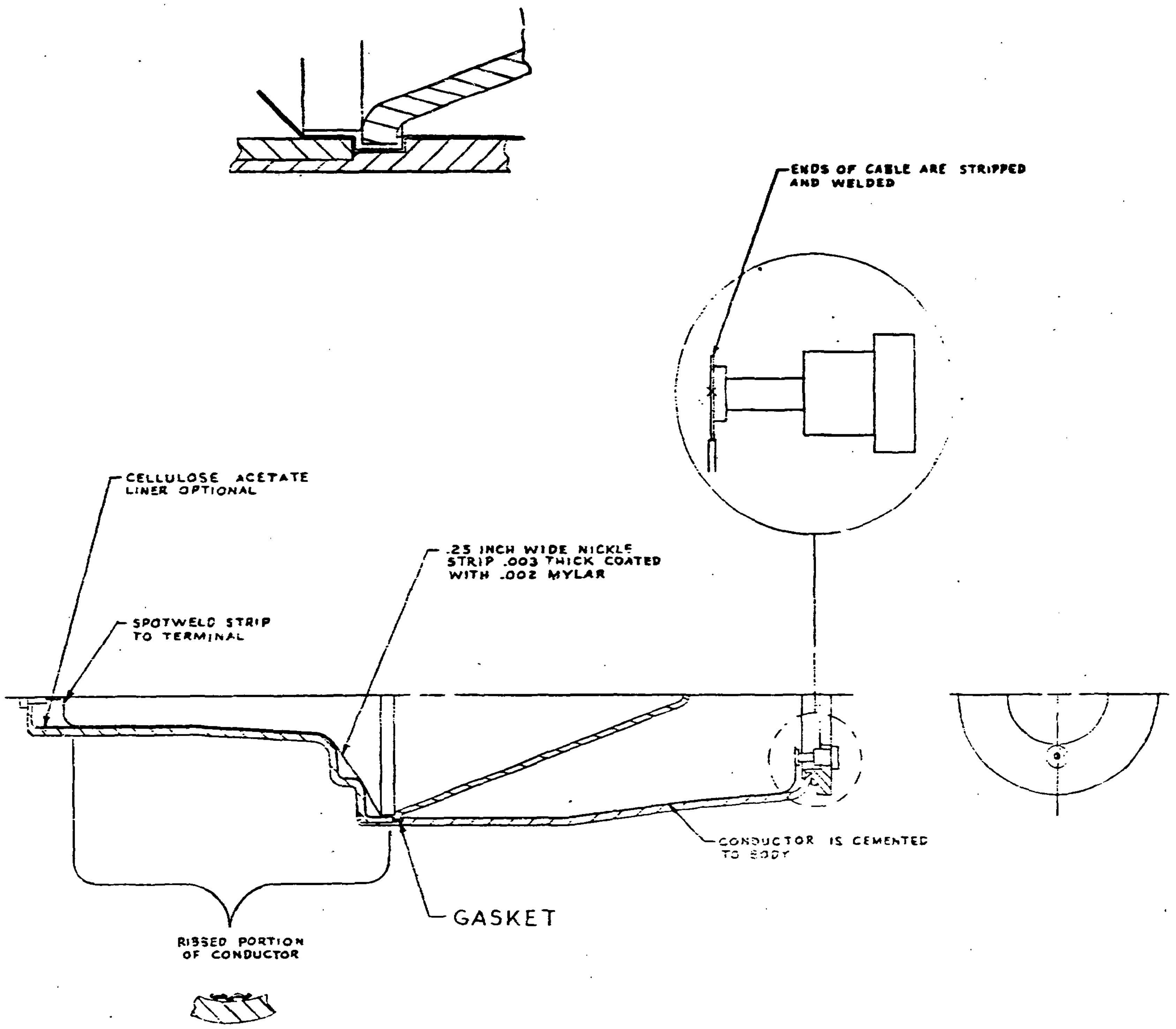


Figure 123 - RIBBON CONDUCTOR

3. Resilient material gasket (polyvinyl cloride or high density polyethylene) placed over the flange of the liner to seal the flange and to permit the ribbon conductor to by-pass the liner.

4. Body then oriented and placed over the nose and crimped in place. (A step was added to the body on which the nose seated to remove the compressive load from the gasket.)

5. Aft electrical connector (attached to the ribbon conductor after it was preformed) now snapped in position by allowing the reduced diameter of the connector to pass through a slot in the adapter.

During the investigation, it was determined that this concept had the following advantages and disadvantages.

Advantages:

- Eliminates the soldered connections and the necessity for threading the wire through the liner.
- Provides a gasket seal at the liner/body interface.
- Does not require orientation of the liner.

Disadvantages:

- Less accurate positioning of the liner.
- Additional cost for the special conductor, gasket, and liner.
- Difficulty of sealing the explosive cavity around the booster due to the slots in the adapter.

(b) Deposited Metal Conductor - The second concept considered is shown in Figure 124. In this approach the interior of the nose and the body and the outer surface of the nose (where it enters the counterbore of the body) were to be spray coated with a polyester film. A metal film would then be deposited on the plastic coating by a vapor or a spraying process.

The adapter was to be crimped in the body prior to application of the films, and assembly would take place in the normal manner. Special terminals would be used to mate with the metallic film as shown in the figure.

During evaluation, it was determined that this concept had the following advantages and disadvantages:

Advantages

- No additional parts or special assembly operations required.
- Very adaptable to automatic assembly techniques.

Disadvantages

- The liner could cut through the plastic film in assembly and cause a short circuit.
- A crack could develop at the adapter/body interface due to a blow or temperature extremes causing an open circuit.
- The vapor deposit process does not work well on internal surfaces.
- Maintaining electrical isolation at the body to nose crimp could be critical.
- The cost of developing a non-standard connector.

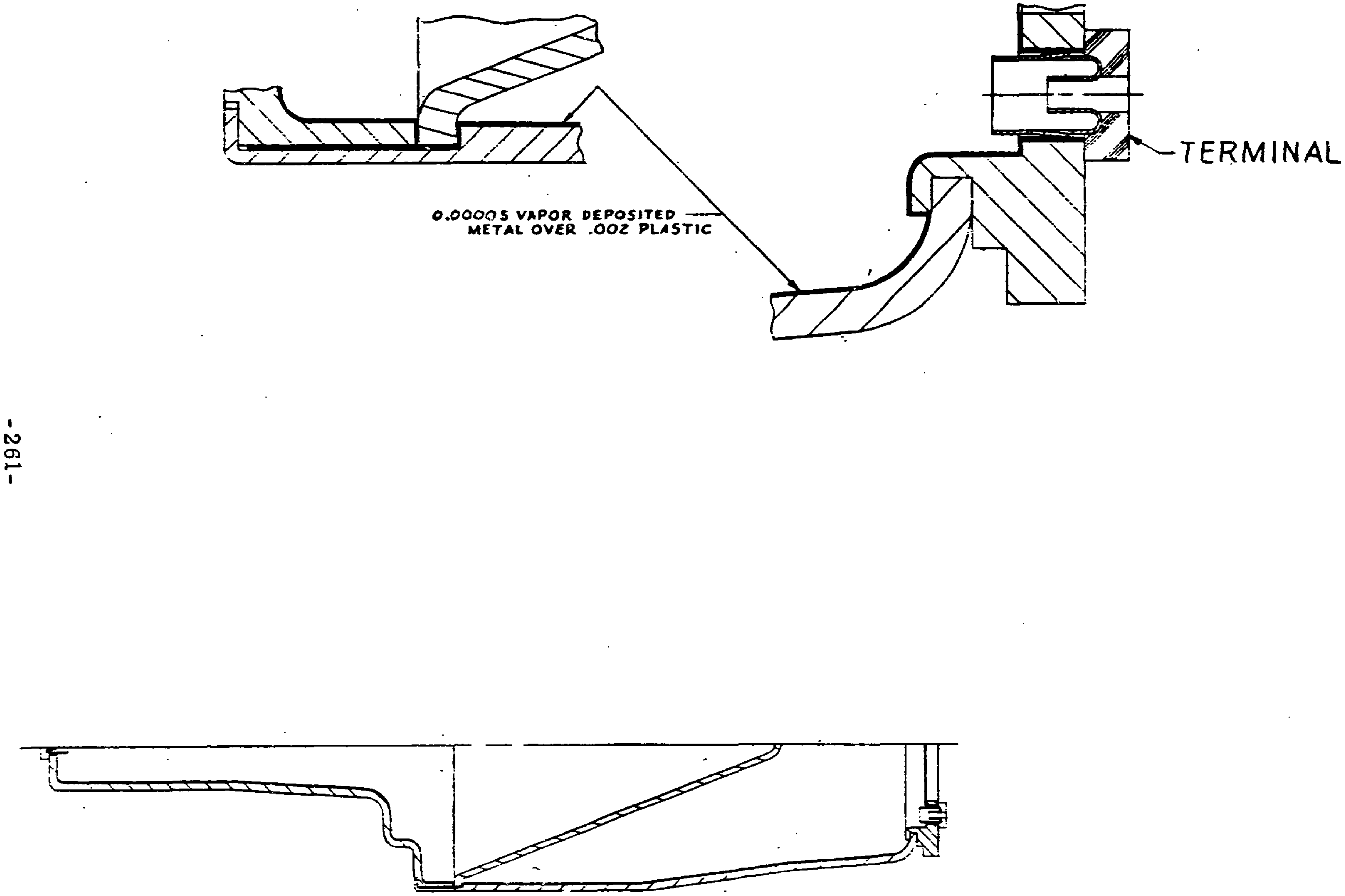


Figure 124 - DEPOSITED METAL CONDUCTOR

A cost analysis of the two concepts just discussed and the present conventional circuit indicated that the development effort necessary to incorporate either one would not justify the small amount of savings which could be realized. With respect to function, the ribbon conductor approach could seriously affect the penetration performance of the bomblet, while the circuit reliability of the second concept under all environments was questionable.

No other changes were made in the design of the electrical concept during the development program.

