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P-3 ELECTRICAL POWER SYSTEM

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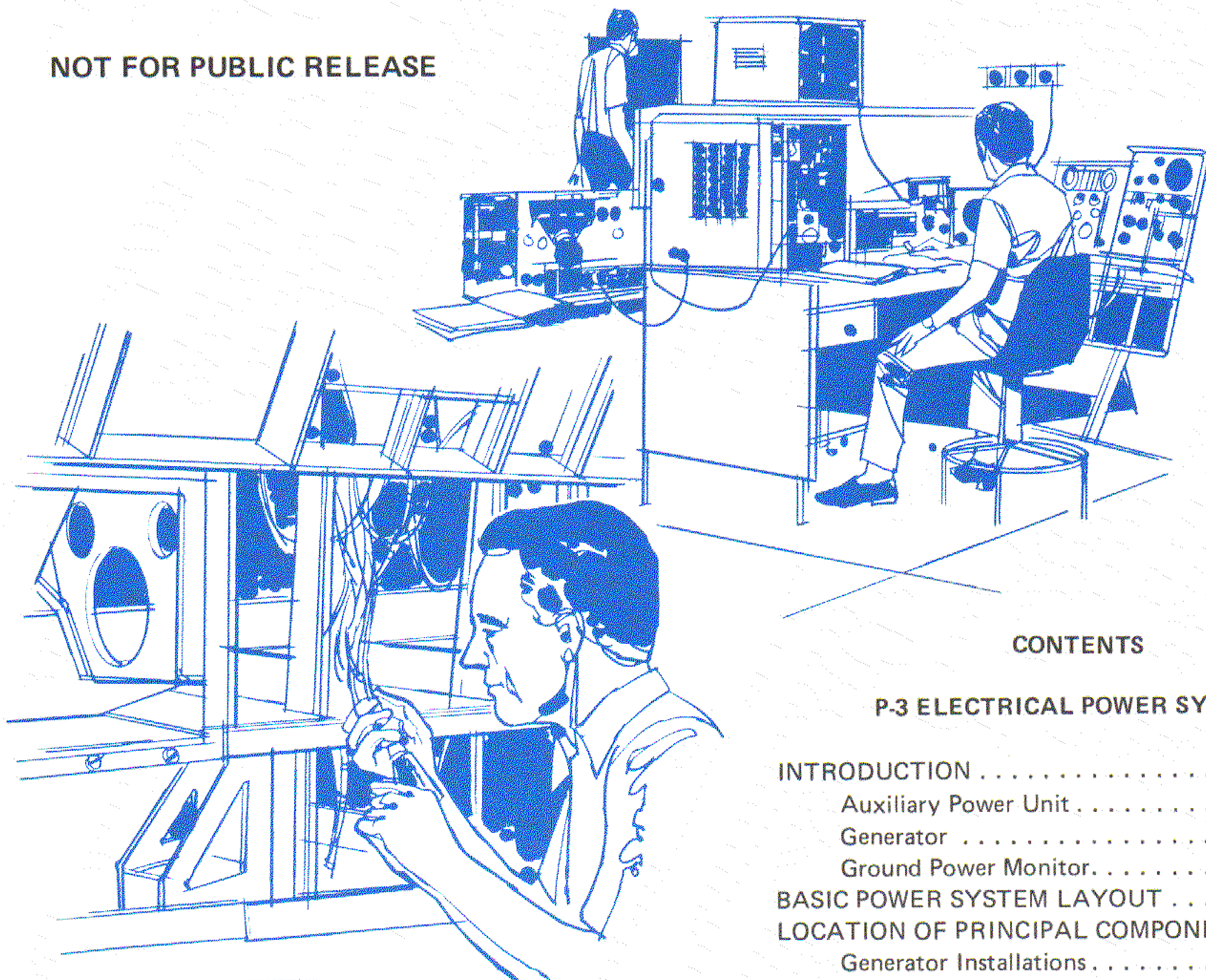

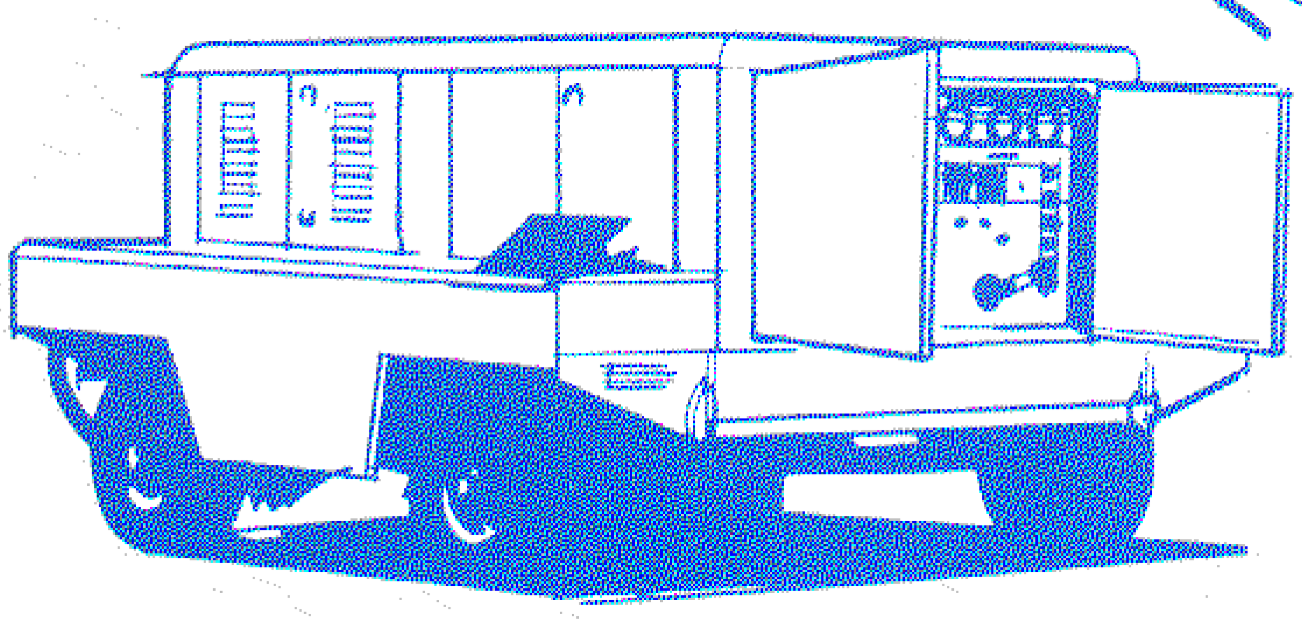

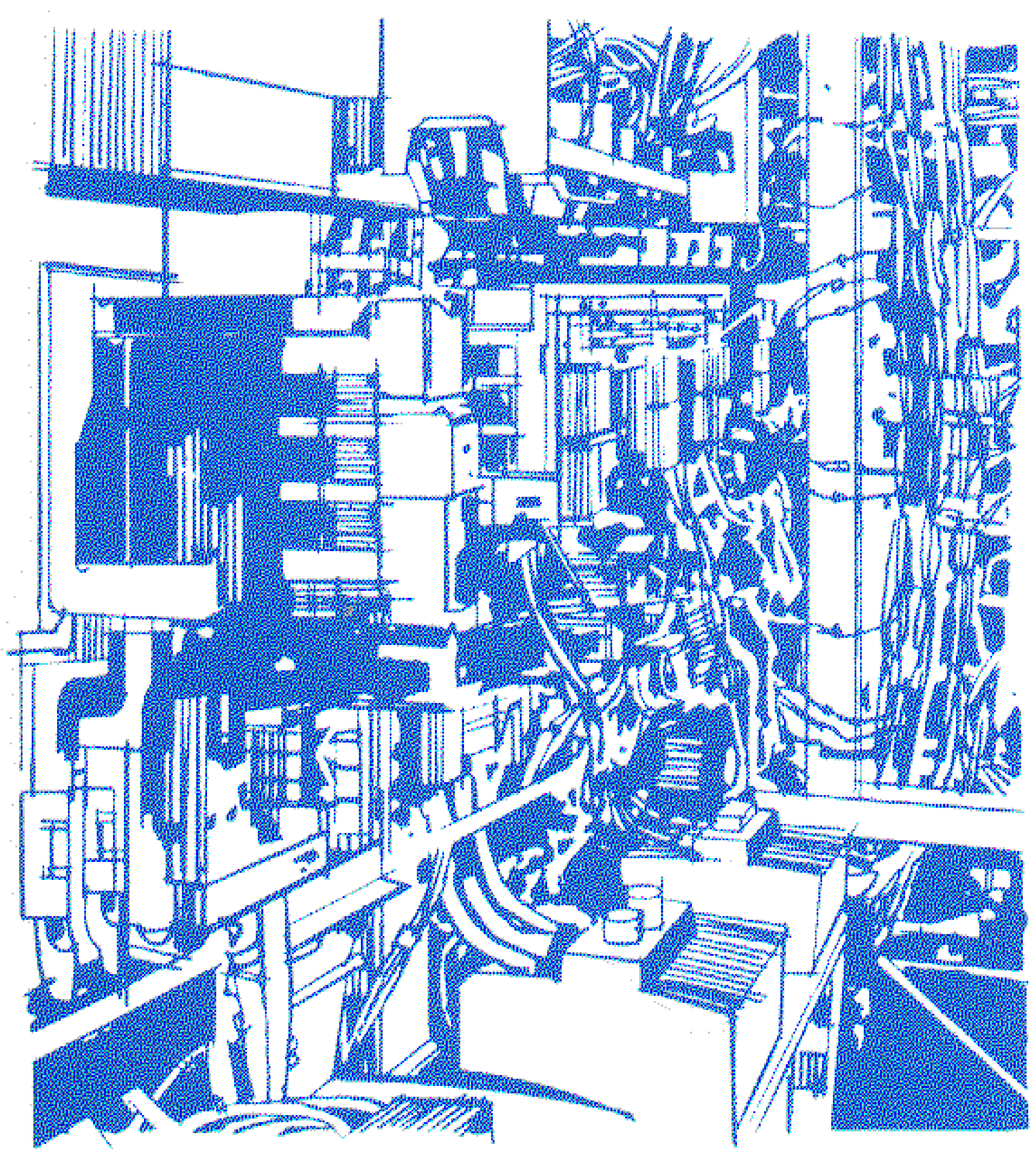

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FRONT AND BACK COVERS

PATRON FORTY-SIX is the oldest, continuously operating patrol squadron in the United States Navy. Commissioned in September 1931 in Coco Solo, Canal Zone as VP-5S, the squadron received eight name changes during the next 17 years until September of 1948 when she acquired her present designation. During more than four and one-half decades of colorful history, the squadron has performed her tasks in twelve different models of aircraft including the PM-2, P2Y-1, PBM-5, P5M, P2V, and all models of the P-3 through the P-3C Update I.

World War II found the squadron operating in the Caribbean. During a two-week period in July 1943, aircraft from VP-32 (as it was then called) located and sank three German U-boats off the southern coast of Puerto Rico. The squadron received the Navy Unit Commendation for this action. During the Korean War, VP-46 was the first seaplane squadron during the conflict to conduct combat aerial patrols off the Chinese coast and in the Formosa Straits. The men of PATRON FORTY-SIX flew 3,583 hours during this action and received a total of 22 flying crosses, 107 air medals and 178 gold stars in lieu of second air medals.

During May of 1961, VP-46 made a most significant transition, trading in the P5M-1 Marlins for the land-based P2V Neptunes. Two years later in January of 1963, the squadron moved to its new homeport, NAS Moffett Field, California. The pace quickened, for just one year later in January of 1964, VP-46 became the first squadron in the Pacific Fleet to be equipped with the P-3A Orion. From 1964 through 1971, VP-46 deployed to various sites in the Pacific including Adak, Alaska; Naha and Kadena, Okinawa; Utapao, Thailand; and Sangley Point, Philippines, many times flying over 7,000 hours during the six-month deployments. Shortly after returning from Kadena, Okinawa in December of 1976, the Gray Knights were recipients of the coveted Captain Arnold Jay Isbell Trophy award. This award is given to the squadron exhibiting "the greatest degree of professionalism and effectiveness during operational ASW missions."

In early 1977, the squadron began transitioning to the P-3C Orion Update I. The squadron is currently employing these aircraft in an operational detachment at NS Adak, Alaska.

VP-46 continues to build on an aviation milestone, the first P-3 squadron to achieve 116,000 accident-free flying hours, some 14 years. Throughout her operational history, in all her transitions, and on all of her deployments, the squadron has proudly displayed the "can do" spirit. This spirit, reflected in the attitude of her officers and men, has won her the title *The Oldest and the Best.*

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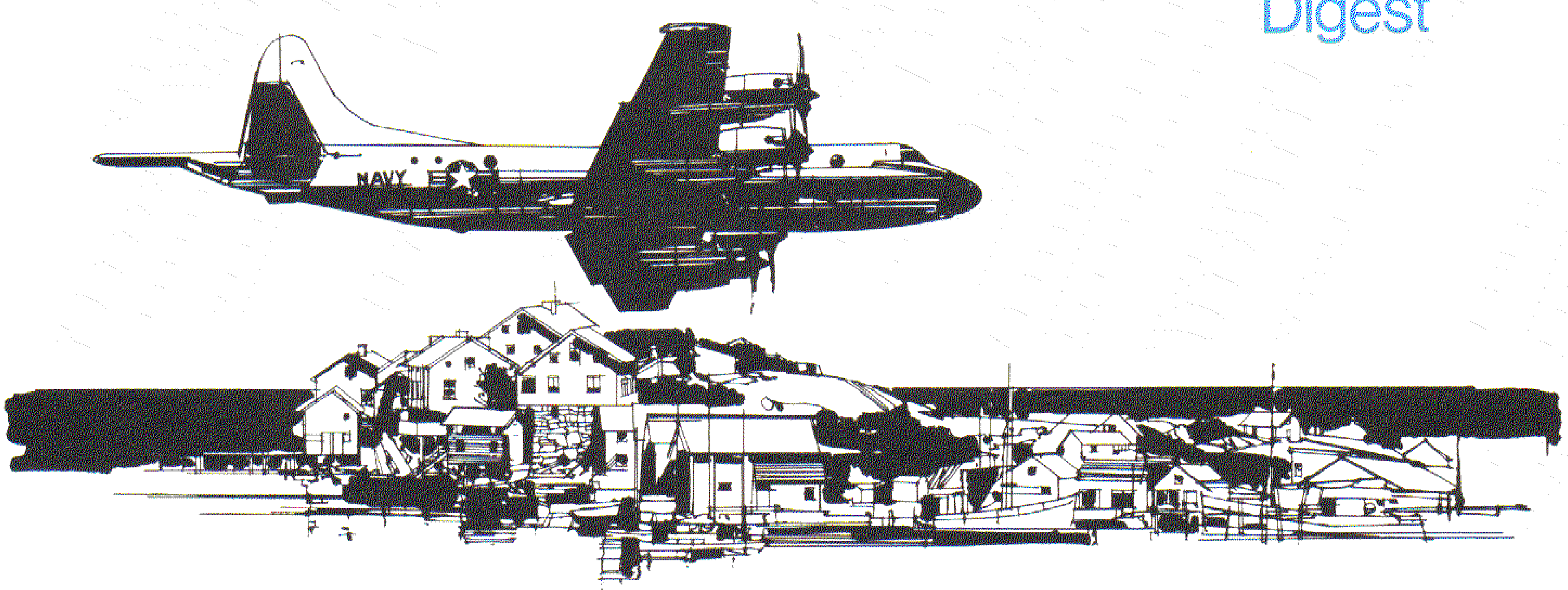


The P-3 Electrical Power System

by Ed Osborn
Design Specialist

INTRODUCTION

The P-3 electrical system is interconnected with all the other aircraft systems and is the prime power source for all electrical functions on the airplane. This article was developed to provide a working knowledge of the electrical system.

This issue discusses the basic power system layout, its major components and its control and distribution. The principal schematics (Supplement A) show the ac and dc power distribution. We have not attempted to show all details and variations of the different P-3 models. Even though the basic electrical system is consistent throughout all P-3s, aircraft may differ from one block to another, and of course, from one model to another. The differences are often relatively minor; for example, the nomenclature on circuit breakers may vary from one aircraft to another, or specific circuits may have been added or deleted depending on specific mission requirements. The schematics and photographs in this article describe P-3 aircraft SERNO 159503 (Lockheed Serial No. 5620). As always, the reader must consult the latest revision to the official NAVAIR manuals to obtain up-to-date information concerning the ever-evolving electric system.

The initial electrical power and distribution system for the P-3 was derived from the "split bus" non-parallel arrangement used on the Electra airliner. The original P-3 aircraft retained the Electra's two-speed gearbox feature but utilized three generators instead of four (one each mounted on engines no. 2, 3, and 4).

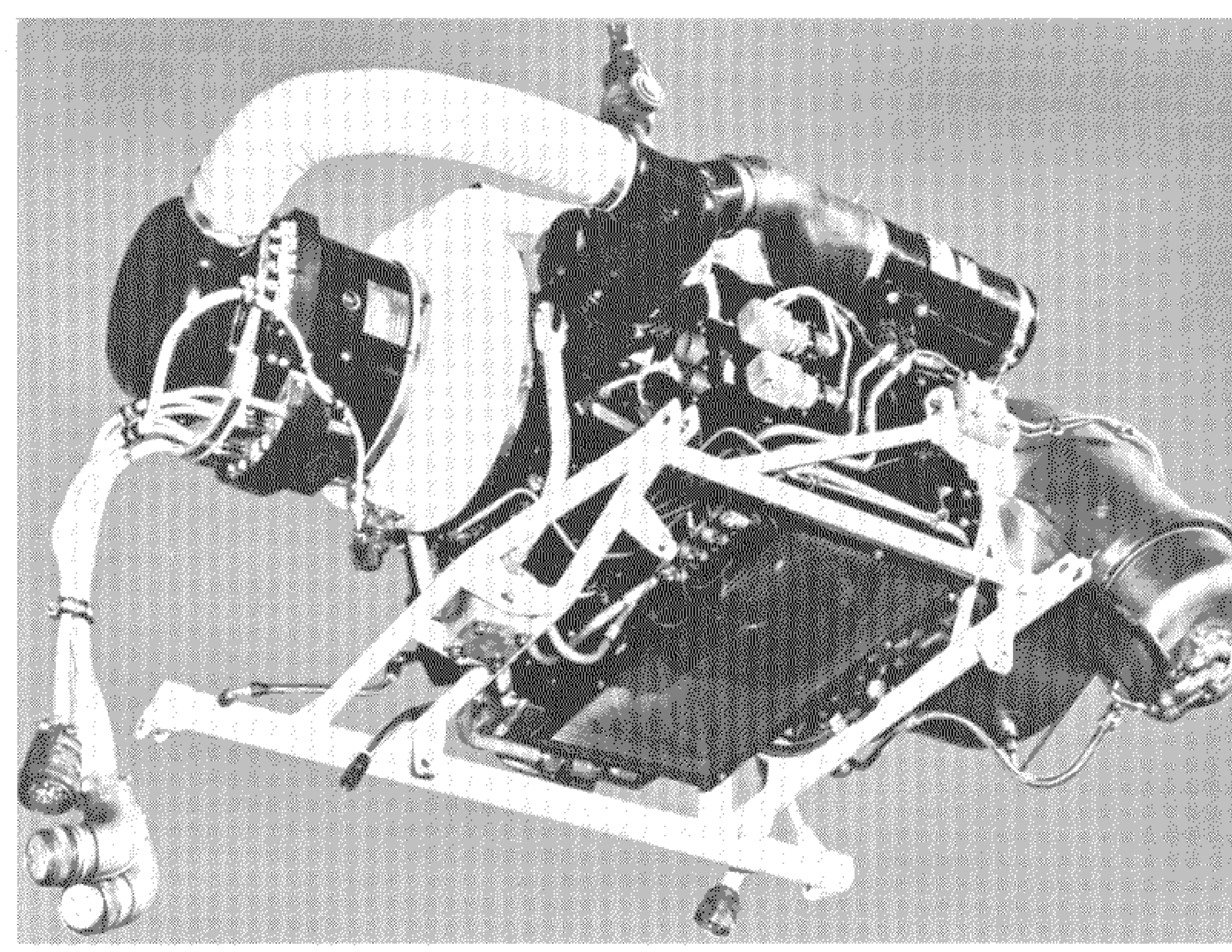
Years of operational experience have prompted a number of changes to be made to the P-3 electrical system. Among these changes were installation of an auxiliary power unit, replacement of the engine-driven, brush-type generators with brushless-type generators, and modifications to the power distribution system to accommodate these changes.

AUXILIARY POWER UNIT The auxiliary power unit (APU) shown in Figure 1 is sometimes referred to as the integral start system (ISS). This unit was first envisioned as a 400-Hz ac ground power source with provisions for supplying pneumatic power, both for engine starting and for ground air-conditioning.

Airframe Change (AFC) 110 implemented installation of the auxiliary power unit. The APU system was updated by AFC-122 to permit emergency in-flight operation of the APU for electrical power only. Installation of the APU made the two-speed gearbox between the no. 4 engine and the generator redundant, so the gearbox was deleted from production aircraft and removed from delivered aircraft by AFC-122.

The original installation of the APU generator provided it with priority over the no. 4 engine-driven generator in the control switching circuitry. Addition of the capability for in-flight use of the APU made it desirable to reverse the order of priority, as the APU is power-restricted above 8,000 feet and cannot fulfill the same power demand as the no. 4 generator. Transfer of this priority to the no. 4 generator was one of the subjects dealt with by AFC-165. This airframe change also made provisions for a simplified load monitoring arrangement for the APU generator. Since the APU turbine requires an electric starter, the 11-ampere-hour battery used on early aircraft was replaced with a 31-ampere-hour battery to handle the increased load. The heavier battery is located

Figure 1. Auxiliary Power Unit With Generator Mounted on Left End of APU



at the aft end of the nosewheel well on a crank-operated elevator support to facilitate maintenance.

GENERATOR The P-3 aircraft brushless-type generator system was first installed on P-3B Orions and retrofitted to the earlier P-3As (see Figure 2). Subsequently, an orifice cap was installed on each generator to reduce water ingestion by the generators.

In 1972 a modification program authorized by Accessory Change (AYC) 314 installed an auxiliary bearing at the drive end of each generator. The addition of this bearing permits engine (and generator) operation after the generator's primary bearing fails, thereby enabling the aircraft to complete the mission. Upon failure of the primary bearing, the auxiliary bearing assumes the load and is capable of operation for about 10 hours. When the auxiliary bearing is under load, its outer race contacts the generator housing and activates a flight station warning light.

A modified generator is scheduled for installation into production Orions late in 1978. Both physical dimensions and electrical output characteristics will remain unchanged, and the generator will be fully compatible with all existing or anticipated equipment. This generator is discussed in the Recent Modifications section of this article.

GROUND POWER MONITOR Originally, the airplane electrical circuits were designed with the assumption that the ground power units would have adequate protective and control circuitry to prevent application of improper power to the aircraft ground power receptacle. The only monitoring device on the aircraft was a phase sequence relay. The only function of the relay was to ensure that the incoming ground power was of the correct phase sequence before it was routed to the bus system. However, there were reports of damage to aircraft on-board equipment by "out of specification" ground power supplied to the aircraft when the ground power unit's protective circuitry was malfunctioning. To correct the problem, AFC-161 authorized replacement of the phase sequence relay with a monitor unit, M24021-4, which provided additional protection in the form of a voltage and frequency-sensitive relay.

