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MAY 1958

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ARROW 2
WEAPON INSTALLATION
REPORT NO. 72/SYSTEMS 26/8-2
ENGINEERING DIVISION
AVRO AIRCRAFT LIMITED.

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ARROW 2

WEAPON INSTALLATION

Report No. 72/SYSTEMS 26/8-2

MAY 1958

This brochure is intended to provide an accurate description of the system(s) or service(s) for the ARROW 2 at the time of writing and is not to be considered binding with respect to changes which may occur subsequent to the date of publication.

Revised by R. Shannon Approved by

Authorized by A.C. Bailey

Engineering Division
Avro Aircraft Limited
Malton - Ontario.

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1.0 INTRODUCTION

The complete weapon installation is incorporated in an interchangeable and quickly removable pack located under the centre fuselage. The weapons used are four Sparrow 2D missiles, each with a pre-launch weight of 430 lb. The missiles are mounted on launching rails which are extended for firing.

2.0 GENERAL DESCRIPTION OF THE INSTALLATION

2.1 THE SPARROW 2D MISSILE

The Sparrow 2D missile is a fully active K-band guided missile which is rapidly accelerated to supersonic speed by a solid propellant rocket motor. The missile is attached to its launcher by a forward button and a rear pair of hooks, as shown in Figure 1.

2.1.1 Arrangement of Missiles

Four missiles are carried in a semi-submerged position with their centre lines at the aircraft skin line as shown in Figure 2. This configuration was chosen to give an optimum extension mechanism and to provide a practical mounting structure. The four missiles are arranged in a staggered formation to prevent wing and tail interference. The missiles are carried with their wings and fins at an angle of 45 degrees to the aircraft skin line.

2.2 WEAPON PACK

When the basic aircraft configuration was being established, several different types of weapons were considered, each of which required a different carrying structure. Therefore, in order to finalize the fuselage design, it was decided to incorporate a removable weapon pack. All flight induced loads would be carried by the fuselage and the pack structure would carry only the loads induced by the weapons themselves. Thus, different weapons could be installed without seriously changing the basic aircraft design. In addition, it was

2.2 WEAPON PACK (cont.)

determined that in order to meet the specified rearming time, weapon pack interchangeability would be essential. The pack was therefore designed as a rapidly interchangeable item.

2.2.1 Weapon Pack Structure

The weapon pack consists of an aluminum alloy structure approximately 16 feet long and 20 inches deep. It occupies the full width of the lower fuselage, midway between the cockpit and engines. The complete missile launchers, with their hydraulic lowering and retraction gear, are built into the pack. Quick disconnects are provided for all electrical and hydraulic services between the pack and the basic airframe structure.

The pack is attached to the fuselage by four bomb release type attachments, one at each corner of the pack (Figures 13 and 14). Vertical loads are taken out by all four attachments. Fore and aft loads are taken out by the rear attachments only. Side loads are taken out on one front attachment and one rear attachment.

2.2.2 Services Connections

The following services are supplied through quick-disconnect fittings:

(a) Hydraulic oil supply and return

(b) Cooling air

(c) Air Pressure (seal inflation)

(d) Electric power supplies

(e) Inputs from fire control sub-system

The hydraulic oil supply and return connections are manually connected and disconnected. They are mounted on universal joint type swivels and are manually positioned for mating. Access to the swivels

2.2.2 Services Connections (cont.)

is gained through a hinged door at the rear of the pack, on the right-hand side. The door is held in the closed position by means of quick-release fasteners. Pack cooling air connections are automatically made as the pack is installed in the aircraft and are of the spring-loaded butting type.

Low pressure air, electric power and fire control circuits enter the top of the pack at the forward end. Access to the connections is gained through a hinged door equipped with quick-release fasteners, on the underside of the pack. The connector is manually inserted and connects the air pressure line, electrical power and fire control wiring, in one operation.

2.2.3 Missile Auxiliaries

The missile auxiliaries associated with the preparation of the missiles for launch are located at the forward end of the pack in the bays between the inboard and outboard missiles.

2.2.4 Pack Sealing

Sealing along the edge of the pack is accomplished by inflatable seals as shown in Figure 8. The air supply for the seals is taken from the equipment pressurizing system. The seals are inflated when the safety disconnect is installed in the firing circuit, provided the engines are running, and are deflated when the disconnect is removed.

2.2.5 Pack Cooling

Discharge air from the cockpit is used for pack "area-cooling" and the missile auxiliaries are cooled by air from the equipment cooling supply. When the pack is installed in the aircraft, these two supplies are automatically connected. The cockpit discharge air enters a gallery pipe at the forward end of the pack. Outlets are provided into each missile bay, and the air is exhausted

2.2.5 Pack Cooling (cont.)

to atmosphere at the rear of the pack. This air will maintain the general temperature level in the pack between 0°F and 130°F. Cooling air is piped direct to the missile auxiliaries, and is exhausted to atmosphere.

2.2.6 Wing and Fin Doors

In order to extend the missile for launch, it is necessary to open doors to permit the wings and fins to pass through the skin lines. Multi-element hydraulically actuated sliding doors were adopted, which run in tracks, as shown in Figures 5 and 6. Each pair of wing or fin doors is actuated by a hydraulic jack, and open or close in 0.50 seconds. The doors are sequenced to open and close during both launcher extension and retraction.

2.2.7 Drag Link Doors

In the case of a forward missile, the drag link swings in an arc so that it passes through the gap left by the missile body in the pack skin line. In the case of a rear missile, the drag link passes through the skin line ahead of the body gap. Therefore, a pair of short chord, inwardly opening doors is provided ahead of each rear missile, actuated by a single jack. These doors are opened prior to launcher extension and closed after retraction.

2.2.8 Operating Envelope

The installation is designed to permit the carriage of missiles in either the extended or the retracted position, at all speeds and accelerations within the flight envelope, although limitations due to thermal conditions restrict the time that the missiles can be left in the extended position. The hydraulic system is designed to retract missiles throughout the flight envelope, except that during accelerations in excess of + 4g, the hydraulic forces may be insufficient to complete retraction, and the missile retraction may pause until the aircraft acceleration is reduced to + 4g or less. The operating envelope for missile extension is from -1g to +4g.

2.2.9 Missile Extension Mechanism

The missiles are mounted on rail type launchers which must be extended to the firing position. All four missiles will be extended simultaneously when a salvo of four is selected, and the selected pair will extend together when two missiles are selected. The extension time has been selected as 1.25 seconds to 1.50 seconds. Each selected missile is lowered by two hydraulic jacks; the forward jack being equipped with a drag link mechanism (Ref. Figure 4). The two jacks are synchronized and regulate vertical distance, while the drag link, which is a rigid member, regulates the fore and aft position. Power to operate the extension system is obtained from the utility hydraulic system (Ref. para. 2.3).

After the missile has been launched, the gap in the skin previously occupied by the missile is filled by retracting the launcher part way. The launcher is of the same planform as the missile and therefore fills the opening.

2.2.10 Missile Launching

The Sparrow 2D is rail-launched. The ARROW installation gives a captive missile travel of 60 inches to eliminate chances of missile-to-missile or missile-to-aircraft collision during initial flight. The missile may be jettisoned from the launcher. The portions of the rail, on which the missile rests in its prelaunch position, are attached to the launcher by explosive bolts. The missile is prevented from moving forward by a hook, which is held in position by a shear pin. This pin will shear when the thrust of the missile motor builds up to about 4,000 lbs.

2.2.11 Missile Sealing

To maintain the air temperature within the pack, a seal, shown in Figure 2 extends the entire length of the missile excluding the radome.

2.2.12 Missile Protection

Attempts are being made to protect the missile from all the environmental conditions that may be encountered during high speed flights. It will also be necessary to protect the missile radome from stones, slush, etc. thrown up by the aircraft nosewheel. This may be accomplished by the installation of a cocoon over the radome and missile body.

2.3 HYDRAULIC SYSTEM

The missile doors and missile extension and retraction actuators are hydraulically operated. The oil is supplied from the utility hydraulic system through quick-disconnect couplings at the rear of the pack. Electrically controlled valves are used throughout, sequenced by hermetically-sealed microswitches.

When the weapon pack is removed from the aircraft, temperature changes will result in changes to the hydraulic oil volume. A relief valve is installed so that pressure can be relieved in the event of a temperature rise. A temperature drop will result in cavitation, but it is not anticipated that this will cause any problems.

Aerodynamic and inertia loading on the missiles is such that under almost all conditions, the forward extension jack is in compression while the rear jack is in tension. On the rare occasions when one or both of these loads are reversed, the magnitude of the reversal is small.

For extension, oil from the pump is delivered to the head end of the rear jack, causing oil to be expelled from the rod end of the jack. This oil is piped to the head end of the forward jack. The rod end volume of the rear jack matches the head volume of the forward jack; therefore, these two jacks are synchronized. At the end of the stroke, the series hook-up is changed to parallel, and pump

2.3 HYDRAULIC SYSTEM (cont.)

pressure is applied directly to the head end of each jack. A diagram of the hydraulic actuation of a single missile linkage is shown in Figure 7.

On the ground, with the engines stopped, hydraulic power for door and missile actuation will be obtained by connecting a ground hydraulic supply into the normal utility system ground connections. Further details of the armament hydraulic system are contained in Report No. 72/SYSTEMS 19/40.

2.4 ELECTRICAL SYSTEM

The emergency DC bus provides power for control of door operation and missile extension. This bus is energized at all times when the master electrical switch is ON.

Electric power for missile jettisoning also comes from the emergency DC bus, but is fed through an interlock so that power will not reach the explosive bolts unless the weight of the aircraft is off the nose landing gear leg, jettison is selected and the launchers are down. The main DC bus provides power for firing and is fed through an interlock so that power cannot reach the firing circuit until all landing gear legs are up and doors are closed.