3. Description of Final Design

The final design of the bomblet is described in this section of the report in terms of physical and functional characteristics. The bomblet is shown in Figure 125 and the structural analysis covering this configuration is contained in Appendix G. The end item was designated the Mark 118 MOD O Anti-Tank Bomb and this designation is used in the following discussion to indicate the complete munition.

a. Physical Characteristics

The Mark 118 MOD O Antitank Bomb consists of a shaped charge kill mechanism; a discriminating type (dual mode function) electro-mechanical fuze; and nose, body, and tail fin sections. The complete assembly weighs 1. 33 pounds and is 13. 54 inches in length and 2. 1 inches in diameter (maximum). The shape of the bomblet (shown in Figure 128) reflects considerations inherent in providing (a) structural support to the fuze and mechanism, (b) an aerodynamic configuration compatible with the intended application and environment, and (c) a packing interface enabling maximum utilization of the dispenser cargo space.

Figure 125 - FINAL DESIGN, MK 118 MOD O ANTI-TANK BOMB

The parts making up a Mark 118 MOD O Antitank Bomb assembly are described in the following paragraphs:

(1) Contact, Electrical

This part, used to assure a good ground contact between the impact sensing element and the nose of the metal parts assembly, is manufactured by stamping the piece from spring temper, phosphor bronze strip stock. This material was selected because it contained the necessary spring qualities and is commonly used in electrical contacts without the necessity of a protective finish. The part is shown in Figure 126.

(2) Jack, Floating Contact

The floating contact jack is purchased as a stock item, and it provides an electrical connection with the impact sensing element and electrically isolates the circuit from ground. The floating contact allows for minor misalignment with the probe of the impact sensing element. The jack is assembled by a press fit in a hole in the nose, and the Teflon body then cold flows outward locking it in place. The part is shown in Figure 127.

(3) Nose

The nose provides the correct standoff distance for the shaped charge and the required spring rate on impact for activating the impact sensing elements discrimination feature. The nose also functions as part of the fuzing ground circuit and has the necessary geometry for crimp fastening the impact sensing element. The unit is stamped out of a cold rolled steel which was selected because its deep drawing qualities and physical properties provide the nose with the required strength and spring rate at impact. During fabrication, the nose surface is finished with electro-deposited tin which is then reflowed. This surface treatment provides excellent corrosion resistance and electrical conductivity. The part is shown in Figure 110.

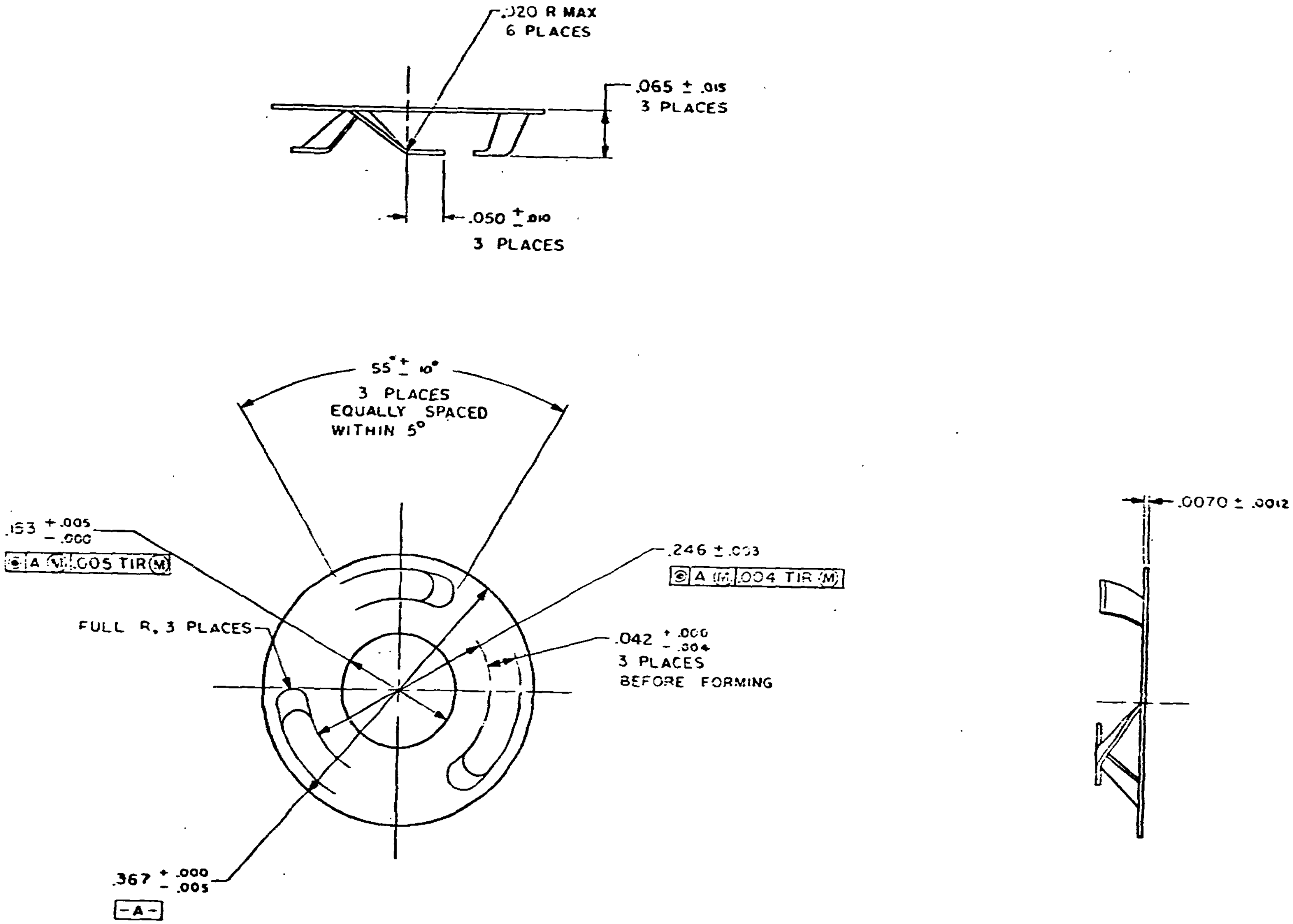


Figure 126 - SPRING, CONTACT

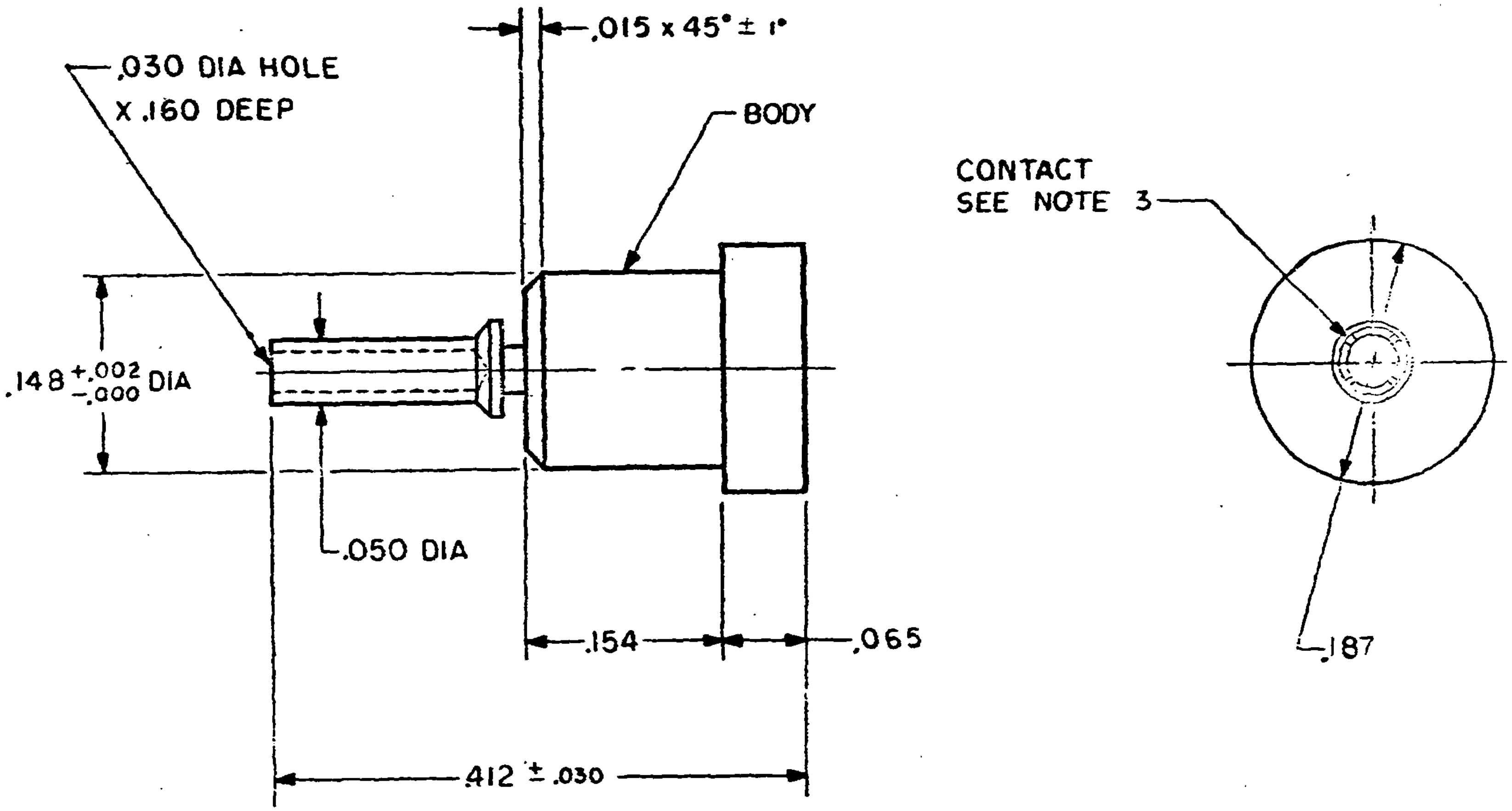


Figure 127 - JACK, FLOATING CONTACT

(4) Body

The body provides the case for housing the shaped charge liner and high explosive. It is shaped to permit stacking of the individual bomblets and to permit the air flow to reach the base fuze arming vane. This part,like the nose,is made from deep drawing quality steel by stamping, trimming, and then machining the counterbore into which is seated the liner and nose. The body material was selected for its drawing qualities and the fragmentation it produced upon shaped charge detonation. This part also is given the reflowed electrodeposited tin plate for corrosion resistance and electrical conductivity. The part is shown in Figure 128.