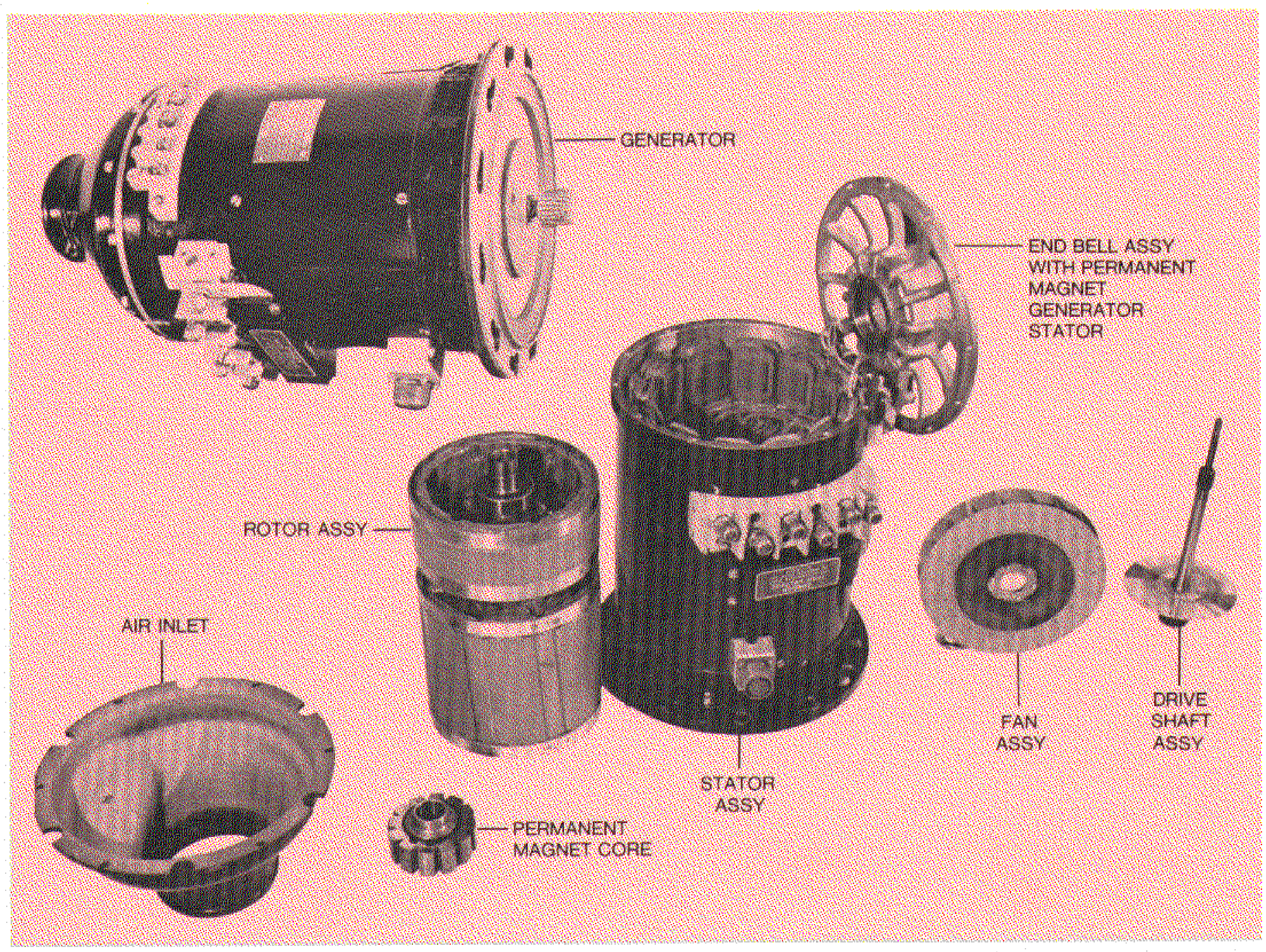


Figure 2. Brushless Generator

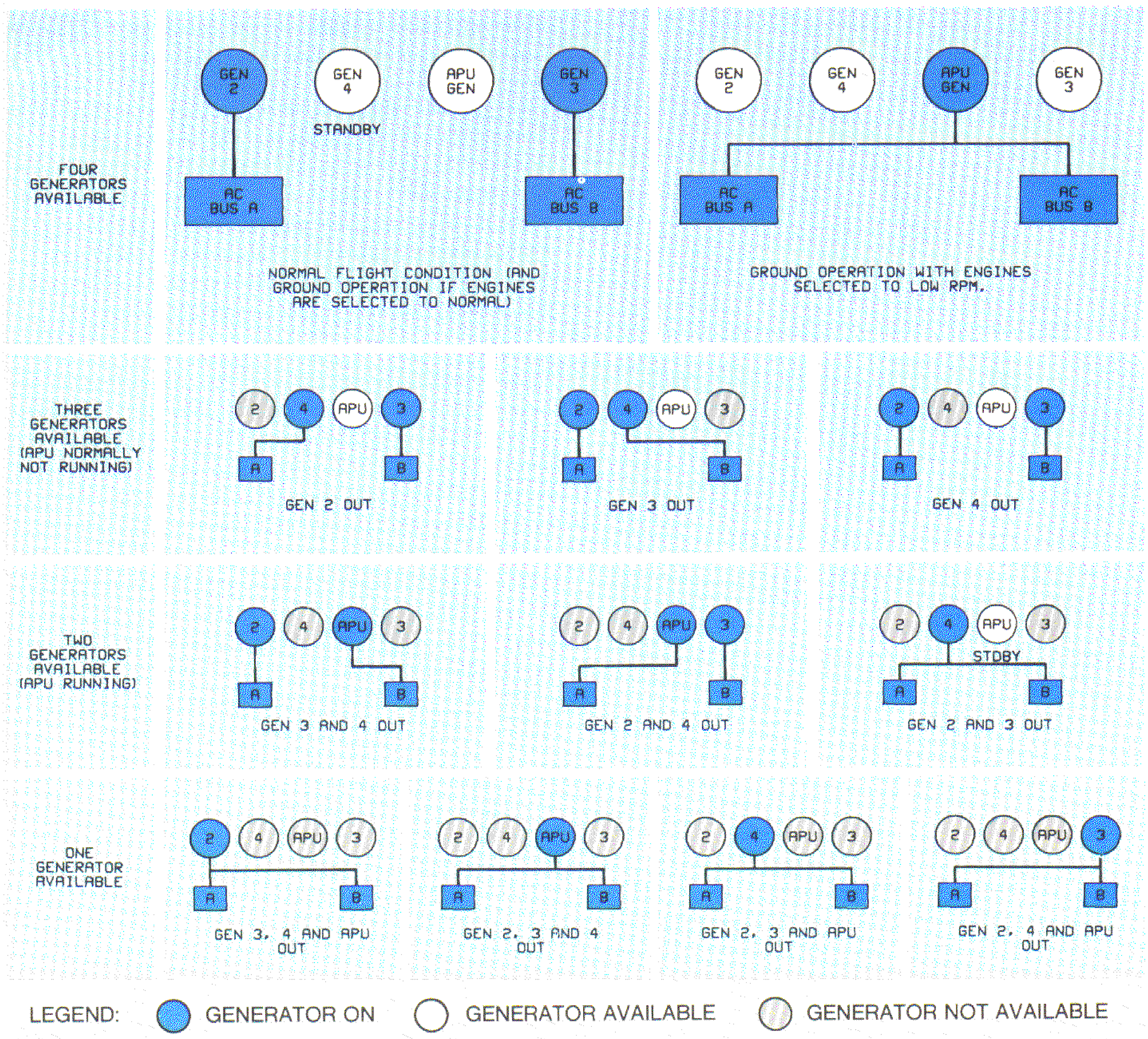


Figure 3. Generator/Bus Support Diagram

BASIC POWER SYSTEM LAYOUT

For all flight conditions, and with the exception of a 31-amphere-hour battery, all electric power on P-3 aircraft is derived from four identical 120/208 volt, 3-phase, 400-Hz alternating current brushless generators. Three of these generators are installed on engines no. 2, 3, and 4 and are numbered correspondingly. They are rated at 60 kva for ground operation and 90 kva for in-flight operation. The fourth generator is mounted on a gas turbine auxiliary power unit (APU) installed low in the forward fuselage. Its output up to the 90 kva maximum is restricted by altitude and ambient air temperature, since these factors determine the maximum available horsepower rating of the turbine drive.

The various generator/bus connections are depicted in Figure 3. An automated transfer system determines the availability of the generators and connects them to (or disconnects them from) two separate groups of loads (buses) in accordance with a predetermined plan. Figure 3 shows the various generator/bus connections allowed for by the plan

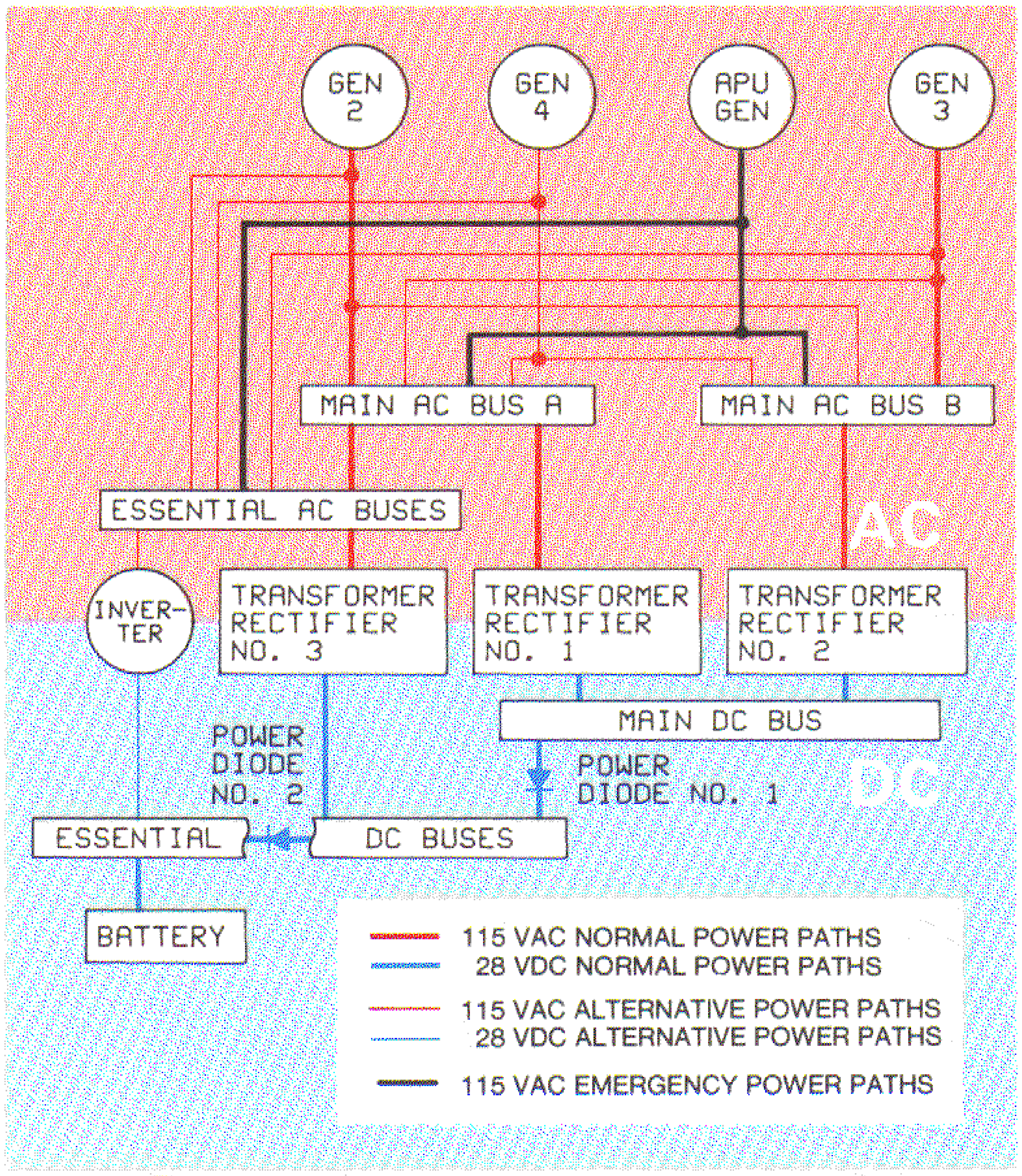


Figure 4. Basic Power System Layout

and the operation of the main ac bus transfer system. The generators never operate in parallel; i.e., a bus is never connected to more than one generator. Figure 3 shows the normal flight operation of the system where generators no. 2 and 3 are operating independently; no. 2 is powering the main ac bus A, no. 3 the main ac bus B, and generator no. 4 is energized but on standby.

Figure 4 shows normal and alternate generator connections and how the other principal power system components are energized. For simplification, the figure shows both the ac and dc essential buses as one bus each, while in reality, each bus consists of several more. For example, the essential ac bus actually consists of three buses: the start essential ac bus, the monitorable essential ac bus, and the flight essential ac bus. The dc essential bus also consists of additional buses. For the sake of the following discussion of the basic power system layout, it is helpful to consider the two groups of essential buses in the manner shown in the figure.

As the term *essential* implies, the essential ac bus feeds a select group of services which are of primary importance to the aircraft's operation. The same statement also applies to the essential dc bus; it feeds the most important direct current services.

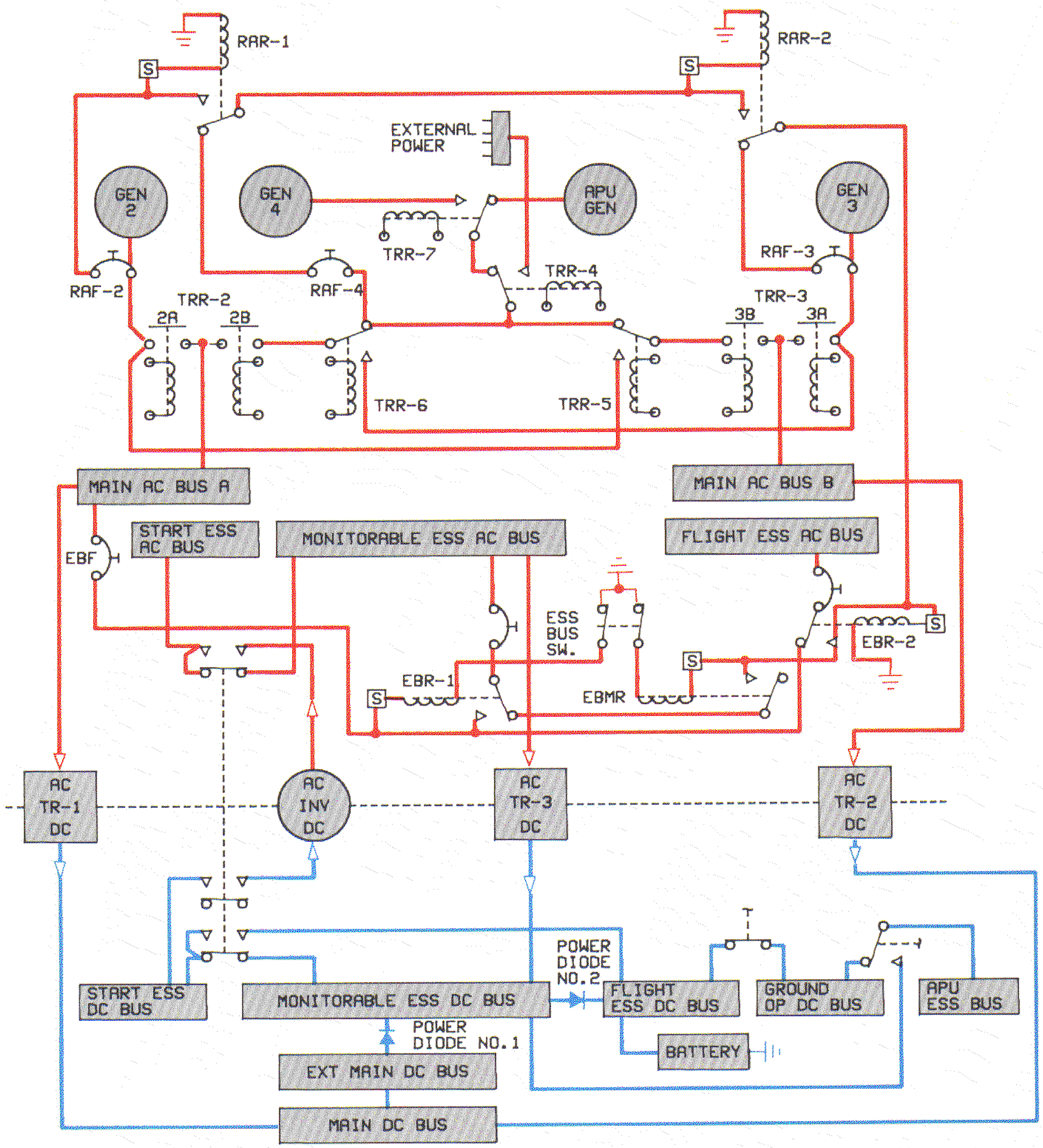
Each of the three ac buses shown on Figure 4 powers one of the three transformer-rectifiers that provide the 28 Vdc power for the P-3. Transformer-rectifiers no. 1 and 2 both supply power to the main dc bus; they are also connected to the essential dc bus through power diode no. 1, which allows current to flow from the main dc bus to the essential dc bus, but not in the reverse direction.

It can be seen from the figure that all three transformer-rectifiers are available even if only one generator is operating. The possible alternate lines of supply to the essential ac bus (connected just below each generator) are also shown. This run-around or bypass system ensures that the essential aircraft services are available even in the event of a complete breakdown of the main ac bus transfer system. A generator can power more than one bus simultaneously, but a bus never receives power from more than one generator at a time. Which generator powers which buses, however, depends upon a comparatively simple automatic circuit that does not involve additional control circuits.

With power on the essential ac bus, the essential dc bus is also energized via transformer-rectifier no. 3. Under emergency conditions involving a partial or total loss of power from the main ac buses, the importance of power diode no. 1 becomes more apparent – the dc output of transformer-rectifier no. 3 is restricted to the essential dc loads on the aircraft and is blocked in the direction of the main dc bus.

The aircraft battery is connected to the essential dc bus and is maintained in a charged condition whenever there is a source of ac power for the aircraft. The battery, in conjunction with the inverter, supplies the minimum ac and dc power necessary for ground operation and emergency situations when no other power source is available. The inverter and battery supply power to only a few essential loads, as can be seen by the presence of power diode no. 2 shown in Figure 4.

A more complete and detailed power and busing arrangement is shown in Figure 5. The figure also depicts the actual breakdown and interconnection of the bus system through the transfer and run-around relays.



LEGEND: AC — DC

RAR = RUNAROUND RELAY
TRR = TRANSFER RELAY
EBR = ESSENTIAL BUS RELAY
EBMR = ESSENTIAL BUS MONITOR RELAY
S = 3 PHASE VOLTAGE SENSOR
RAF = RUNAROUND FEEDER
EBF = ESSENTIAL BUS FEEDER
TR = TRANSFORMER-RECTIFIER

Figure 5. Electrical Bus Circuit Diagram

LOCATION OF PRINCIPAL COMPONENTS

The majority of the electric power system components are located in three main areas shown in Figure 6 and identified as follows:

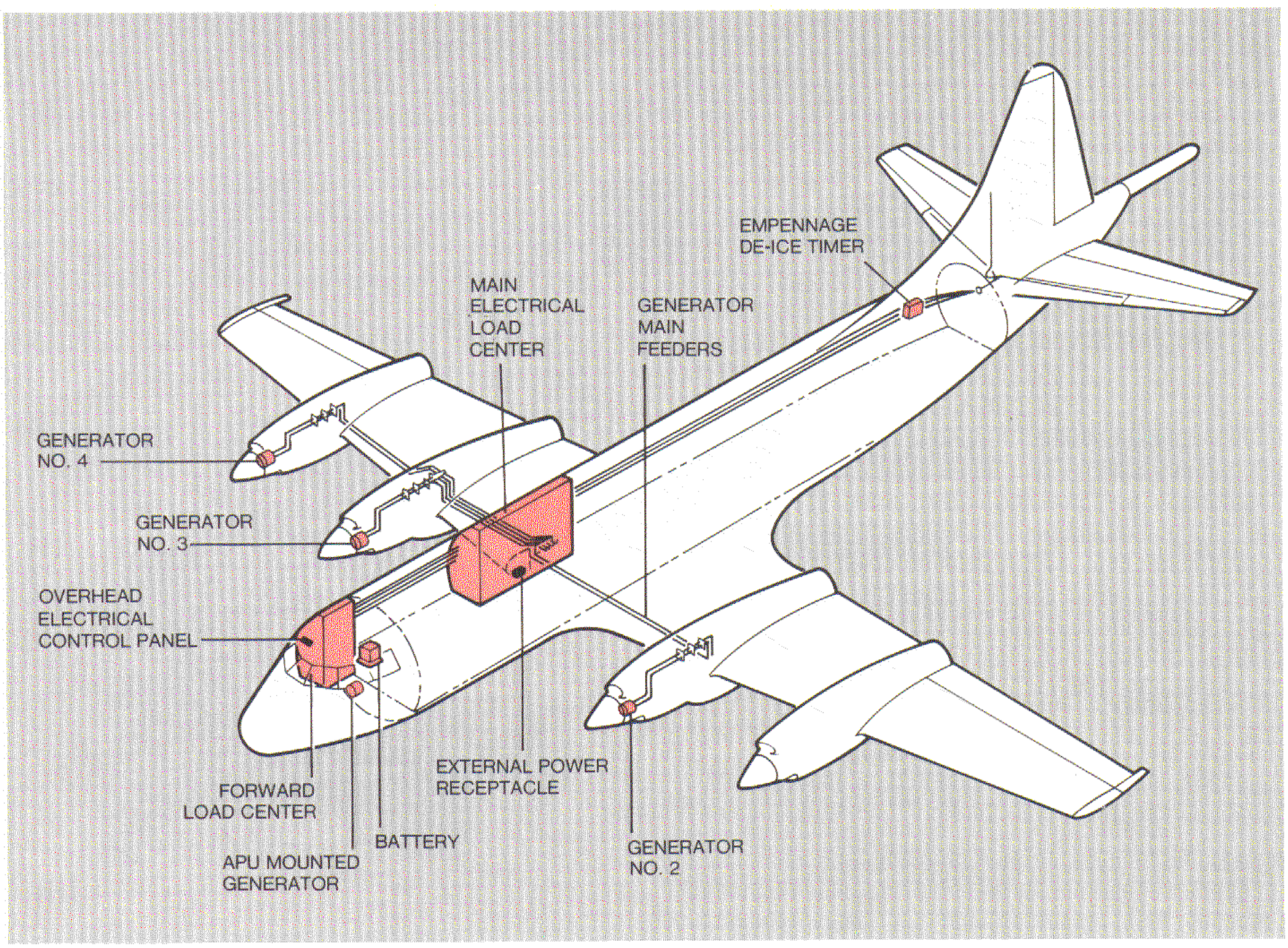
1. Generator installations
   a. Main power plants
   b. Auxiliary power unit
2. Main load center
3. Forward load center

GENERATOR INSTALLATIONS Three of the generators are mounted on the main power plants, and another is mounted on the auxiliary power unit.

Main Power Plants With the exception of engine no. 1, a generator is mounted on the aft right-hand side of each engine/propeller reduction gear box. The no. 2, 3, and 4 generator installations are identical (see Figure 7).

For nearly all operational conditions (in normal rpm), the Allison prop-jet engines maintain a relatively constant speed of 13,820 rpm. It is this constant-speed characteristic of the engine which enables each generator to be driven directly by the engine through suitable gearing, and thus avoid the supplementary use of complicated constant-speed drive devices. The reduction gearing to the generator drive (0.4316 to 1) produces a nominal generator speed of 5965 rpm. The rotating field of each generator has four pairs of magnetic poles so that each revolution of the generator produces 4 cycles (for each phase). The output frequency of the generator is thus 4 times 5965, which equals

Figure 6. Location of Electrical Equipment



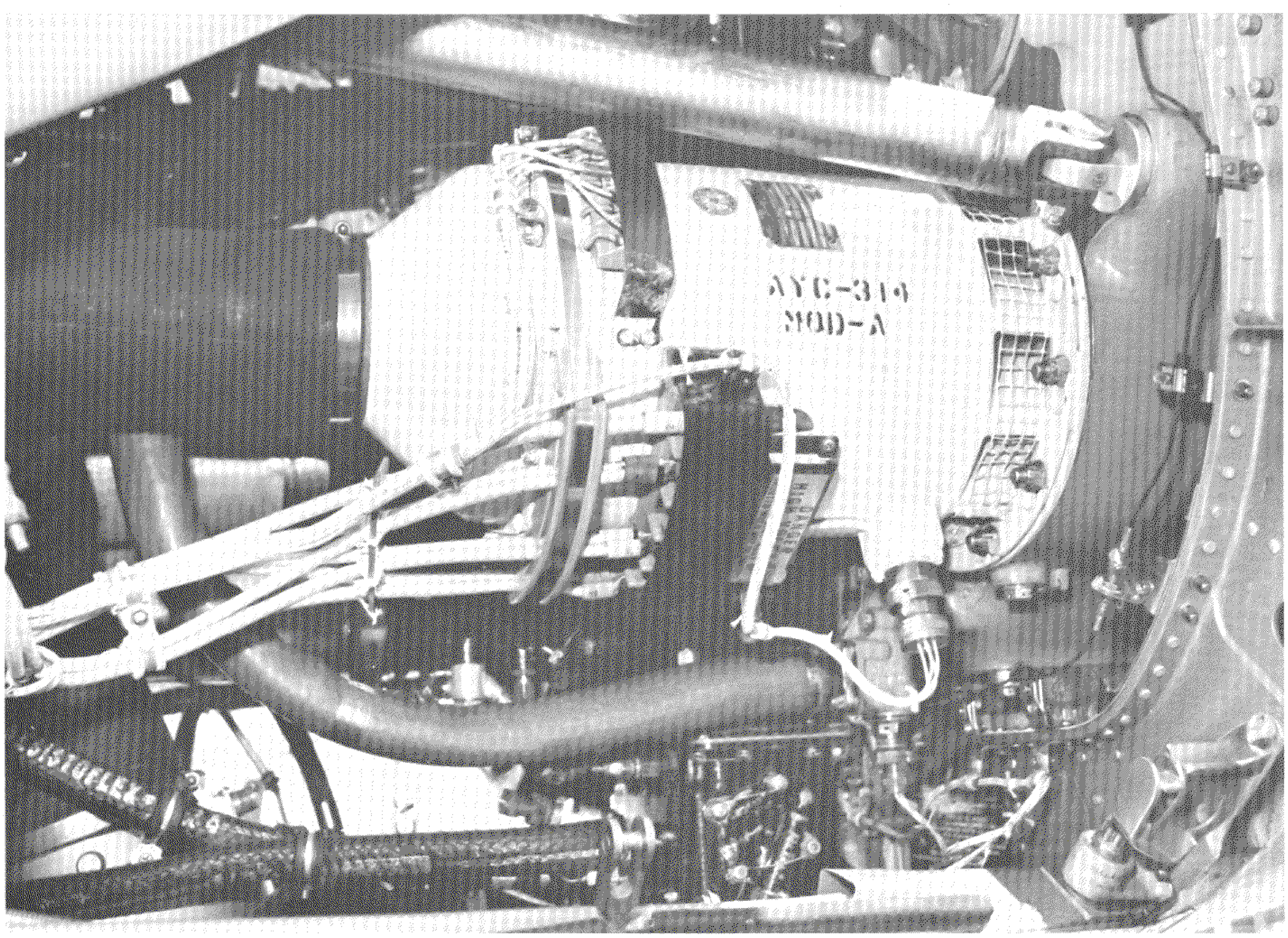
23,860 cycles per minute or 23,860 divided by 60, which equals 397.7 Hz. With this direct-drive arrangement, any slight variation in frequency due to engine rpm fluctuation is well within the airplane's electrical equipment limits of 380 to 420 Hz.