Electric power for missile preparation comes from the main buses which are energized whenever the engines are running, or the ground supply is plugged in.

2.5 COCKPIT CONTROLS AND INDICATORS

The following cockpit controls and indicators are provided:

(1) On the armament control panel, located on the pilot's right-hand console:

(a) A SAFE-ARM switch - No power is applied to the firing circuits when the switch is in the SAFE position.

(b) A MISSILE SELECTOR switch - This switch is labelled OFF - FWD PAIR - ALL. Power is supplied for preparation of the missiles when the switch is

2.5 COCKPIT CONTROLS AND INDICATORS (cont.)

(1) (b) moved from the OFF position. For a four-missile pass the switch is placed at ALL. For a two-missile pass the switch is placed at FWD PAIR and for a second two missile pass, the switch is then placed at ALL.

(c) A MODE SELECTOR switch - This switch is labelled, VISUAL IDENT- OPTICAL-LEAD PURSUIT - LEAD COLLISION - REJECT - SNAP UP.

(d) A RETRACT button - This button is provided to retract missiles which remain extended after an attack.

(e) A SPENT-AVAILABLE indicator - This indicates whether or not the selected missiles are available.

(2) On the main panel

(a) A MISSILE READY indicator - This will show when one or more of the missiles are locked on to the target.

(b) A MISSILE MALFUNCTION indicator - This will show when a missile has failed to fire after receiving a firing pulse.

(c) A stores JETTISON switch. This switch is used to jettison the external fuel tanks and missiles.

(3) On the control column

(a) A toggle switch to permit the selection of automatic or manual attack and a trigger to control the selected mode of firing. Operation of the toggle switch to manual will extend missiles if they are not already extended and will enable firing without range or angle interlocks.

2.6 MISSILE JETTISONING

A missile can be jettisoned by actuating explosive bolts in the launcher. This will disconnect the portions of the launcher track to which the missile is attached and allow the assembly to drop. When it is desired to jettison all four missiles from the stowed position, the stores jettison control in the cockpit is actuated.

2.6 MISSILE JETTISONING (cont.)

This will open the doors and extend the missiles. The explosive bolts in the rear launchers (lower missiles) will be exploded simultaneously. As soon as the rear missiles are clear, the rear launchers will retract in order to give the forward missiles a clear jettisoning path. Immediately the rear launchers are clear, the forward missiles will be jettisoned in a similar fashion to the rear missiles. The forward launchers will then retract.

Wind tunnel tests have been conducted to establish jettisoning characteristics.

2.7 INSTALLATION WEIGHT

The weapon pack, complete with four Sparrow 2D missiles, is expected to weigh 3,928 lb. which is divided as follows:

Structure	912 lb.
Hydraulics	332 lb.
Mechanisms	553 lb.
Electrical	217 lb.
Missile Auxiliaries	186 lb.
Missiles	1,728 lb.
Total	3,928 lb.

3.0 PREPARATION OF MISSILES FOR FIRING

3.1 MISSILE CONDITIONS

Missiles can be carried on the aircraft in four conditions:

(1) OFF - In this condition, no power is applied to the missile except for internal heaters. Missiles will normally be carried in this condition until an attack is committed.

(2) Condition 1 - In this condition, the missile is readied for extension and immediate lock-on. The minimum time for condition 1, to avoid

3.1 MISSILE CONDITIONS (cont.)

(2) internal overheating of the missile, is two minutes. During this period, power is supplied to the missile, and angle slaving of the missile seeker is initiated in conjunction with the A.I. Radar Lock-On.

(3) Condition 2 - This condition is initiated when the missile is extended quarter way to the firing position. While in this condition, range slaving action commences, with the missile seeker transmitting. During this time, the missile range gate is compared with the AI range gate and a gate positioning voltage is obtained. The missile video and range gates are sampled until coincidence is obtained; this is the condition of lock-on and the missile goes into auto-track.

(4) Condition 3 - This is initiated by a firing pulse from the intervalometer and the condition continues while the missile is transferred to internal power and the gyros are uncaged. This missile is now ready to fire, and will be fired following the automatic closing of a control relay, supplying power to the missile motor igniter.

4.0 MISSILE LAUNCH

4.1 SALVO EFFECTIVENESS

The Sparrow 2D can be fired with fairly constant effectiveness from any point within its launch zone. Outside the launch zone, missile effectiveness falls off sharply. At higher altitudes and against higher performance targets, the launch zone is reduced in volume, and placement problems may result in the interceptor cutting across a segment of such a launch zone. In order to maximize effectiveness, a salvo should be concentrated into the minimum period

4.1 SALVO EFFECTIVENESS (cont.)

of time possible. For this reason, a 4 x 4 system has been adopted (i.e. this permits the launching of 1, 2, 3 or 4 missiles depending on selection and lock-on).

In the 4 x 4 system, angle and range slaving of all four missiles is performed simultaneously. If a 4 missile attack is selected in automatic firing mode, all four missiles are extended simultaneously at two seconds before target area (R_{max}).

4.2 FIRING CIRCUIT

The firing circuit is designed to fire missiles in order of lock-on at nominal intervals of one-half second. To receive a firing pulse, the missile must have locked on a target and the pilot's stick trigger must be depressed. Additionally, in an automatic firing mode, the range must be between R_{max} and R_{min} and the lead angle must be within the tolerances calculated by the computer (δ_{max}). The attack is terminated at any time by releasing the trigger. When all missiles have fired, the empty launchers will be automatically retracted. If a missile has received a firing pulse but has not fired at the end of the attack, all missiles and launchers will remain extended and the missile malfunction indicator will show. In the event of a failure to fire, the pilot can, at his discretion, retract or jettison the remaining missiles.

The breakaway signal will be a cross on the pilot's scope indicating that all selected missiles have fired, or that the interceptor has closed to the minimum range distance.

5.0 FLIGHT OPERATION OF THE INSTALLATION

The missiles are switched into Condition 1 at, or soon after, take-off. The present minimum time between applying power to the missiles (Condition 1) and

5.0 FLIGHT OPERATION OF THE INSTALLATION (cont.)

firing them, is two minutes. At the appropriate time the pilot will select the desired attack mode and the missiles he wishes to fire.

5.1 AUTOMATIC FIRING IN THE LEAD PURSUIT AND LEAD COLLISION MODES

Two seconds before entering the firing area, the selected missiles will be extended to the launch position. Quarter way to the extended position, the missiles will be put into Condition 2.

As the aircraft enters the firing area, the pilot must depress the firing trigger. When the missile ready indicator shows that at least one missile has locked on, and the firing trigger is still depressed, missile firing will commence. After all the missiles have been fired, the launchers will be automatically retracted until they fill the gap in the skin, originally filled by the missile. If a missile has received a firing pulse and has not fired, the missile malfunction indicator will show, and all the launchers will remain extended until the pilot has decided whether to retract or jettison.

5.2 OPTICAL MODE

When the pilot wishes to make an optical attack, selection of OPTICAL on the mode selector switch will slave the antenna of the selected missiles straight ahead. To extend the missiles for launch, the pilot must actuate the AUTO-MANUAL switch on the control column. Quarter way to the extended position, the missiles will be put into Condition 2, and the range gates will be swept over a wide range. The pilot will then depress the firing trigger and the attack will proceed as outlined in para. 5.1.

5.3 MANUAL FIRING IN THE LEAD PURSUIT OR LEAD COLLISION MODES

It is possible to fire from outside the mechanized firing area. If, on any attack, the pilot finds that he is unable to close to R_{max}, or to get the

5.3 MANUAL FIRING IN THE LEAD PURSUIT OR LEAD COLLISION MODES (cont.)

steering dot within the circle, he may convert to a manual firing attack by selecting the AUTO-MANUAL switch on the control column to MANUAL. This switch will lower the selected missiles if they are not already extended, and will remove range and lead angle firing interlocks. Otherwise the attack proceeds as in an automatic firing mode.

5.4 SPOTLIGHT MODE

The ASTRA 1 system is capable of functioning in the so-called spotlight mode, although cockpit controls for this mode, are not being installed in the aircraft.

The spotlight mode is intended for attacking targets which radiate jamming capable of preventing the interceptor's radar from achieving, or maintaining lock-on. The use of the spotlight mode will overcome this situation. On selection of this mode, the missile will be lowered and energized, and the missile antenna slaved to the AI antenna. The AI antenna will be controlled by the radar operator's hand control. The operator, by reducing the intensity of the search display, is expected to be able to spotlight the target by means of the hand control and, if the missile antenna is looking at the target, missile lock-on will be achieved when the range gate sweeps through the target echo. Upon missile lock-on the pilot's lock-on indicator will be illuminated, and the pilot will fire when he is within maximum missile range.

6.0 SERVICING AND GROUND HANDLING

The weapon pack has been designed for ease of removal and replacement, so that rearming could be achieved by interchange of packs. As an alternative, rearming with Sparrow 2D missiles can be achieved with the pack in position. This method of rearming will take considerably longer, than the replacement of an armed pack. The individual loading of missiles is an RCAF requirement and

6.0 SERVICING AND GROUND HANDLING (cont.)

every effort will be made to minimize the time required for this form of re-arming.

Quick release units are used to attach the pack to the airframe, and ground handling is facilitated by the use of a combined dolly and hoist.

6.1 DOLLY HOIST

The combined dolly hoist is equipped with four wheels and can be towed either forward or sideways. Four hoisting cables are attached to the aircraft by end fittings which are hooked into spring-loaded lugs located on each side of the fuselage. The cables are pneumatically extended and retracted by means of controls on the dolly assembly. Sufficient air pressure for six raising and lowering cycles is stored in bottles located on the dolly.