(5) Liner

The liner provides the geometric shape to ensure maximum penetration of the shaped charge. It is manufactured from powdered metal by metallurgical techniques using granular copper purchased to a specific sieve analysis. This process was chosen because it was the most economical way to produce the liner to the required dimensions for optimum penetration. The geometry of the liner was determined in a development program during which various shaped charge parameters were investigated. The part is shown in Figure 129.

(6) Adapter

The adapter is used to provide the interface between the base fuze, the body, and the fin assemblies. It must provide adequate strength to survive the high impact loads to which the fin assembly is subjected upon being released from the dispenser. It is also a part of the electrical ground circuit. The part is manufactured on a screw machine and is made from leaded, free machining steel, which was selected for its machinability and ease of crimping. Since steel is also used in the body (to which the adapter is assembled), the possibility of galvanic corrosion is precluded. This part is also reflowed electrodeposited tin plated. The part is shown in Figure 112.

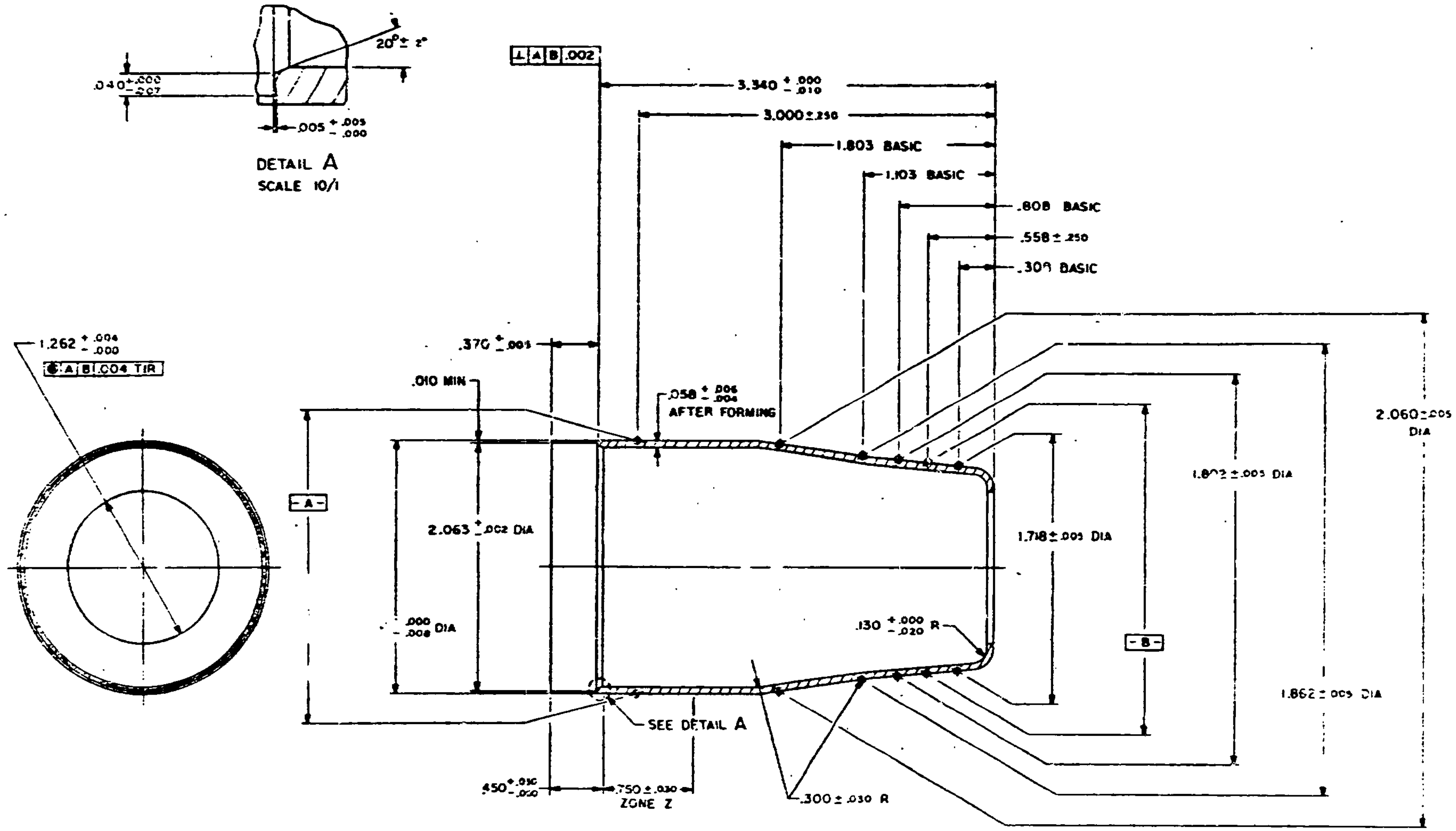


Figure 128 - BOMBLET BODY, FINAL DESIGN

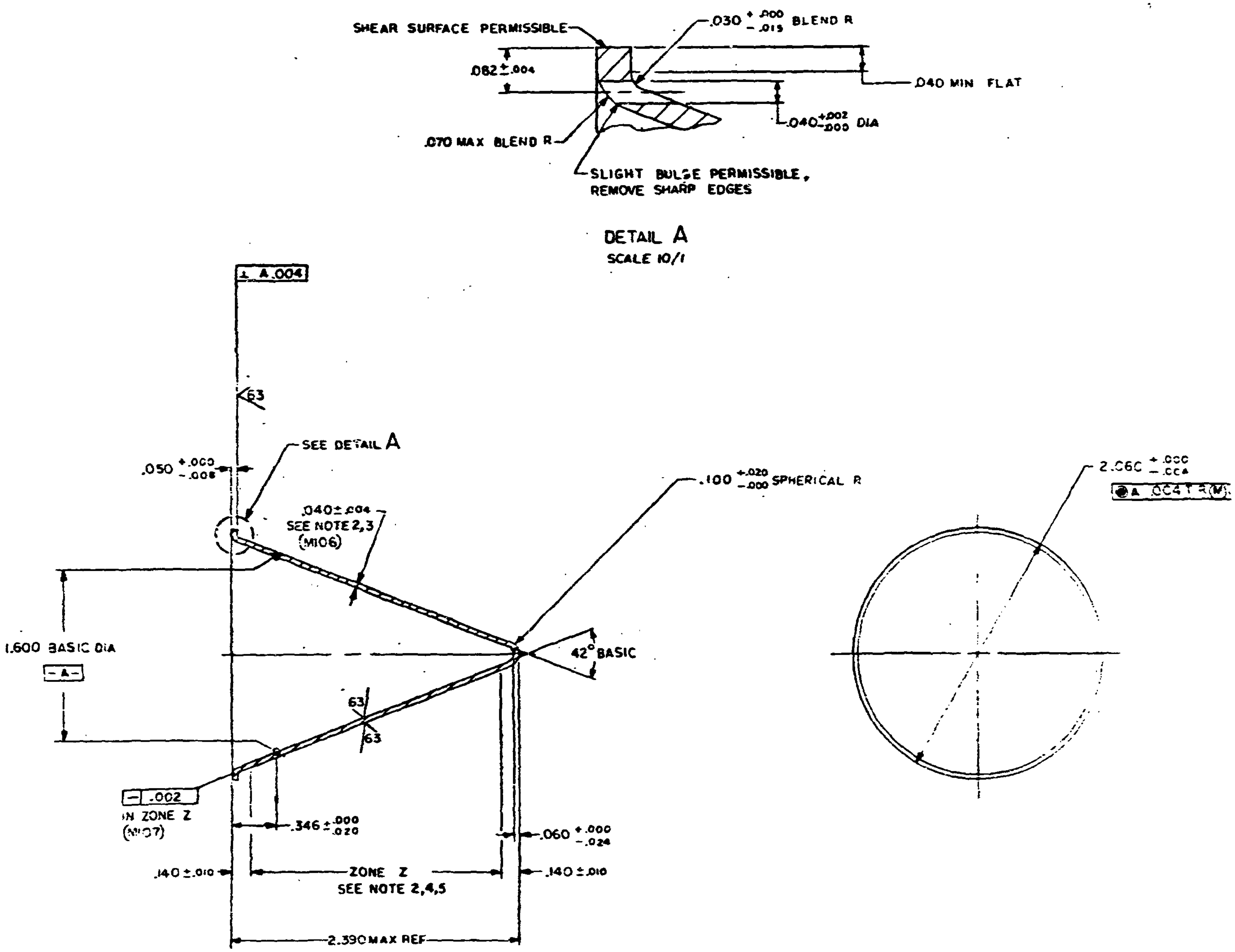


Figure 129 - SHAPED CHARGE LINER, FINAL DESIGN

(7) Contact, Electrical, Ground

The electrical ground contact provides the ground connection for the base fuze assembly. It also is used as an indexing pin to assure proper assembly with the base fuze. The unit is made on a screw machine from type 303 stainless steel, selected because of its corrosion resistance and strength. This part projects out from the assembly and is subject to rough usage during handling. This part is shown in Figure 130.

(8) Jack

This part is a purchased stock item and is similar to Figure 130(floating contact jack) except it does not contain a floating contact. The jack provides the electrically isolated circuit connection with the base fuze. It is constructed so that, when assembled, it will provide a sealed unit. The jack assembles with a press fit into the adapter and is locked in place when the Teflon body cold flows out. The part is shown in Figure 131.

(9) Insert

The insert is molded into the fin assembly,and in the Mark 118, MOD O Antitank Bomb,it serves as the crimp ring that secures the fin assembly to the adapter, capturing and retaining the base fuze cover in the process. The part is a stamping and is made from stainless steel strip. This material was selected because its physical properties enable it to withstand the loads imposed on the crimp. It also does not require a protective finish which could be marred during the crimp operation. The part is shown in Figure 132.