This gear ratio was found to be the optimum. A one tooth change on the gear would have resulted in a generator speed of 6047 rpm or 403 Hz. An increase in engine rated speed is undesirable for the propeller. Rated speed would then be closer to propeller pitchlock rpm which makes pitchlock more probable. Investigations have been made into the feasibility of increasing pitchlock speed in order to provide additional margin above rated speed. It was found that such increase was not possible due to overlap interference with fuel control governor rpm tolerances.

The general operating speed of the P-3 engine is somewhere between 99 percent and 101 percent at high power lever range (flight) and somewhere between 96 percent and 99 percent at low power range (ground idle). The generator frequency will be somewhere between 394 Hz and 402 Hz in the high power lever range and 382 Hz and 394 Hz in the low power lever range.

Each of the three engine-driven generators is cooled by air which is tapped from the engine oil cooler scoop and directed to the aft end of the generator through a 4-inch flexible duct. On engine no. 1 a blast cap is installed instead of a flexible duct, which discharges air directly into the nacelle. A mechanically operated shutoff valve, located at the intake of each duct or blast cap, is one of many items controlled by an emergency engine shutdown handle. There are four such handles, one per engine,

Figure 7. Generator Installation



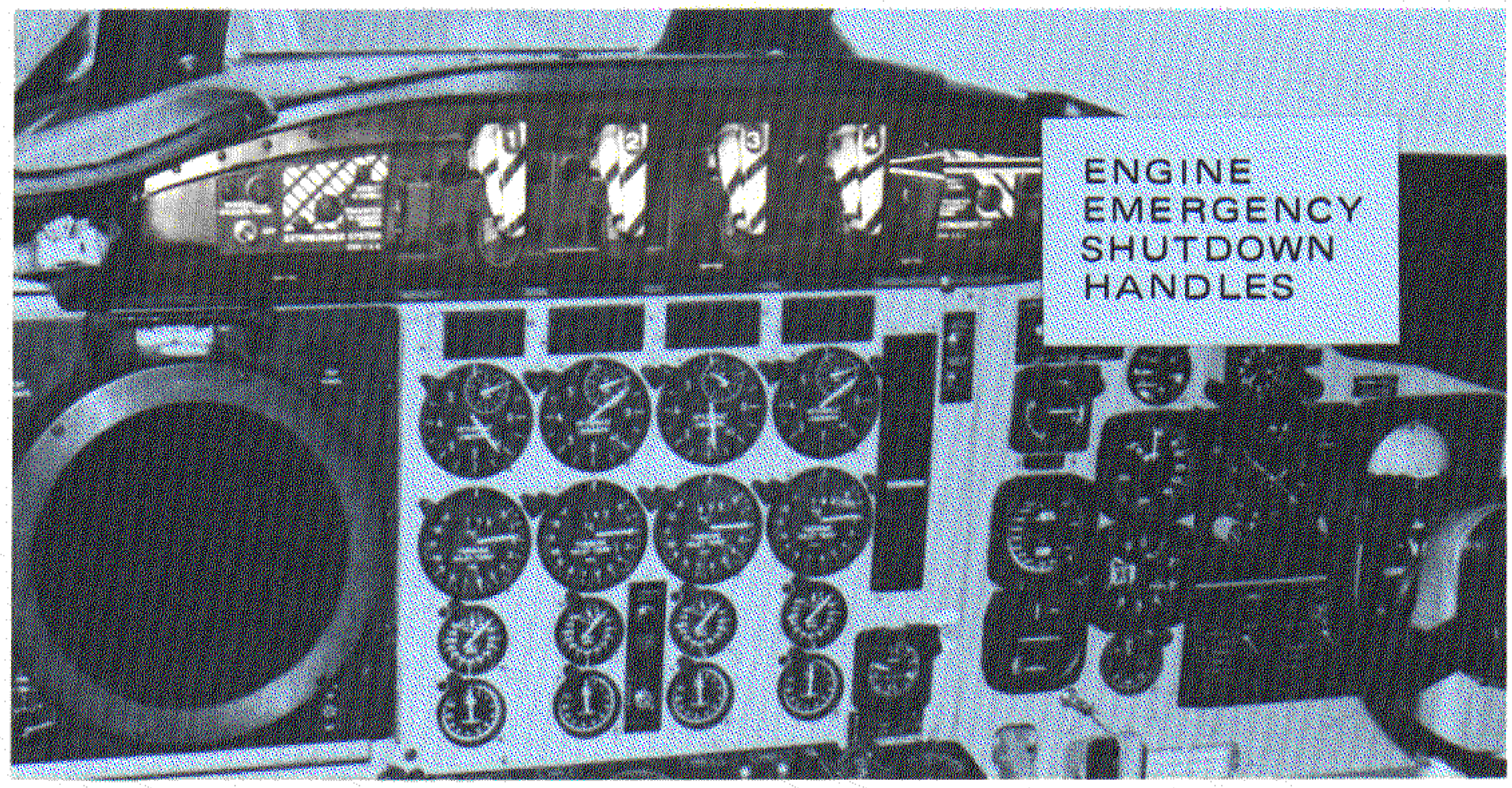


Figure 8. Engine Emergency Shutdown Handles in Flight Station

and they are located below the center windshield in the flight station (see Figure 8).

The power rating of the generator is a function of the volume of cooling air passing through it. In the case of an engine-mounted generator used during ground operations, the rating is determined by the volume of cooling air which can be forced through the generator by its own internal fan without any other assistance. The maximum power rating under these circumstances is 60 kva. In-flight conditions provide additional forced air flow through the generator which is sufficient to allow it to be rated at 90 kva continuously.

Each generator weighs about 110 pounds. Although this is extremely light in relation to its power output, it is still rather heavy for handling during installation and removal. However, either task can be accomplished by two men without too much difficulty, provided a workstand of suitable height is used and the generator installation nuts are left on the studs (tops of nuts flush with tops of studs) when removing or replacing the generator. The latter proviso permits easy rotation of the generator, which has keyhole type mounting holes in the attachment flange.

The 6-gauge wires are used for each phase output from the generator rather than a single heavier gauge wire. Thus each of the 3-phase generators has a total of six main feeder wires, and a single 4-gauge wire serves as the generator neutral or ground. To minimize the possibility of crossed wires, the wiring and the terminals of each generator are color coded, and this practice has been used on many of the 3-phase circuits on the airplane.

Each generator installation includes the smaller wires of various warning and control circuits, which are as far as practicable, routed separately from the power wiring. However, all generator wiring passes through the engine firewall, and all the ground wires (including the generator neutral) are terminated on the nacelle structure aft of each engine firewall. The remainder of the wiring progresses inboard inside the wing leading edge (see Figure 9), enters the pressurized fuselage shell through pressure seals, and thence into the main load or service center. Between the generators and the service center, the only break in the main feeder wires is at the engine firewalls, where fireproof connectors are provided for all wires to facilitate powerplant removal.

Auxiliary Power Unit A fourth generator, identical to the engine-installed generators is mounted on the auxiliary power unit. The APU is attached to a mounting frame and installed in the lower fuselage between the nosewheel well and the bomb bay (see Figures 1 and 6).

MAIN LOAD CENTER The main load center compartment (Figure 10) is located just forward of the wing center section on the starboard side of the

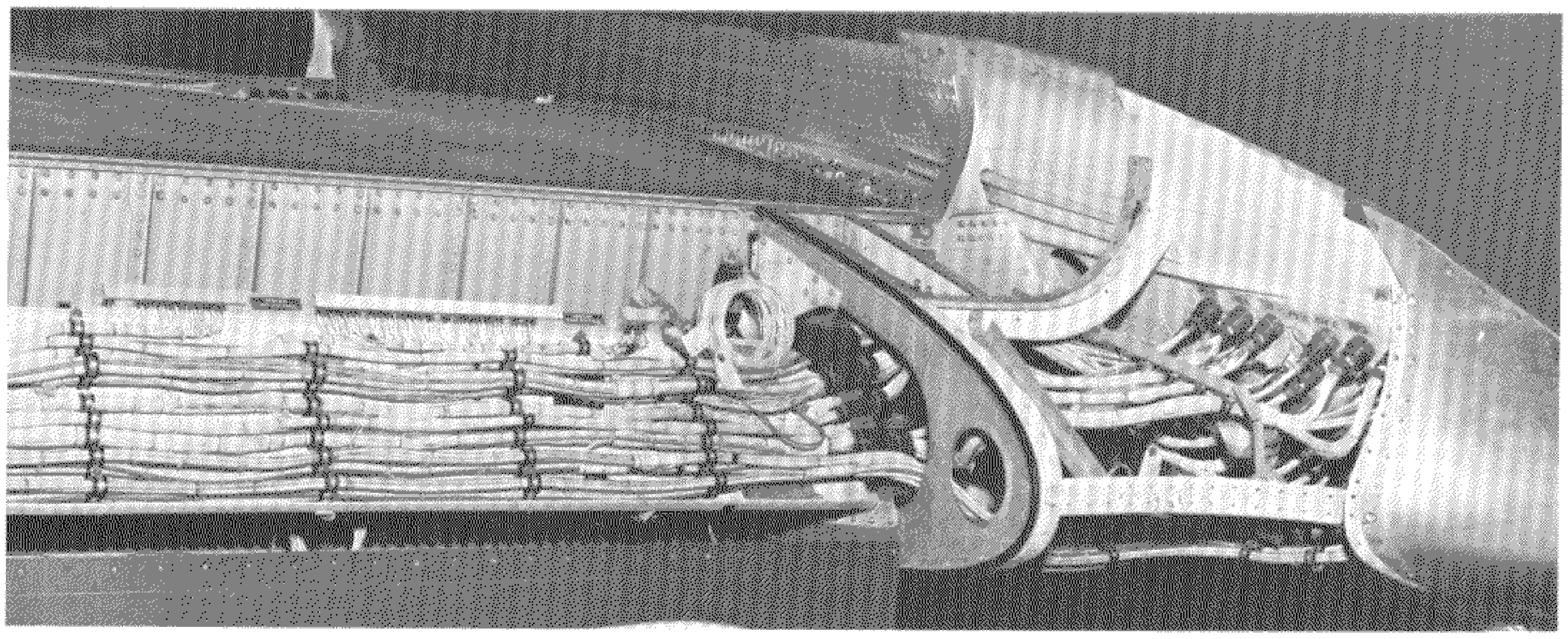


Figure 9. Wire Runs in Wing Leading Edge

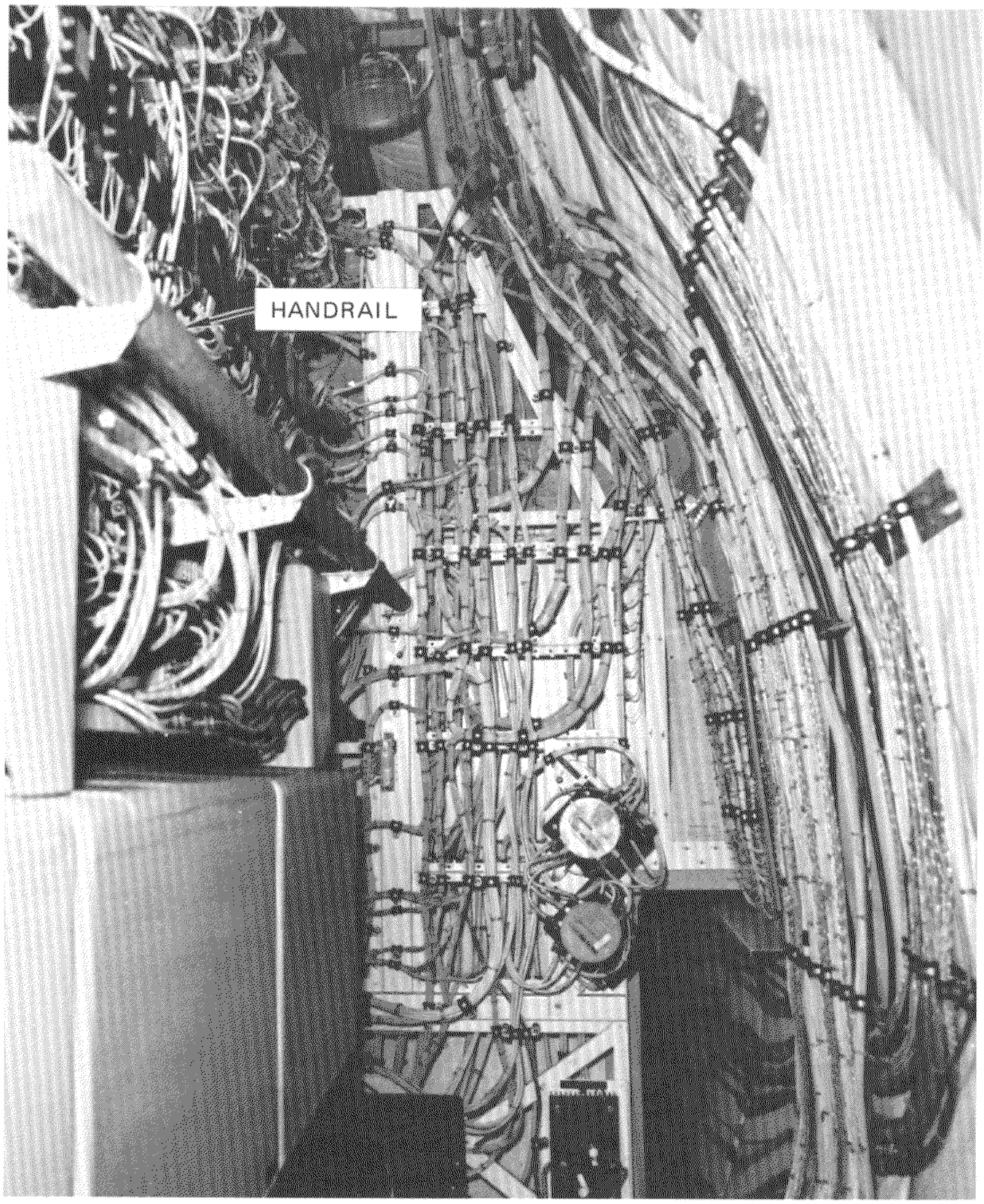


Figure 10. Main Load Center

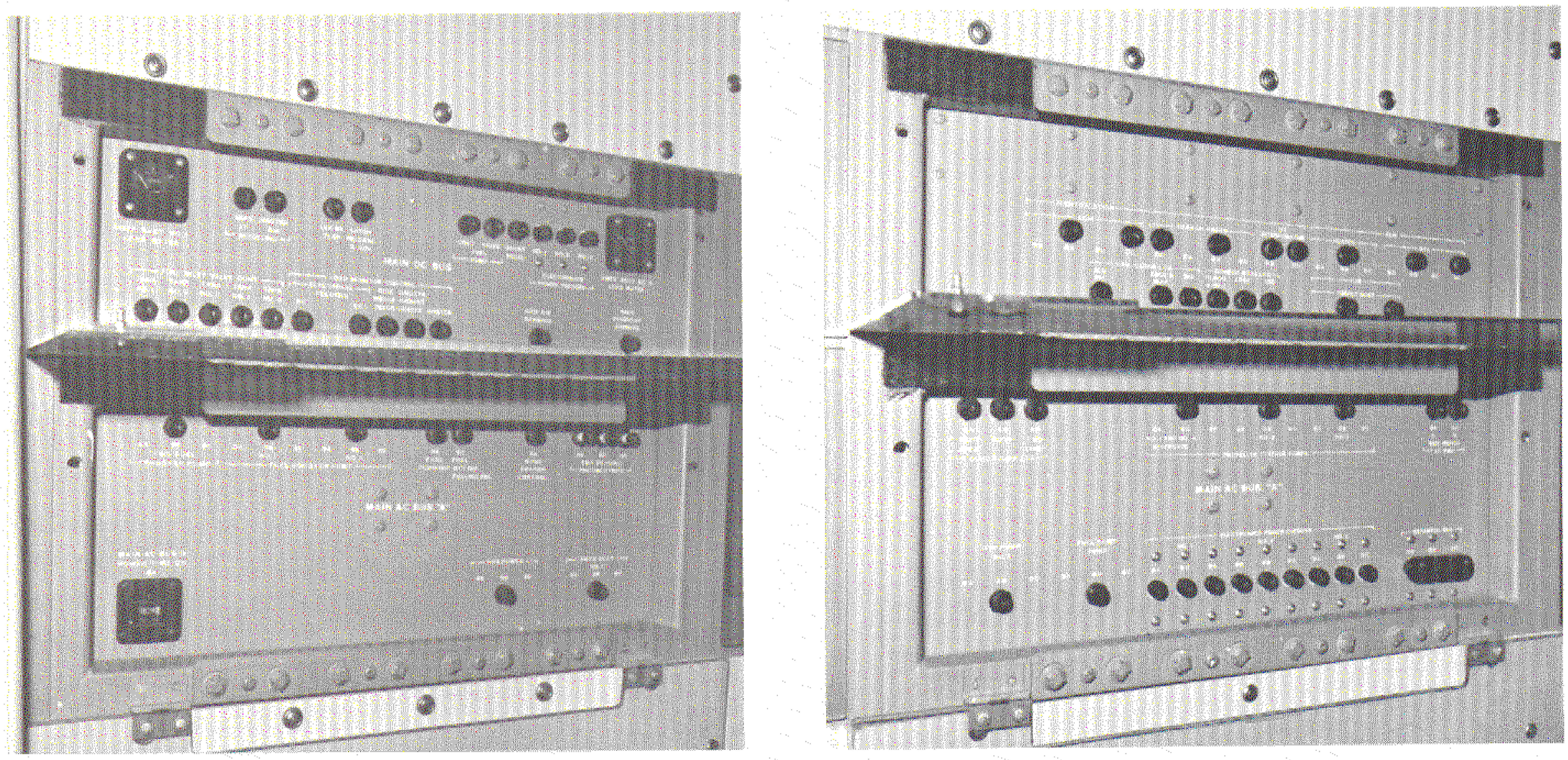
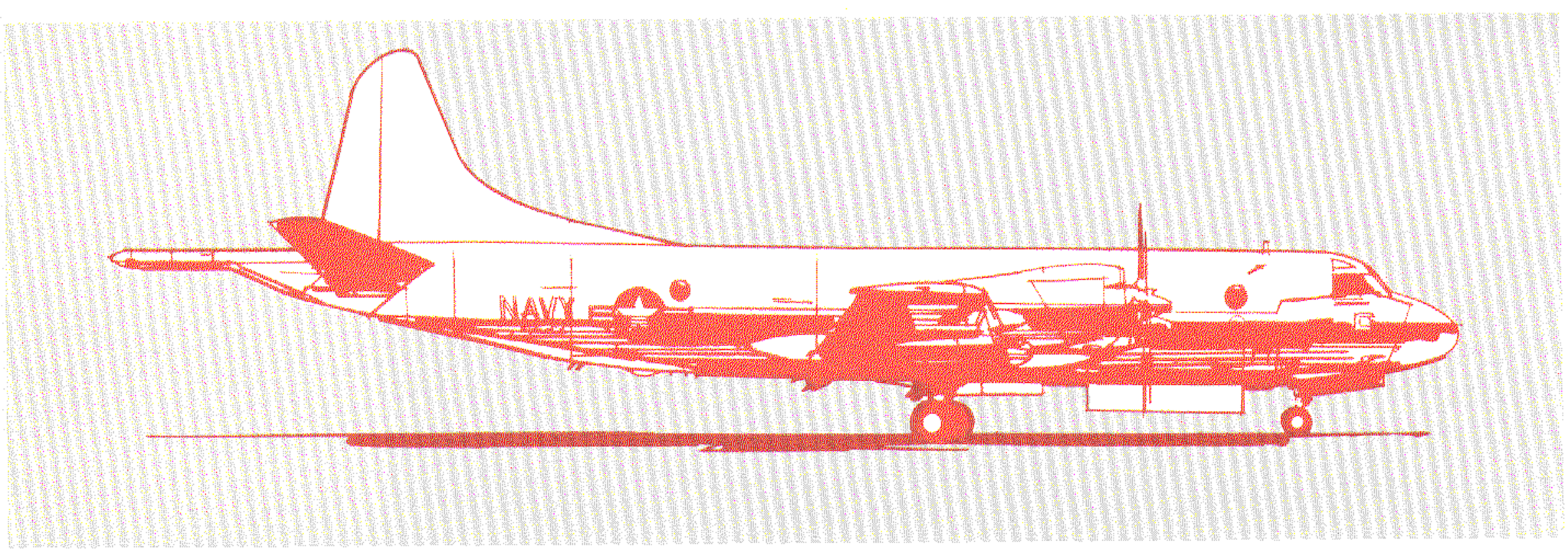


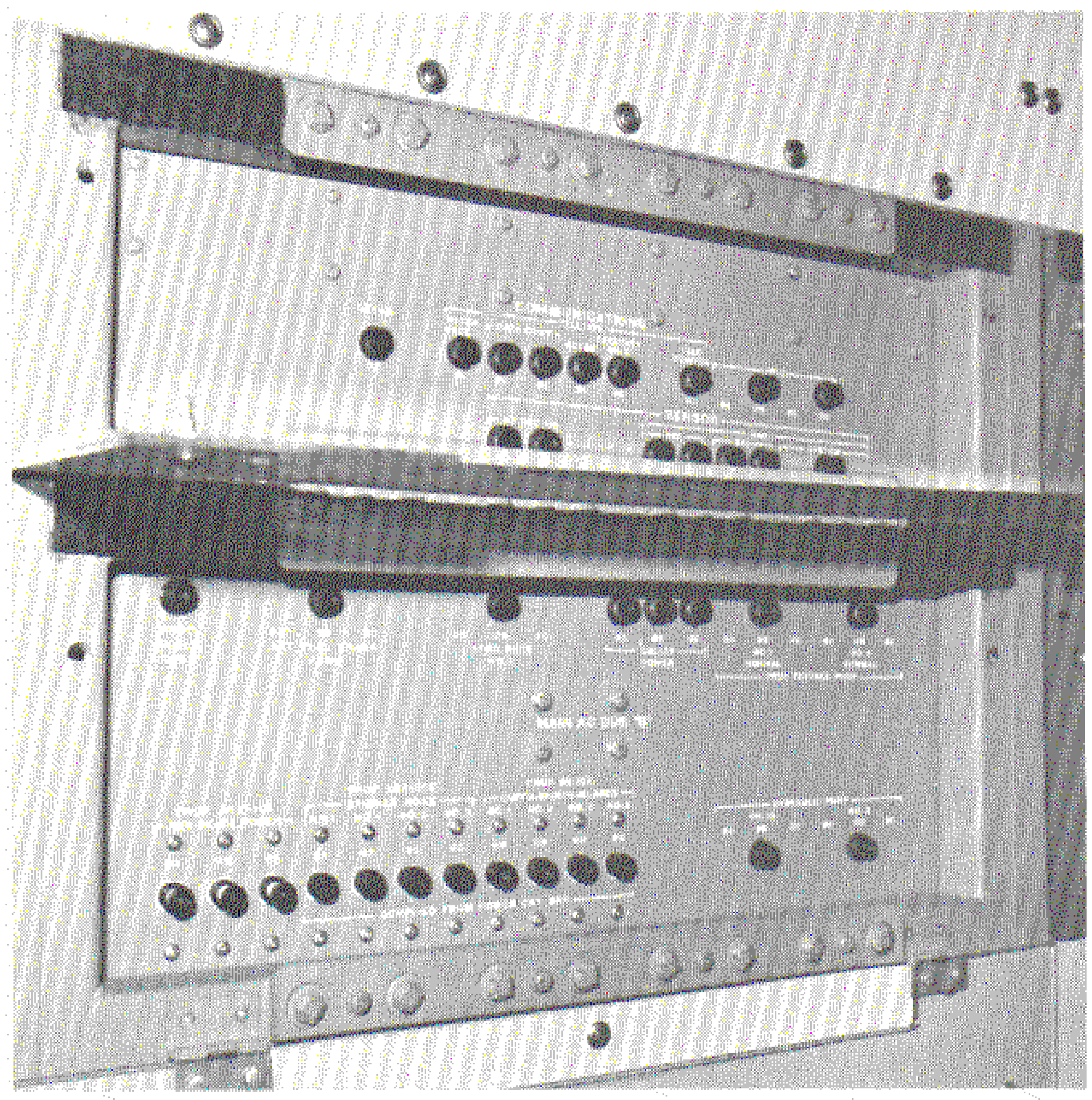
Figure 11. Main Load Center Circuit Breaker Panels

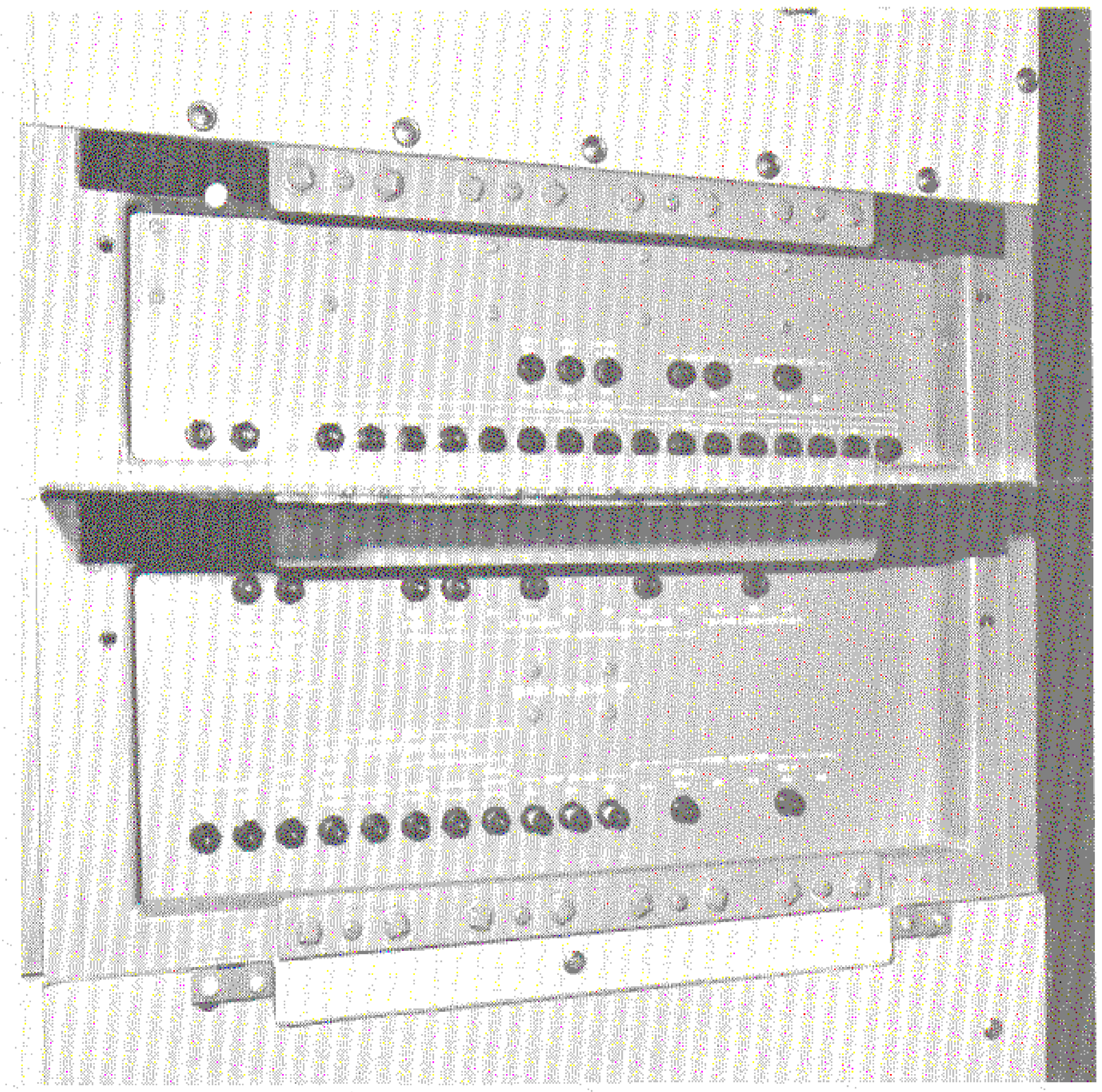
cabin. It may be considered the nerve center of the Orion's electric system since all the components which control and protect each of the generators are located here, together with both main ac buses and their associated circuit breaker panels and the main ac bus transfer system – consisting of five large relays and the automatic transfer control circuitry.

