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SUPPLEMENT TO
29 FEBRUARY 1968

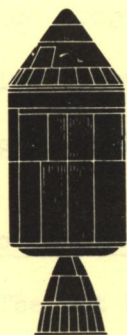
APOLLO TRAINING

APOLLO OPERATIONS HANDBOOK-
CSM BLOCK II, PRELIMINARY

SUBSECTION 2.9
SEQUENTIAL SYSTEMS

FOR TRAINING PURPOSES ONLY





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2.9.5

PERFORMANCE AND DESIGN DATA

The need is apparent in the sequential systems for one-shot, high-energy, quick-response systems for rocket motor ignition, physical separations, and deployment of earth recovery devices. To support these needs an electrical hotwire initiator was selected as the standard activation medium for the high-order ordnance systems required to satisfy vehicle requirements. Range safety requirements dictate that electrically activated ordnance components be capable of withstanding 1 watt and 1 ampere for five minutes at the electrical-explosive interface without firing or without degradation of initiator performance.

2.9.5.1

Apollo Standard Initiator

The hot bridgewire initiator, hereinafter referred to as the Apollo Standard Initiator (ASI), is illustrated in figure 2.9-32. This device has a primary ignition charge that is ignited by electrically heating a 1 ohm bridgewire. The primary charge ignites the main charge of the initiator, which in turn generates high-temperature gasses sufficient to initiate the main charge of the specialized explosive device. The ASI is designed to comply with the range safety requirements recapitulated in paragraph 2.9.5. A current of 3.5 amperes on the bridgewire will cause the ASI to ignite in 10 milliseconds or less when subjected to a temperature range of -65 to 300 degrees fahrenheit. A current of 5.0 amperes on the bridgewire will cause the ASI to ignite in 15 milliseconds or less from -260 to -65 degrees fahrenheit.

ELECTRICAL HOTWIRE INITIATOR

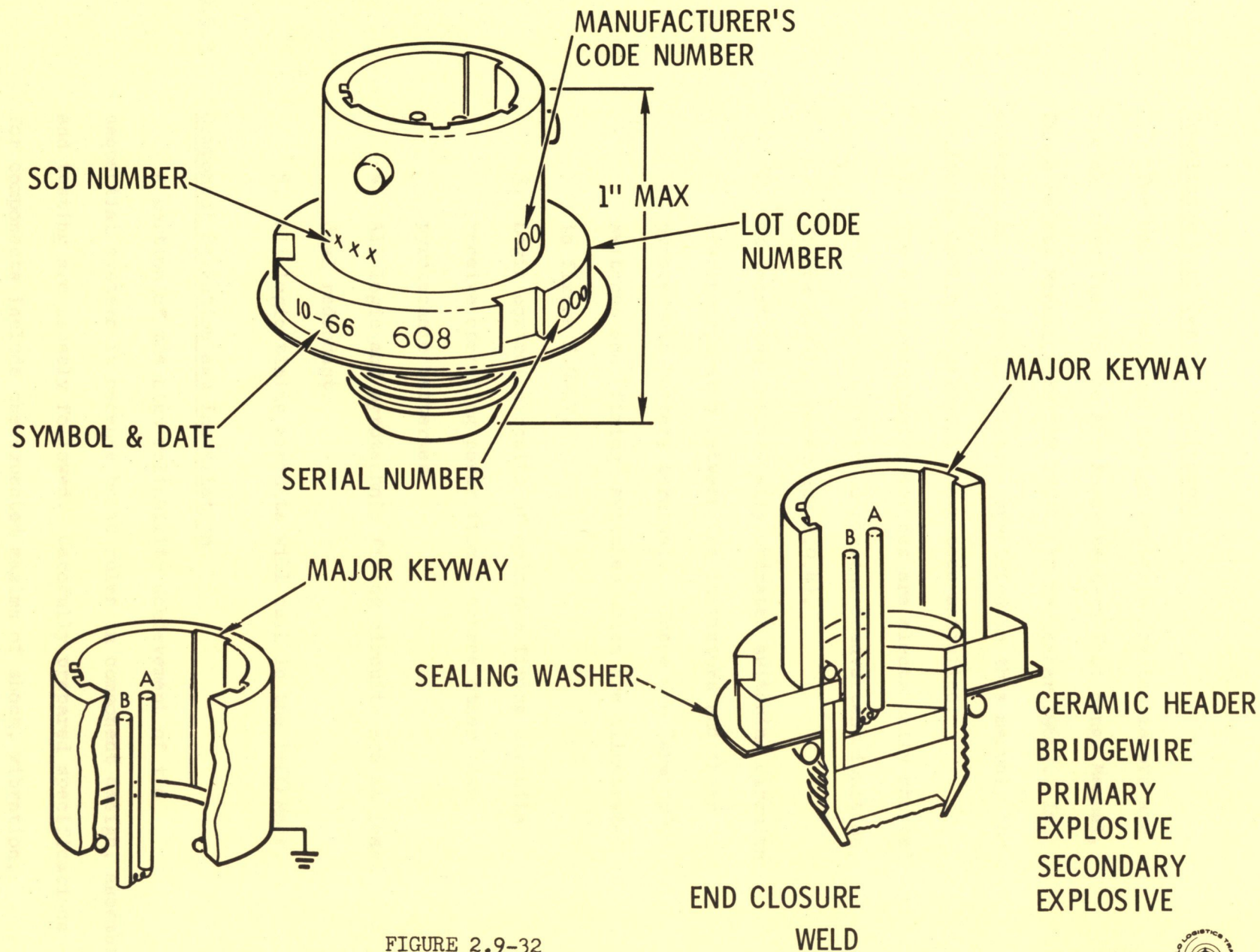


FIGURE 2.9-32

ST-9025B



2.9.5.2 Compliance With Design Requirements

The basic electrical design criteria for initiators are rigidly specified in the Air Force Eastern Test Range Manual, Range Safety Manual, AFE TRM 127-1 (10 September 1965). In addition to the design criteria specified in this manual, the following Apollo requirements have been satisfied:

1. The electroexplosive devices are electrically shorted until they are fired to prevent inadvertent ignition, figure 2.9-15 (paragraph 2.9.4).
2. At least two individually operated switching circuits are incorporated between the initiators and their pyrotechnic battery terminals. These are "arming" switches and "firing" switches which are illustrated in figure 2.9-17.
3. Logic control circuits of ordnance firing circuits receive operating power from a source other than pyrotechnic batteries.
4. All logic and pyrotechnic firing circuits are at least dual redundant.
5. All logic timing circuits will fail in the T=OO Mode.

2.9.5.3 Component Selection and Installation

A portion of the high reliability achievement of the sequential systems is because basic rules in component design, assembly and testing are closely followed. Carefully prepared specifications for components include the expected maxima of shock, vibration,

acceleration, temperatures, margins, etc., not only at the time and interval of use, but throughout the whole flight. Relay contact environment has been controlled by hermetically sealed cases and potting. Components are screened 100 percent, that is, each relay is individually tested through repeated cycling prior to acceptance. In the implementation of the series contact circuits, the physical relays are mounted orthogonal to each other to ensure the abnormal vibration or acceleration forces, which may be of sufficient magnitude to prematurely close a given set of contacts, will not be reflected into the same actuation plane of the other relay of the same firing circuit. Verification of circuit integrity is important to ensure that all circuit elements have been properly assembled and installed. Resistance measurements can validate that circuit continuity is within acceptable limits in order that the required current values to the ASI can be guaranteed.