6.1.1 Pack Changing

To change a pack, an empty dolly is wheeled under the aircraft, and the lifting wires are attached to the fuselage. By operating the hoist controls, the dolly is lifted up to the aircraft until it is firmly against the package. While the dolly is being lifted, the weapon pack's hydraulic, electrical, and air connections are disconnected by hand. The pack attachments to the fuselage are then unlocked and the hoist controls operated to lower the pack and dolly. When the dolly has been lowered, the lifting wires are disconnected from the aircraft, and the pack and dolly can be towed away.

The dolly, with the replacement pack, can then be wheeled under the aircraft, the lifting wires attached, and the pack lifted vertically into the weapon pack bay. Guide rails on the rear pack attachment mate with rollers on the aircraft. When the guide rails are engaged in the follers, hoisting can continue and all four attachments will mate automatically. The attachments are then locked and the

6.1.1 Pack Changing (cont.)

hydraulic, electrical and air supplies connected and the access doors closed. When the dolly is lowered to the ground, the lifting cables are disconnected and the dolly can then be wheeled away.

Trials with mock-up packs have resulted in pack inter-change times of about five minutes.

6.2 FIRING CIRCUIT SAFETY

A hinged panel is located towards the rear of the pack, on the left-hand side, for access to the firing safety plug. The final link in each missile firing circuit is led through the safety plug, which must be disconnected at all times when the aircraft is on the ground. An indicator attached to the plug will give visible evidence that the plug is disconnected. Switches for raising and lowering missiles on the ground are located adjacent to the safety plug. These switches are inoperative until a switch behind the safety plug is operated. In its released position this switch cuts off all power to the pack. The switch is held in the depressed position by the safety plug during flight.

6.3 PACK SERVICING

When the pack is separated from the aircraft, servicing will be conducted in a pack servicing stand, which will contain aircraft pack attachments and lifting cable attachments.

The pack can be cleaned after firing, inspected and functioned in the stand. Test boxes will be required to check out the auxiliaries, the actuation circuitry and the firing circuitry.

6.4 REARMING ON THE AIRCRAFT

Although rearming by replacing individual missiles may not meet the turnaround requirements, occasions may arise when it is necessary to rearm the aircraft

6.4 REARMING ON THE AIRCRAFT (cont.)

in this manner. The CF-100 missile hoist can be used for loading single missiles while the pack is installed in the aircraft.

7.0 DEVELOPMENT PROGRAM

7.1 DESIGN CONFIRMATION TESTS

Several tests are being performed to confirm design decisions. These tests will not be complete before the first pack has been manufactured. They will, however, give the necessary lead time for redesign before flight testing, should this be necessary.

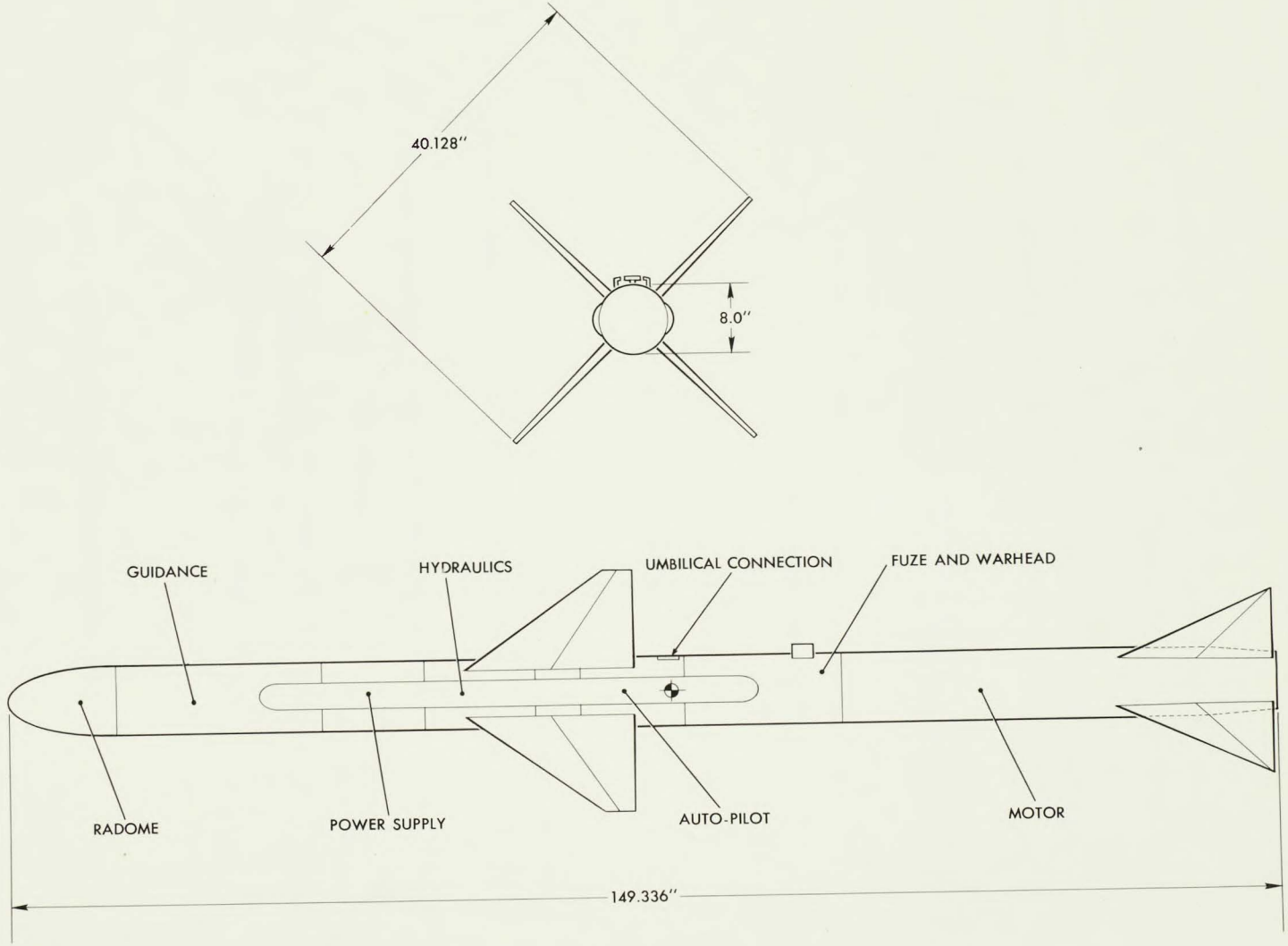

FIG. 1 THE SPARROW 2 MISSILE

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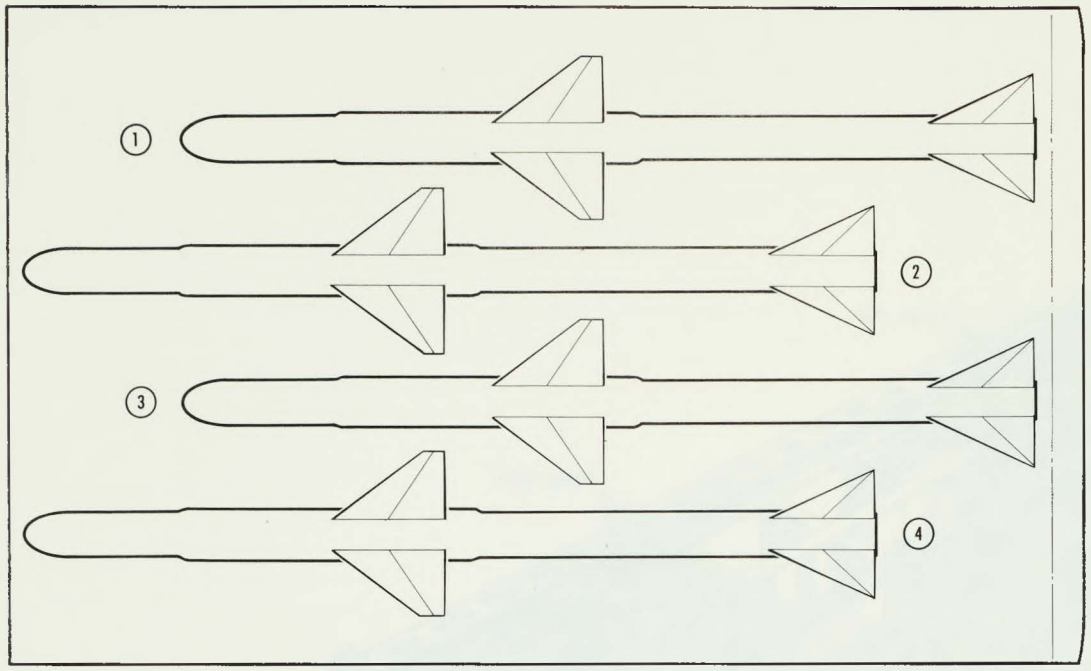
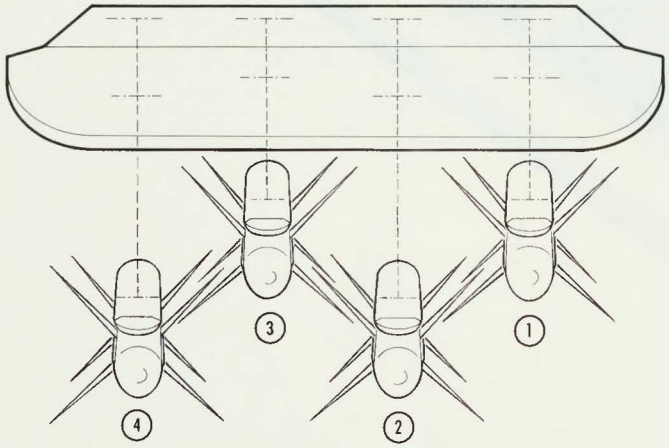
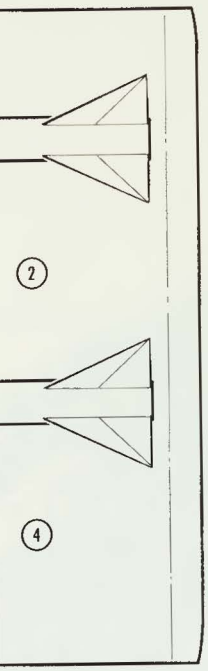