The no. 1 and 2 transformer-rectifiers are also located in the main load center. Separately powered from the two main ac buses, these two transformer-rectifiers, as previously mentioned, supply 28-Vdc power to the main dc bus. This bus, with its associated circuit breaker panel, is found in the main load center but an *extension* of the main dc bus (and so named) is located in the forward load center.

Advantage has been taken of the ample cabin space available on the P-3. All the various electrical units have been installed along one side of the load center compartment, with room to walk between them and the fuselage side. There is an entry door at the aft end of the load center, and an insulated



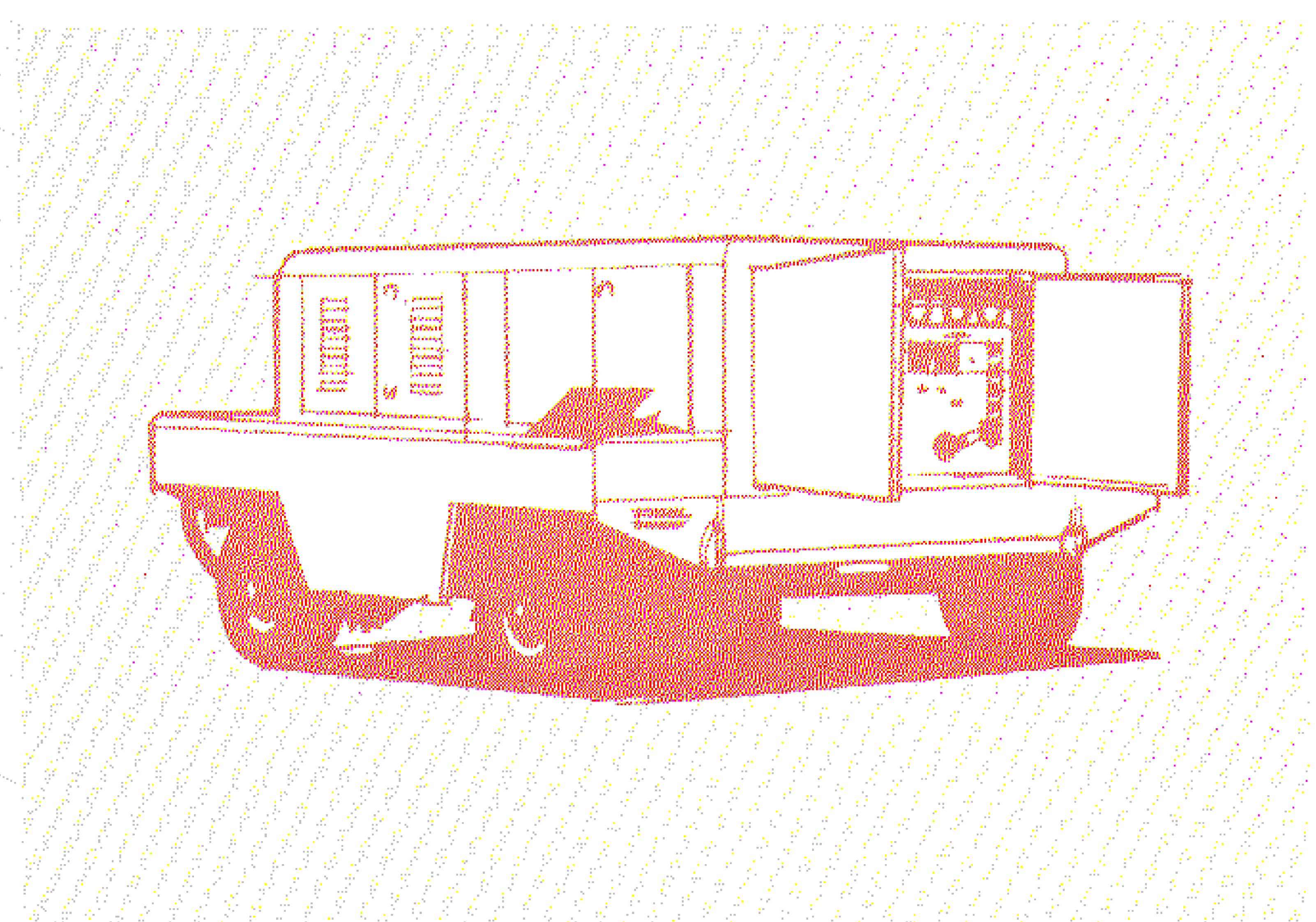




hand rail has been provided so that in an emergency, the compartment may be entered during flight. The arrangement of equipment provides maximum accessibility. All units can be removed and installed without disturbing other units. The main transfer relays have been mounted on panels allowing relay removal from outside the compartment after relay electrical disconnections have been made, making it unnecessary to dismantle the bus bar connections on nearby components. The circuit breaker panel arrangement on the front of the main load center compartment is shown on Figure 11. As noted, this and subsequent figures are of SERNO 159503 (Lockheed Serial No. 5620), and the reader may find some differences between the figures herein and the P-3 with which he is familiar.

Like other major service centers in the main cabin, a cooling system is provided for the main load center to maintain temperatures below 130°F (54°C) under the most adverse conditions. Cabin air enters the bottom of the equipment racks, rises through the various units, and is drawn off at the top into a trunk line that ducts the air overboard through the cabin pressure outflow valve. Whenever electric power is on, an exhaust blower near the outflow valve operates constantly and maintains the necessary cooling flow for the electrical equipment even if the cabin is not pressurized.

Each set of generator main feeders is first routed to its associated control components. From these, branch feeders go to the transfer system of the main ac buses and also to the essential ac bus transfer system – the latter being more generally known as the runaround system. An external ground power receptable is located in the lower leading edge fillet area of the right-hand wing, immediately below the main load center. Ground power feeders from the receptacle are directed to the main ac bus transfer relay system.



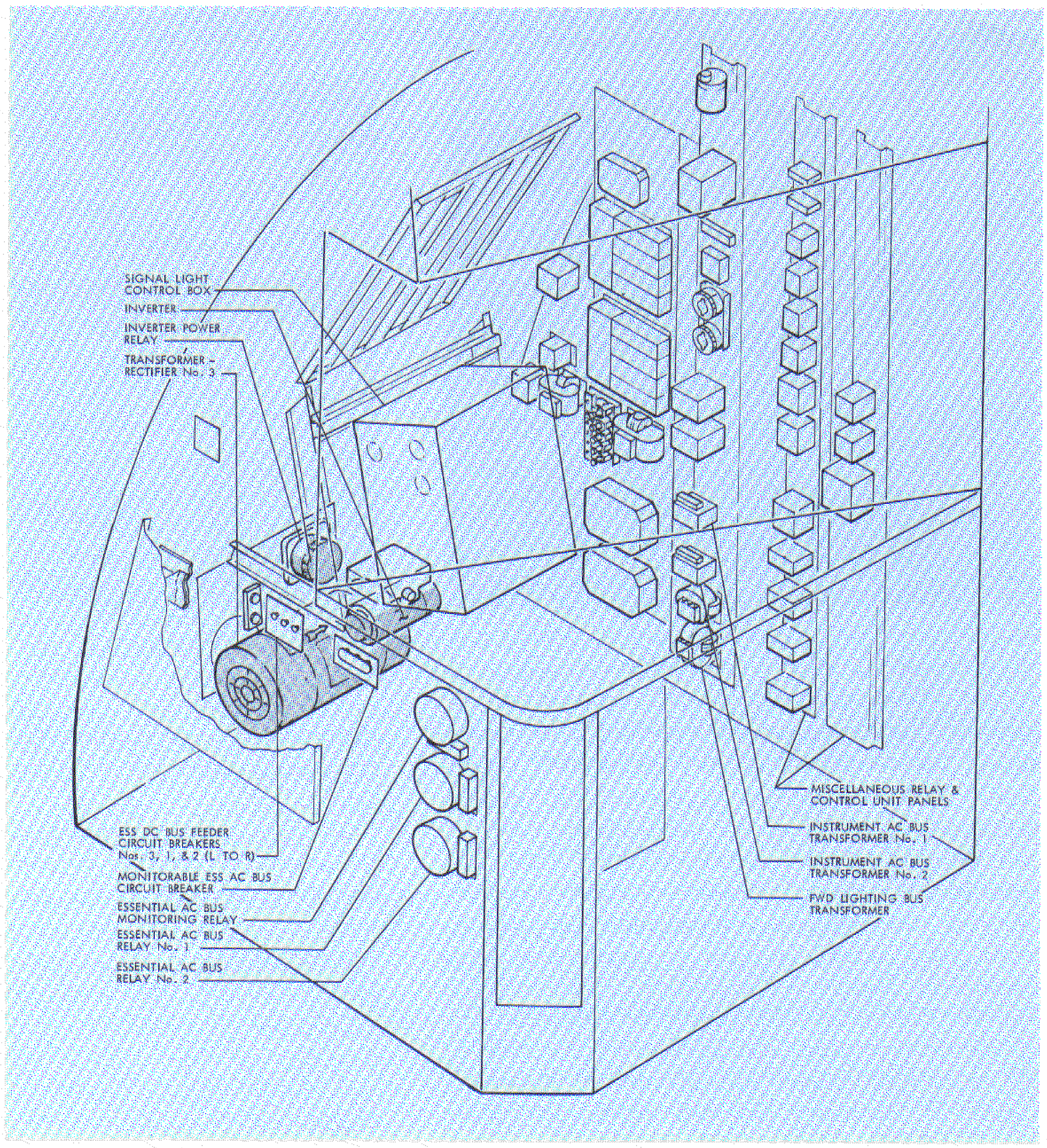


Figure 12. Forward Load Center

FORWARD LOAD CENTER The forward load center is located on the right-hand side of the flight station. It contains principally the monitorable essential ac bus, the extension main dc bus, and the monitorable essential dc bus, together with their associated circuit breaker panels. Transformer-rectifier no. 3, the inverter, a signal light control box, and various relays are also contained in this load center (see Figures 12 and 13).

Two sets of 3-phase feeders to the monitorable essential ac bus and three direct-current feeders to the extension main dc bus supply power from the main load center to the forward load center. These power feeders and other wiring runs are installed on the right-hand side of the fuselage behind readily removable access panels.

The equipment installed in the forward load center is accessible through the hinged circuit breaker panels and the removable lower panel. A fixed panel near the floor carries the flight essential ac and dc buses so that they are, as far as possible, physically and electrically isolated from the other buses and components. This location of the essential buses also provides minimum wire length between them and the battery and the inverter.

The battery is located at the aft end of the nose-wheel well on a crank-operated elevator support to facilitate service and removal (see Figure 14). The 31-ampere-hour capacity battery is provided with a quick disconnect fitting for both positive and negative leads.

Most of the power system control switches and indicator lights are mounted on a control panel located overhead between the flight engineer and copilot positions, also accessible to the pilot. The control panel, the engine low rpm switches, the engine start selector, and various caution and warning lights are shown in Figure 15.

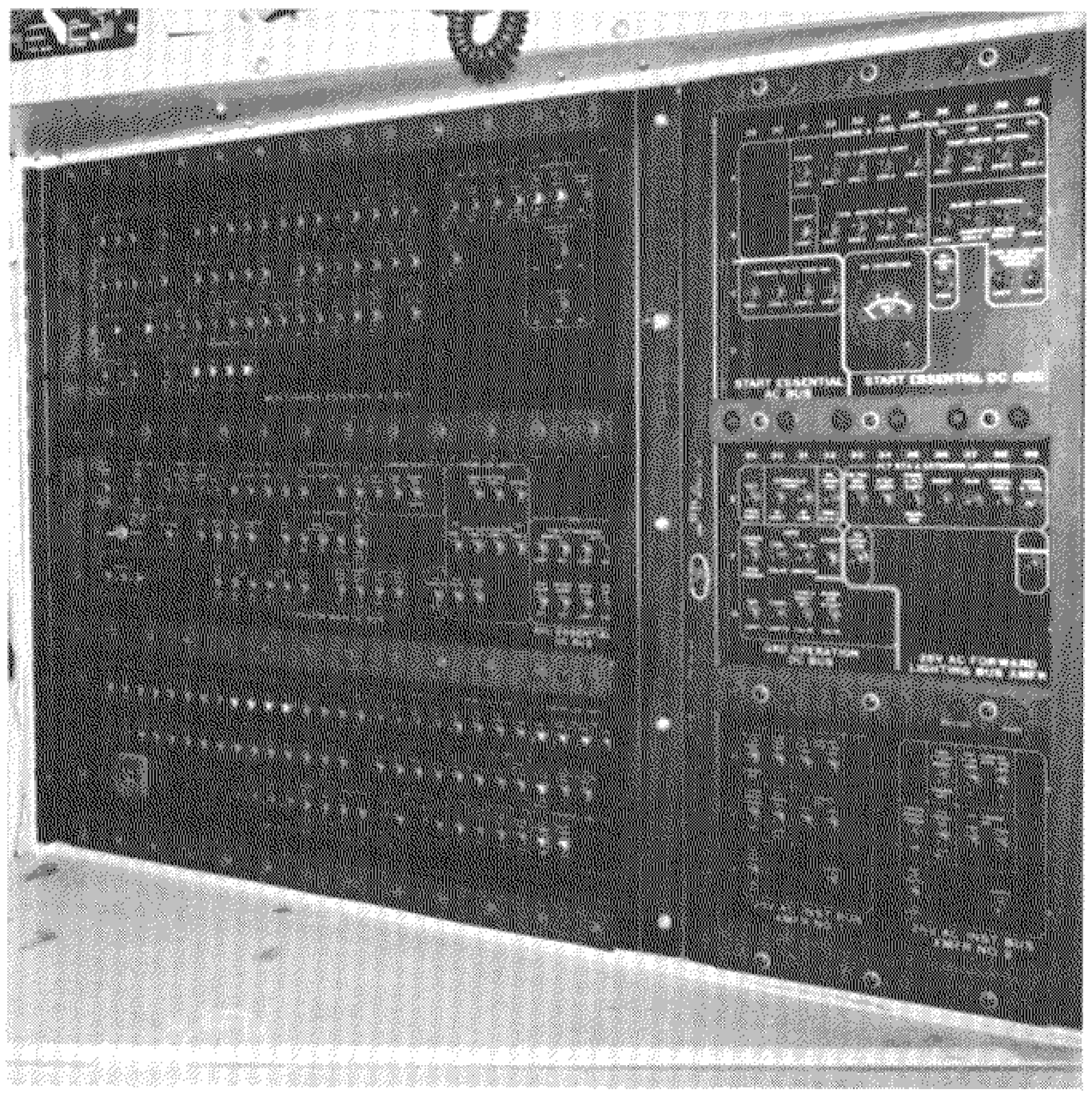


Figure 13. Forward Load Center Circuit Breaker Panels (Upper)

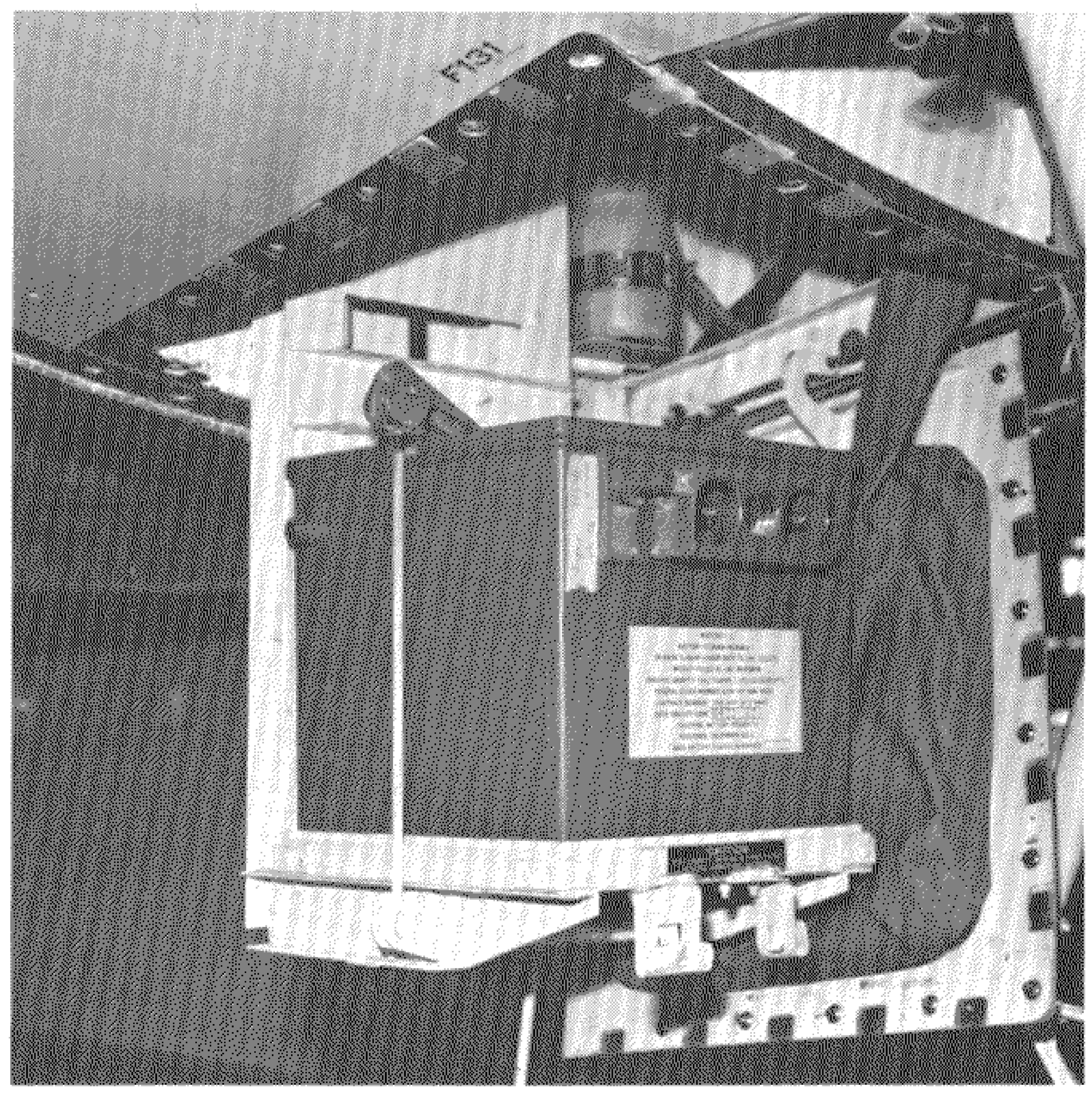


Figure 14. Battery Installation In Lowered Position (Battery Not Connected)

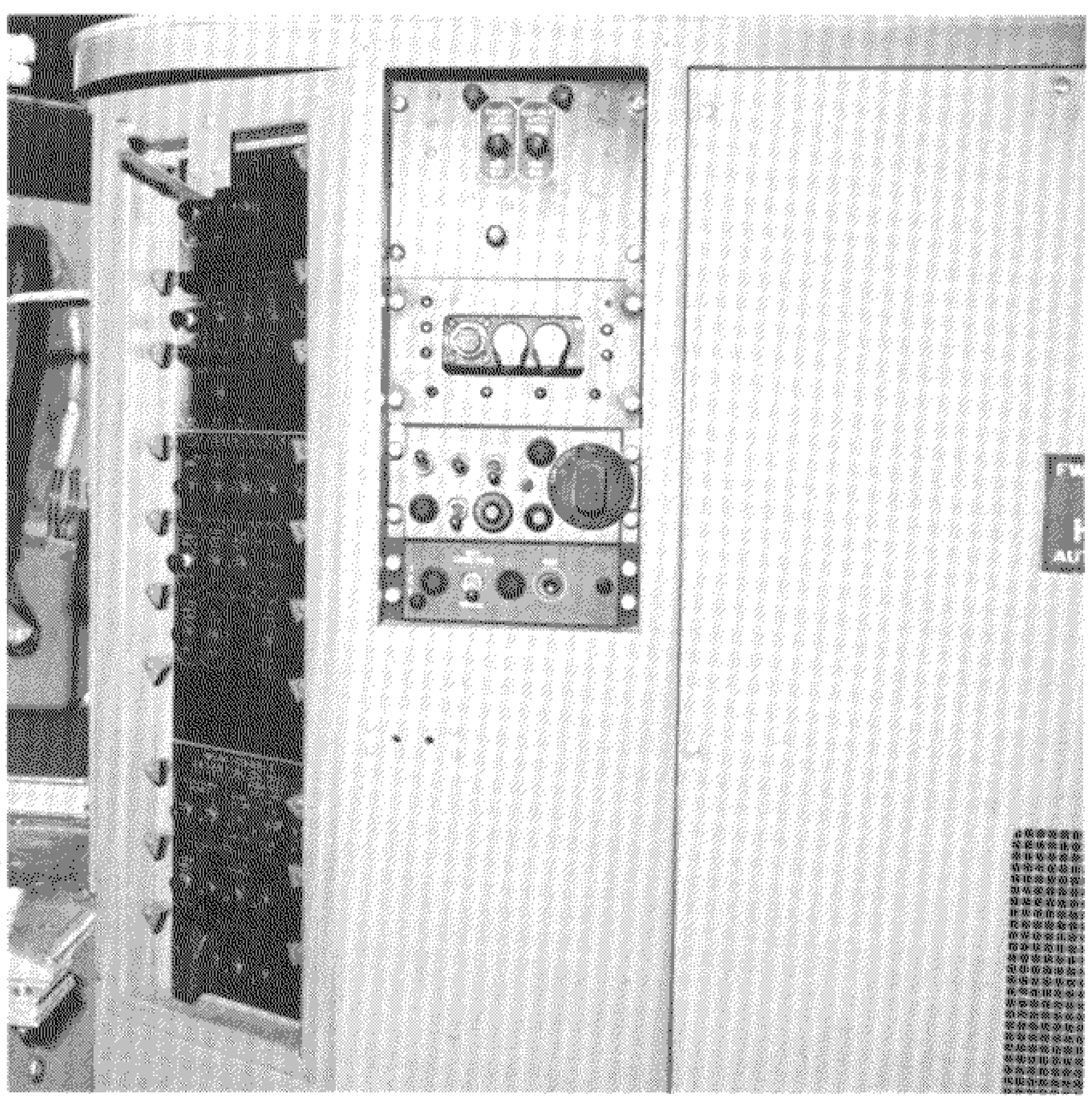


Figure 13. Foward Load Center Circuit Breaker Panels (Lower)