2.9.5.4 Firing Circuit Protection

Fusistors are located in series with the output contacts of the firing relays, figure 2.9-15. Thus individual protection of each pyrotechnic firing circuit will prevent a current leakage path on any given firing line. A continual discharge of pyrotechnic battery power is impossible in this circuit design. These fusistors are specially designed to withstand high acceleration and vibration

levels. The resistance value of these devices is 0.95 to 1.10 ohms at 25 degrees Centigrade. The time-current operating characteristics are reflected in the following tabulation:

AMPERES	SECONDS
20.0	0.03 to 0.17
10.0	0.20 to 1.20
8.0	0.30 to 8.00
7.0	0.40 to 20.00

2.9.5.5 Induced Current Protection

Consideration was given to the susceptibility of the firing circuit wiring to other energy sources. Unprotected the circuits leading to the ASI could act as receiving antennas, thus funneling more energy to the ASI than it could pick up by itself. To minimize RF pickup, the electrical leads from the firing relay contacts are twisted (20 twists per 12 inches) and are shielded with the shield grounded at the firing relay interface and at the case of the ASI. Full 360-degree shielding is provided between the shield and the ASI case.

2.9.5.6 Pyro Arm Switch Lock

The Range Safety Manual requires that a positive mechanical lock be used in the ARM/SAFE actuation device to prevent movement from the safe to the armed position. A device developed for this purpose is illustrated in figure 2.9-33. Removal of the lock is accomplished by the insertion of a key that is provided to the astronaut during the final prelaunch preparations.

PYRO ARM SWITCH GUARD

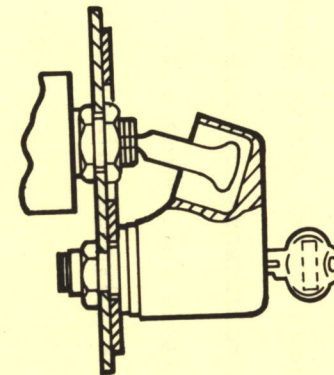
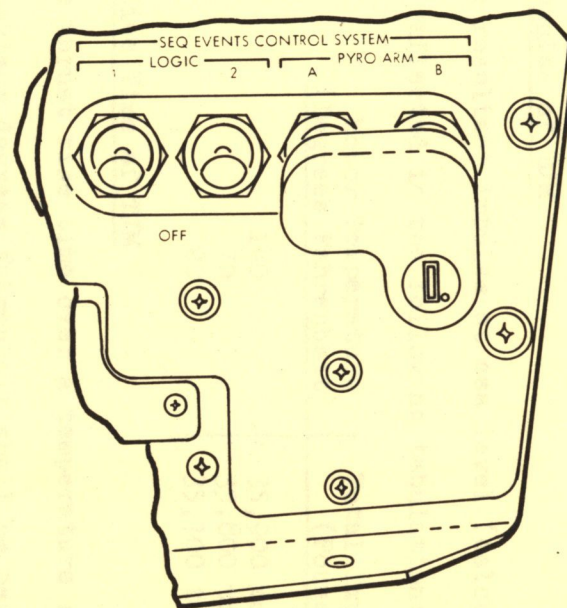


FIGURE 2.9-33

SEQ-556



2.9.5.7 Tower Jettison Motor

The TJM, Figure 2.9-34, is intended to provide thrust capability, under normal mission operation, to effect adequate separation of the LES from the CM, while the latter is undergoing acceleration by the second stage booster; and under abort conditions, to achieve adequate separation of the LES from the CM after LEM burn out. The propellant charge of the TJM consists of a case bonded, star grain employing a polysulfide ammonium perchlorate formulation.

2.9.5.7.1 Thrust of TJM

The average resultant thrust over the burning time when measured at sea level is reflected in the following tabulation:

<u>Motor Temperature (Degrees Fahrenheit)</u>	<u>Thrust Range (Pounds Force)</u>
140	31,200 to 36,000
70	29,400 to 33,900
20	28,000 to 32,400

2.9.5.7.2 Total Impulse of TJM

The resultant impulse at sea level (calculated) over the action time is reflected in the following tabulation:

<u>Motor Temperature (Degrees Fahrenheit)</u>	<u>Total Impulse Range (Pounds Force)</u>
140	35,900 to 37,700
70	35,800 to 37,600
20	35,700 to 37,500

2.9.5.7.3 Thrust Rise Time of TJM

The thrust rise time over a temperature range of 20 minimum to 140 maximum degrees Fahrenheit shall be between 75 and 150 milliseconds.

TOWER JETTISON MOTOR

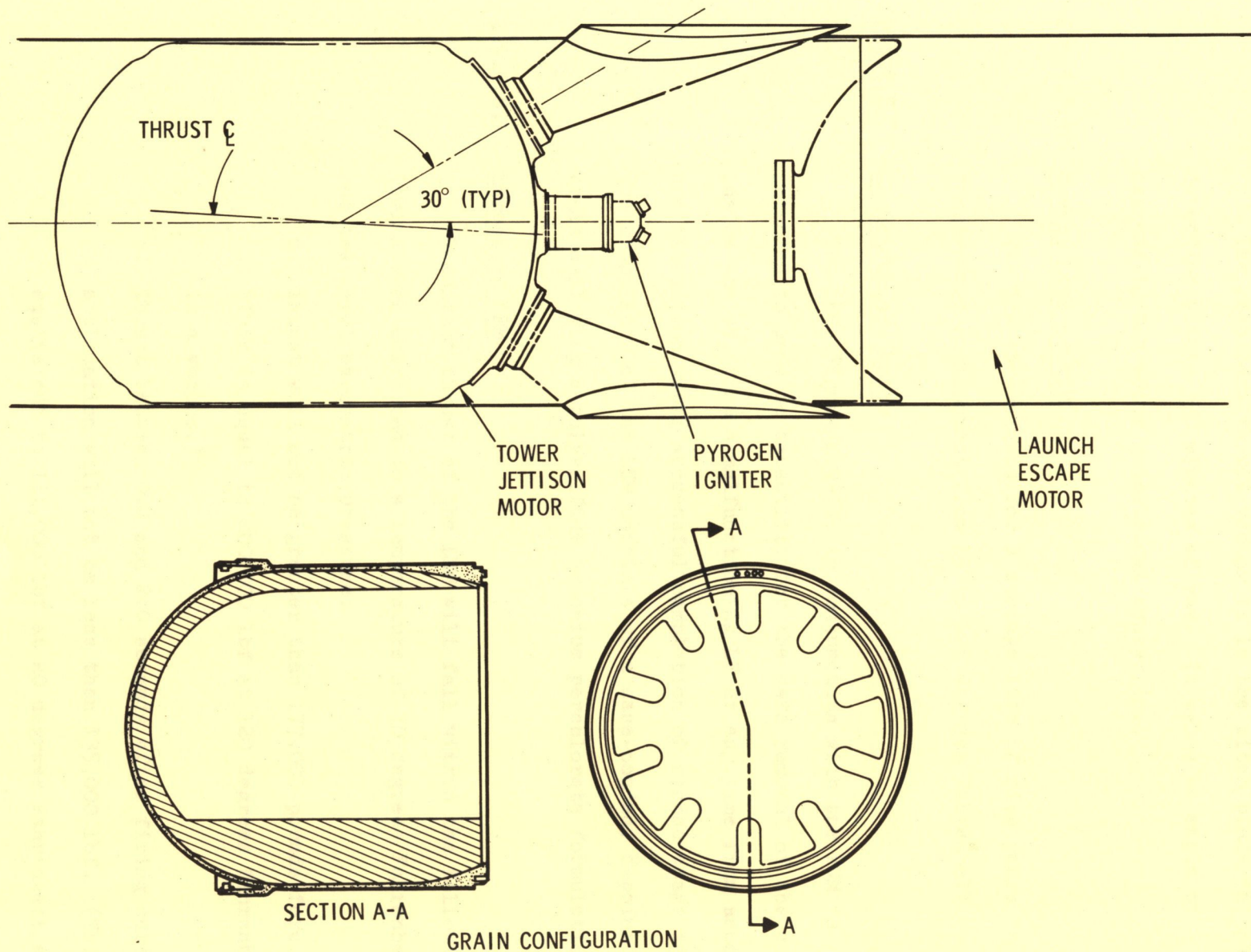


FIGURE 2.9-34

2.9.5.7.4 Thrust Vector Alignment of TJM

The resultant thrust vector is in the pitch plane in the +Z direction within +30 minutes of yaw. It makes an angle of 3 to 4.5 degrees to the motor geometrical centerline.