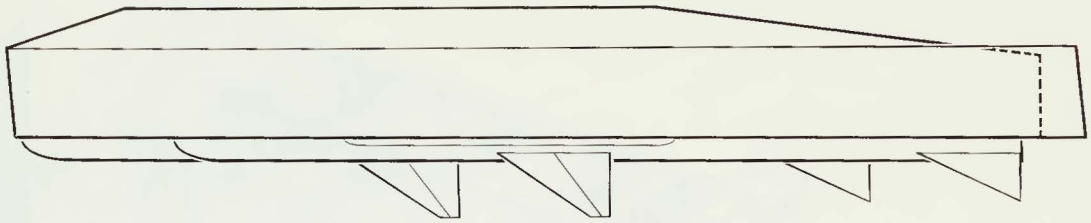
INVERTED PLAN VIEW - MISSILES STOWED



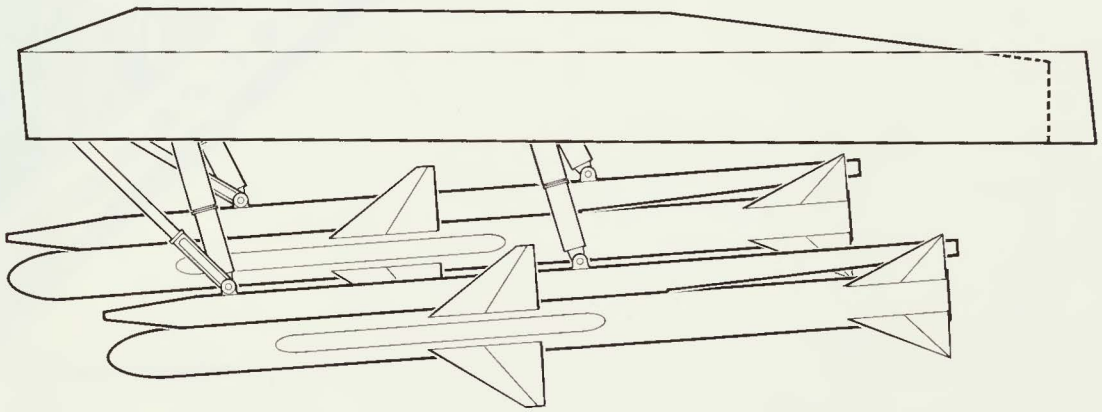
FRONT ELEVATION - MISSILES EXTENDED

FIG. 2 ARRANGEMENT OF MI





SIDE VIEW- MISSILES STOWED



SIDE VIEW-MISSILES EXTENDED

FIG. 2 ARRANGEMENT OF MISSILES

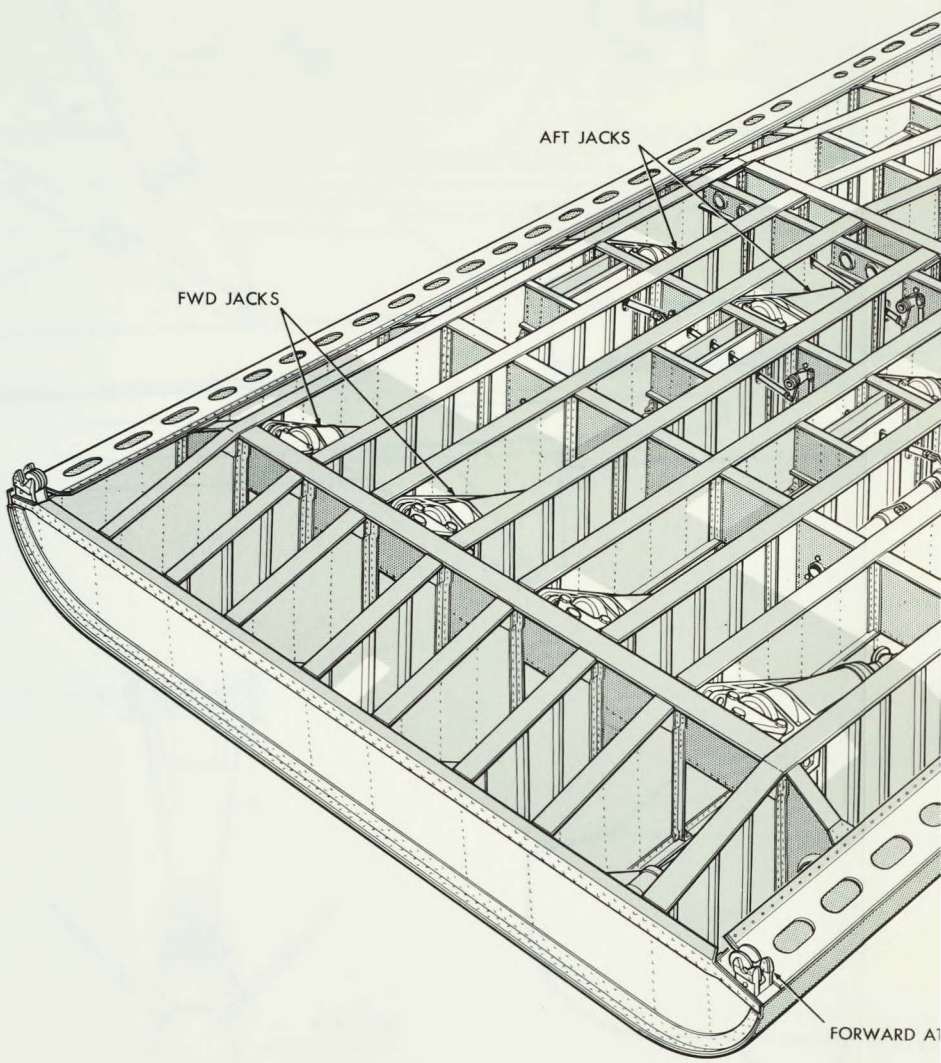


FIG. 3 PACKAGE STRUCTUR

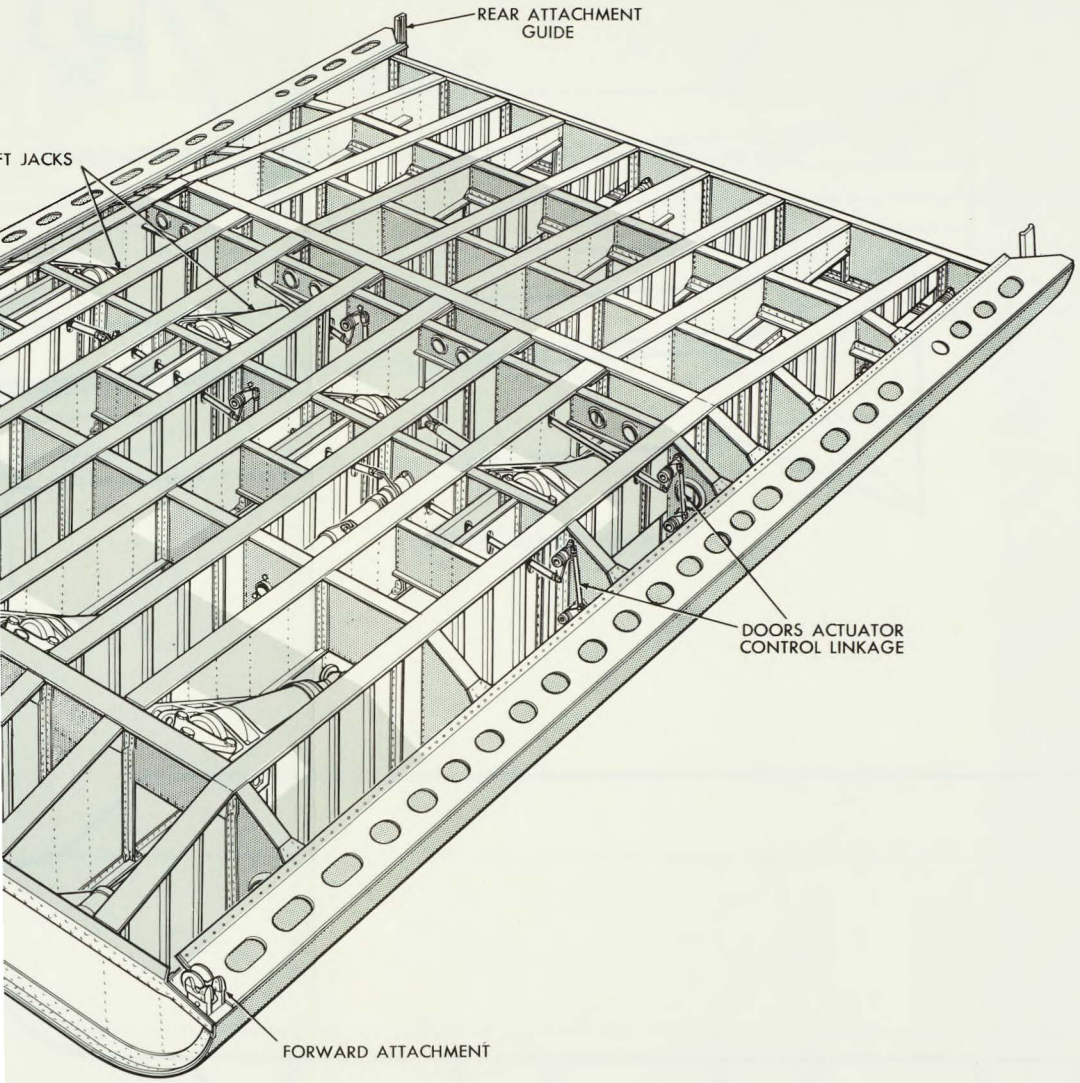