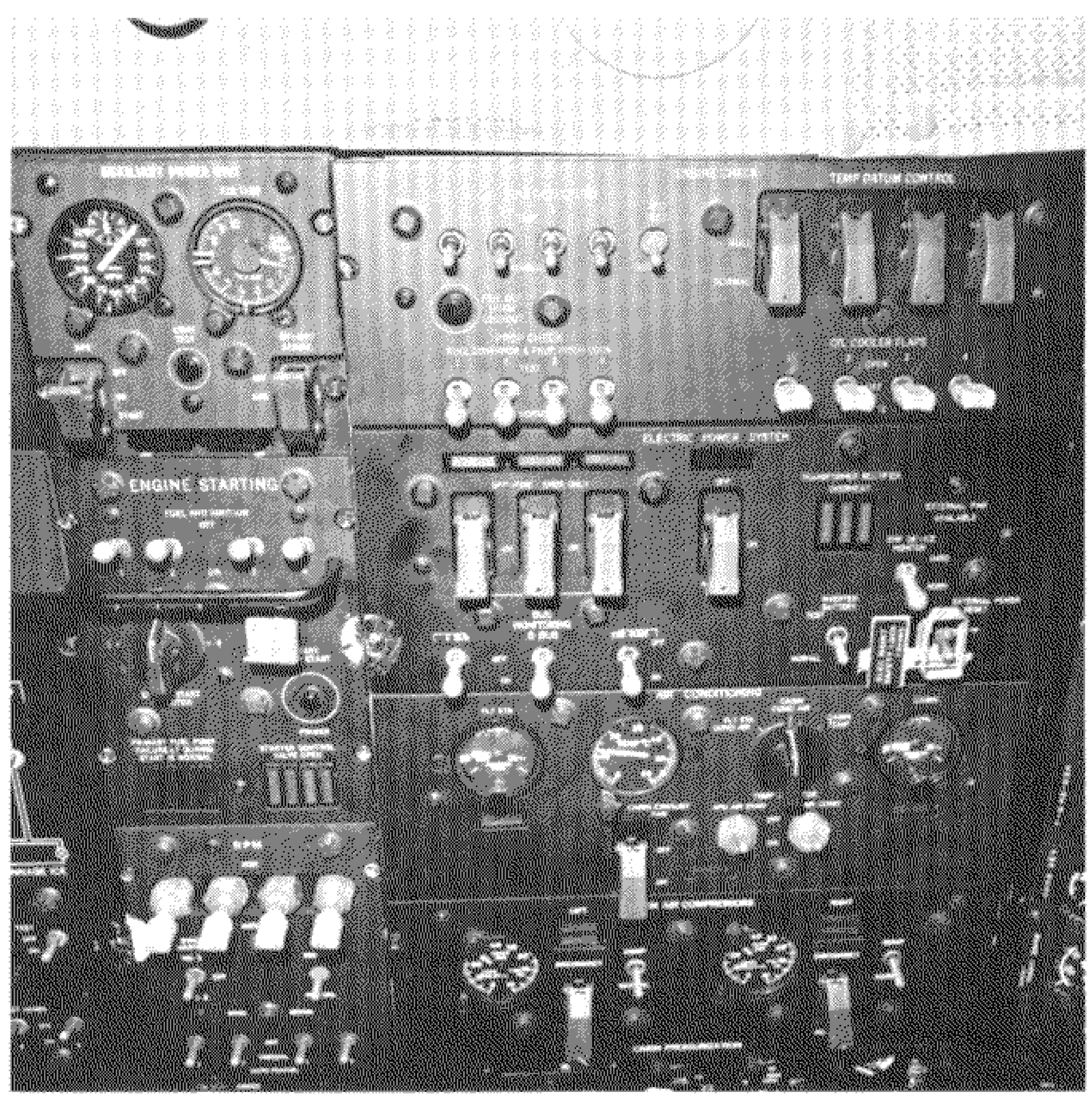


Figure 15. Electrical Power System Controls and Indicators In Flight Station Overhead Panel

POWER SYSTEM DESCRIPTION

The preceding section discussed the basic design concepts of the electric power system and described the physical locations of the principal electrical components. A more functional description of the system is given in this section. Figure 31 shows both the power distribution and the control circuitry of the electrical system and generally gives a basic overview of the relationships between the major power components. Because it is frequently referenced throughout the balance of this article, this figure is a fold-out on the inside back cover.

POWER GENERATION SYSTEM The arrangement of the flight station control switches and warning lights are shown in Figures 16, 17, and 18. The output of each Bendix 28B95-15D Brushless Generator is monitored and controlled by a corresponding Bendix 21B18-1C Generator Control Unit (GCU), also called a supervisory panel, located in the main load center.

Each ac generator is controlled independently by its own three-position switch and is operated by placing the switch in the normal (guarded) ON position. A momentary RESET position is provided for use if the generator becomes deenergized. The switch is placed in the OFF position if the generator fails to reset. The generator control switches are normally placed in

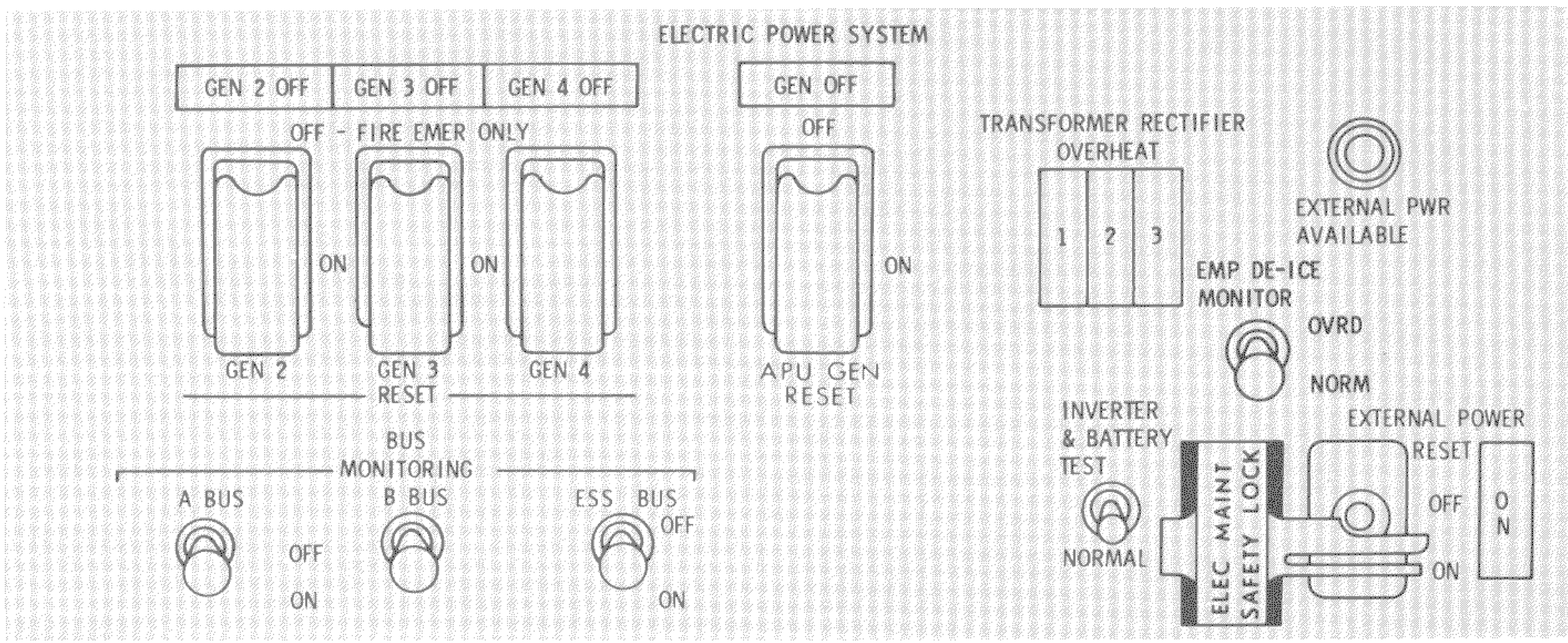


Figure 16. Generator Control Panel

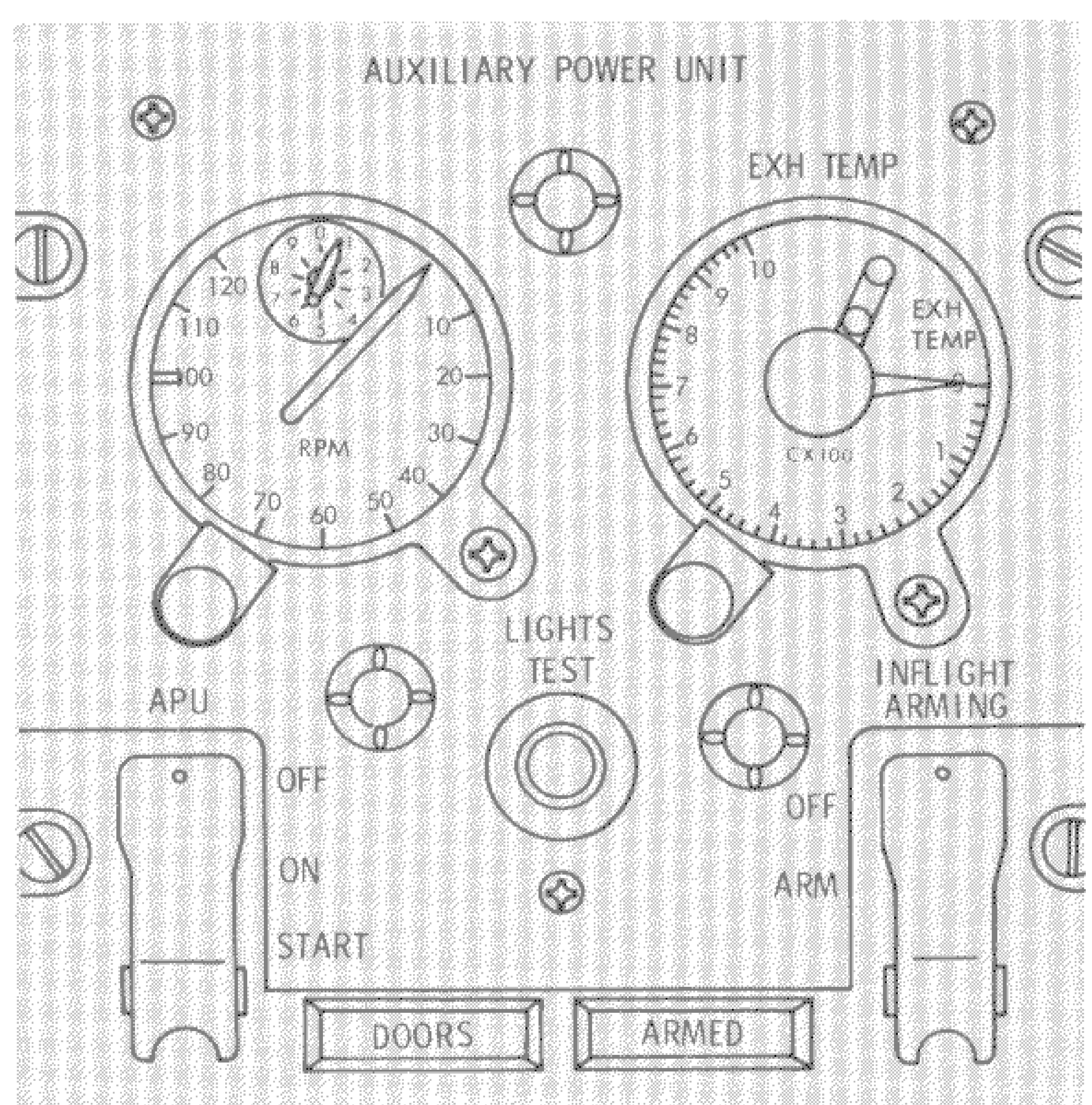


Figure 17. Unit Control Panel Auxiliary Power

the ON position, and the system operates automatically. A light above each generator control switch will illuminate if its associated generator is deenergized (see Figures 15 and 16). However, the APU GEN OFF light will not illuminate unless the APU switch shown in Figure 17 on the auxiliary power unit control panel is placed in either the ON or START position.

In addition, an ELEC POWER master caution light shown in Figure 18 is located on the center instrument panel. This master light is illuminated whenever no. 2, 3, or 4 GEN OFF light is illuminated but is not interconnected with the APU GEN OFF light. The function of the master caution light is to alert the crew when one of the GEN OFF lights is illuminated. Subsequently, the master light can be extinguished by momentarily depressing the MASTER RESET switch adjacent to it. The master light is thereby disconnected from the specific circuit signaling the fault until the fault is corrected. The light, however, will be available to the remaining connected circuits.

There are three other warning lights associated with generators 2, 3, and 4 respectively, which are red and mounted on the center instrument panel. The functions of these lights are discussed in the Generator Mechanical Failure Indication section.

P-3 Brushless Generator The three engine-driven generating systems and the APU generating system are identical, except for the air blast adapter. The following discussion applies equally to all four systems.

Each system is electrically self-sufficient and includes an ac generator, a supervisory/voltage regulator panel, differential protection current transformers, and a control switch. With the exception of the APU, the generator ratings in respect to load capacity, rotational speed, voltage, etc. are essentially the same. The brushless generator, as its name implies, does not have any physical electrical contact points, such as brushes or sliprings, which wear rapidly and produce metal and carbon particles that tend to contaminate and deteriorate other portions of the generator.

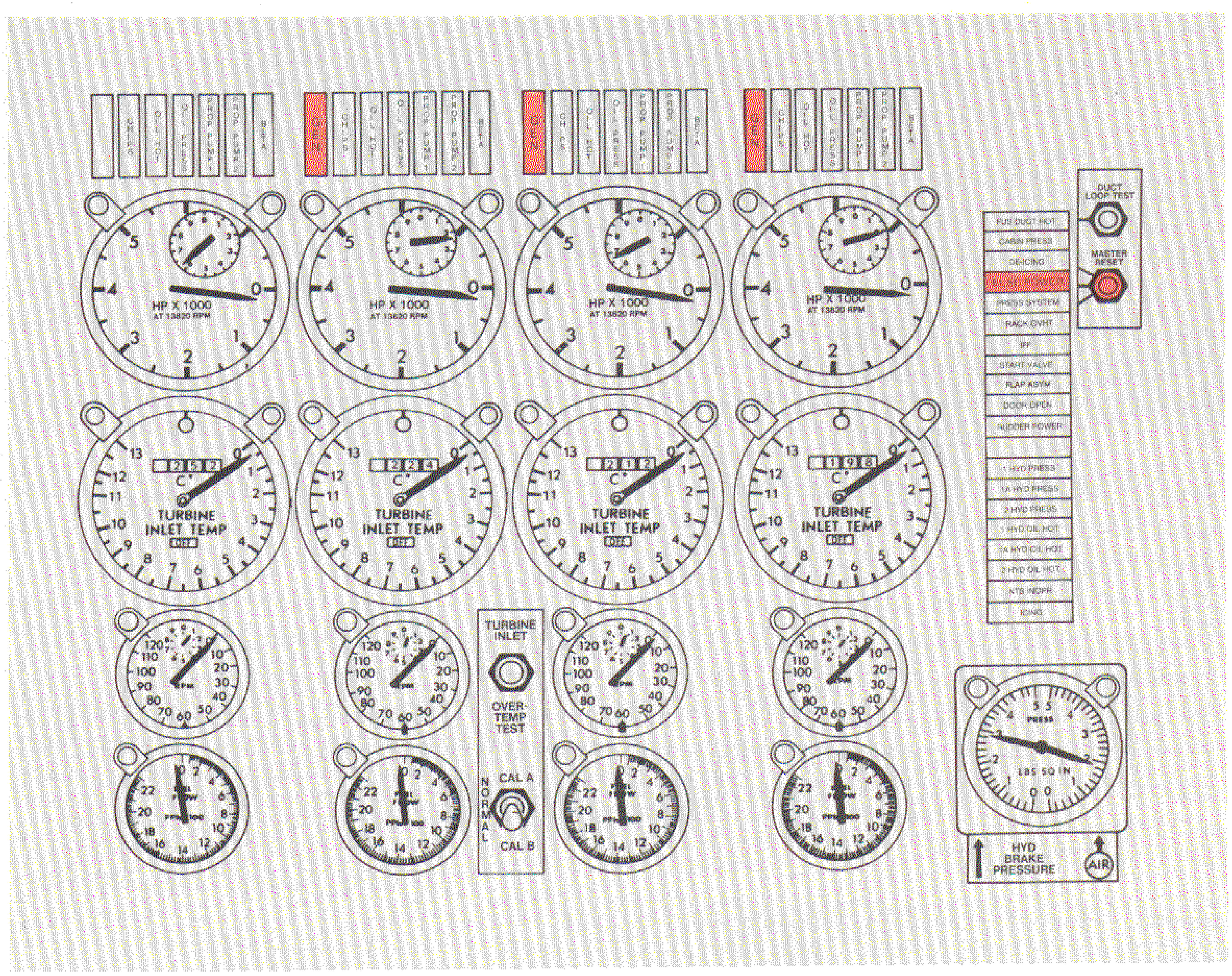


Figure 18. Generator Warning and Caution Lights on Pilot's Center Instrument Panel

THE ELECTRICAL DIAGRAM SYMBOL FOR THE SCR (O—▶|—O) IS THE SAME AS THE DIODE SYMBOL (O—▶|—O) EXCEPT FOR THE ADDED CONNECTION FOR THE CONTROL CIRCUIT, WHICH IS KNOWN AS THE "GATE" TERMINAL. THE SCR HAS THE CHARACTERISTICS OF A DIODE, IN THAT IT IS A SOLID-STATE SEMI-CONDUCTOR THAT PRESENTS A NEARLY INSURMOUNTABLE RESISTANCE TO CURRENT FLOW OF "REVERSE" POLARITY. UNLIKE THE DIODE, HOWEVER, THE SCR BLOCKS CURRENT FLOW OF FORWARD POLARITY (IN THE DIRECTION INDICATED BY THE SYMBOLIC ARROW) UNTIL A "TRIGGER" VOLTAGE IS APPLIED TO THE GATE TERMINAL, AT WHICH TIME THE SCR "FIRES," THAT IS, IT IS TRANSFORMED ALMOST INSTANTLY INTO A TRUE DIODE. ONCE FIRED, THE SCR CONTINUES TO CONDUCT -- EVEN THOUGH THE TRIGGER VOLTAGE IS REMOVED -- SO LONG AS VOLTAGE OF THE CORRECT POLARITY IS AVAILABLE TO THE MAIN TERMINALS. WHEN THE MAIN TERMINAL VOLTAGE IS REMOVED, THE SCR REGAINS ITS ORIGINAL CHARACTERISTICS, BLOCKING CURRENT FLOW IN EITHER DIRECTION.

RELAY	TITLE	ENERGIZED:	DE-ENERGIZED:	FUNCTION
ACR	AUXILIARY CONTROL RELAY	WHEN GENERATOR VOLTAGE IS ABOVE MIN. VALUE AND FREQ. WITHIN LIMITS	WHEN GEN. VOLTAGE OR FREQ. OUT OF TOLERANCE OR FEEDER FAULT IS SENSED	CONTROLS BUS TRANSFER RELAYS, ARMS UNDERVOLTAGE 3-SEC TIME DELAY
DLR	DIFFERENTIAL PROTECTION LATCH OUT RELAY	WHEN FEEDER FAULT OR UNDER VOLTAGE IS DETECTED	BY UNDERVOLTAGE OR FEEDER FAULT RESET PROCEDURE	ENERGIZES LOCK OUT RELAY (LOR)
DPR	DIFFERENTIAL PROTECTION RELAY	WHEN FEEDER FAULT IS SENSED	BY REMOVING PMG & BUS POWER	ENERGIZES DLR, LOR DE-ENERGIZES ACR & GCR
GCR	GENERATOR CONTROL RELAY	3 SECONDS AFTER GEN. FREQ. COMES WITHIN LIMITS	3 SECONDS AFTER GEN. FREQ. RISES ABOVE OR DROPS BELOW LIMITS	UNGROUNDS EXCITER FIELD & APPLIES PMG POWER TO REGULATING CIRCUIT
LOR	LOCKOUT RELAY	WHEN FEEDER FAULT, UNDERVOLTAGE OR OVERVOLTAGE IS SENSED	BY RESET PROCEDURES FOR UNDER-VOLTAGE, OVER-VOLTAGE, OR FEEDER FAULT	DE-ENERGIZES ULR, ACR, AND GCR
ULR	UNDERVOLTAGE LOCKOUT RELAY	3 SECONDS AFTER UNDER-VOLTAGE IS SENSED	BY UNDER-VOLTAGE RESET PROCEDURES	STARTS 1-SECOND TIME DELAY
UOR	UNDER/OVER FREQUENCY RELAY	WHEN GEN. FREQ. IS WITHIN LIMITS	WHEN GEN. FREQ. GOES BEYOND LIMITS	STARTS 3-SECOND TIME DELAY AND CHANGES LOW FREQUENCY DROP-OUT TO 365 ± 5 CPS

⚠ NOTE: P226 (GENERATOR PLUG) AND P220 (MAIN LOAD CENTER TRANSFORMER PLUG)

SHORT CIRCUIT SECONDARIES OF BOTH CURRENT TRANSFORMERS AS DEPICTED ABOVE IF GENERATOR IS TO BE OPERATED WITH TRANSFORMER LEADS DISCONNECTED FOR TEST PURPOSES.

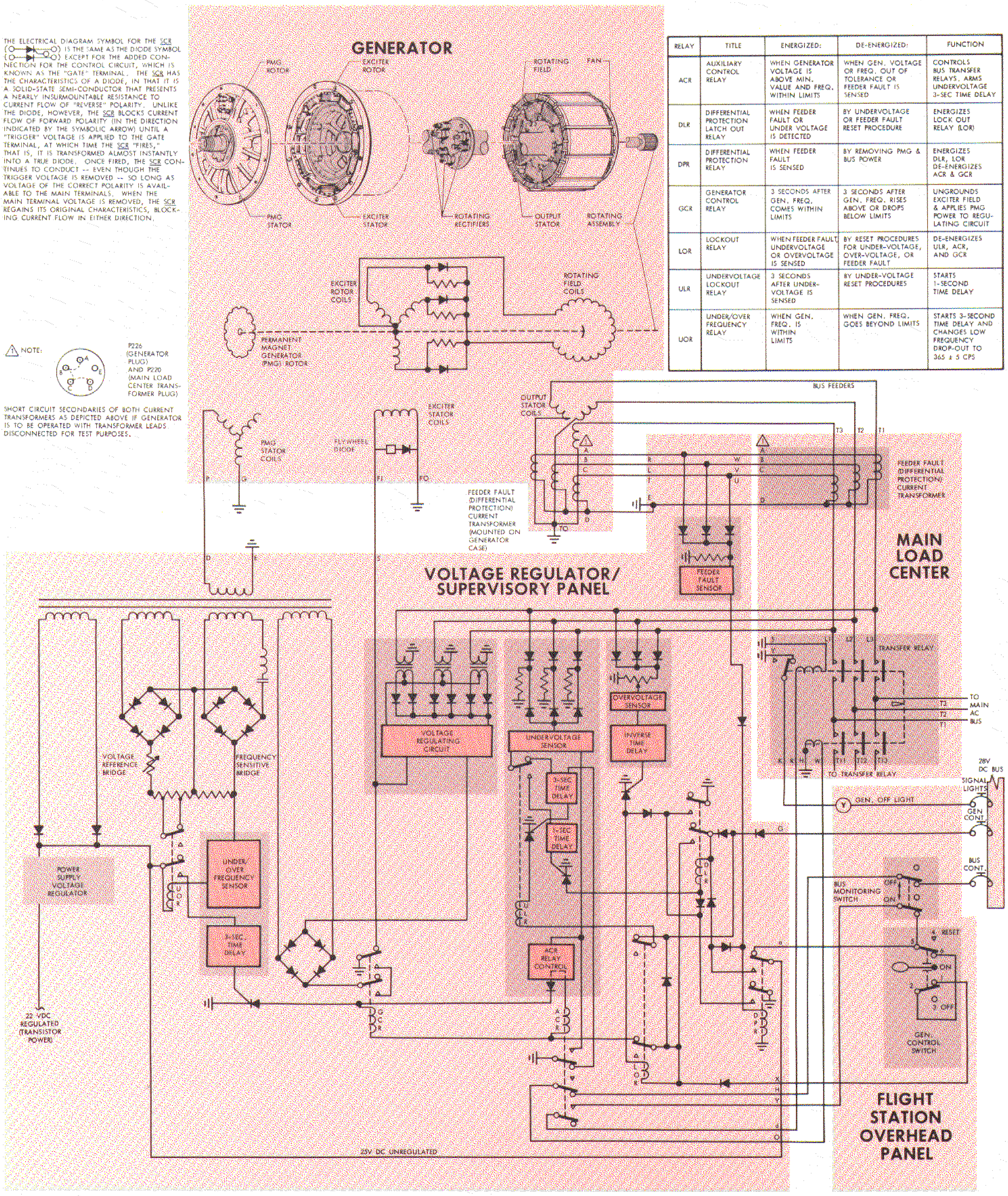


Figure 19. Simplified Generator System Circuit (Typical)

The operating principles of the generating system are shown in Figure 19. The generator is essentially a three-part unit with its excitation power as well as the supervisory panel power supplied by the integral permanent magnet generator (PMG). The PMG's 12-pole magnetized iron rotor is mounted at the aft end of the generator shaft. When the shaft is rotated by turbine power, the rotor induces a voltage in the stator. The PMG stator has a 3-phase, wye-connected winding (without a center-tap common return line) but only two windings are utilized in the P-3 to produce a single-phase, 39-volt, 600-Hz output. The stator output is routed to the supervisory panel, rectified, and a regulated dc current is returned to the main generator exciter stator. The exciter's electromagnetic field, in turn, induces a voltage in the exciter 3-phase rotor coils. Each of the exciter coil's outputs is half-wave rectified by the shaft-mounted "rotating rectifier" and the resultant dc is applied directly to the rotating field winding of the main generator. The rotating electromagnetic field induces 117 volts ac in each of the fixed, wye-connected output windings of the main generator stator. From the fixed stator windings, power is transferred by aircraft feeders to the aircraft load circuits. Thus, the entire generating procedure takes place by inductive transfer of energy with no electrical contact between the rotating and the stationary portions of the generator.