2.9.5.7.5 Useful Life of TJM

The TJM is designed for a storage life of five years in a temperature environment from 25 to 105 degrees Fahrenheit.

2.9.5.8 Launch Escape Motor

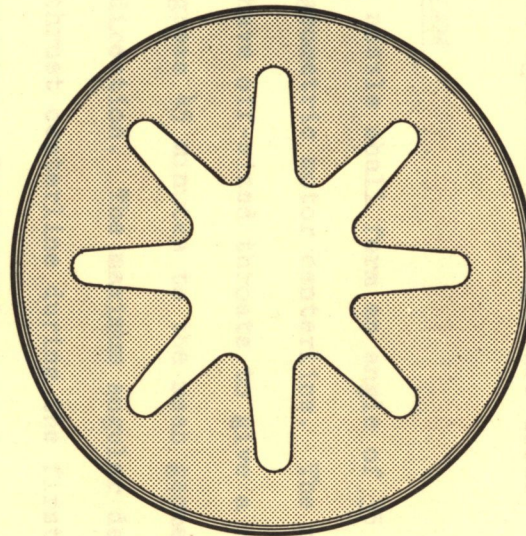
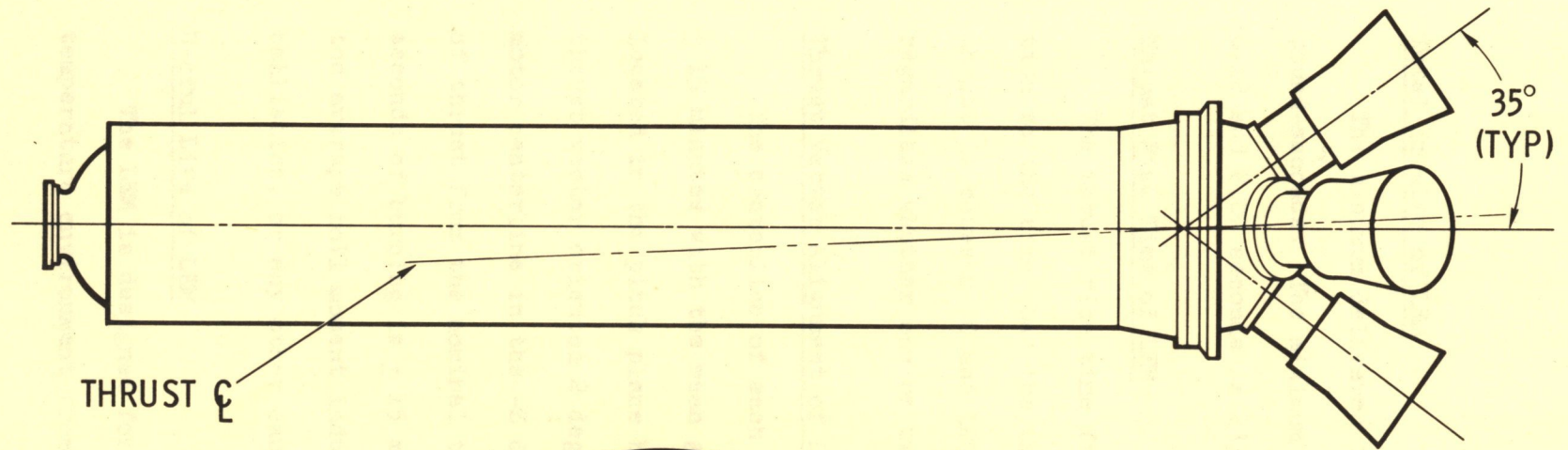
The LEM, Figure 2.9-35, in conjunction with the PCM is intended to provide capability for the safe removal of the crew, inside the CM, from a malfunctioning LV at any time from access arm retraction until successful completion of second stage ignition. The propellant of the LEM consists of a case-bonded, 8-point star grain employing a polysulfide ammonium perchlorate formulation.

2.9.5.8.1 Thrust of LEM

Resultant thrust of the LEM will fall within the following limits when corrected to a temperature of 70 degrees Fahrenheit and sea level barometric pressure.

- a. Thrust will not be greater than 177,000 pounds force (lbf).
(This is equal to 200,000 lbf at 120 degrees Fahrenheit in a vacuum.)
- b. Thrust between 0.2 and 2.0 seconds after firing current application will not be less than 135,000 lbf. (This is equivalent to 121,000 lbf at 20 degrees Fahrenheit and sea level barometric pressure.)

LAUNCH ESCAPE MOTOR



GRAIN CONFIGURATION

FIGURE 2.9-35

2.9.5.8.2 Total Impulse of LEM

The minimum delivered total impulse of the LEM is 515,000 pound-seconds. The minimum delivered total impulse between 0.12 and 2.00 seconds is 233,064 pound-seconds.

2.9.5.8.3 Thrust Rise Time of LEM

The thrust rise time from the time of firing current application to the time that the thrust reaches 90 percent of ignition thrust is between 50 and 120 milliseconds. These limits apply regardless whether one or two igniter cartridges are used.

2.9.5.8.4 Thrust Vector Alignment of LEM

The centerline of each nozzle shall form an angle of 35 degrees \pm 15 minutes with the mean geometric motor centerline. The nozzles located in the pitch plane have off-sized throats to give a resultant thrust vector oriented 2 degrees 45 minutes to the mean geometric motor centerline in the -Z direction. The maximum angular deviation of thrust from the nominal thrust centerline during the first 0.20 seconds of burning is \pm 15 minutes. During this same time period, the average roll moment induced by nozzle alignment, internal ballistics, or any other cause will not exceed 200 pound-feet.

2.9.5.8.5 Useful Life of LEM

The LEM is designed for a storage life of five years in a temperature environment from 25 to 105 degrees Fahrenheit.

2.9.5.9 Pitch Control Motor

The PCM, Figure 2.9-36, in conjunction with the LEM is employed to place the LEV in the correct flight attitude for a successful escape during mode 1A aborts. The propellant of the PCM consists of a case-bonded, 14 point star grain employing a polysulfide ammonium perchlorate formulation.

2.9.5.9.1 Thrust of PCM

Resultant thrust of the PCM will not exceed 3,550 lbf at 70 degrees Fahrenheit and sea level barometric pressure. This is equivalent to 4,000 lbf at 140 degrees Fahrenheit in a vacuum.

2.9.5.9.2 Total Impulse of PCM

The total delivered impulse of the PCM will be 1,750 pound-seconds $\pm 3\%$ at 70 degrees Fahrenheit and sea level barometric pressure.

2.9.5.9.3 Thrust Rise Time of PCM

The thrust rise time from time of firing current application to the time at which the thrust reaches 80 percent of maximum will be between 60 and 120 milliseconds, at 70 degrees Fahrenheit.

2.9.5.9.4 Thrust Vector Alignment of PCM

The PCM is designed so that the resultant thrust vector coincides with the centerline of the motor chamber mounting surfaces within ± 30 minutes.

2.9.5.9.5 Useful Life of PCM

The PCM is designed for a storage life of five years in a temperature environment from 25 to 105 degrees Fahrenheit.