(10) Fin Assembly

The fin assembly provides the necessary aerodynamic features to orient and stabilize the bomblet in flight. It also provides a shroud around the

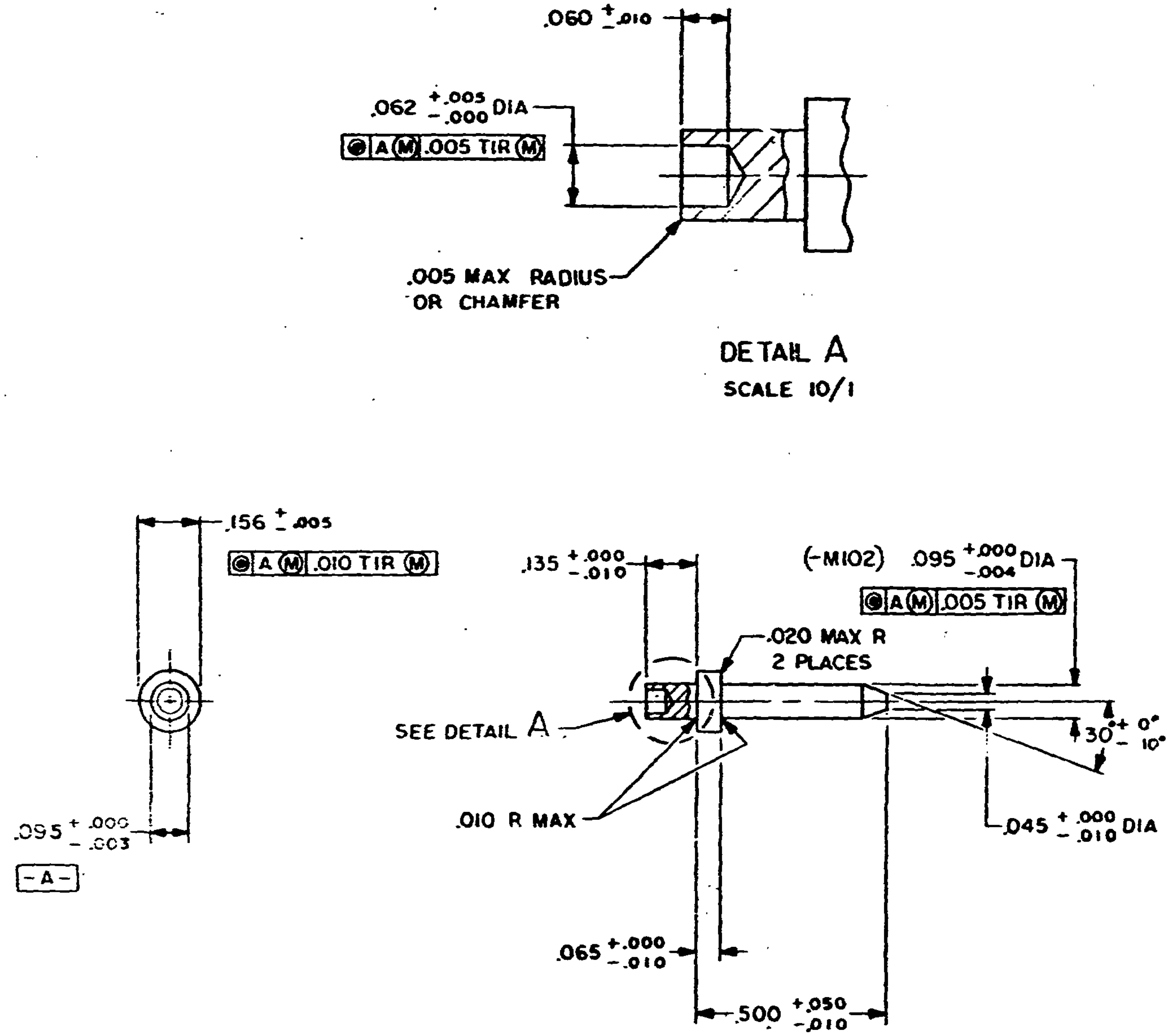


Figure 130 - ELECTRICAL CONTACT, FINAL DESIGN

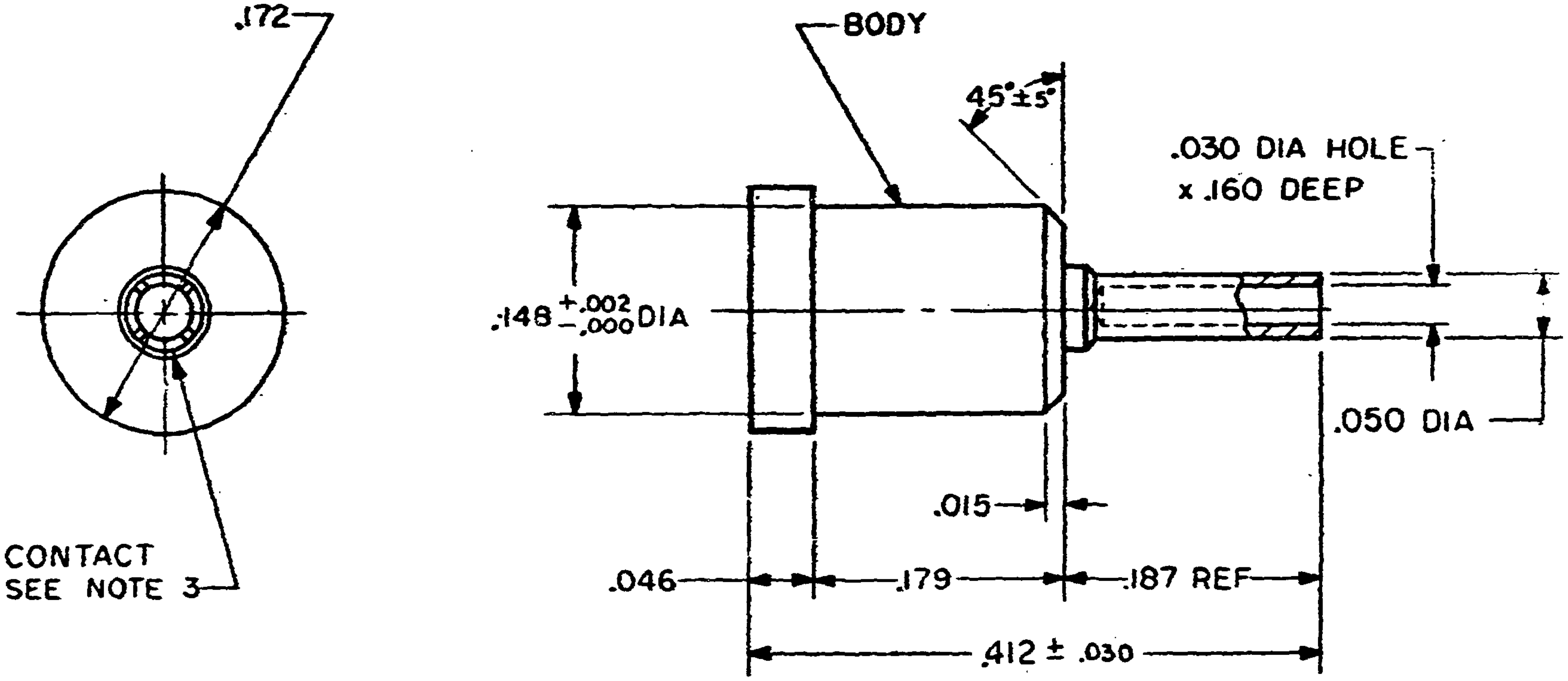


Figure 131 - ELECTRICAL CONNECTOR, FINAL DESIGN

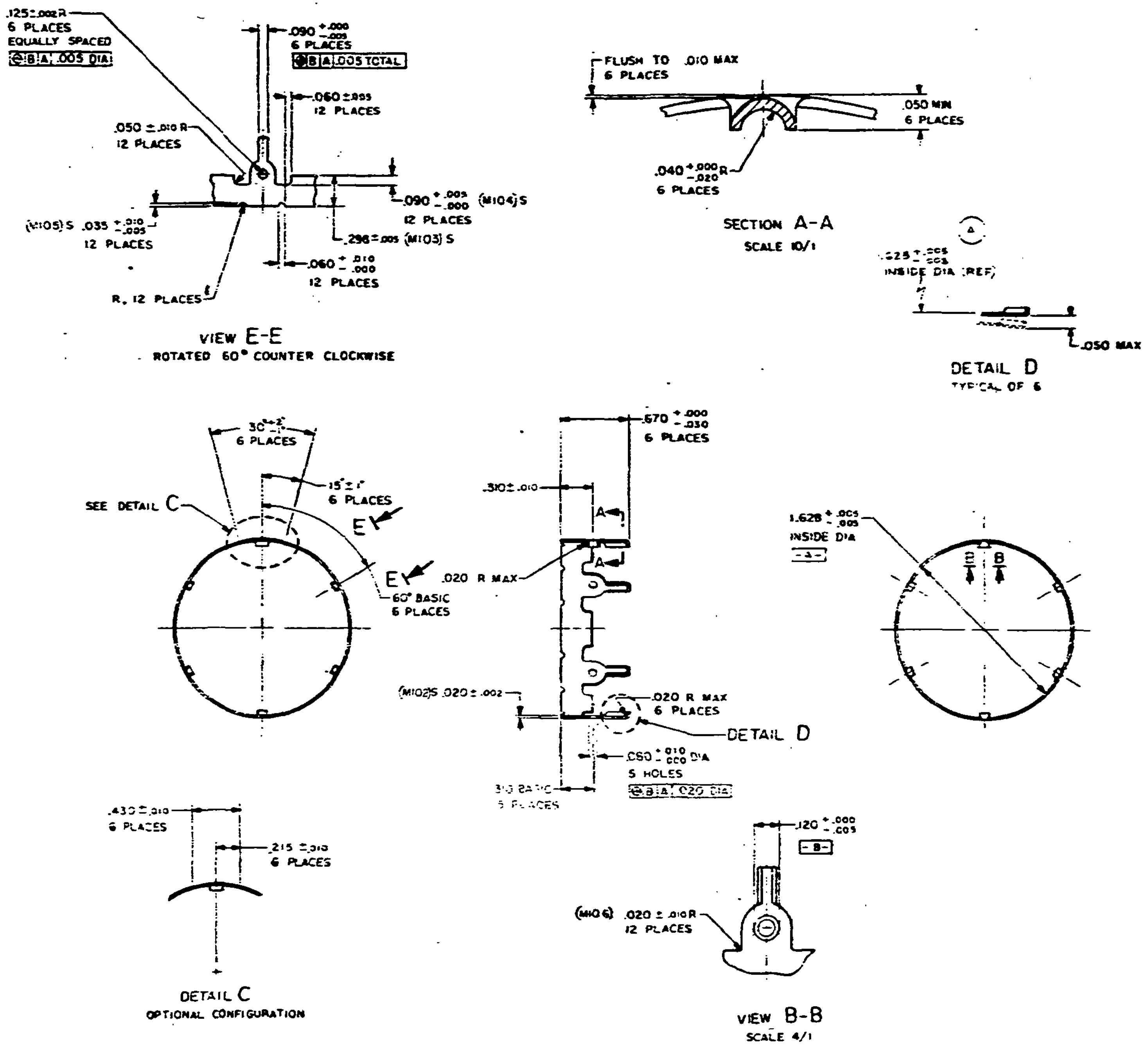


Figure 132 - INSERT, FINAL DESIGN

base fuze assembly vane which protects it from damage and ducts the air flow into the vane. The part is injection molded with the insert (Part No. 1569568) molded in place. The fin assembly is made from Zytel 31 Nylon (Nylon 6/10) and contains a 40% fill by weight of glass fibers. This material was selected after a comparative impact test with other types of plastic and aluminum. Drop tests of weapons containing bomblets with fins of this material showed the least amount of breakage. The requirements for the fin material are that the material must have high impact resistance and not deform under impact (which could result in aerodynamic perturbations). The material selected has its yield point and ultimate strength at the same stress level. The part is shown in Figures 133 and 134.