The P-3 generator has a unique, hollow-centered shaft that allows part of the blast cooling air to be ducted through the shaft and exhausted over the drive bearing close to the point of maximum heat generation (see Figure 20). The generator rotor is driven by a torsion stub shaft designed with a shear section to protect the engine accessory reduction gearing in the event of generator rotor seizure.

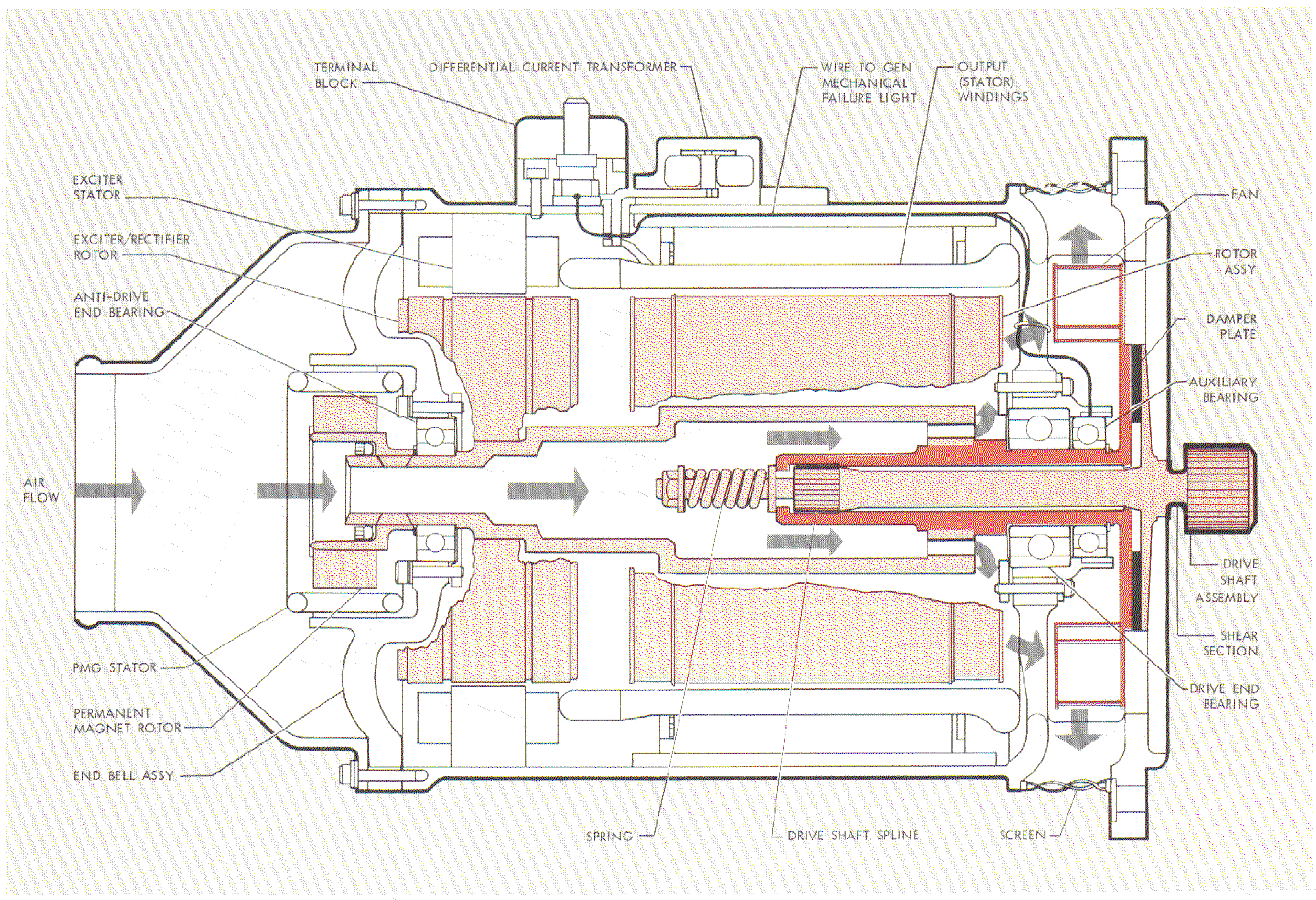


Figure 20. Generator Mechanical Construction

Engine torque is transmitted to the hollow rotor shaft via the torsion shaft that is equipped with a centrally located spline section and a spring-loaded damper plate at its drive end. The friction between this plate and a rotor-mounted plate provides a sort of clutch that can "slip" slightly when a sudden load is applied (the torsion shaft can yield to cushion a shock load), but it dampens out the torsion shaft's tendency to oscillate under high frequency cyclic loads. The shaft-within-a-shaft arrangement also allows for some axial misalignment with the engine mount.

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Generator Mechanical Failure Indication As previously discussed, generators reworked to AYC-314 incorporate a third, auxiliary bearing at the drive end of each generator. Prior to the introduction of this third bearing, a GEN warning light on the center instrument panel (see Figure 18) would illuminate if the rotor of the corresponding generator started to rub against the stator. With the incorporation of the third bearing, this warning light's "switching" function was changed to indicate when the auxiliary bearing is under load.

Initial experience with generators equipped with the auxiliary bearings disclosed excessive generator (bearing) failure warning light illuminations. Investigation revealed that there had been no actual generator failures, but rather failures of the switching arrangement that activated the warning light. These failures were traced to the use of incorrect procedures in coating the auxiliary bearing's outer race with an insulating material (heresite), which resulted in the formation of minute bubbles in the coating. The increase in temperature during normal generator operation caused these bubbles to expand and leave voids in the insulation. Any moisture in the cavity completed the circuit to ground and illuminated the warning light. Cases were reported of generator warning lights illuminating after the aircraft had gone through the washrack.

During modification of a generator to the auxiliary bearing configuration, the coating process involving the heresite insulating material is critical. The presence of air bubbles in the material or application of too thin a layer may cause activation of a warning light for an otherwise properly functioning generator. On the other hand, too thick a coating may cause the auxiliary bearing to hang up so that it is not running free in an air gap, but instead is rotating all the time. Thus, it is imperative that the rework procedures outlined by the manufacturer be followed strictly.

The functions of a generator equipped with the auxiliary bearing are summarized as follows:

1. The auxiliary bearing is a backup for the generator front end bearing. If the front end bearing fails, the armature will be supported by the auxiliary bearing.
2. The generator mechanical failure (red) warning light (GEN, Figure 19) will illuminate any time the auxiliary bearing is supporting the rotor, indicating failure of the front end bearing.
3. Failure of the generator *rear end* bearing will not illuminate the mechanical failure warning light.
4. Any internal failure of the generator other than one which causes the rotor to be supported by the auxiliary bearing will not illuminate the generator mechanical failure warning light.
5. Seizure of the armature shaft from any cause other than one which causes the rotor to be supported by the third bearing will not illuminate the generator mechanical failure warning light, but will cause the shaft to shear and, of course, will cause illumination of the GEN OFF caution light on the electrical power control panel (Figure 16).
6. The lights' test switch will check the condition of the caution/warning light bulbs only. The mechanical failure light circuitry to the generator cannot be checked with this switch.

Generator Protective Circuits The preceding explanation of generator operation has described the method by which power is produced and omitted all reference to the following control and protective functions provided by the PMG-powered supervisory panel:

1. Voltage regulation and bus transfer control
2. Under/over frequency protection
3. Under/over voltage protection
4. Generator output winding or feeder fault protection (phase-to-phase or phase-to-ground short circuits)
5. Lockout and anticycle.

It is, of course, very important that the generator output voltage be rigidly controlled between very narrow limits to protect the many ac loads on the bus. Voltage protection is provided by three separate transistorized circuits: the normal voltage regulating circuit (to adjust output for changing load conditions), an undervoltage sensor circuit, and an overvoltage sensor circuit (to prevent damage to bus loads due to voltage extremes).

The voltage regulating circuit provides continuous and practically instantaneous control of the generator output power even beyond the normal rated load range of the generator as shown in Figure 21. This is accomplished by sensing any small voltage variation of the 3-phase output at the point of regulation on the main ac bus, and using this change to alter the output of the amplifier which feeds back rectified PMG current to the exciter stator.

The 3-phase output voltage is controlled to 117±2 volts for a wide range of bus loads extending from zero to a 120-kva peak overload of short duration, hence maintaining a nominal voltage of 115 Vac at the using equipment terminals. Even though the load on one phase of the generator may be as much as one third higher or lower than the others, output voltage will not vary more than about 3 volts between the phases.

The undervoltage sensing and control circuit makes generator output available to a bus when the voltage rises to approximately 105 Vac during the start cycle but does not deenergize and disconnect the generator feeders until one or more phases are

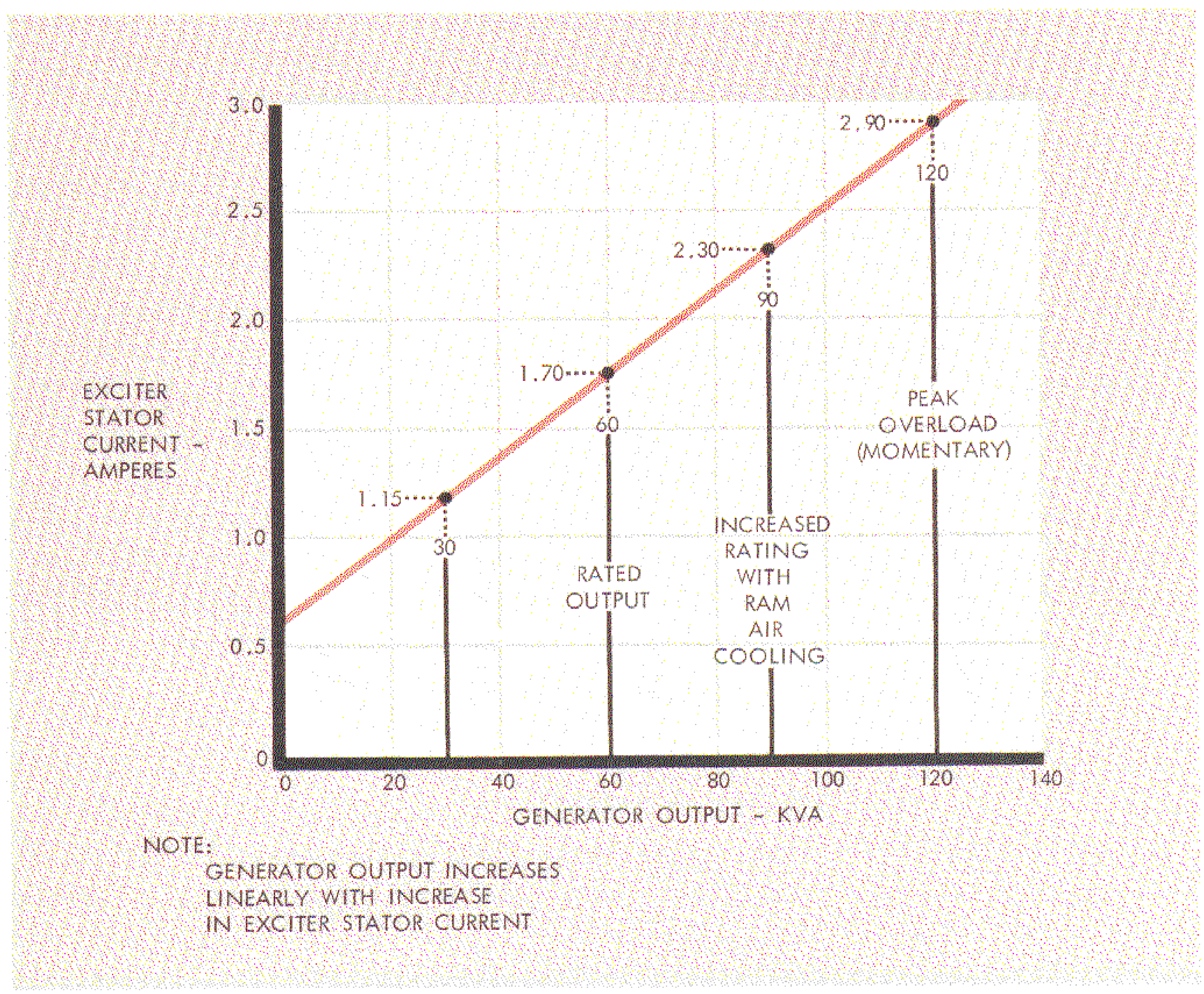
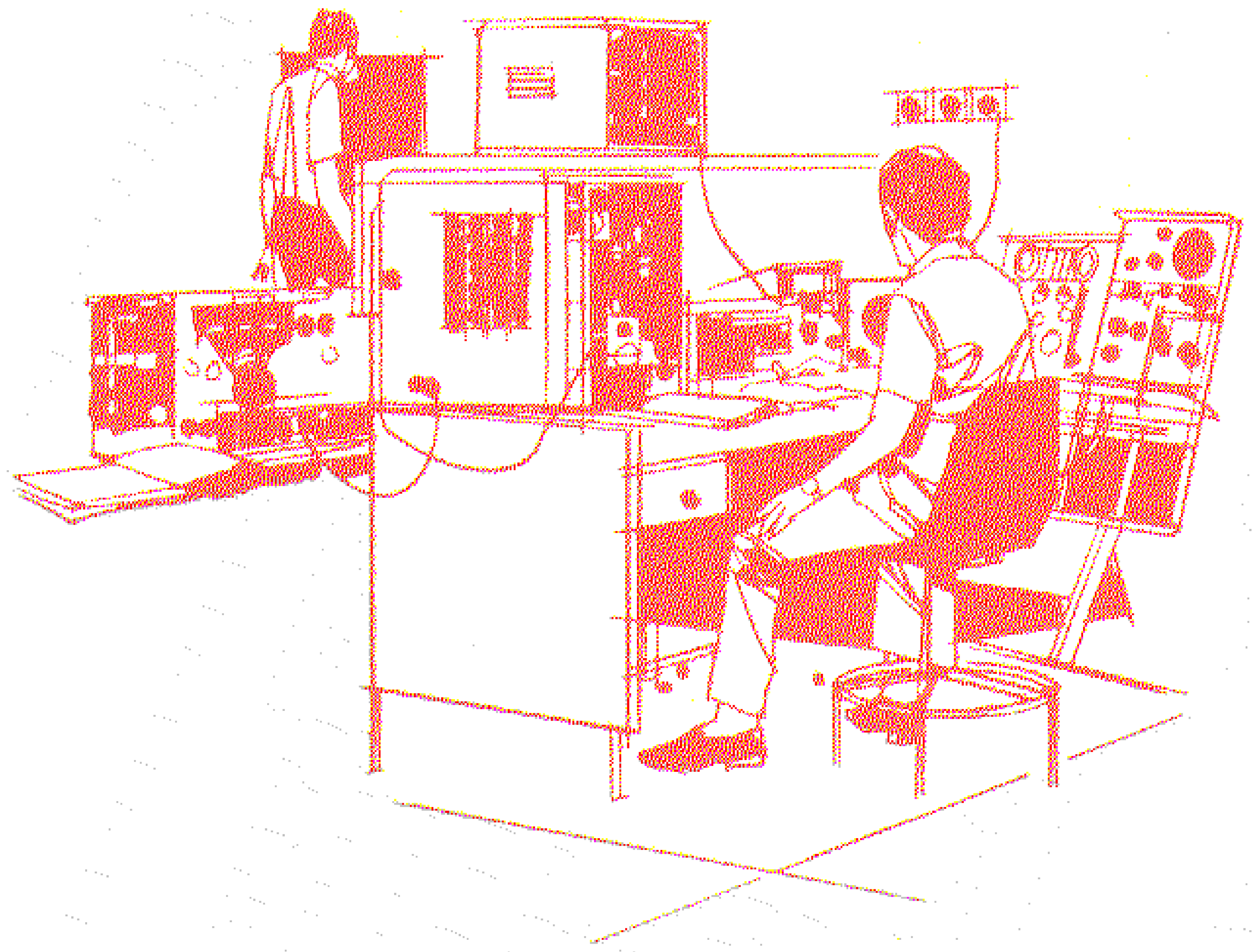


Figure 21. Generator Output Power Versus Exciter Stator Current



reduced to 90±2 volts. The undervoltage sensing amplifier monitors the generator output through a 3-phase, half-wave diode rectifier and, in conjunction with the under/over frequency circuit, energizes the auxiliary control relay (ACR) when voltage has built up to 105 volts.

When the ACR is energized, its contacts arm a timing circuit that will act automatically when one or more phases are reduced to 90 volts. The timing cycle duration is divided electronically into a 3-second period and a 1-second period in that sequence. The two are additive and the total time involved before an undervoltage trip occurs is about 4 seconds. The delay circuitry is intended primarily to allow time for corrective measures to occur (circuit breakers or current limiters to open) and remove the cause of the undervoltage.

If the cause of the undervoltage is removed and voltage rises to at least 105 volts before the initial time delay lapses, the generator continues to supply the bus and the lapsed increment is voided; i.e., the full 4-second delay is reinstated. However, after a 4-second delay, undervoltage lockout occurs, the generator is deenergized, and the loads carried by that generator are transferred to another generator. When the cause of the undervoltage trip is corrected, the generator can be returned to duty by setting the generator control switch to OFF, opening and closing the appropriate GEN CONT circuit breaker, and then setting the generator control switch to ON. If the foregoing procedure fails to restore a generator to operation, it is important that the generator control switch be set to OFF and the GEN CONT circuit breaker be left closed for the remainder of the flight (see also Feeder Fault Protection discussion).

Another function of the undervoltage protection circuit is to detect an open circuit in one or more of the feeders from the generator to the main load center. Since the supervisory panel sensing input is attached to the main load center end of the feeder wires, an open-circuited feeder will also remove voltage from one phase of the supervisory panel input. This is equivalent to the voltage on one phase dropping to zero causing the undervoltage sensor to initiate the 4-second time delay which eventually deenergizes the generator.

An overvoltage tripped condition of the P-3 generator system is not likely to occur unless the voltage regulator malfunctions. Under normal conditions a voltage rise of one or more phases will signal the fast acting regulator to decrease field excitation and thus reduce the voltage of all three phases before an overvoltage trip can occur. In fact, an increase of a single phase input to the supervisory panel can actually result in the voltage of the other two phases being lowered to the point of an undervoltage trip before the overvoltage trip limit is reached.

Practically, the overvoltage sensor only protects the generator and its loads when the regulator fails and then operates in the following manner. An overvoltage condition of one or more phases of a generator output is detected by a separate circuit which consists of a 3-phase, half-wave diode rectifier; a transistorized voltage comparison circuit; and an inverse time delay circuit. The voltage comparison circuit is designed to operate on receipt of approximately 10 volts dc from the 3-phase rectifier. The rectifier output is adjustable and is set to turn on the comparison circuit when all three phases of the generator rise to 129±1 volts.

Operation of the comparison circuit initiates the inverse time delay start. Its duration is determined by the amplitude of the overvoltage, i.e., the higher the overvoltage, the shorter the time delay. Since the outputs of the 3-phase diode rectifiers are averaged to produce the 10-volt input to the compar-

ison circuit, a severe 3-phase overvoltage may shorten the time delay to a small fraction of a second, whereas a mild single-phase overvoltage can prolong the delay to as much as 3 to 4 seconds.

If an overvoltage condition is eliminated before the end of the time delay period, the generator will continue to operate. Conversely, once the appropriate delay period expires, the comparison circuit energizes relays that deenergize the generator and its loads transfer to another generator. Thereafter, the generator can be reenergized by momentarily placing the generator control switch to RESET position, but if the overvoltage continues it will trip off again when the delay period expires.

Feeder Fault Protection Two differential current transformers and a transistorized sensing circuit protect the generators against feeder faults. Since a short circuit to structure at some point between the generator terminals and the main load center constitutes a great hazard that warrants a positive lockout, this circuit is designed to detect a shorted feeder only. An open feeder fault will be detected indirectly as an undervoltage condition.

As shown in Figure 19, the feeders from the generator to the main load center pass through a three-circuit current transformer located in the main load center. A second current transformer is a part of the generator and is mounted on the outer case adjacent to the output terminals with the neutral side of each phase of the stator output passing through a separate sensing coil (secondary winding). This arrangement affords protection from a phase-to-phase or a phase-to-ground short of either the feeder wires or of the generator output stator windings.

The transformer windings for each phase are so connected that the net voltage at the sensing point is essentially zero when equal currents are passing through both transformers. When either a feeder or a generator stator winding develops a short at some point between the paired transformers, unequal currents flow in them, and a voltage appears at the fault sensor. If the short causes an imbalance greater than 35 amperes, the differential protection and lockout relays prevent inadvertent or intentional resetting of the generator until the generator drive has been shut down and then restarted.

It should be emphasized that if an unsuccessful attempt is made to restore a generator to operation using the procedure given in the Undervoltage discussion, there is a possibility that the lockout was caused by a feeder fault. Therefore, a feeder fault must be assumed since it is the more hazardous of the two, and it is recommended that the generator control switch be set to OFF and the GEN CONT circuit breaker be left closed for the remainder of the flight. This will provide backup power for generator lockout if the engine is shut down and restarted during the flight. It will also guard against an unexpected reapplication of power from the generator if the initial problem was an undervoltage due to an intermittent circuit.

If the current transformer leads are disconnected for any reason – for example, while troubleshooting the feeder fault circuitry – they must be reconnected or the secondary windings short-circuited as shown in Figure 19 before operating the generator. This simple precaution is absolutely essential to prevent damaging the transformer's insulation. In the *current* transformer, the number of primary ampere turns is a fixed quantity (assuming a constant primary current) and is thus not reduced when the secondary circuit is opened, as it is in the case of a power transformer. If, therefore, a current transformer has its secondary circuit opened when current is flowing in its primary circuit, a very high flux density is produced in the transformer's core owing to the absence of "back" ampere-turns due to absence of current in the secondary winding. This high flux density induces a very high voltage in the secondary winding that imposes severe strain on the insulation.

The under/over frequency circuit automatically controls the application and removal of exciter current to the generator exciter field by energizing and deenergizing the generator control relay (GCR). Also, in conjunction with the undervoltage circuit, it controls the auxiliary control relay (ACR) thereby causing a transfer of the associated bus to an available generator. The frequency monitoring circuits sense the PMG frequency rather than the main generator frequency since the PMG is self-excited and has an output voltage even when the shaft is rotating at slower than normal speed. The main generator has only a relatively small residual output until the control panel energizes the exciter field 3 seconds after normal shaft speed is reached.

The output of the PMG is continuously monitored by two diode bridge circuits, one of which is frequency sensitive. The second diode bridge establishes a voltage reference only, and the combined output of the bridge circuits initiates a 3-second time delay to allow engine speed to stabilize before the generator is energized or connected to an aircraft bus.

When the PMG reaches a frequency that is equivalent to 372±5 Hz of the main generator, the time delay is initiated by the under/over frequency relay (UOR). Other contacts of the UOR permit continued operation until the frequency drops to 365±5 Hz. At the completion of the time period a control transistor is turned on to energize the GCR which applies exciter current to the generator. The GCR control transistor also completes the circuit for the ACR control transistor which will then energize the ACR as soon as the generator output rises to 105 volts. Thus, both voltage and frequency must be within tolerance limits before ACR operation makes the generator output available for energizing a bus.

Generator frequency is a function of engine speed. The maximum "normal" engine overspeed that can occur before initiation of engine protective devices is on the ground during landing where the engine can overspeed up to 109 percent before pitchlock occurs. Generator frequency at 109 percent engine speed is approximately 432 Hz. A generator overfrequency condition is sensed by the same circuits that sense underfrequency and will deactivate the generator at 435±5 Hz.

The generator will be reactivated automatically (after the previously mentioned time delay) when the rotor speed is reduced sufficiently to produce an output frequency of 422±5 Hz. Therefore, an overfrequency trip would occur only after failure of the engine overspeed protective devices.