PITCH CONTROL MOTOR

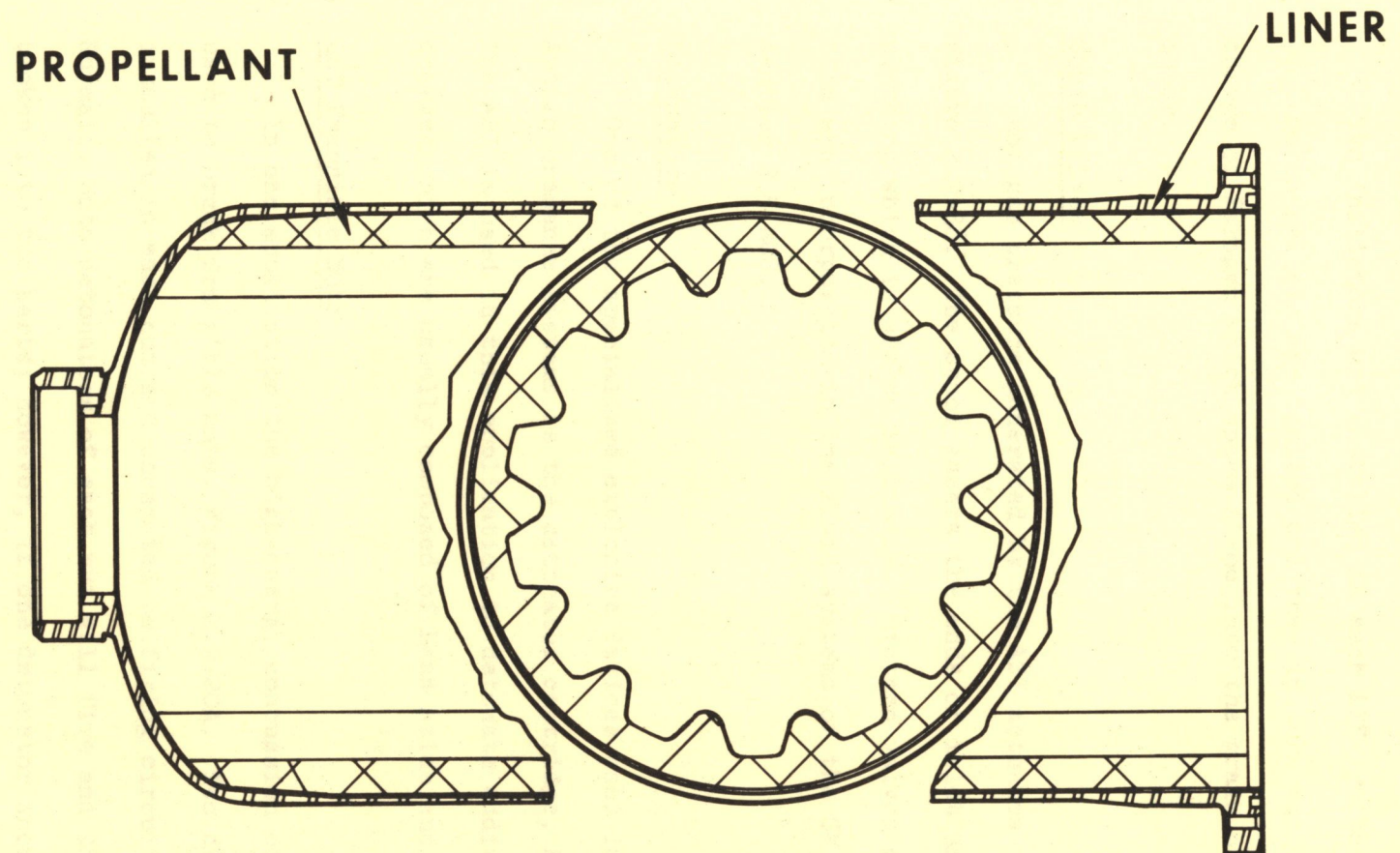


FIGURE 2.9-36

2.9.5.10 LES Igniter

Two initiators are installed in each LES ignitor, Figure 2.9-37. Boron pellets are ignited and they in turn ignite the main charge of Pyrogen which spews flame into the grain of the rocket motor.

2.9.5.11 Squib Valves

Hot gas pressure generated by the ASI actuates the squib valve, Figure 2.9-38. The spool shears the ends of inlet and outlet plumbing which is sealed initially. Sixteen valves of this configuration are incorporated in the fluid systems of the CM RCS, see section 2.5 RCS.

2.9.5.12 Detonators

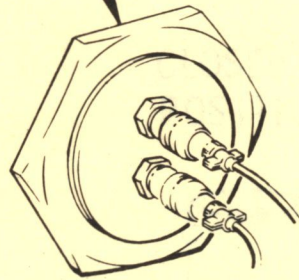
One of the specialized explosive devices used in some of the Apollo ordnance systems is the detonator cartridge, Figure 2.9-39. The ASI is used in this application to detonate additional explosive charges which are usually composed of Lead Azide and RDX.

2.9.5.12.1 LET Frangible Nuts

In one application the high-energy concussion of detonators is used to break frangible nuts, Figure 2.9-20A. Two detonators are installed in each nut and connected to firing circuits A and B. Normally both detonators of each nut will fire and the nut will be broken into two parts; however, if one detonator should fail the nut will be spread enough for thread clearance. Sympathetic concussion will not result in detonation in this installation.