(11) Cup, Booster

The booster cup serves to house the booster pellet, thus keeping the booster explosive physically isolated from the high explosive. The cup is stamped from 0. 005 thick aluminum foil. This material was selected because it is easily formed and does not detract from the explosive output of the booster. The part is shown in Figure 135.

(12) Cover, Booster

The booster cover, like the booster cup, is used to protect the booster pellet. The part is made by stamping from the same type material and for the booster cup. The part is shown in Figure 136.

(13) Pellet, Booster

The booster pellet is made by pressing RDX explosive composition CH-6 to the desired shape. The density of the pellet is 1. 65 ± . 03 grams per cubic centimeter. The pellet is used to provide the required explosive output to detonate the Octol high explosive. The pellet also has the required sensitivity

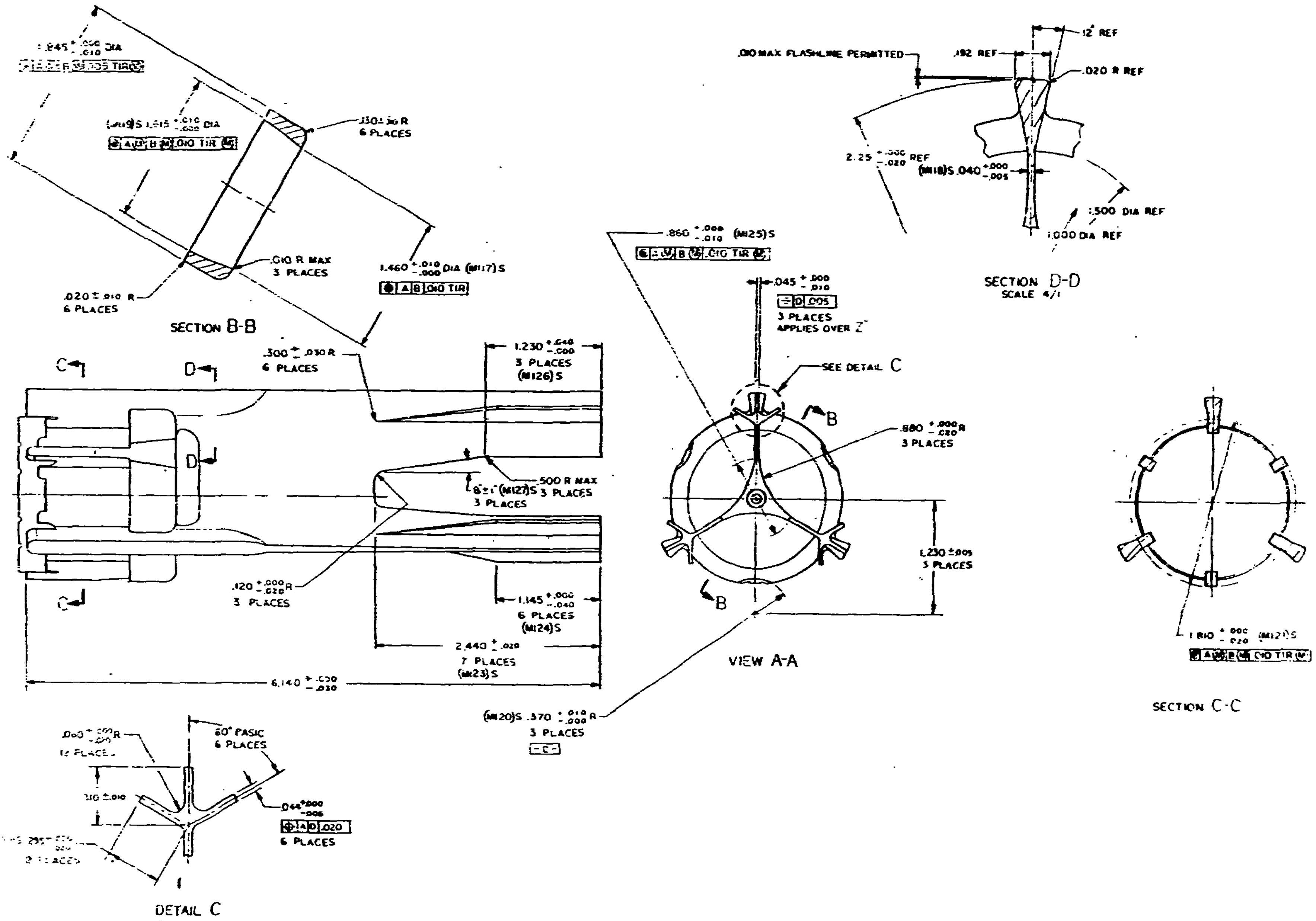


Figure 133 - FIN ASSEMBLY, FINAL DESIGN

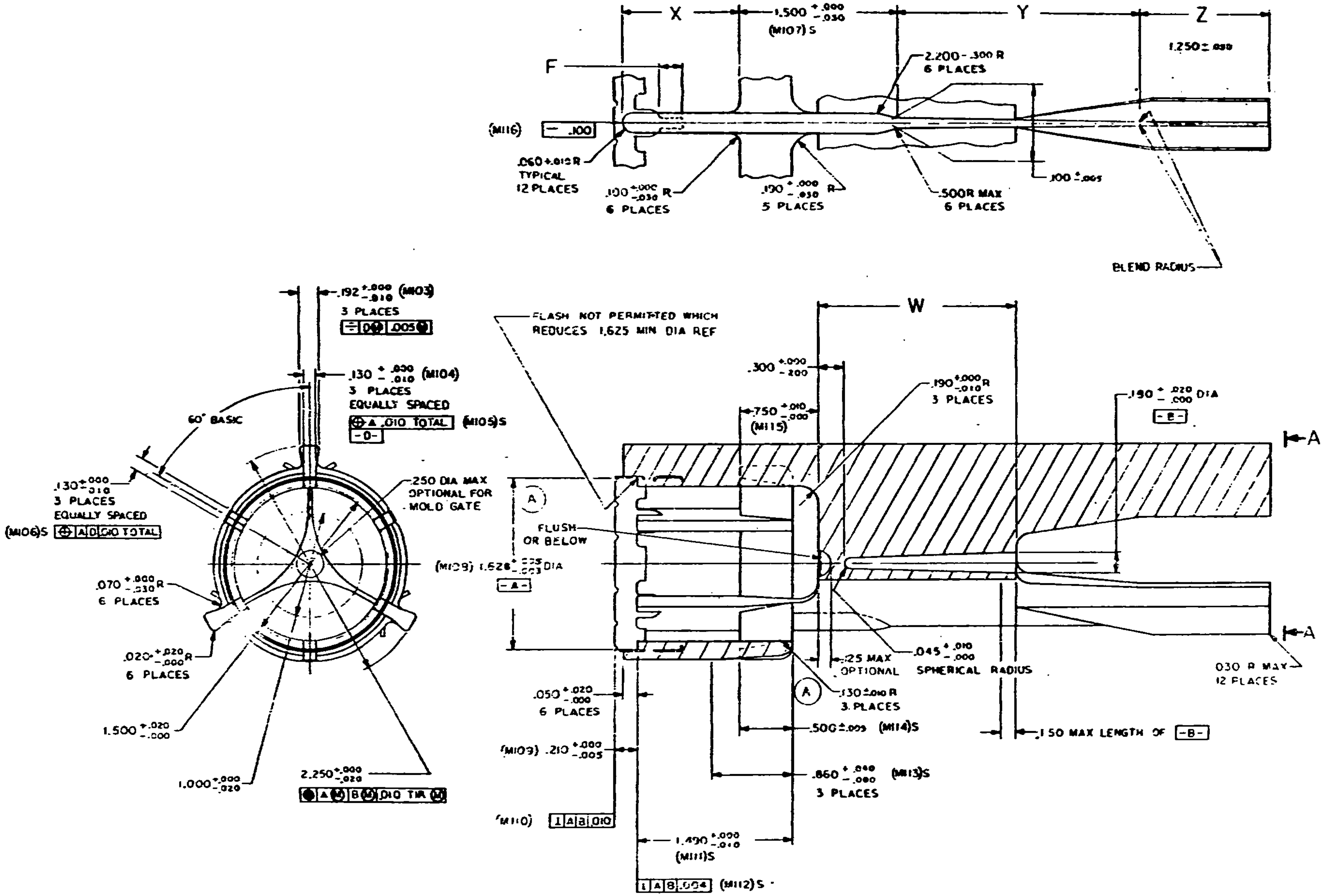


Figure 134 - FIN ASSEMBLY, FINAL DESIGN

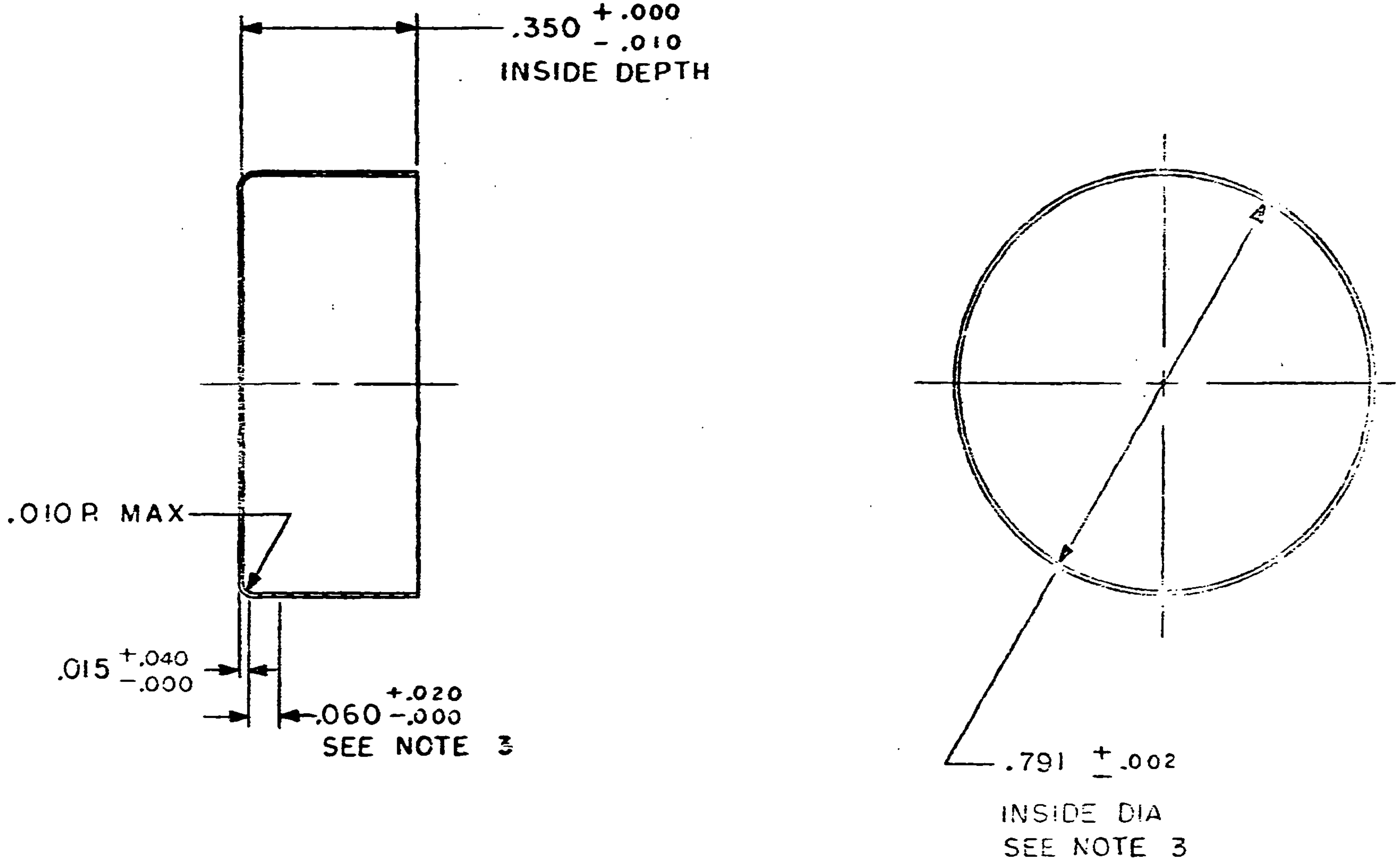


Figure 135 - BOOSTER CUP, FINAL DESIGN

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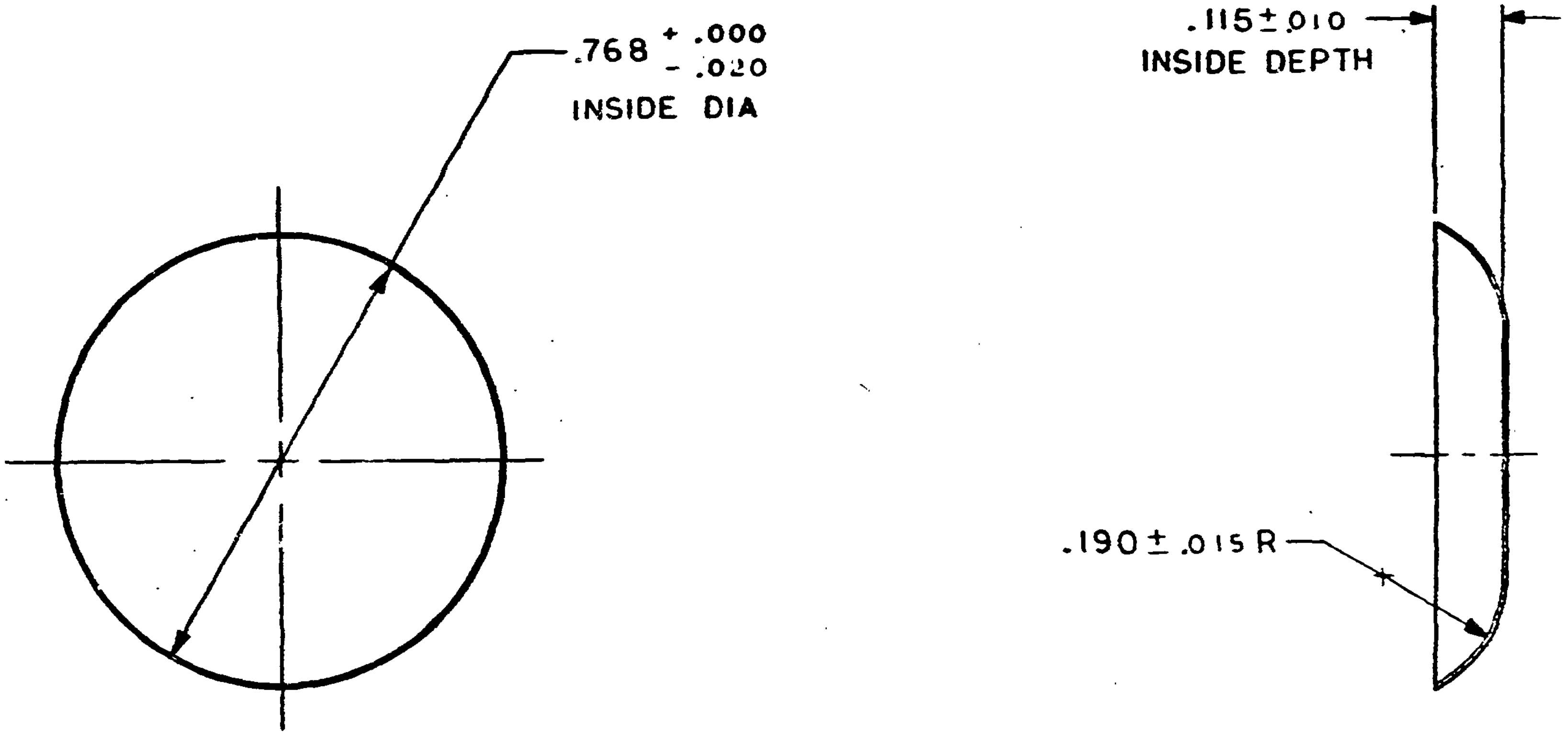


Figure 136 - BOOSTER COVER, FINAL DESIGN

CONFIDENTIAL

to be detonated high order by the tetryl lead in the base fuze assembly. The part is shown in Figure 137.

(14) Booster Assembly

The booster assembly consists of the cup, cover, and pellet previously described. The part is shown in Figure 138. Assembly is accomplished by crimping the edge of the cup over the cover. This crimp interface is later sealed with room temperature vulcanizing sealant when the booster assembly is installed in the loaded warhead.

The parts described above are all components of the Metal Parts Assembly as shown in Figure 139. The sequence of operations for the assembly follow:

(a) The adapter (Figure 112) is crimped into the body (Figure 111).

(b) The jack (Figure 131) is soldered to the proper length of Teflon coated wire.

(c) The contact, ground (Figure 130) is staked into the adapter.

(d) The jack (Figure 131) is installed by threading the wire through the hole in the adapter and then pushing the jack, which is a press fit, into the adapter. The Teflon body then cold flows over the adapter locking the jack in place.

(e) Apply sealant (RTV) to counterbore of body, and remove any excess from interior body surface.

(f) The liner (Figure 129) is installed in the body counterbore. During installation of the liner, the wire is threaded through the leadwire hole in the liner.