FIG. 3 PACKAGE STRUCTURE

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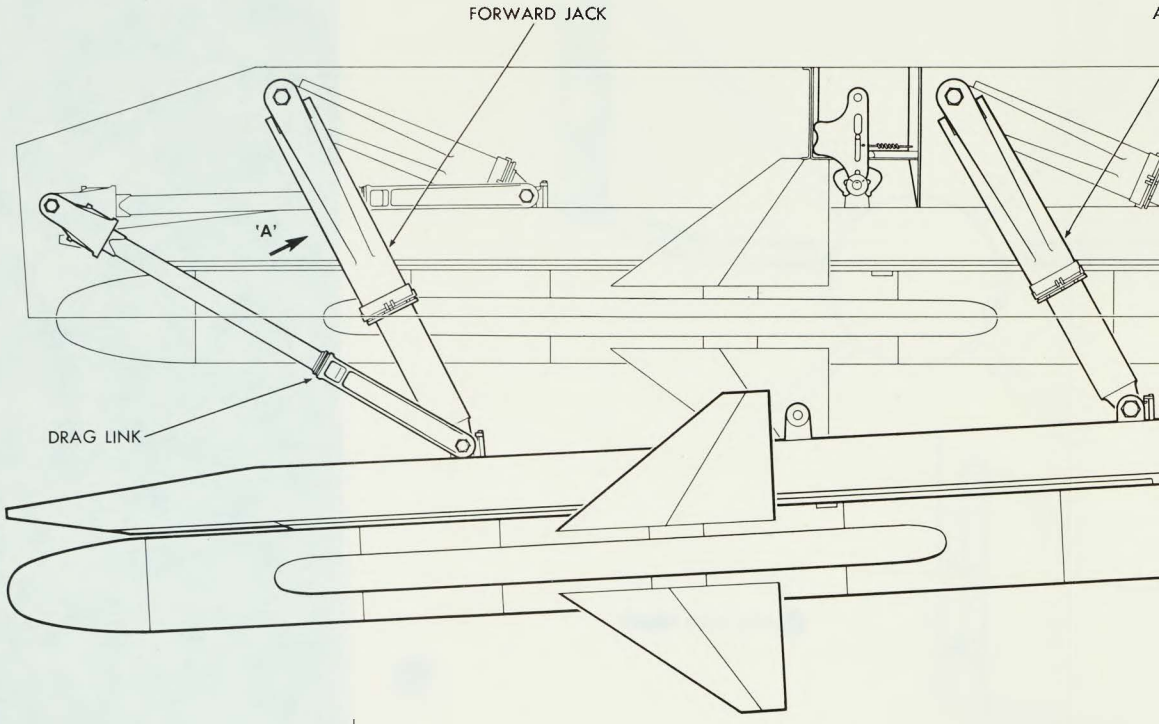

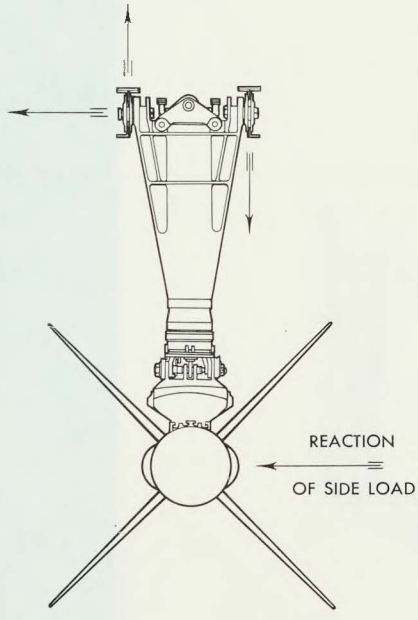

VIEW ON ARROW 'A'

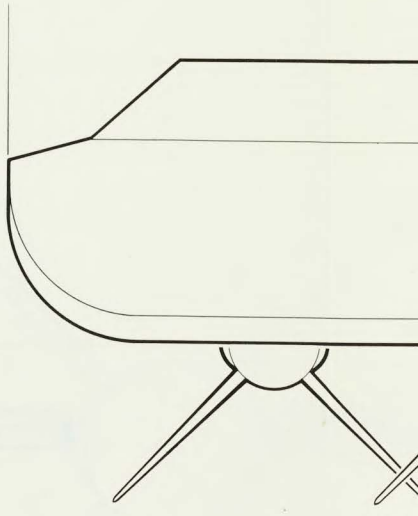

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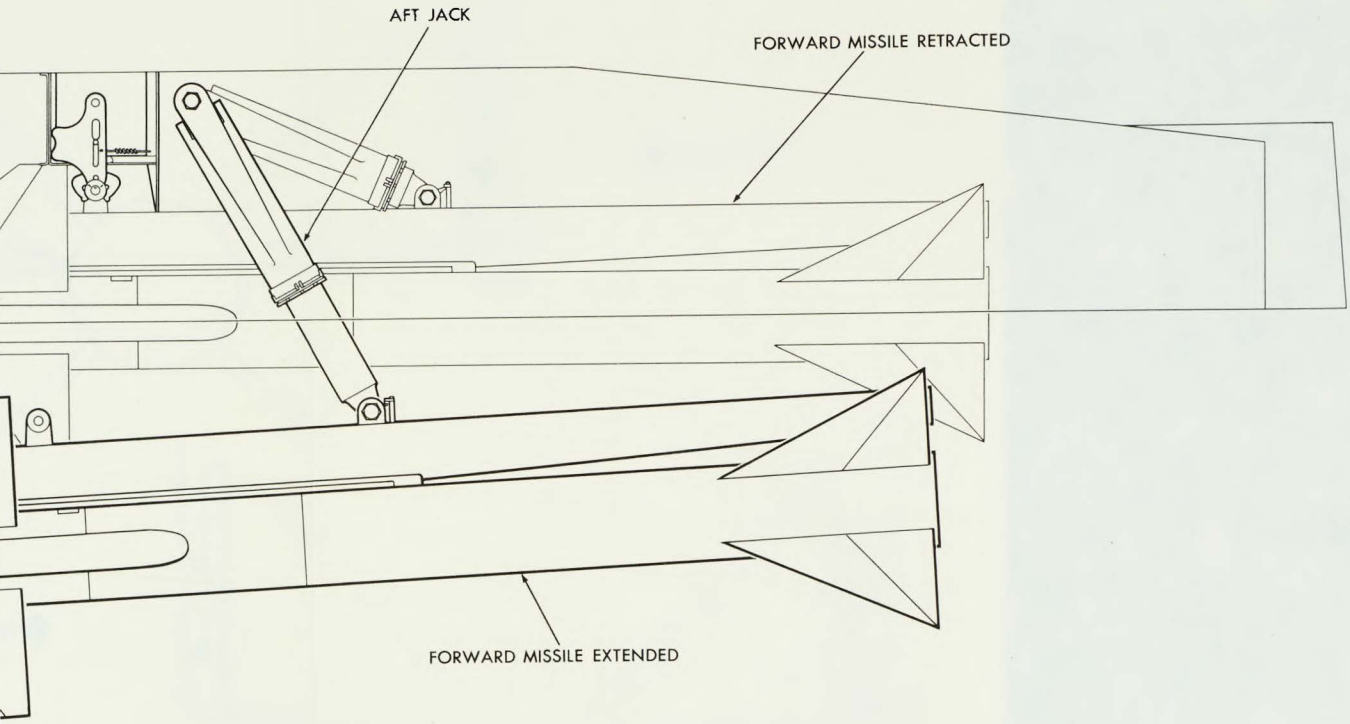
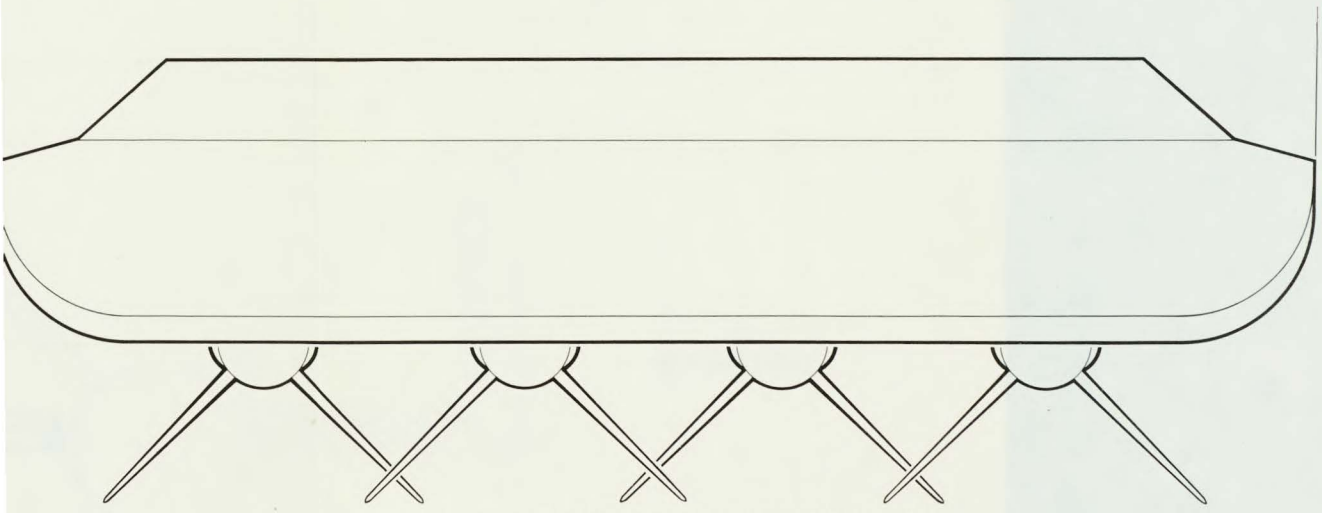
FIG. 4 MISSILE EXTENSION MEC