LES IGNITERS

PITCH
CONTROL
MOTOR

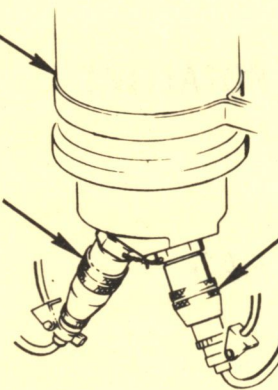


DETAIL A

JETTISON
MOTOR

SYSTEM B

SYSTEM A



PELLET BASKET

SYSTEM B

SYSTEM A

LAUNCH
ESCAPE MOTOR

PYROGEN UNIT

SECTION A-A

DETAIL B

FIGURE 2.9-37

SEQ-79



TYPICAL C/M SQUIB VALVE

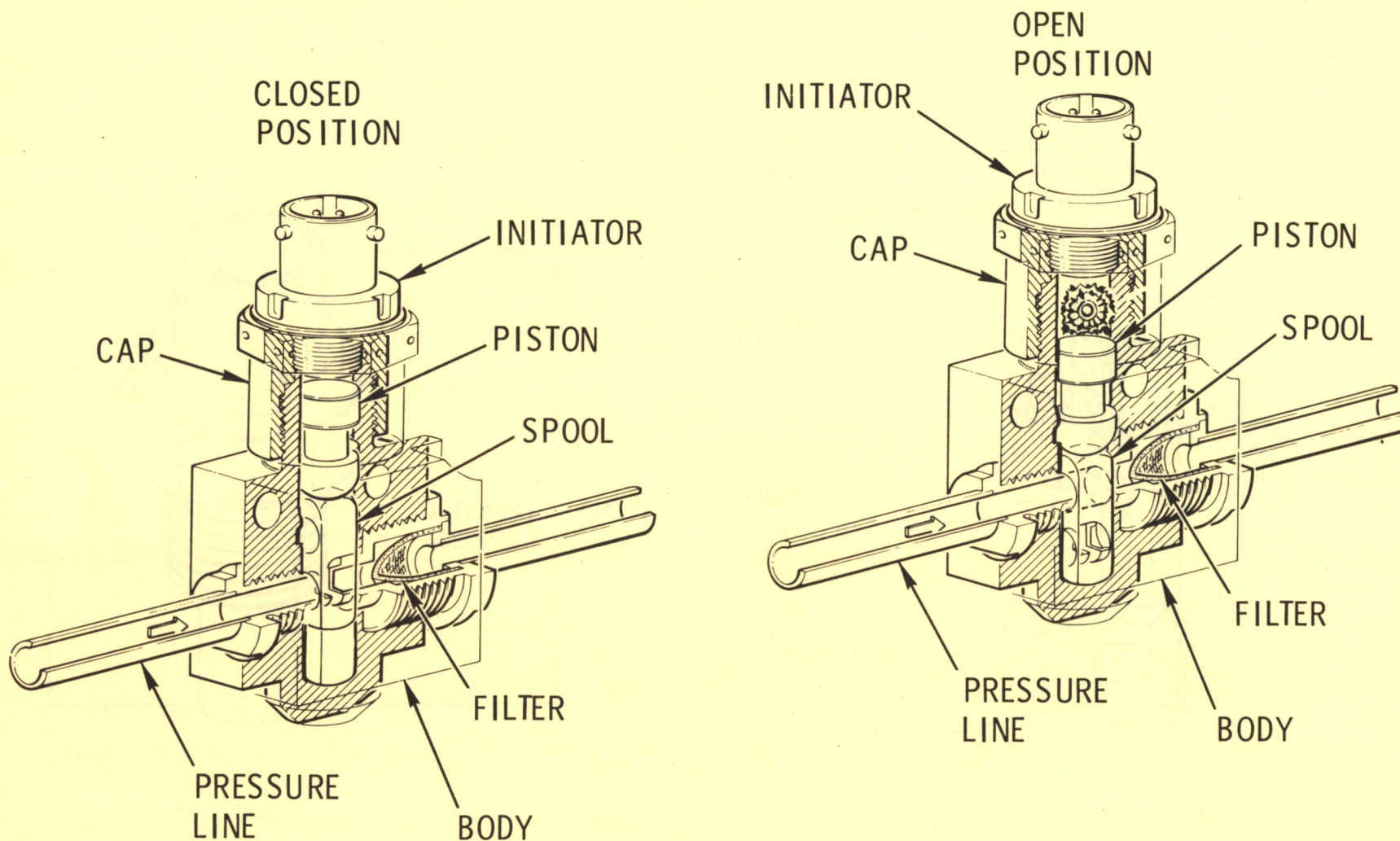


FIGURE 2.9-38

DETONATOR CARTRIDGE ASSEMBLY

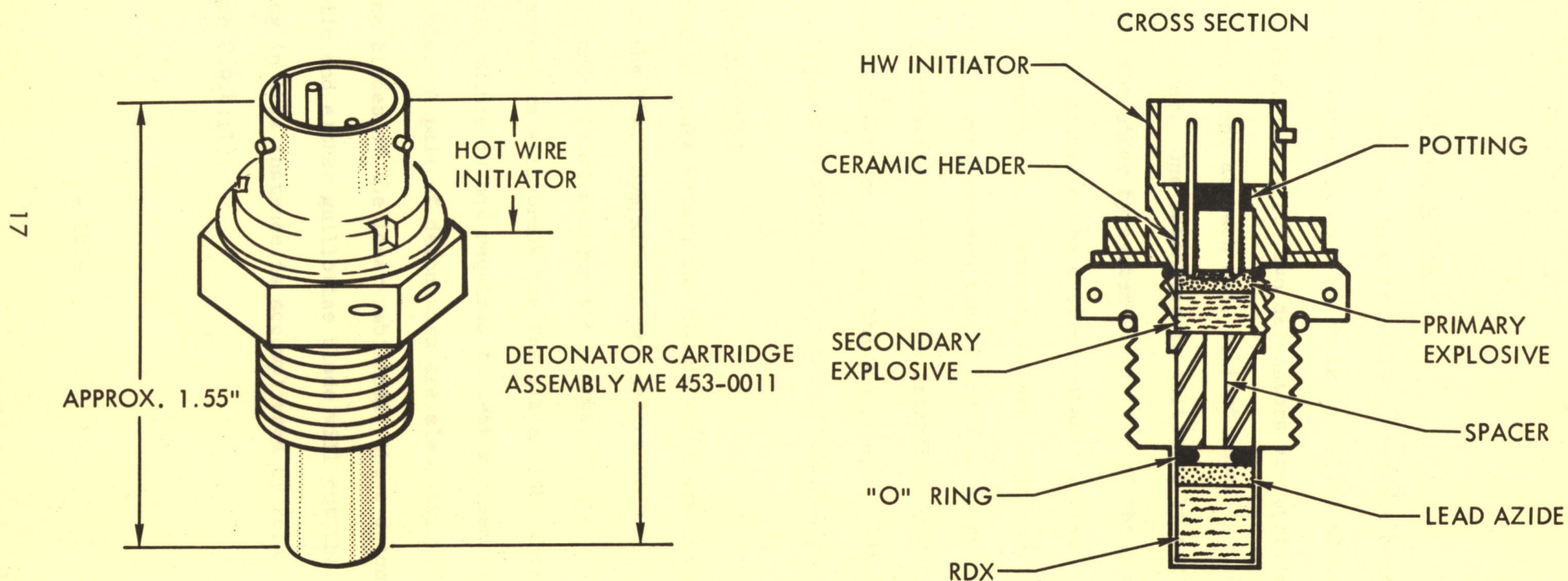


FIGURE 2.9-39

2.9.5.12.2 SLA Separation Ordnance System

Confined detonating fuse is used to transmit concussion from detonators to detonating cord which is installed along cutting planes of the SLA, Figure 2.9-21. Two detonators are utilized in this explosive train, one at each end, so that shock is transmitted toward the center. One detonator is initiated by system A firing circuits and the other by system B. Either of the nonsympathetic detonators will activate the entire ordnance system. Umbilical separation disconnect plug assemblies are blown apart disconnecting the electrical wiring between the LV and SC. An umbilical disconnect swing arm is activated, which is the interface between the LM and the GSE flyaway umbilical on one of the SLA panels. Eight panel thrusters are also activated to start deployment of the SLA panels.

2.9.5.12.3 LM Separation System

Frangible links retain the clamps which are used to secure the LM legs to the SLA. Sympathetic detonators are used to break the links and spring loading opens the clamps, Figure 2.9-40. Either of the detonators will break the frangible link, therefore the sympathetic nature is not required to meet minimum reliability requirements. A pair of detonators are also utilized to activate guillotine blades of the lower umbilical; these detonators are not sympathetic and either guillotine blade will cut the wire bundle. Deadfacing in this instance is accomplished by relay logic (paragraph 2.9.4.11).