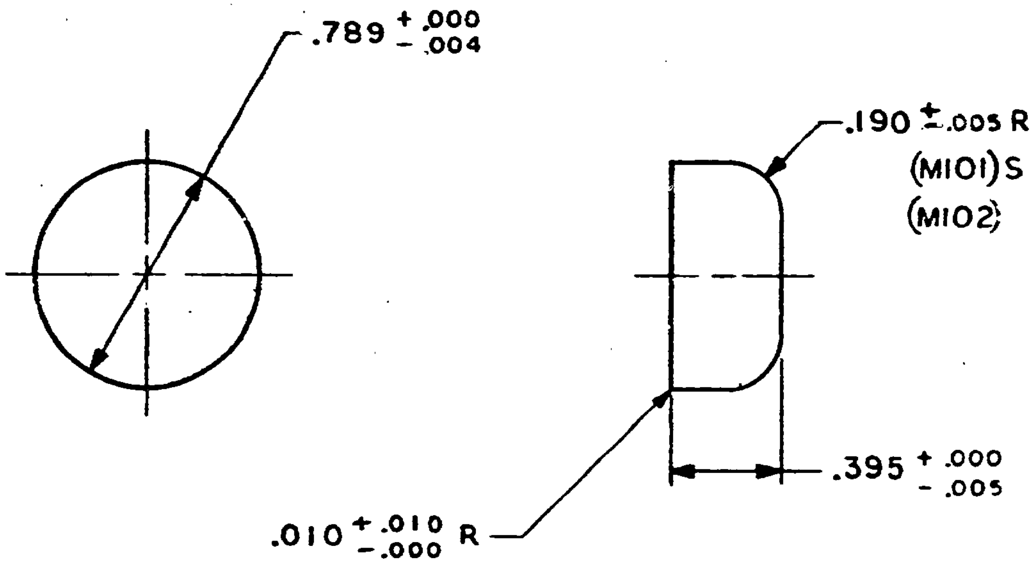


Figure 137 - BOOSTER PELLET, FINAL DESIGN

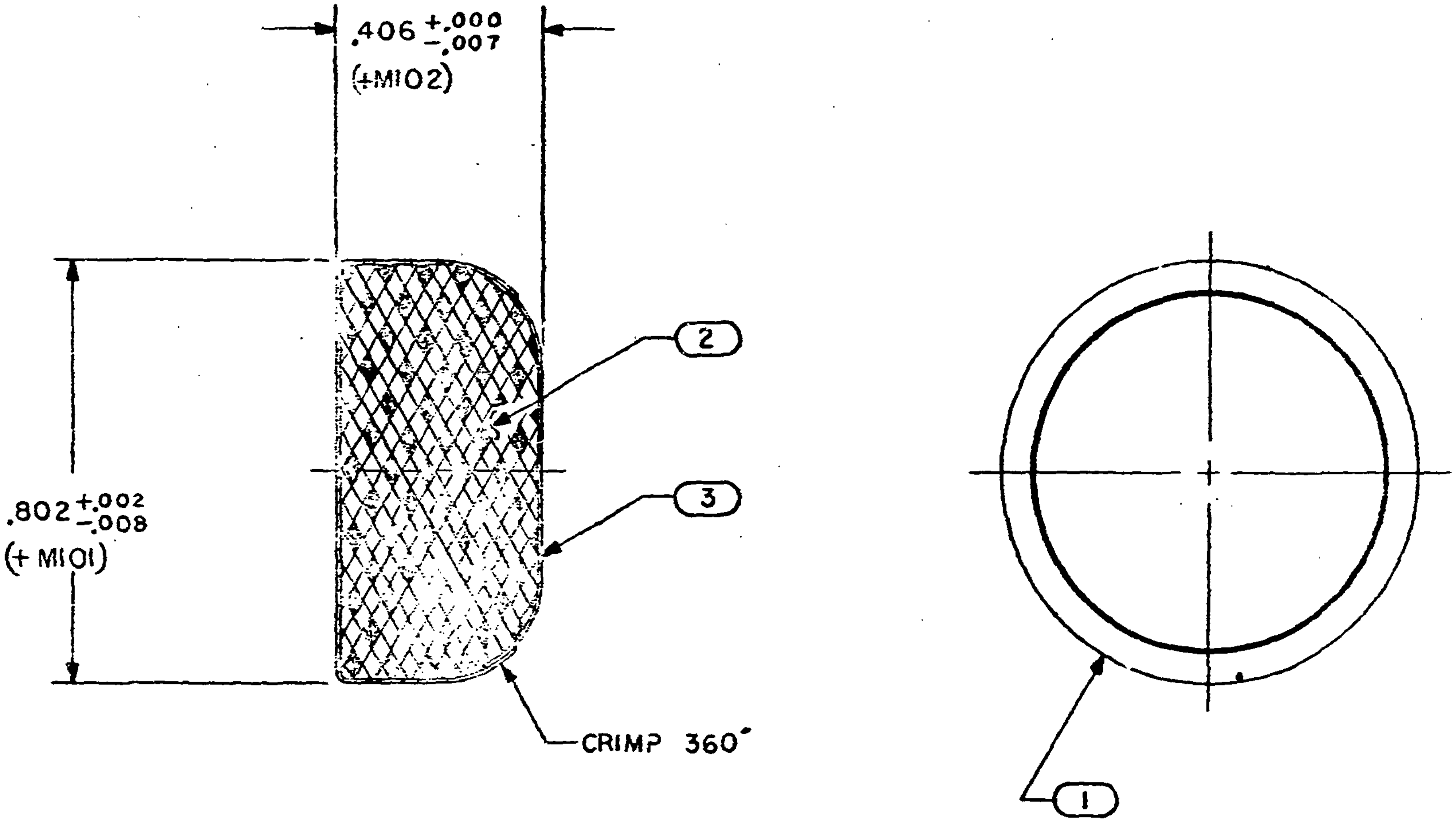


Figure 138 - BOOSTER ASSEMBLY

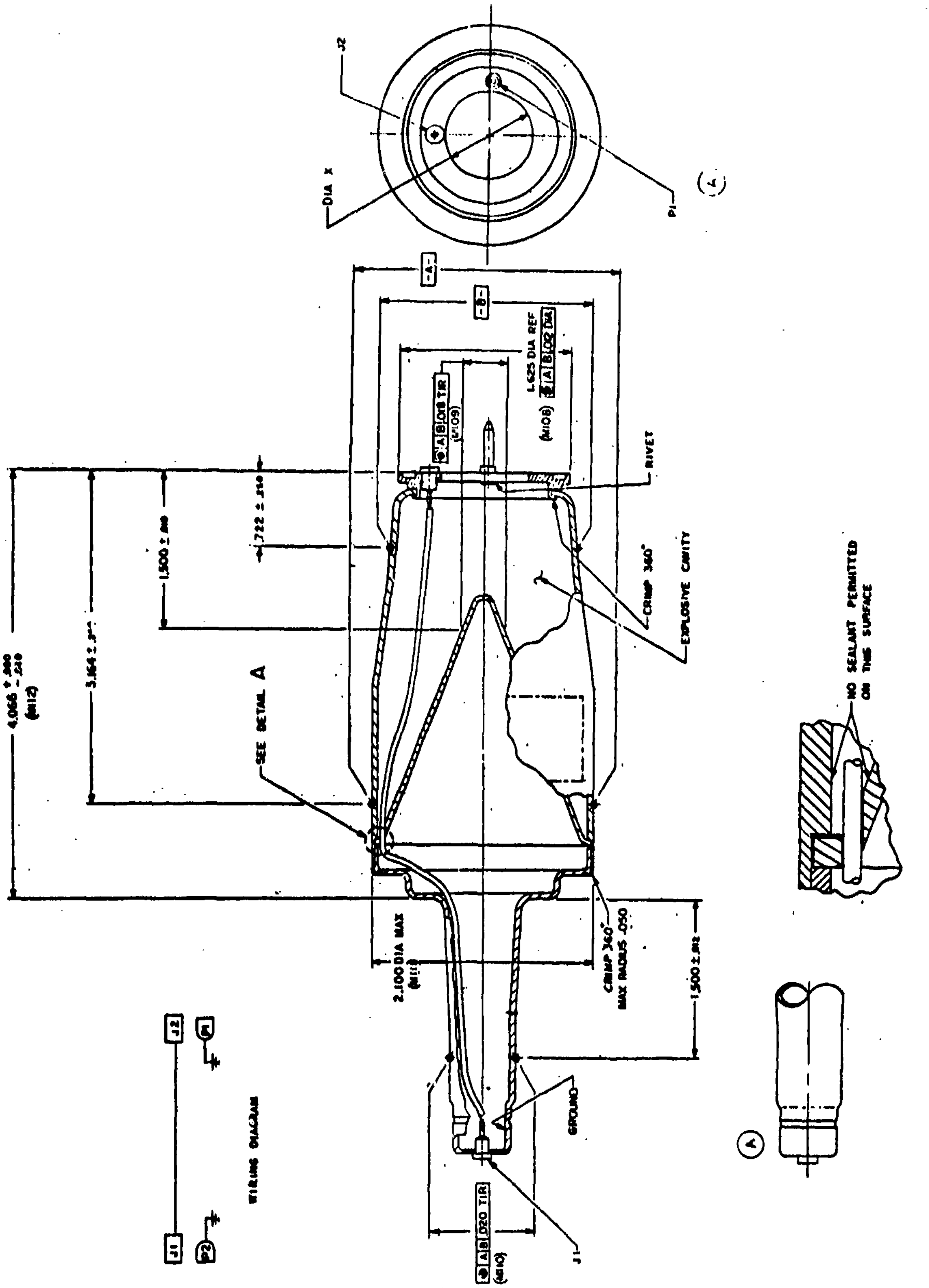


Figure 139 - METAL PARTS ASSEMBLY

(g) Apply RTV sealant to leadwire/liner interface.

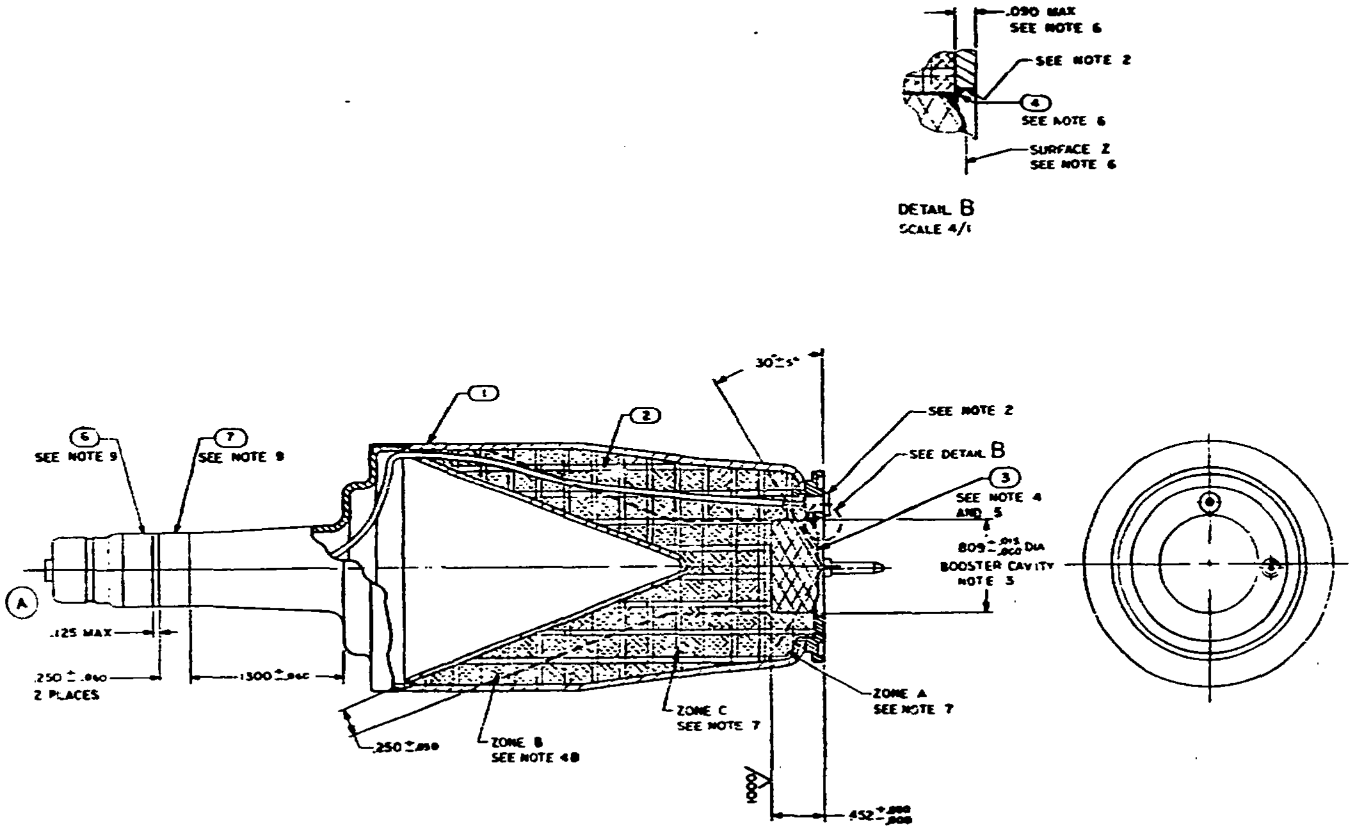
(h) The nose (Figure 110) is then installed in the body counterbore next to the liner. During this operation the wire is threaded through the hole in the nose. The nose and the liner are oriented and then retained in place by a 360 degree crimp on the body edge.