FRONT VIEW OF PACK SHOWING SEMI-SUBMERGED STOWED MISSILES

FIG. 4 MISSILE EXTENSION MECHANISM

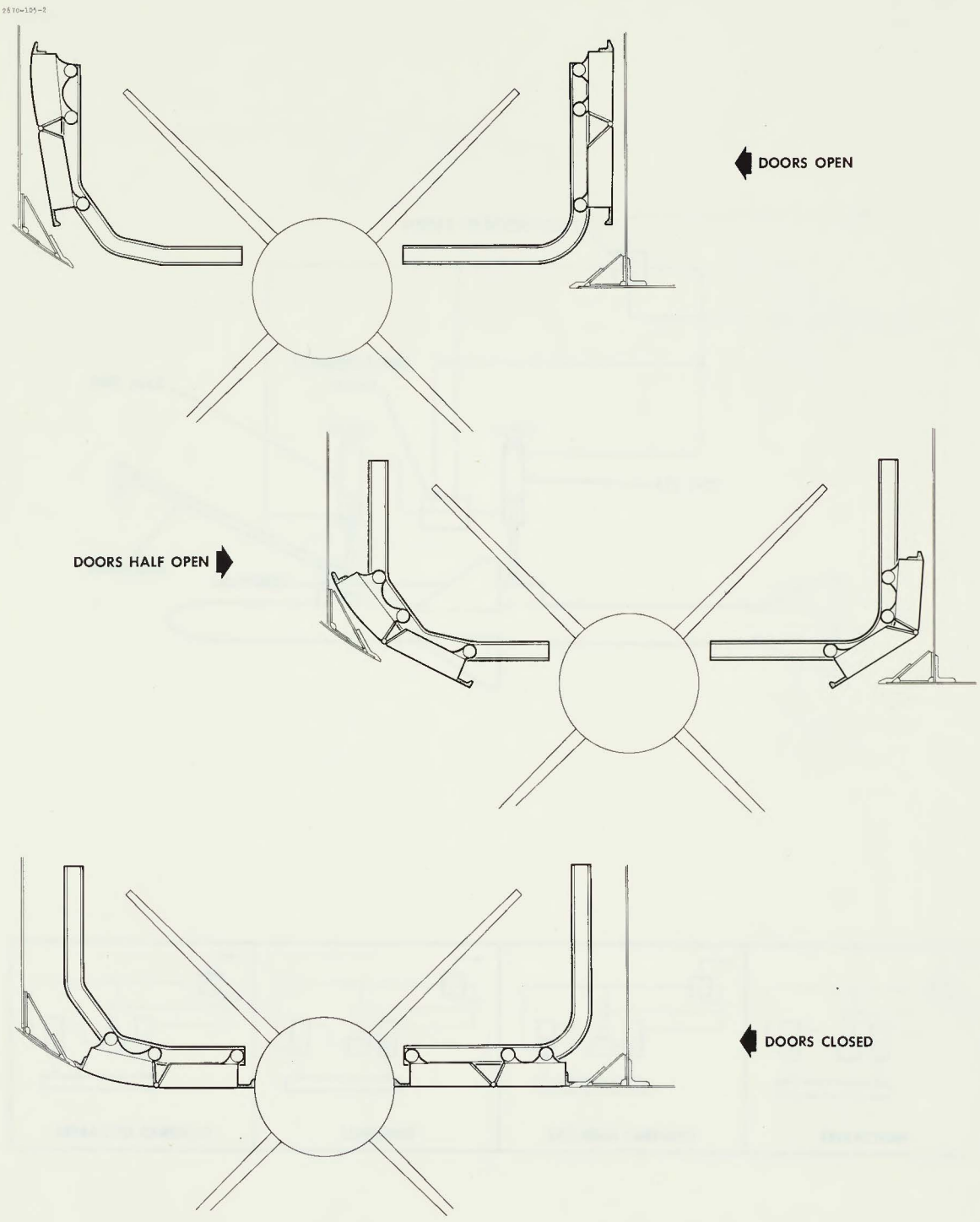
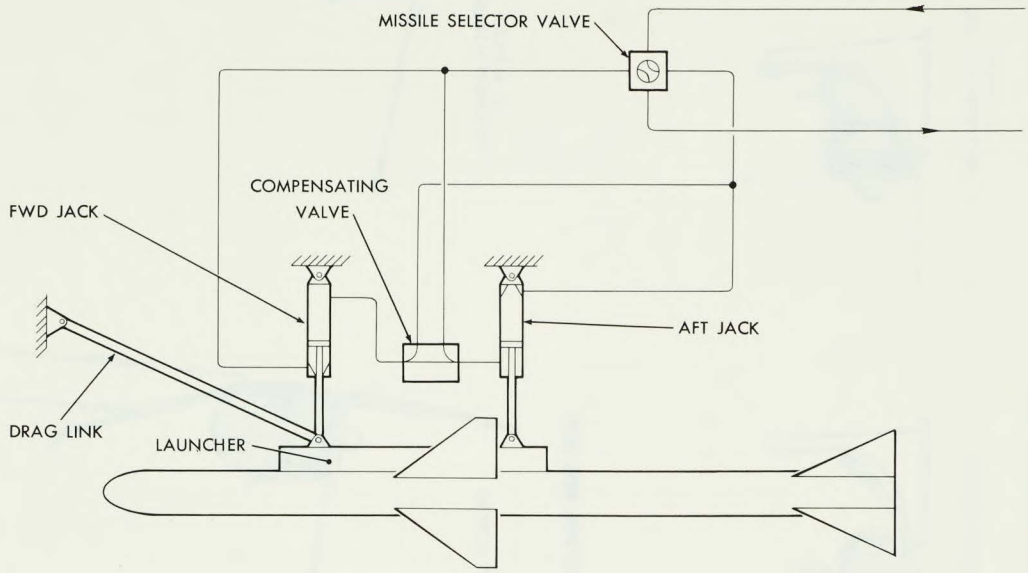