LM SEPARATION SYSTEM BLOCK II

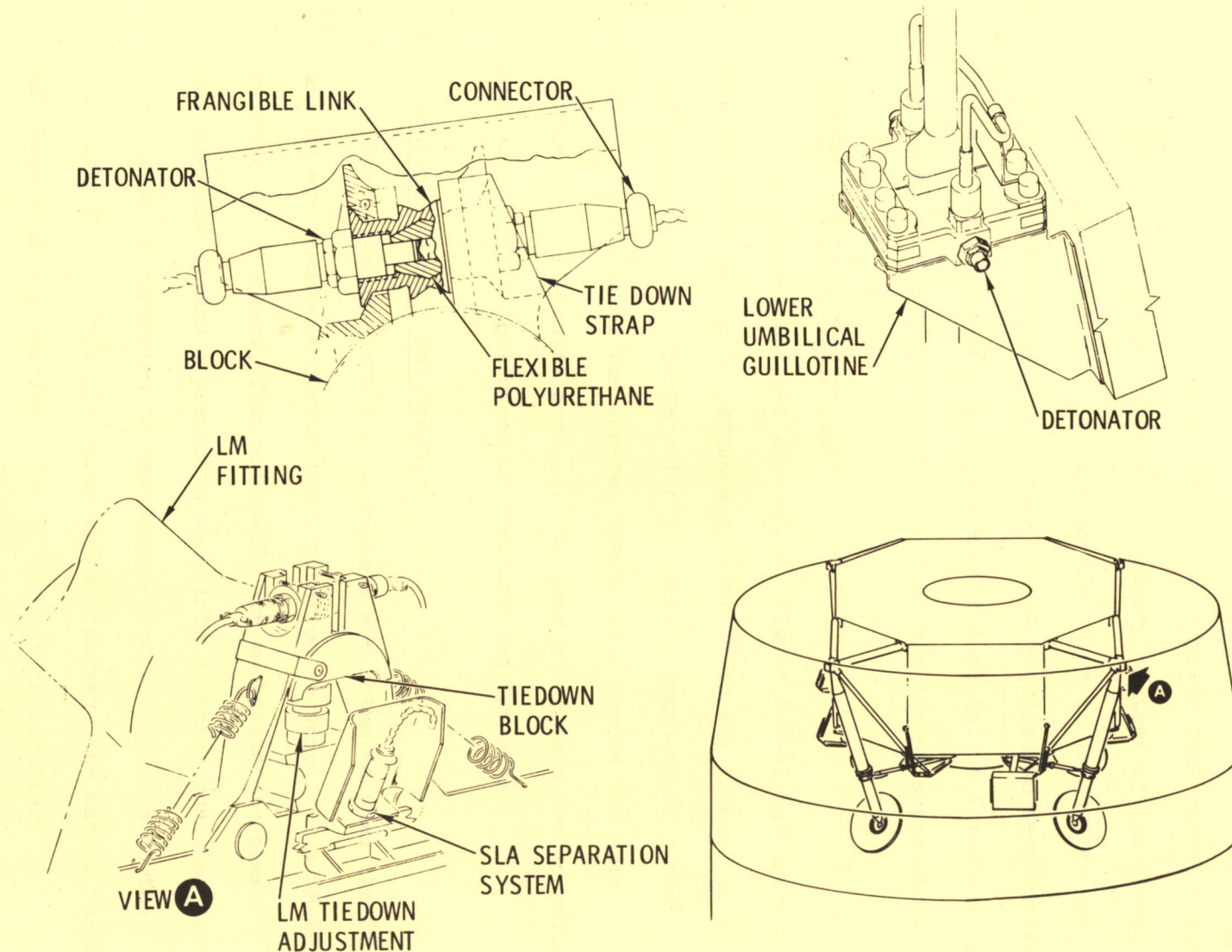


FIGURE 2.9-40

2.9.5.12.4 CM-SM Separation System

Redundant linear shape charges are used to cut three tension tie straps which constitute the physical bond of the CM and SM, Figure 2.9-25. A detonator is used to explode each linear shape charge which is sympathetic to the other. Either of the linear shape charges will cut the tension tie strap it is mounted on; therefore, the sympathetic nature is not required to meet minimum reliability requirements. The electrical-explosive interface wiring to each detonator is also cut by the linear shape charge.

2.9.5.13 Pressure Cartridge Assemblies

Solid propellant gas generators, Figure 2.9-41 have several applications in Apollo ordnance systems. The ASI is used to initiate a booster charge which is usually composed of pistol powder. Burning of the booster charge will ignite the main charge which liberates hot gas. The number of main charge pellets may be specified contingent on pressure requirements.

2.9.5.13.1 Electrical Circuit Interrupters

Two types of circuit interrupters are actuated when the CM and SM are deadfaced during the separation sequence. Two CM-SM circuit interrupters, figure 2.9-23, are mechanized by cams. Gas pressure forces a piston to move into a locked position and the piston is connected to cam forks. Inclined planes on the cam forks forces lift plates up which separates the mating parts of electrical receptacles. Two SC circuit interrupters

HOTWIRE PRESSURE CARTRIDGE ASSEMBLY ELECTRICALLY INITIATED

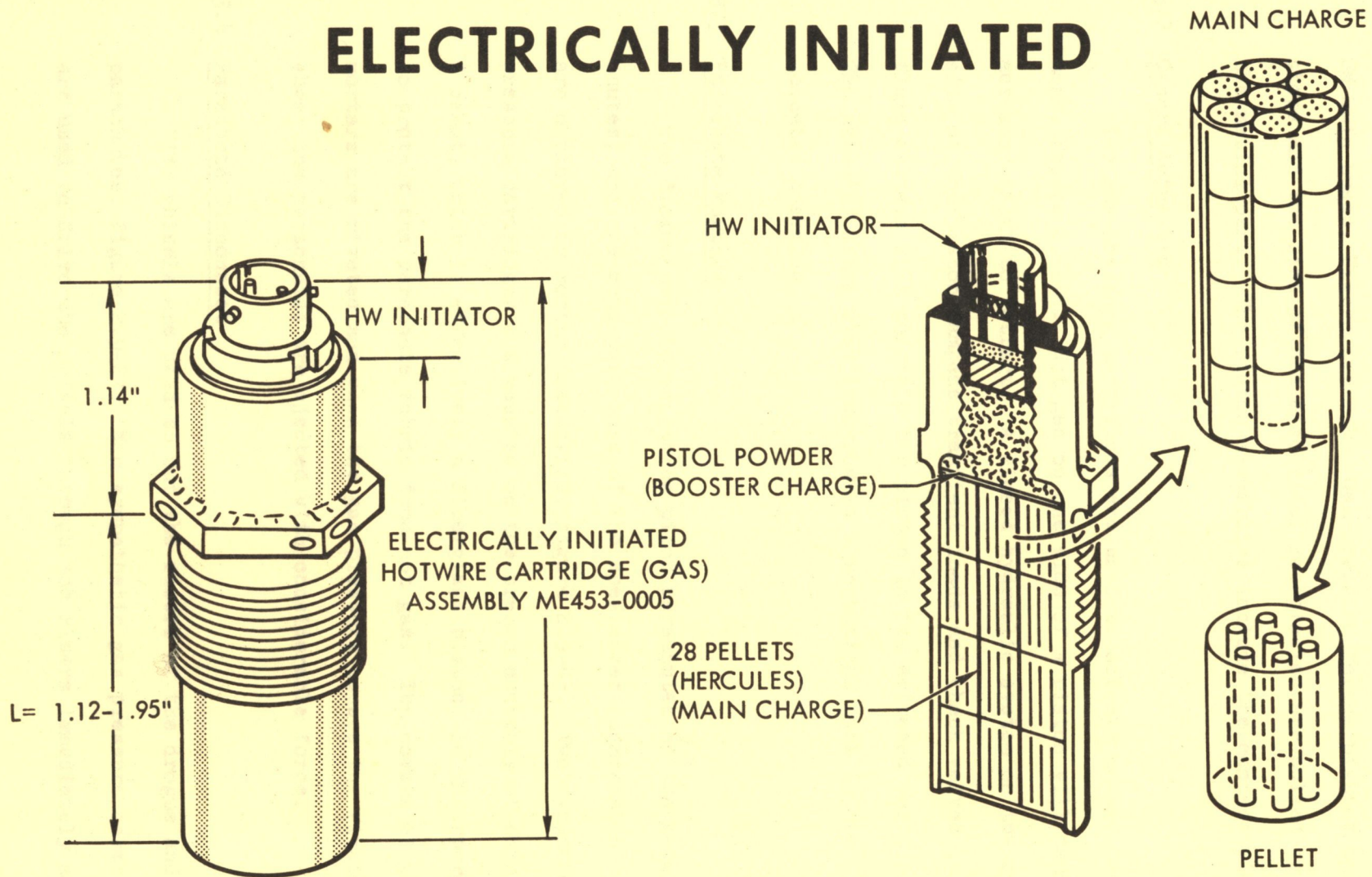


FIGURE 2.9-41

will deadface battery power, together with ground returns, to the SM main buses, Figure 2.9-23A. Gas pressure forces pistons against stops and the pins of the electrical receptacles are pulled from the mating part. The piston assemblies include the contact pins.

2.9.5.13.2 Canard Actuators

Two gas pressure cartridges are used to actuate canard deployment, Figure 2.9-42. Hot gas on one side of a piston will cause the actuator shaft to retract. A closed hydraulic system on the opposite side of the piston dampens transient loads and check valves in the fluid systems will maintain the piston in its actuated position. The actuator shaft also incorporates a mechanical lock in the actuated position.