Auxiliary Power Unit The APU is attached to a mounting frame and installed in the lower fuselage, between the nosewheel well and the bomb bay. A fire barrier of elastomeric blankets installed on the APU compartment bulkheads and overhead isolates the area from the remainder of the aircraft. As a further precaution, this compartment has its own automatic fire detection and extinguishing system. The APU draws fuel from the aircraft supply.

During the APU starting cycle, the unit draws electrical power from the aircraft's battery whenever power is not available from the aircraft's main electrical system or external sources. The controls for both the APU and its fire extinguisher system are located in the flight station (see Figure 17). Electrical power is available from the APU whenever the unit is operating above 95 percent rpm. The APU can be operated in flight to supply emergency electrical power.

The APU generator power rating is identical to that of the engine-driven units, but its load must be restricted as a function of altitude and ambient air temperature. These factors determine to a great extent the maximum available horsepower rating of the APU turbine drive.

Airborne operation of the APU is limited to an altitude of 20,000 feet at an indicated airspeed not to exceed 225 knots. Also, it is necessary to monitor certain electrical loads at various altitudes as detailed in the emergency operation section of the NATOPS Flight Manual (NAVAIR 01-75PAA-1 or NAVAIR 01-75PAC-1). The APU will not normally be running in flight, but is started after two of the three engine-driven generators have failed.

Both the APU essential dc bus and the ground operation dc bus must be energized for APU operation. Since the ground operation dc bus is normally deenergized in flight by the "gear up" position of the nose gear uplock switch, an APU in-flight arming switch is incorporated on the center overhead panel (see Figure 17). This switch deenergizes the ground operation bus relay just as the NLG uplock switch does in its "gear not up" position, thereby connecting the ground operation dc bus to the flight essential dc bus. Power for the APU essential dc bus is normally supplied by the monitorable essential dc bus, but it can be energized by the ground operation dc bus (through the deenergized contacts of the monitorable essential dc bus power sensing relay) if the battery is the only source of dc power available.

The aircraft battery supplies dc power for "all generators out" emergency engine starting as well as for energizing the ground operation dc bus (when the nose gear is down) in the same manner as before. It also supplies power to start and operate the APU when no other power source is available. Note, however, that the APU power loads are supported only by the battery when none of the transformer-rectifiers are operating.

BUS SUPPORT AND CONTROL PHILOSOPHY

The power distribution system is divided into two principal power paths via the A and B main buses. These buses are supported normally by no. 2 and 3 generators respectively, with loads divided about equally between them. An elaborate automatic bus transfer system (described later) will allow any available generator to support one or both paths for every conceivable combination of generator failures.

There is also a remote possibility that a fault at some point within one of the principal power paths (rather than at the generator) could make it imperative to deenergize that path. Accordingly, a manual monitoring switch is provided for each main bus to isolate the bus and its connected loads from all generators. Although there is no specific monitoring switch for the direct current portion of the power system, operation of both main ac bus monitoring switches (A bus and B bus) removes power from the no. 1 and 2 transformer-rectifiers, thereby deenergizing the main dc bus and its extensions.

Services are divided between the two main power paths in such a way that the loss of one bus would not ordinarily cause a loss of power to vital aircraft systems. However, some services are practically indispensable to every flight. In order to provide a special priority for these services, they are collected on the flight essential buses. A bypass arrangement known as the runaround system sustains these flight essential buses, even when one or both main bus monitoring switches are off. Figure 31 shows that the flight essential dc bus can be powered directly from the aircraft battery or from transformer-rectifier no. 3 via power diode no. 2, a path that does not require power from the main ac buses.

The flight essential ac bus too is normally independent of the main buses. Like the main buses, it can draw power from any ac generator, but unlike them it cannot be deenergized readily by a monitoring switch.

Between the heavy loads of lesser importance (relegated to the main buses) and the extremely important services (supported by the flight essential buses) lies a middle group of services. They are important enough to deserve the term *essential,* but they can be dispensed with if the flight crew deems it advisable. These services are collected on the monitorable essential buses. The monitorable essential ac bus is normally supported by the main ac bus A, but it will automatically transfer to the runaround system if main ac bus A becomes deenergized, thus attaining the same capability of direct, all-generator support that the main ac and flight essential ac buses enjoy. A separate essential bus monitoring switch is located adjacent to the main bus monitoring switches (Figure 16). Turning the essential bus monitoring switch off isolates the monitorable essential ac bus from the main ac bus A and the runaround system.

Monitoring any bus must always be regarded as a serious emergency measure, especially the monitorable essential ac bus in view of the multitude of varied and unduplicated services that it supports. Air crew members should be doubly wary of

inadvertently deenergizing this bus. In addition to the essential bus monitoring switch, the bus could be isolated by pulling the 50-ampere MON ESS AC BUS circuit breaker located on the front panel of the forward load center. A spring-loaded plastic guard is fitted over this circuit breaker to reduce the possibility that it will be opened inadvertently. Installation of the plastic guard was authorized by AFC-150.

All three ac bus monitoring switches must be turned off to deenergize the monitorable essential dc bus and its subsidiaries, for it is necessary to deenergize the power sources of all three transformers-rectifiers, main ac buses A and B plus the monitorable essential ac bus. When this is done, the flight essential ac bus retains access to any operating generator. But, since no transformer-rectifiers are operating, the battery is the sole remaining source of dc power. A permanent connection from the battery to the flight essential dc bus ensures that power is always available to this bus, and that dc power is available to energize other buses through relays as required.

If an engine is selected at the engine start selector, battery power is extended to the start essential dc bus through the inverter power relay contacts to the start essential ac bus. On all configurations, lowering the landing gear automatically extends battery power to the ground operation dc bus. Operation of the APU in-flight arming switch performs the same function, and the power is relayed to the APU essential dc bus automatically (assuming, as we are, that no other source of dc power is available on the aircraft).

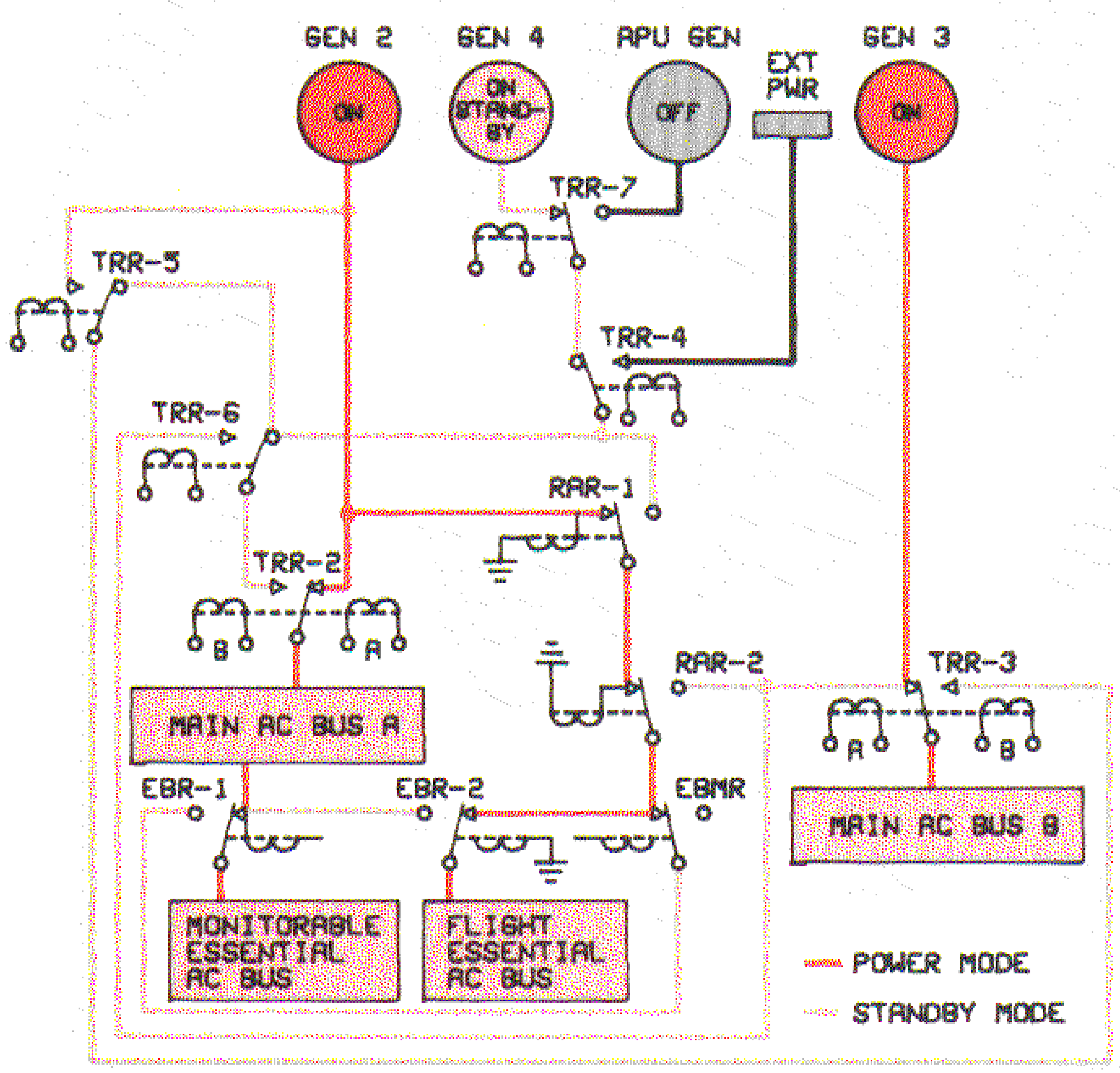


Figure 22a. Power Distribution Arrangement for Normal Operation: Generators No. 2 and 3 ON, Generator No. 4 on STANDBY and APU Generator OFF

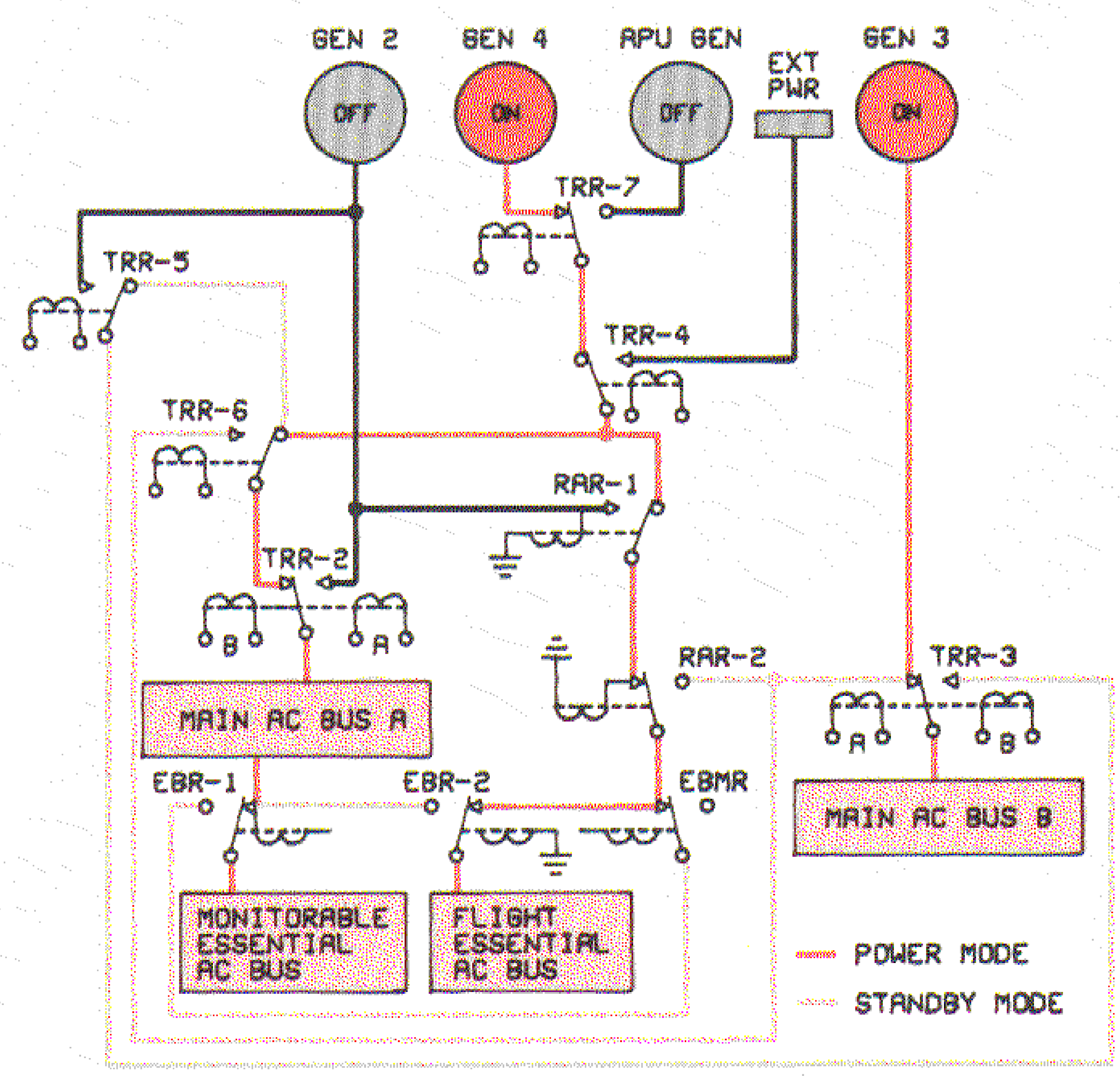


Figure 22b. Generators No. 3 and 4 ON, Generator No. 2 and APU Generator OFF

LEGEND:

TRR = TRANSFER RELAY
RAR = RUNAROUND RELAY
EBR = ESSENTIAL BUS RELAY
EBMR = ESSENTIAL BUS MONITORING RELAY

POWER CONTROL AND DISTRIBUTION

The power distribution arrangement for normal operation of the system (generators no. 2 and 3 on and generator no. 4 on, but on standby) is shown in Figure 22a. The red lines depict the power paths from the generators to their respective buses. Figures 22b, c, and d show the arrangement for two engine-driven generators on and the third one off. Figures 22e, f, and g depict the power distribution arrangement with only one engine-driven generator on. Figures 22h and i show the power distribution combinations with one engine-driven generator operating with the APU generator. Figure 22j shows the distribution arrangement with only the APU generator operating. Figure 22k shows the arrangement for external power operation. The control functions which cause the various relays to energize and deenergize are shown in Figure 31.

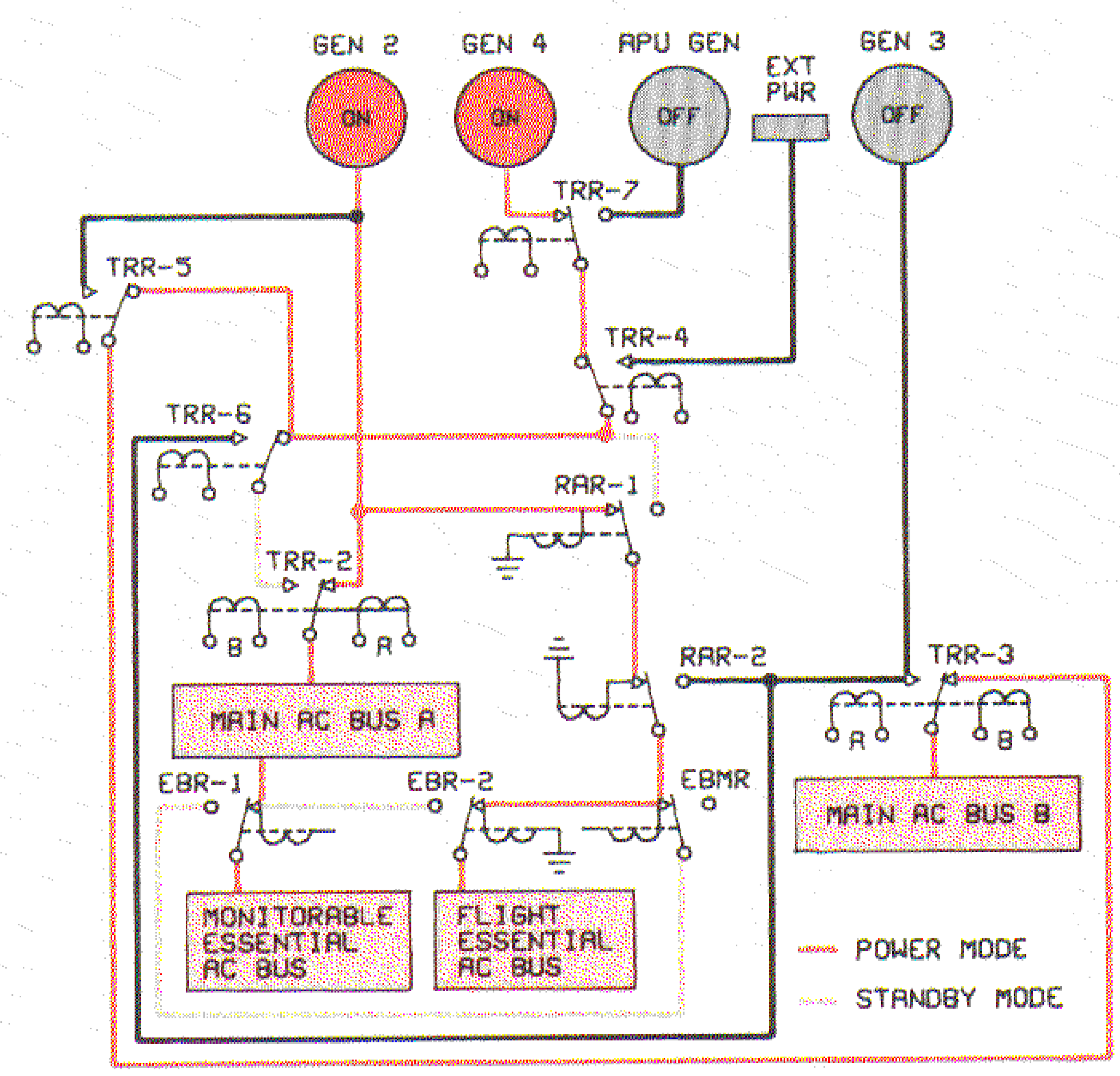


Figure 22c. Generators No. 2 and 4 ON, Generator No. 3 and APU Generator OFF

At this time it is appropriate to introduce Supplement A which shows the complete ac and dc power and distribution systems, including the disposition of the circuit breakers for the various utility loads. The circuit breaker and feeder arrangement shown is for the P-3C, Update I model, which started at SERNO 159503 (Lockheed Serial No. 5620). In addition, equipment installed for Update II starting