FIG. 6 MISSILE FIN DOORS

2664-105-2



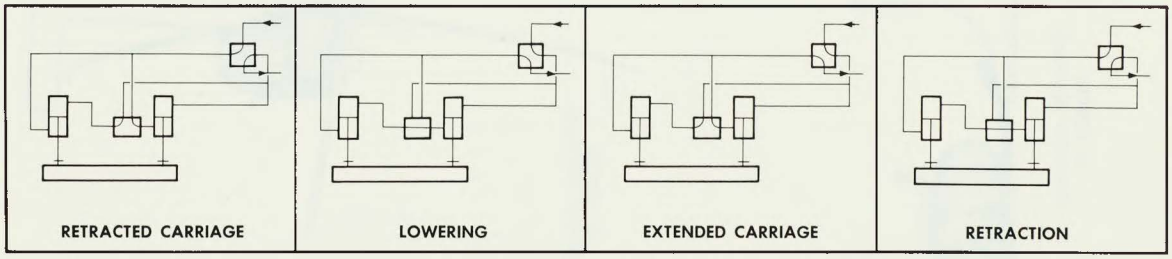


FIG. 7 HYDRAULIC ACTUATION - SINGLE MISSILE

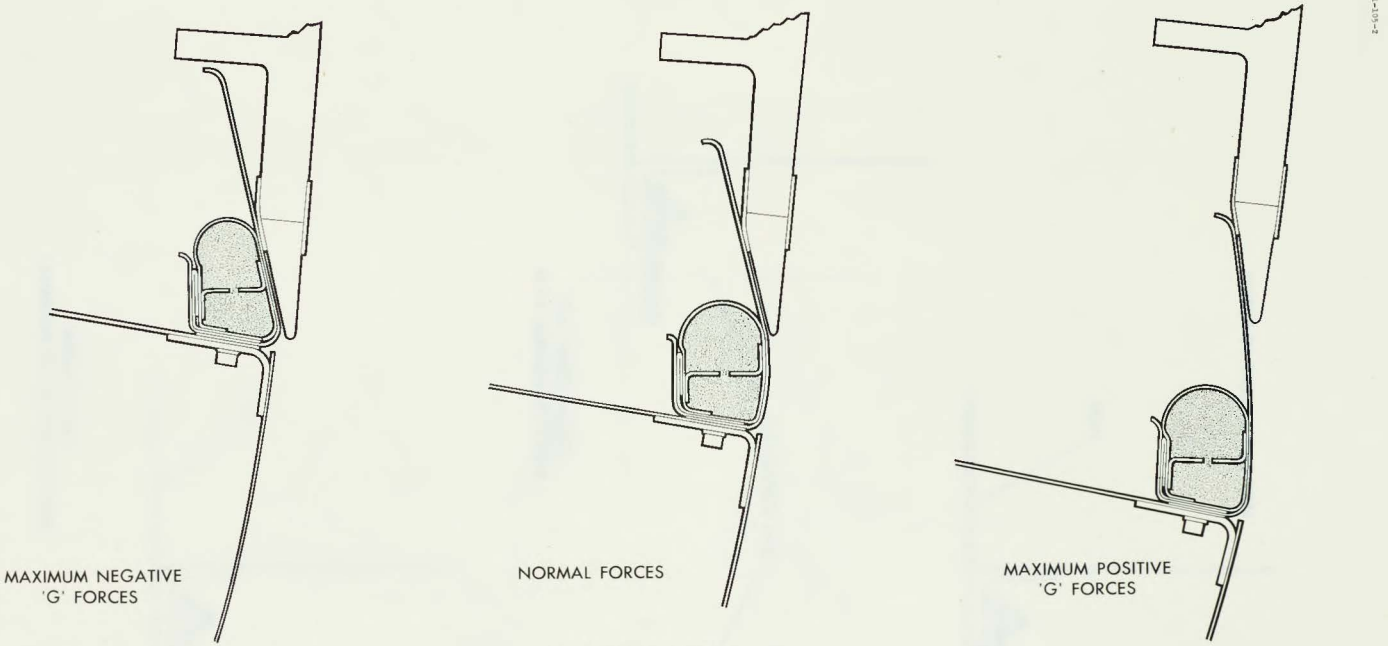


FIG. 8 WEAPON PACKAGE SEALS

3424-105-1

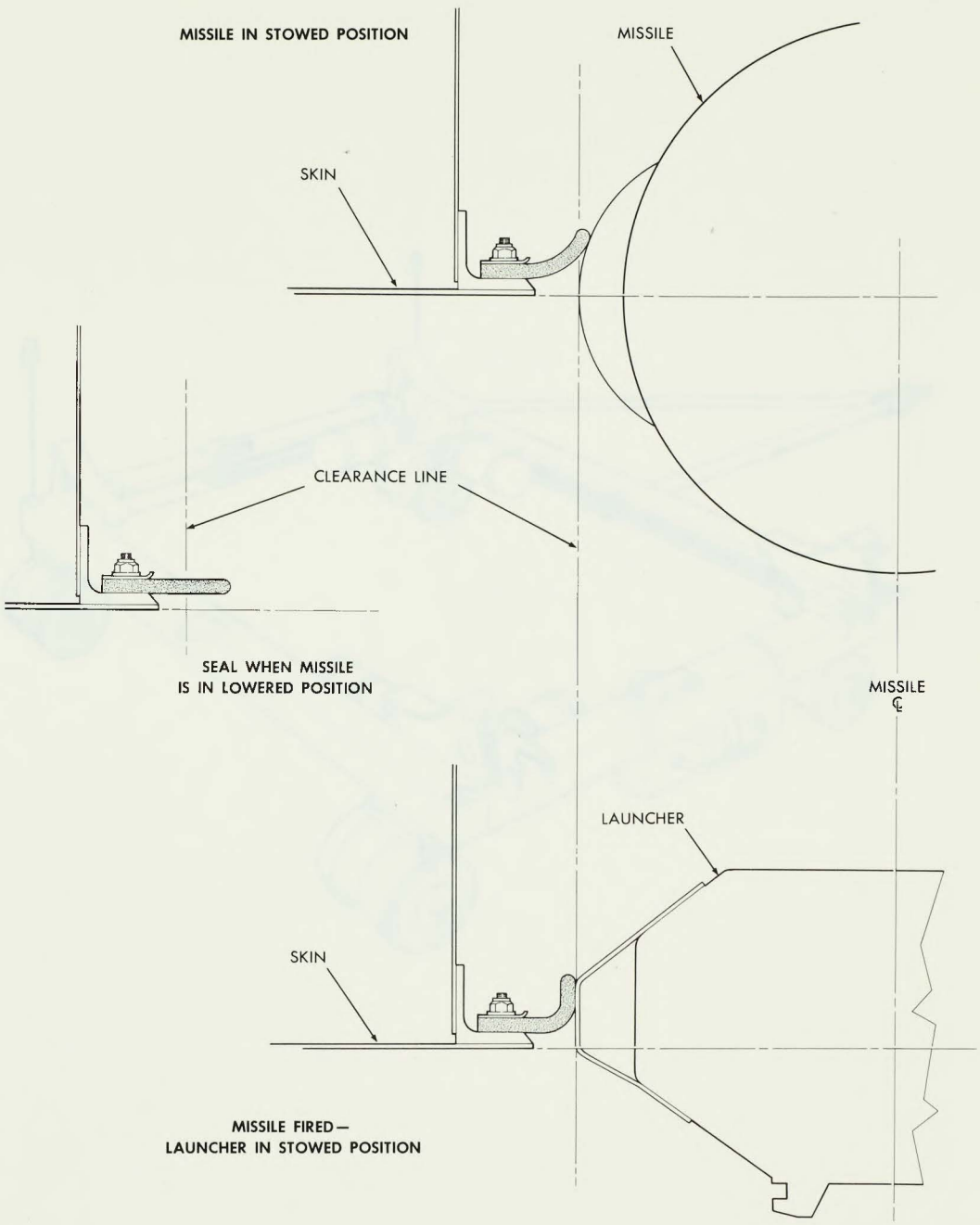


FIG. 9 MISSILE SEALS

2662-105-2

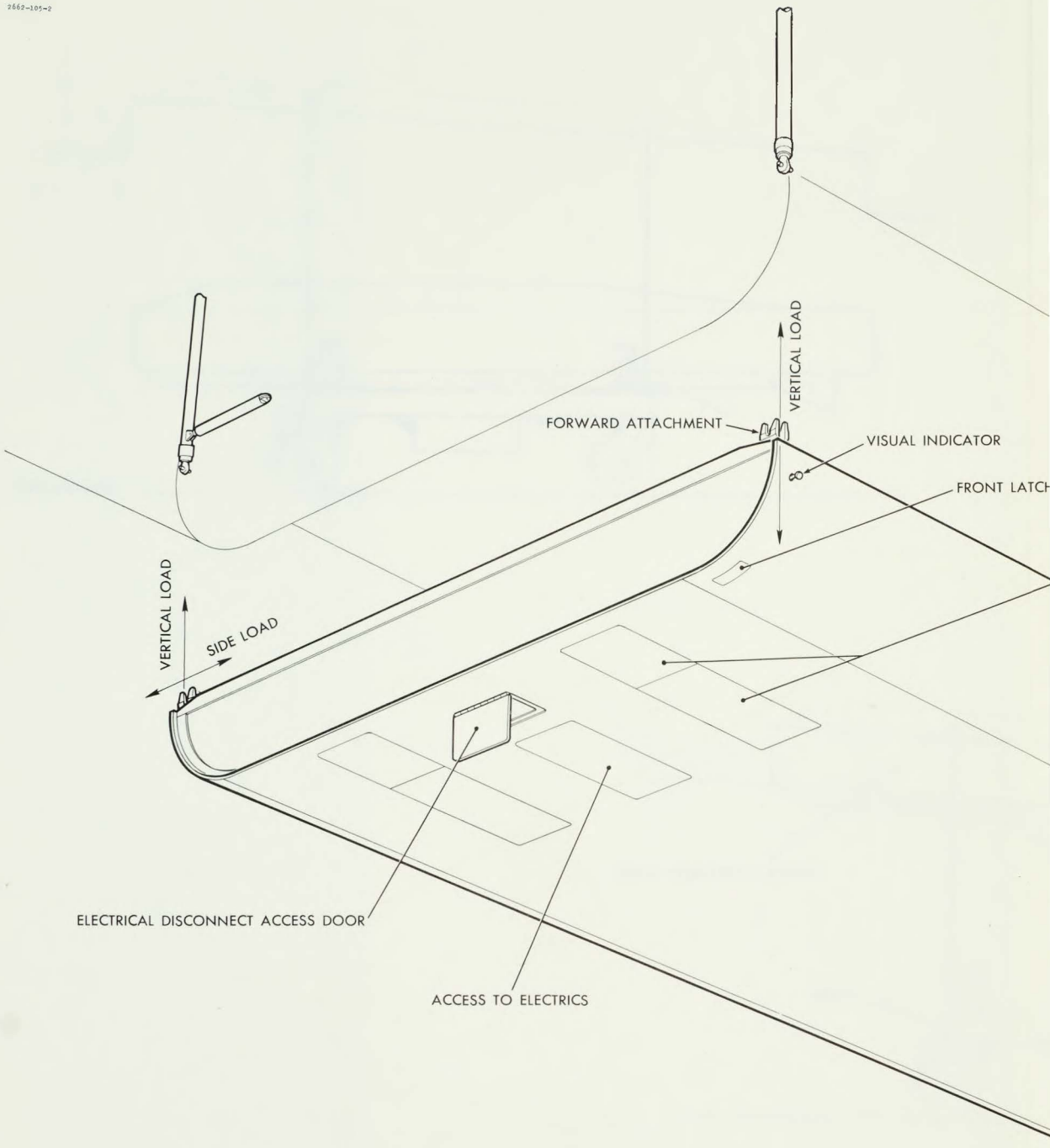