2.9.5.13.3 Parachute Mortars

Two drogue parachutes; three pilot parachutes of the main parachutes; and one drag parachute of the apex cover augmentation system are deployed by mortar assemblies, Figure 2.9-43. Two sympathetic pressure cartridges are mounted on the breech assembly of each mortar. A sabot, which is effectively a fiberglass piston, is incorporated to protect the parachute fabric from hot gas. The covers of the mortars are riveted and when the gas pressure causes the rivets to shear the parachutes are ejected with considerable force.

2.9.5.13.4 Parachute Disconnect

Five chisels are used to cut the risers of the drogue and main parachutes, Figure 2.9-27. Non sympathetic gas pressure cartridges are used to drive the chisels through the risers immediately above

CANARD ACTUATOR

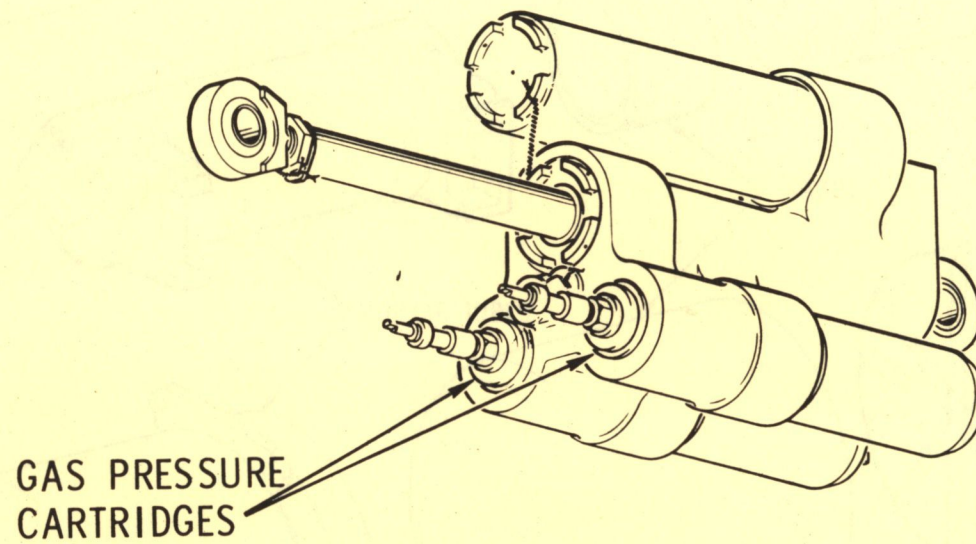
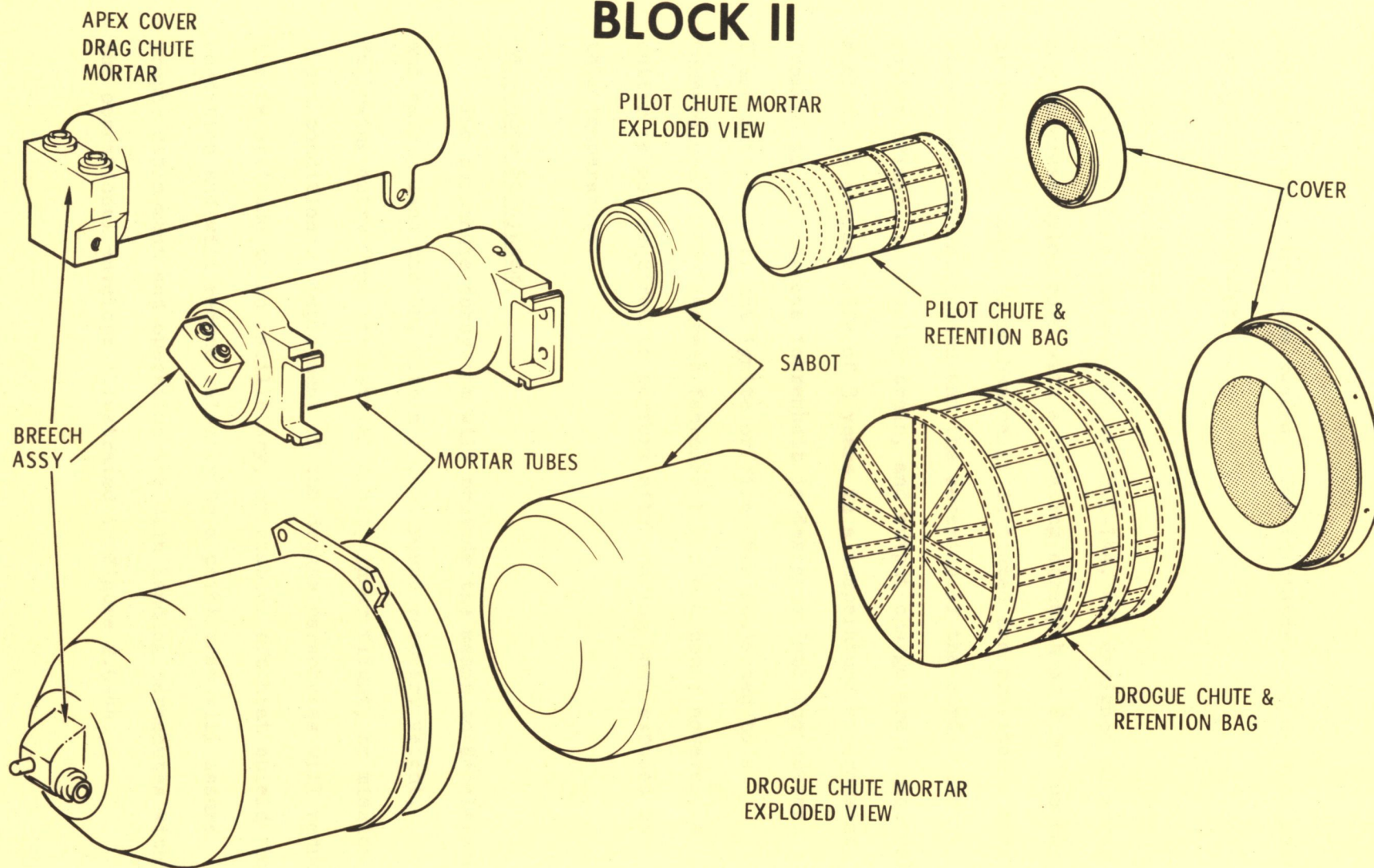


FIGURE 2.9-42

MORTAR ASSEMBLIES BLOCK II



24

FIGURE 2.9-43

the point where they are swaged. Two initiators are used on each gas pressure cartridge.

2.9.5.14 Reefing Line Cutters

Reefing line cutters, Figure 2.9-14A, are designed to sever any coreless nylon cord with a breaking strength of 2,000 pounds or less. The unit is mechanically initiated and provides a time elapse between initiation and the severing of the cord. The cutter primer, time delay train, and output charge are hermetically sealed. A storage life of 3 years in a temperature environment from 20 to 140 degrees fahrenheit is designed into the cutter. These cutters will not ignite or fire when subjected to a temperature of 275 degrees fahrenheit for one hour; however, a cutter is not required to perform after having been exposed to this temperature.

2.9.5.15 Parachute Subsystem

The parachute subsystem will provide the means to decelerate and safely land the CM, with a 13,000 pound recovery weight, following entry from terrestrial orbit, lunar flight, or mission abort conditions. Deployment of the drogue parachutes will reduce the CM attitude to an oscillatory, or stable, aft heat shield forward condition and will reduce velocity to a point that will assure proper deployment and operation the main landing parachutes within the operational envelope illustrated in Figure 2.9-44.