(i) The spring, contact, (Figure 126) is then dropped over the wire, and the jack, floating contact, (Figure 127) is soldered to the wire and pushed (press fit) into the nose capturing and locating the spring, contact.

This completes the assembly of the metal parts (Figure 139), and the bomblet is now ready for explosive loading. The metal parts assembly, loaded is shown in Figure 140. The 75/25 Octol explosive is cast by pouring through the hole in the adapter. Upon cooling, the riser is broken off and the booster cavity is machined. The booster assembly is then installed in the cavity and sealed with RTV sealant between the booster and adapter. Loaded assemblies are then X-rayed on a sampling basis to verify the quality of the explosive load. Final assembly of the Mark 118, Mod 0 is accomplished by crimping the impact sensing element to the nose and installing the base fuze and fin assembly by crimping the fin insert to the adapter.

b. Functional Characteristics

The Mark 118 Mod 0 Antitank Bomb is an aircraft delivered antitank munition that is also highly effective against personnel and material targets. Upon release from the dispenser, the bomblets separate and assume stable free flight. The high drag surface at the base of the bomblet nose provides a terminal velocity of approximately 250 feet per second, a speed consistent with maximum utilization of the shaped charge upon impact initiation.



NOTE:

(M101)S 1. EXPLOSIVE CAVITY AND SURFACES OF EXPLOSIVE CAVITY SHALL BE FREE OF FOREIGN MATERIAL BEFORE LOADING. SEE DD FOR DESCRIPTION OF ONE SUITABLE METHOD OF LOADING.

(C1) 2. NO EXPLOSIVE PERMITTED, IN AREA INDICATED OR ON ANY OTHER EXTERIOR SURFACES.

3. [illegible] IN BOOSTER CAVITY PERMITTED WITHIN PRESCRIBED TOLERANCE.

4. ITEM 3 SHALL BE FREE OF FOREIGN MATERIAL AND [illegible], TEARS, HOLES OR OTHER DISCONTINUITIES.

(M102) 5. ITEM 3 SHALL BE FULLY SEATED IN 0.809 BOOSTER CAVITY.

(M103) 6. SEAL WITH ITEM 4 OR ITEM 5. SEAL FILLET SHALL BE CONTINUOUS WITHOUT VOIDS AND FLUSH OR BELOW SURFACE Z.

(M104) 7. ASSEMBLY SHALL MEET RADIOGRAPHIC INSPECTION REQUIREMENTS OF [illegible].

8. SUMMARY OF ANNOTATED CLASSIFICATION OF CHARACTERISTICS ON THIS DRAWING TO BE VERIFIED IN ACCORDANCE WITH MIL-STD-105 UNLESS OTHERWISE SPECIFIED.

CRITICAL (C1) THRU (C2)
MAJOR (M101) THRU (M104)
MINOR ( ) THRU ( )

UNLESS OTHERWISE SPECIFIED UNLISTED CHARACTERISTICS AND CHARACTERISTICS WITH THE SUFFIX S (SPECIAL) SHALL BE VERIFIED TO THE SATISFACTION OF THE GOVERNMENT REPRESENTATIVE.

(C2) 9. APPLY COLOR CODE BANDS AT POSITION SHOWN USING ITEM 6 AND ITEM 7.

Figure 140 - LOADED METAL PARTS ASSEMBLY

Fuze arming is accomplished by the wind stream through the fin shroud activating the vane arming device. At bomblet speeds in excess of 200 knots, the fuze is normally armed after a delay of from 0.9 to 1.4 seconds.

Upon striking the target, the fuze functions in one of two modes depending on the resistance of the impact media. If the target has a high resistance (1/16-or plus inch thick mild steel plate), the impact sensing element in the nose functions in the superquick mode (35 to 76 microseconds), generating an electrical current which is transmitted to and initiates the base fuze. On targets having a resistance comparable to or less than that of 1/4-inch plywood, the nose element does not receive sufficient impact force for activation. In this case the base delay element, which has a functional delay of from 445 to 1825 microseconds depending on the angle of impact, initiates the fuze.

This two-mode, or discriminating, functional capability enables the bomblet to defeat countermeasures such as sandbags or light framework standoffs used to protect tanks. The slight delay the fuze provides on impacting the countermeasure structure allows the bomblet to penetrate sufficiently so that the shaped charge is positioned for maximum effectiveness when detonated. A concomitant advantage, greater effectiveness against light materiel targets, was attained with this arrangement. The bomblet will penetrate such targets (aircraft skins, improvised storage shelters, POL tanks) before detonating so that the maximum effect of the shaped charge , blast and lateral fragmentation is realized.

C. DEVELOPMENT GOALS VERSUS PROGRAM ACHIEVEMENTS

The MK 118 MOD O Antitank Bomb has completed many of its final qualification tests, and the results convincingly testify to its effectiveness against heavy tanks, personnel, and materiel. Consequently, the major development goal--a munition with a high lethality against a range, or a complex, of tactical targets--was fully achieved.

Determining the shaped charge configuration that would provide the penetration desired was one of the major efforts associated with the program. Through a detailed and comprehensive investigation, the parameters influencing penetration were varied and empirically evaluated until an optimum shaped charge design was established. It must be regarded as fortunate that during the development effort the penetration capability of the unit declined, necessitating detailed analyses of the fabrication materials and processes - fortunate because the investigation results provided information enabling the establishment of manufacturing controls assuring maximum penetration performance for the production units. This directly benefited the Rockeye II program and added to the state-of-the-art knowledge on factors influencing shaped charge effectiveness.

The aerodynamic profile of the MK 118 MOD 0 Anti-tank Bomb satisfies all stability and terminal descent requirements. It represents an optimized configuration - - a design reflecting an amalgam of diverse and frequently competing interests such as stand-off, packing efficiency, and fuze arming. Achieving the desired aerodynamic characteristics without defeating any of these interests was an accomplishment of significance in the program. Achieving a bomblet design compatible with the high force aerodynamic environment at dispenser event must also be regarded as an important developmental attainment.

The success of the MK 118 MOD 0 Anti-tank Bomb program is patently evident in the results of the many qualification tests the unit has thus far completed. These results indicate that the bomblet, as an integral part of the Rockeye II weapon, will be a valuable addition to the ordnance of tactical Navy aircraft.

DOCUMENT CONTROL DATA - R&D

(Security classification of title, body of abstract and indexing annotation must be entered when the overall report is classified)

1. ORIGINATING ACTIVITY *(Corporate author)* Honeywell, Incorporated Ordnance Division Hopkins, Minnesota	2a. REPORT SECURITY CLASSIFICATION CONFIDENTIAL 2b GROUP 4

3. REPORT TITLE
Final Report
ROCKEYE II WEAPON SYSTEM DEVELOPMENT PROGRAM
Vol. 1, Part A. (U)

4. DESCRIPTIVE NOTES *(Type of report and inclusive dates)*
Historical, (Design & Development) 23 June 1963–31 March 1966

5. AUTHOR(S) *(Last name, first name, initial)*
Honeywell, Incorporated, for the Naval Ordnance Test Station,
China Lake, California

6. REPORT DATE 31 March 1967	7a. TOTAL NO. OF PAGES 286	7b. NO. OF REFS none

8a. CONTRACT OR GRANT NO. N123(60530)33998A	9a. ORIGINATOR'S REPORT NUMBER(S) Contract N123(60530)33998A, Final Report, Vol. 1, Part A
b. PROJECT NO. c. d.	9b. OTHER REPORT NO(S) *(Any other numbers that may be assigned this report)*

10. AVAILABILITY/LIMITATION NOTICES
In addition to security requirements which apply to this document and must be met, each transmittal outside the agencies of the U.S. Government must have prior approval of the Naval Air Systems Command, Code AIR 532E.

11. SUPPLEMENTARY NOTES Design and Development History	12. SPONSORING MILITARY ACTIVITY U.S. Naval Ordnance Test Station China Lake, California 93555

13. ABSTRACT

This report covers the Honeywell effort in the design and development of the Rockeye II dispenser and bomblet under contract N123(60530)33998A to the Naval Ordnance Test Station, China Lake, California. The design requirements and development history are presented in Volume I. Engineering support activity efforts of reliability, functional and development evaluation, production, value engineering, and quality assurance are presented in Volume II. (U)

14. KEY WORDS	LINK A		LINK B		LINK C	
	ROLE	WT	ROLE	WT	ROLE	WT
Rockeye II						
Bomb cluster Mk 20 Mod 0						
Dispenser Mk 7 Mod 0						
Cargo section						
Bomblet						
Shaped charge						
Anti-tank						
Anti-personnel						

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