FIG. 11 WEAPON PACKAGE -

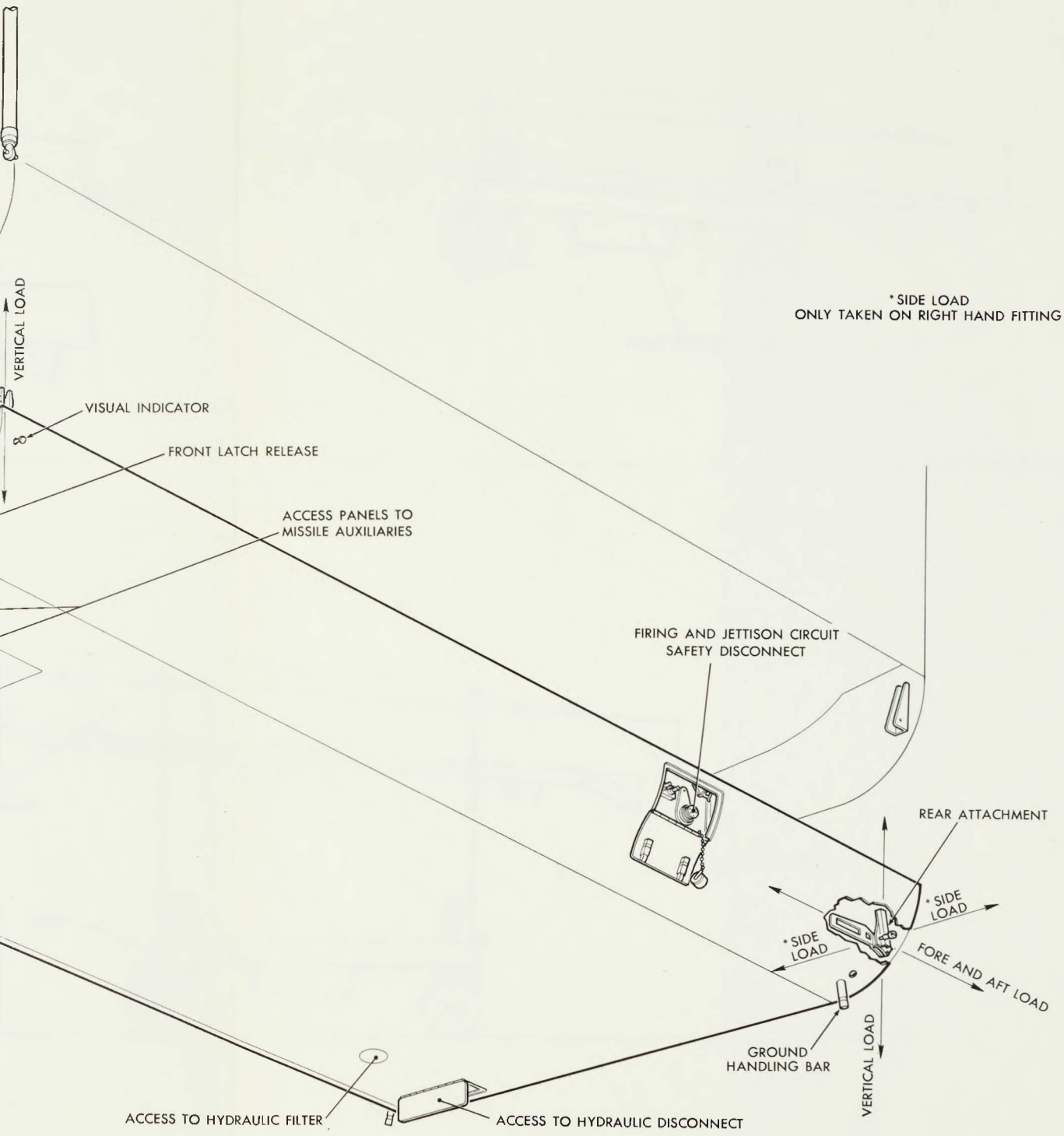
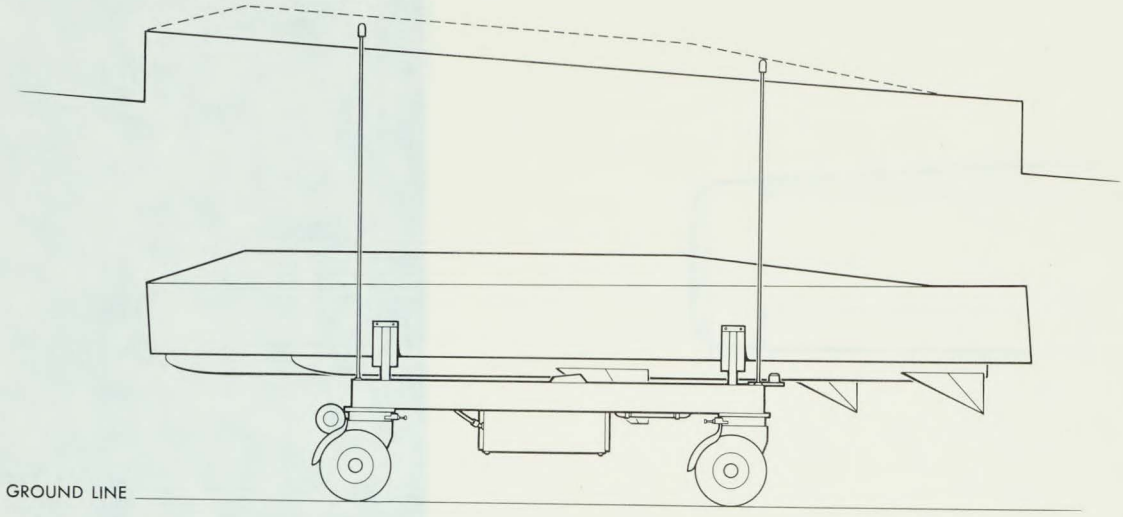


FIG. 11 WEAPON PACKAGE - ACCESS DOORS

2669-105-2



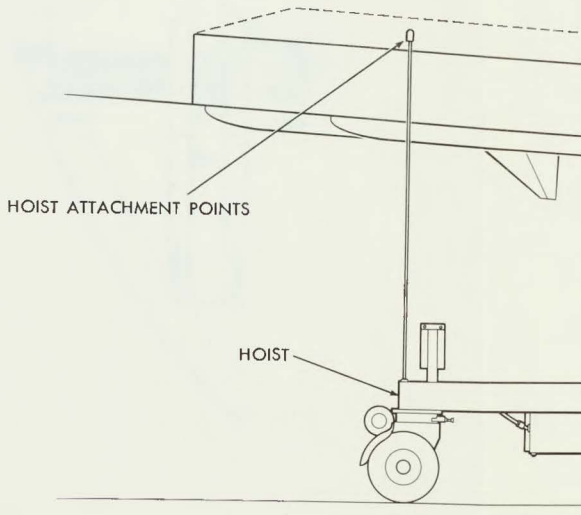
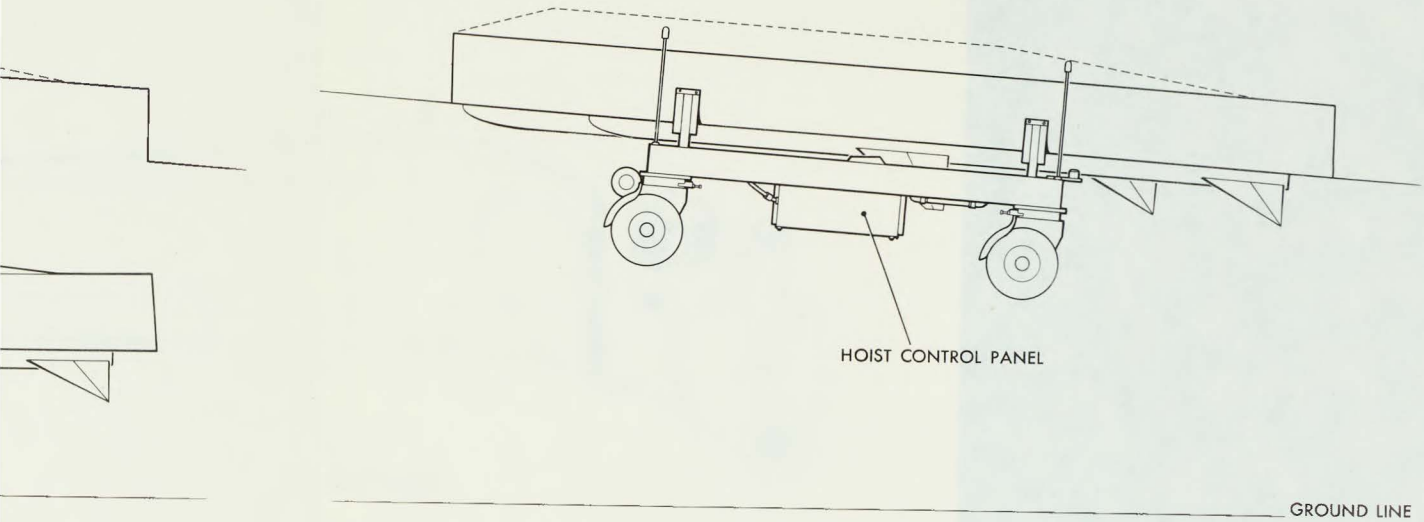


FIG. 12 WEAPON PACKAGE AN



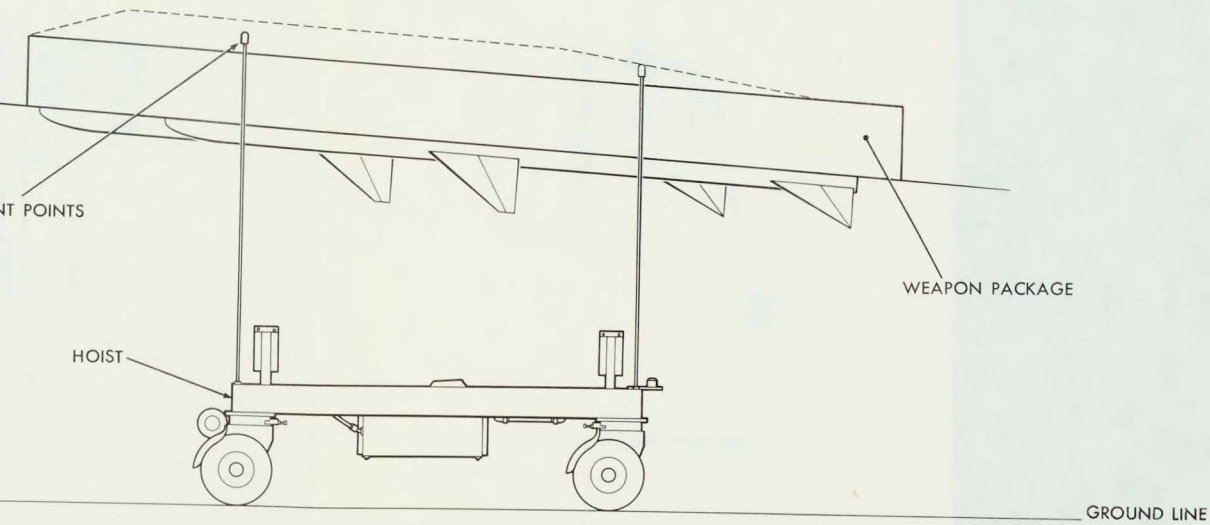


FIG. 12 WEAPON PACKAGE AND HOIST