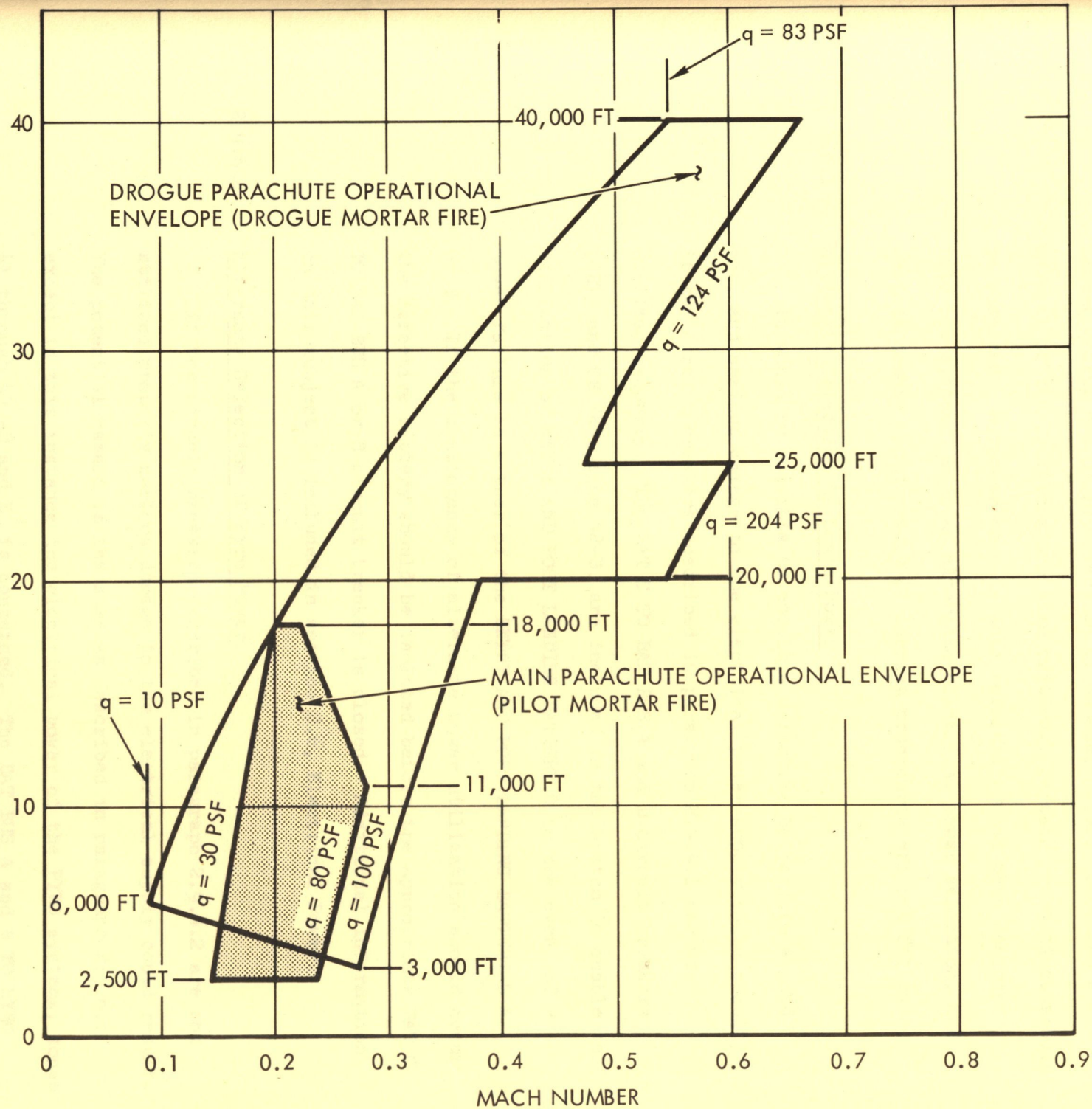
ALTITUDE - FT X 10⁻³

FIGURE 2.9-44

SM-2A-896A

2.9.6

OPERATIONAL LIMITATIONS AND RESTRICTIONS

Since the sequential systems include numerous controls for manual backup and/or intervention of automated functions, and since several of the functions are time critical, certain precautions should be observed. Moreover considerable versatility has been designed into the systems, such as alternate electrical power selection, and serious damage could result if correct procedures are not followed.

2.9.6.1

Alternate Selection of Logic Power

It would be possible to couple a defective battery to a good one, and serious damage to the electrical power supply could result, if the circuit breakers described in paragraph 2.9.4.1 are not utilized properly. The BAT C TO BAT BUS A and B circuit breakers (CB15 and CB 24), zone 42-B, are included in the system to enable the utilization of ENTRY AND POST LANDING BATTERY C in the event of a power failure in either of the ENTRY AND POST LANDING BATTERIES A or B. If the contingency of alternate power utilization should occur the defective battery should be isolated before the appropriate BAT C TO BAT BUS A or B circuit breaker is closed. Additional information on this subject is included in section 2.6, Electrical Power.

2.9.6.2

Alternate Selection of Pyro Power

If the circuit breakers described in paragraph 2.9.4.2 are not utilized properly serious damage to the electrical supply could result. The potential hazard is the same as described in paragraph 2.9.6.1 except in this instance the electrical power of the PYRO systems, zones 41 through 43 -D and E, is concerned. The BAT BUS A and B TO PYRO BUS TIE circuit breakers (CB 18 and CB 19) are included in the system

to be used in the event of a failure of PYRO BATTERY A or B.

If such a power failure should occur the appropriate SEQ A or B circuit breaker (CB 16 or CB 17) should be opened before coupling the appropriate ENTRY AND POST LANDING battery to the PYRO power system.

2.9.6.3 Control For Arming Pyro Systems

Battery power is required to arm or safe PYRO buses (paragraph 2.9.4.3). It is therefore necessary to close the SECS ARM BAT A circuit breakers (CB 1), and/or its counterpart in system B, zone 39-C, before the motor switch (K1) in the LDEC, zones 39 and 40 -E and F, can be operated to energize or de-energize the PYRO buses. This feature is designed into the system for power conservation during a mission when the docking probe is being used. The procedures for the utilization of battery power for control of PYRO power will consequently differ somewhat during the various phases of a mission.

2.9.6.4 Status of Logic and Pyro Buses

It will be necessary for the flight crew to verify the status of LOGIC and PYRO buses, i.e., armed or safe, through the MSFN. Displays for this status are not included in the CM.

2.9.6.5 Utilization of Controls for CSM/LV Separation

When the CSM/LV SEP switch is used (paragraph 2.9.4.9) it should be held closed for approximately one second (0.8 seconds minimum) for the time delay relay logic to perform as it was designed.

2.9.6.6 Utilization of Controls for CM/SM Separation

When the CM/SM SEP switches are used they must be held closed for approximately two seconds for the time delay relay logic to perform as it was designed (paragraph 2.9.4.13.1).

2.9.6.7 Manual Control of ELSC Functions

Under certain entry conditions, erratic aerodynamic damping coefficients, wind gusts, and shears the CM may become unstable. If this should occur, the apex cover and drogue parachutes may be manually deployed early. This will stabilize and keep the CM in the proper descending attitude, see figure 2.9-44 for the drogue deployment design envelope. The following precautions should be observed:

- a. Manual initiation of drogue parachute deployment should never be accomplished above 40,000 feet during entry.
- b. The CM RCS must be turned off prior to apex cover jettison.
- c. Manual initiation of apex cover jettison must not be executed with the apex cover on the vehicle.
- d. Manual initiation of drogue parachute deployment must not be executed with the apex cover on the vehicle.
- e. Manual initiation of main parachute deployment must not be executed prior to drogue deployment.
- f. Manual initiation of main parachute deployment must be accomplished above 2,500 feet.

h. It is impossible to release the main parachute with the ELS switch in the MAN position. This switch must be in the AUTO position and the 14 second time delays in the ELSC (TD 3 and TD 4), zone 6-C, expired before the MAIN RELEASE switch is armed.