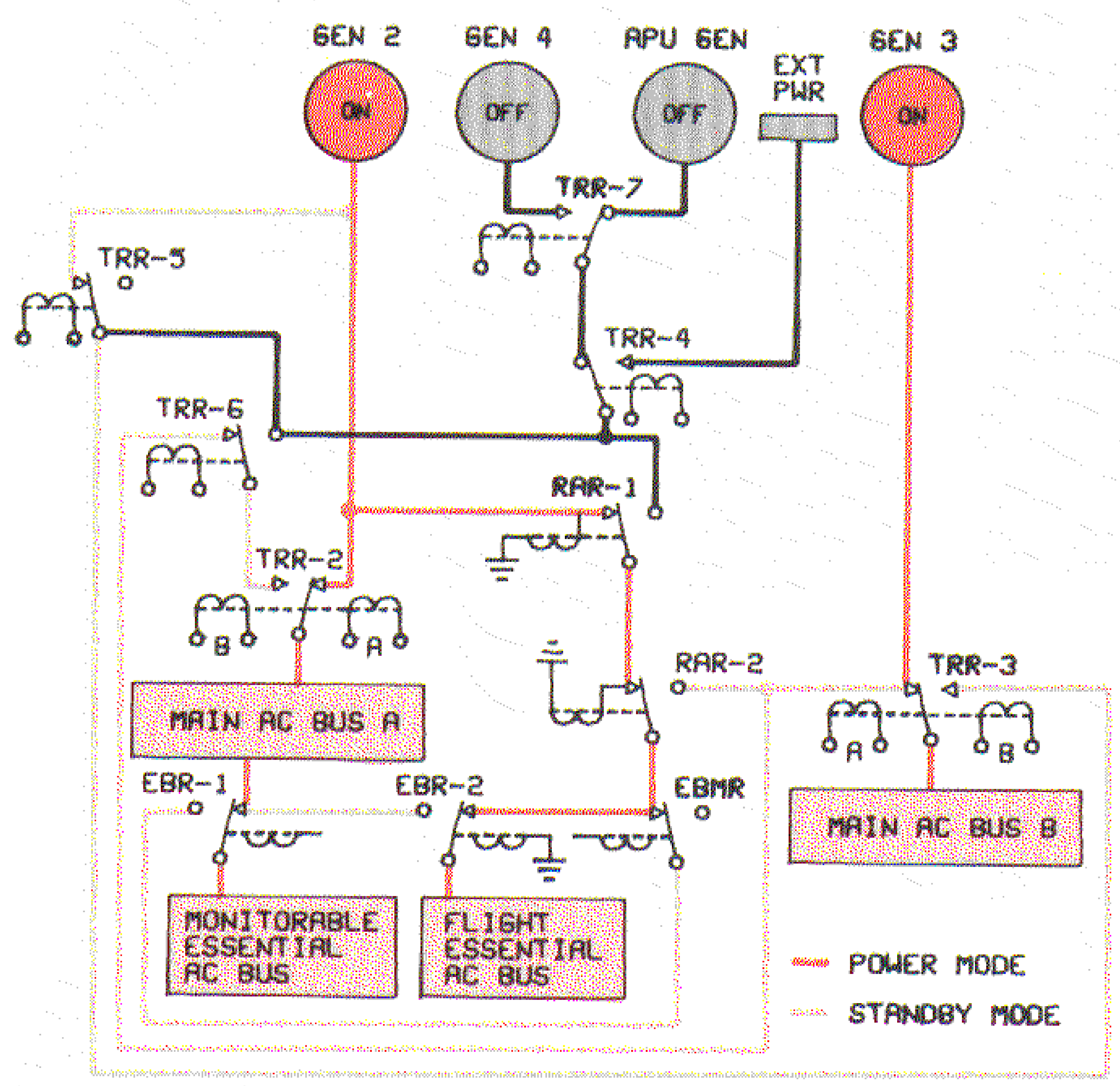


Figure 22d. *Generators No. 2 and 3 ON, Generator No. 4 and APU Generator OFF*

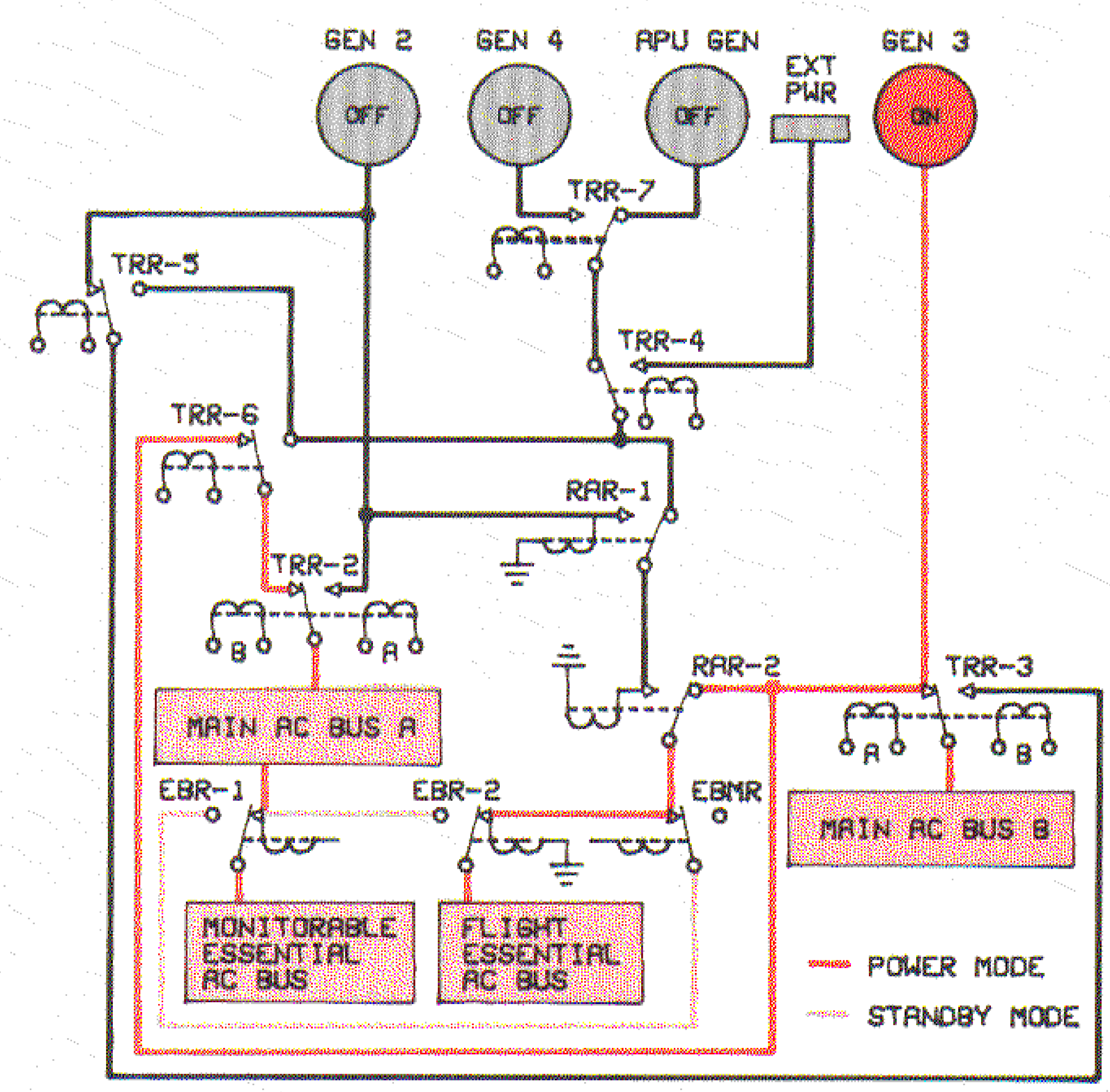


Figure 22f. *Generator No. 3 ON, Generators No. 2, 4, and APU Generator OFF*

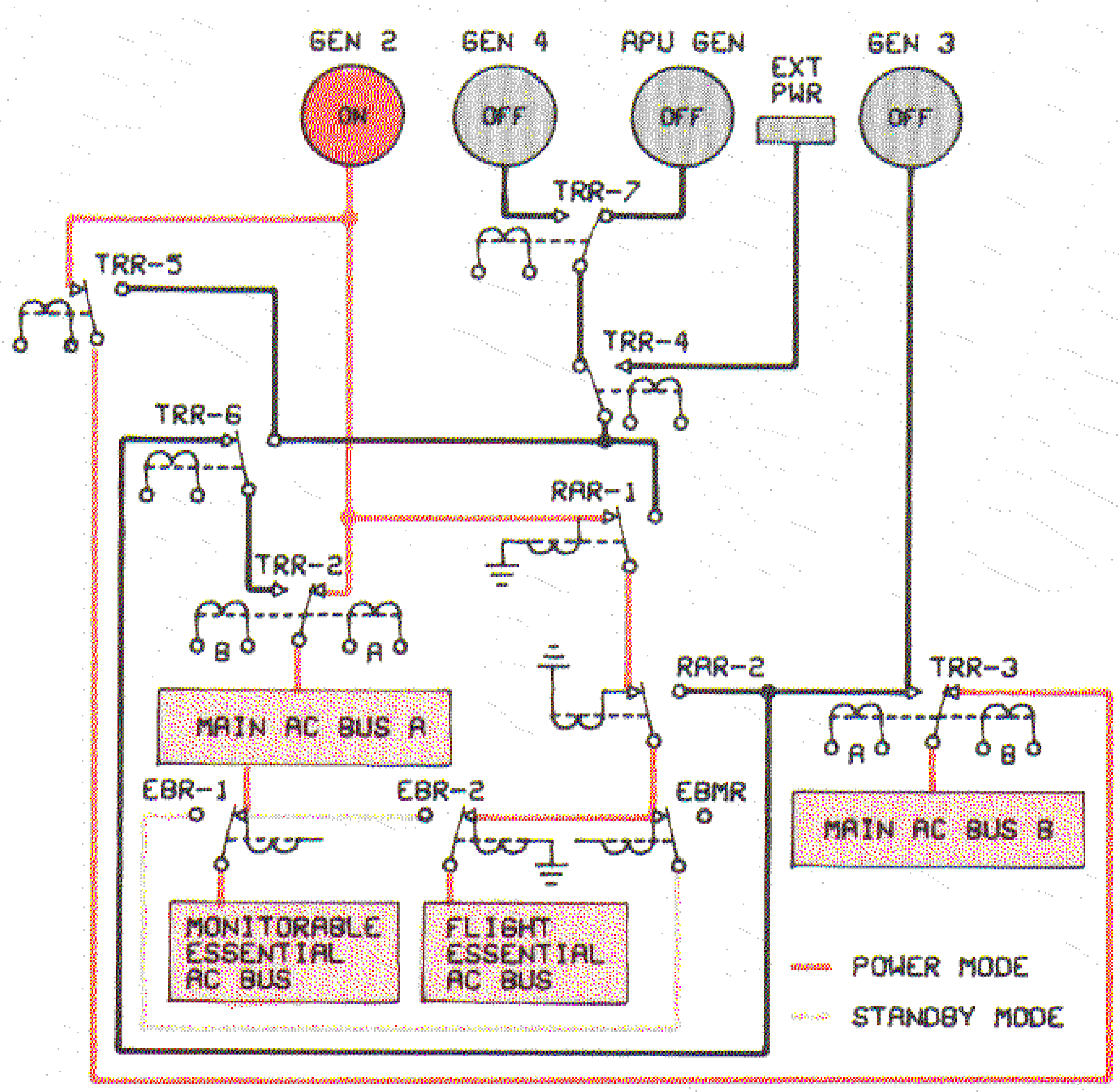


Figure 22e. *Generator No. 2 ON, Generators No. 3, 4, and APU Generator OFF*

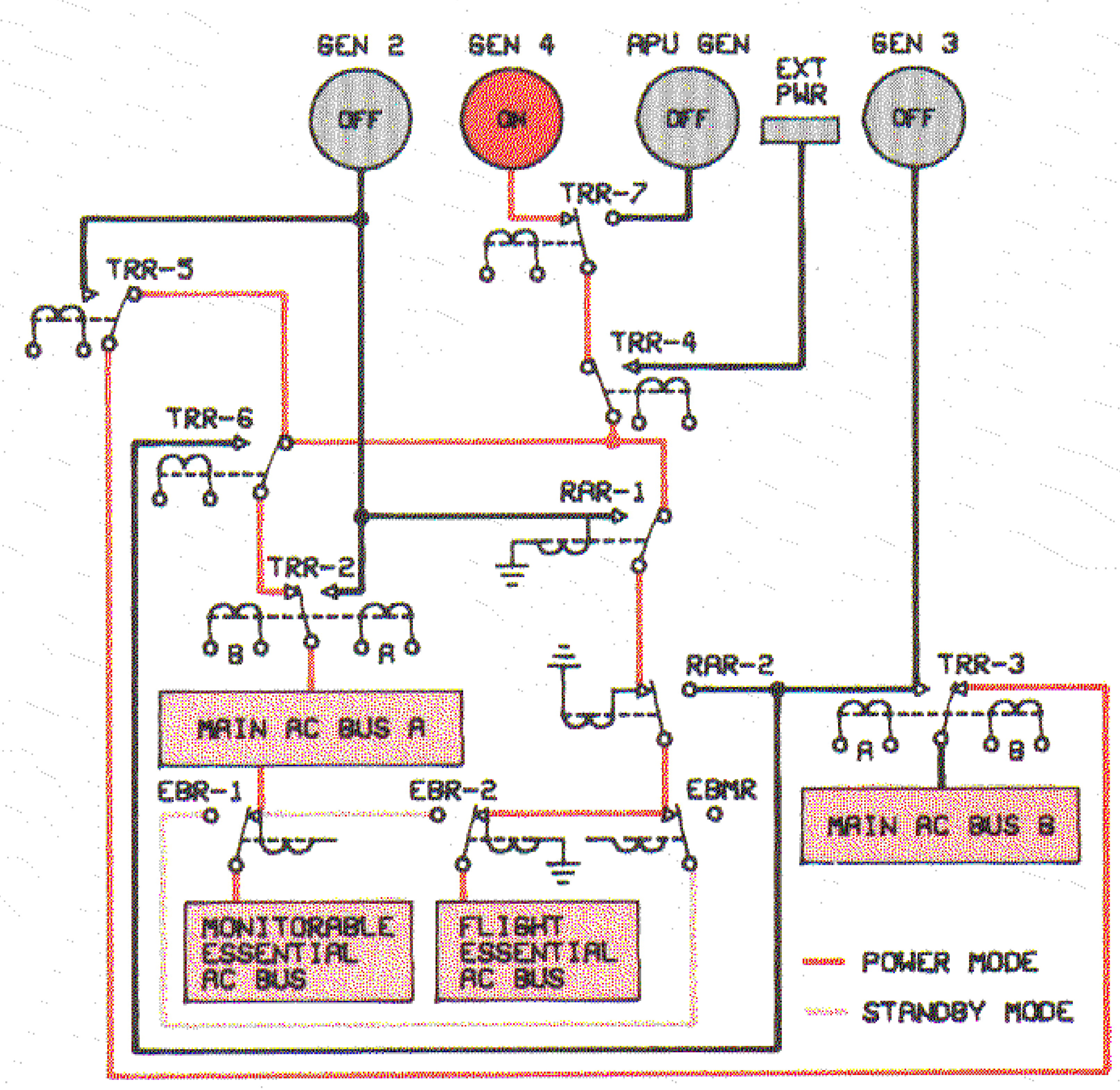


Figure 22g. *Generator No. 4 ON, Generators No. 2, 3, and APU Generator OFF*

at SERNO 160290 (Lockheed Serial No. 5653) is also shown. (Refer to Recent Modifications section.) In general, except for some variations of utility equipment, specifically in the avionic complement, the P-3C electrical systems are basically as shown on Supplement A. Therefore, this supplement when used in conjunction with the generator/relay control circuitry shown on Figure 31 provides a useful tool for understanding the system. The layout, when read from left to right, depicts the feeders, circuit breaker panels, and relays in their relative positions on the aircraft from nose to tail.

Supplement A depicts the distribution of all 115 Vac and 28 Vdc power up to the circuit breakers that furnish power to each individual

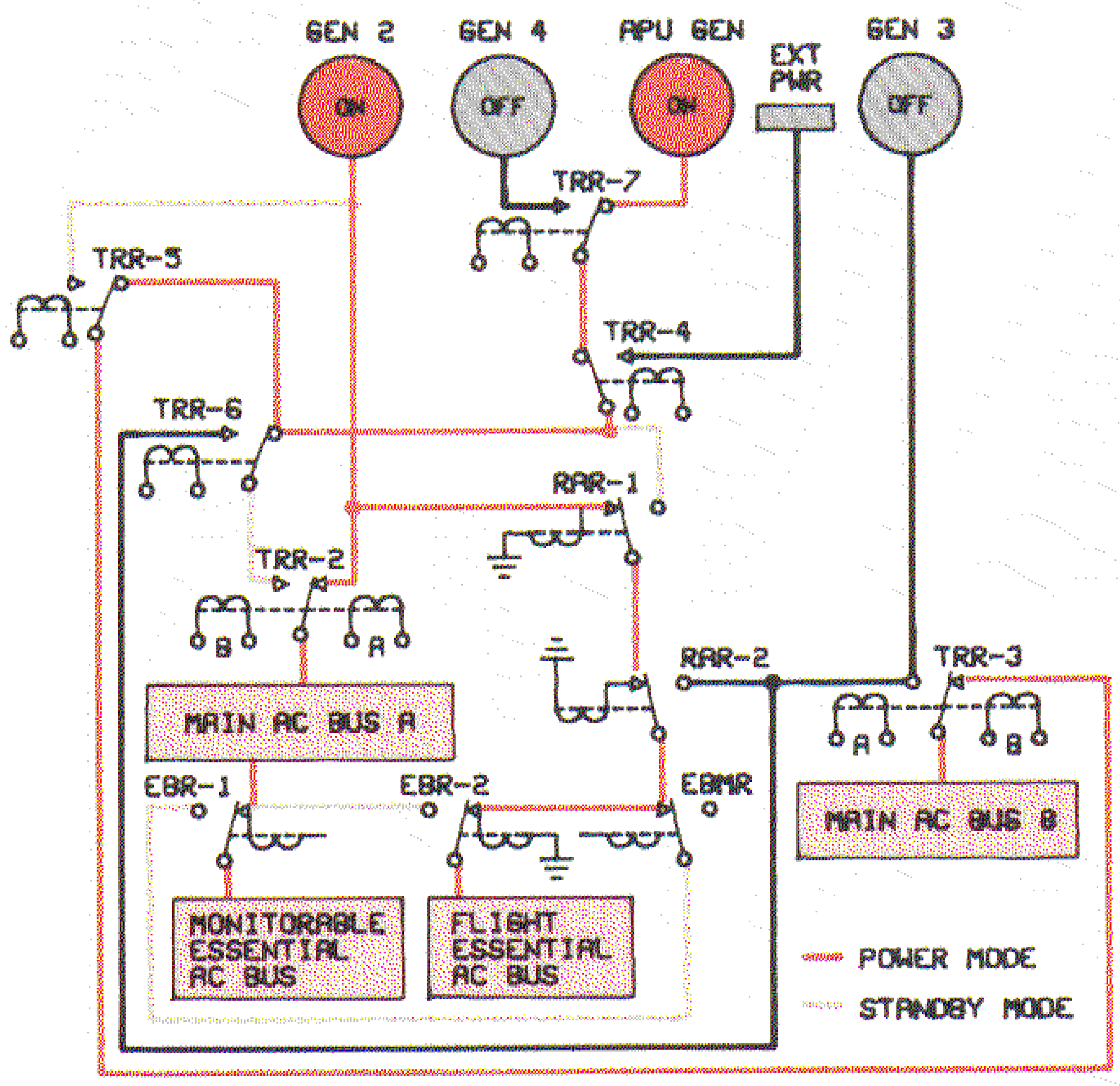


Figure 22h. Generator No. 2 and APU Generator ON, Generators No. 3 and 4 OFF

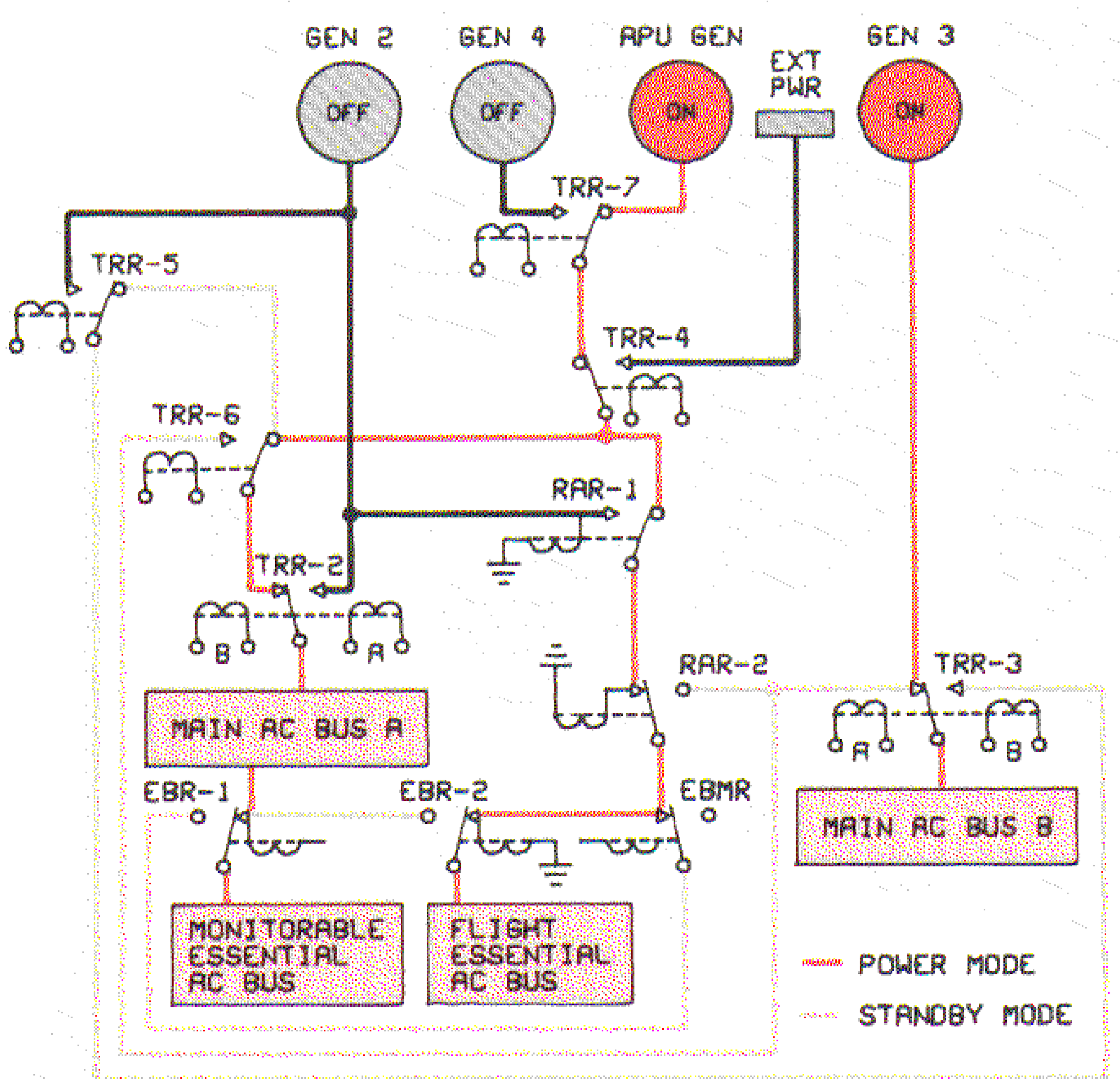


Figure 22i. Generator No. 3 and APU Generator ON, Generators No. 2 and 4 OFF

LEGEND:
TRR = TRANSFER RELAY
RAR = RUNAROUND RELAY
EBR = ESSENTIAL BUS RELAY
EBMR = ESSENTIAL BUS MONITORING RELAY

system. Lower-voltage circuits used for area illumination and panel lighting are also shown. It also depicts the ground operation dc bus and the APU

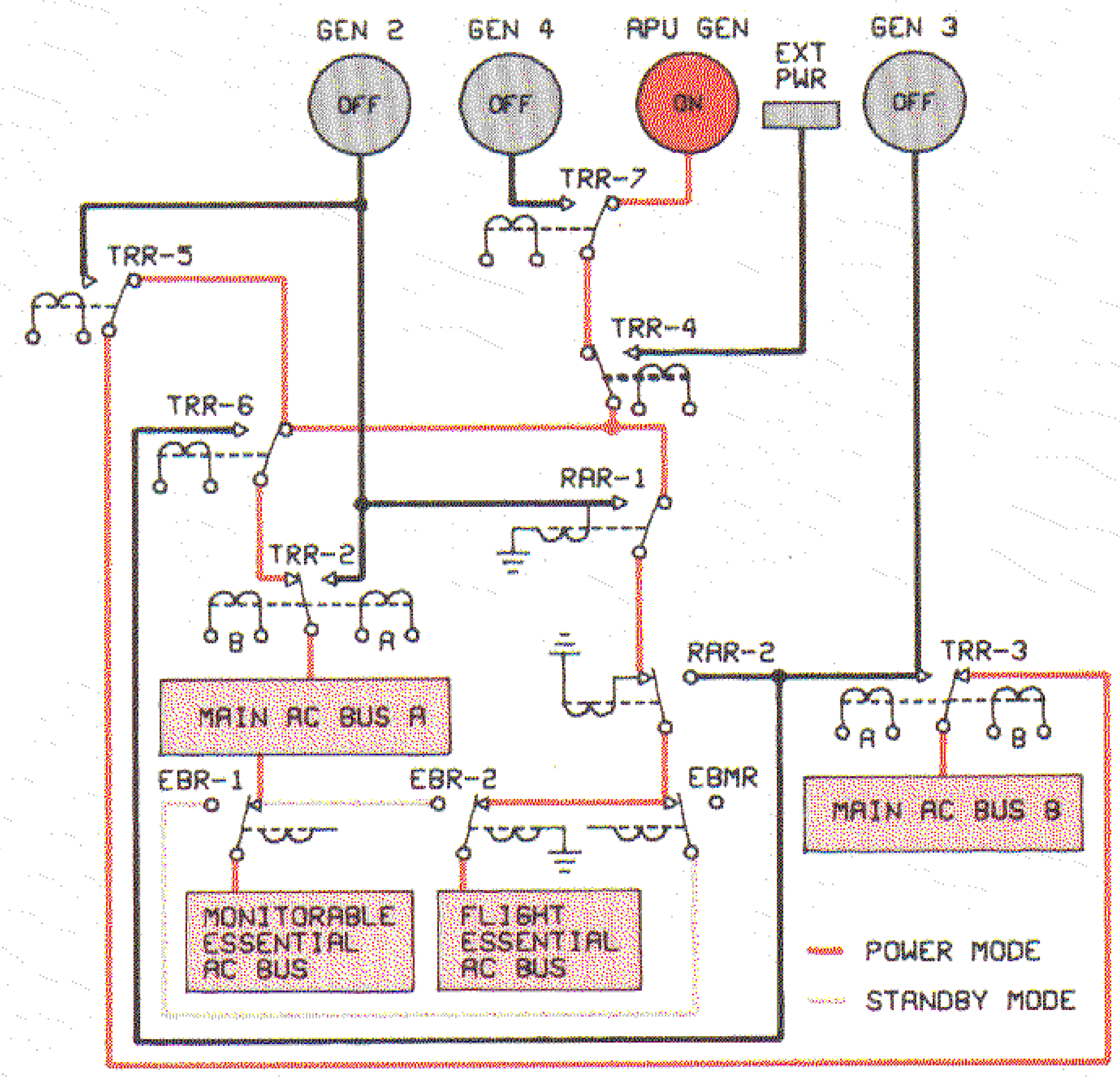


Figure 22j. APU Generator ON, Generators NO. 2, 3, and 4 OFF

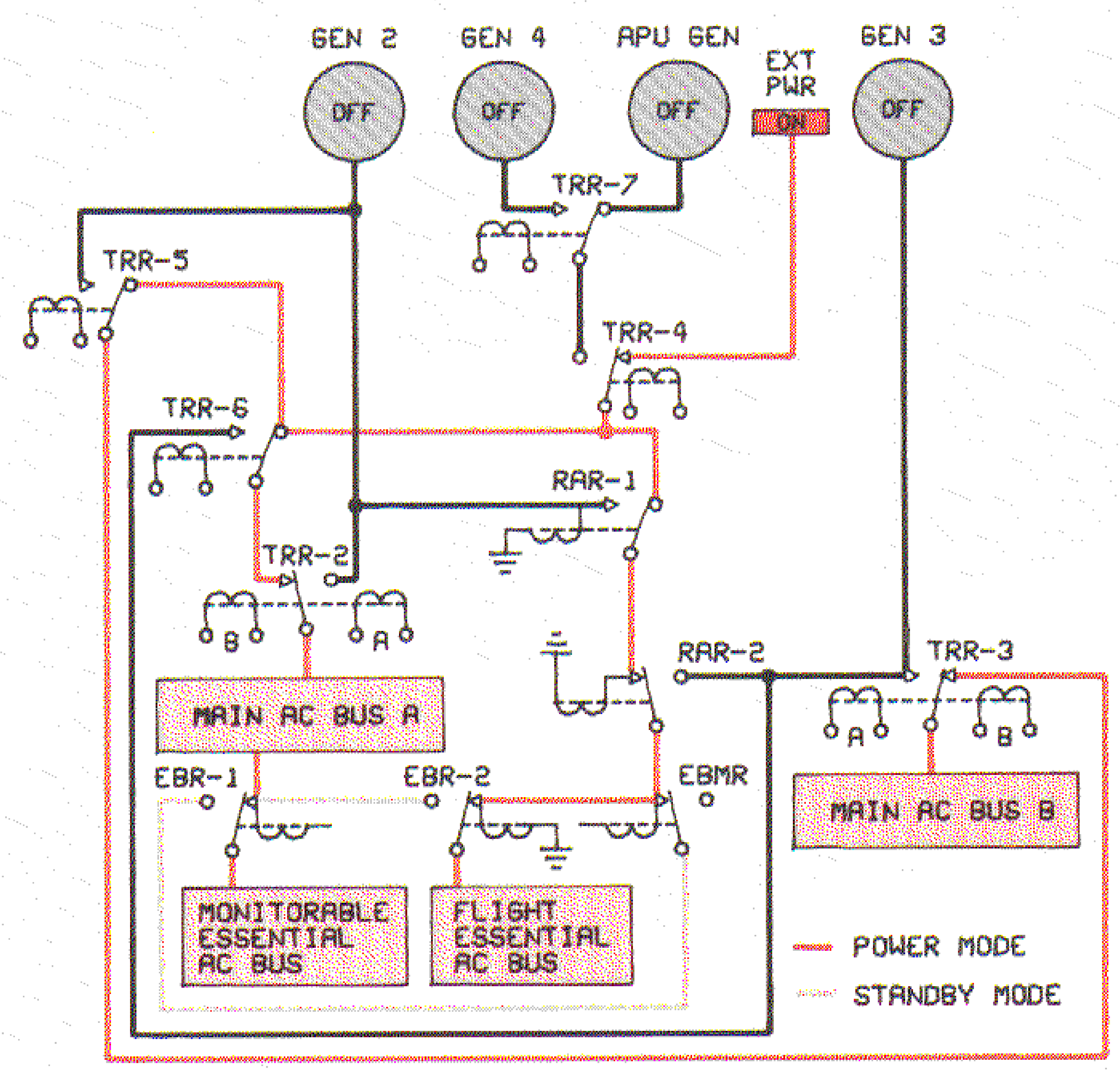


Figure 22k. External Power ON, Generators No. 2, 3, 4, and APU Generator OFF

essential dc bus which serves as an extension of either the ground operation dc bus or the monitorable essential dc bus for starting, control, and operation of the integral start system.

EXTERNAL POWER – POWER-ON SEQUENCE

It is assumed now that the aircraft is on the ground with all engines stopped, no external power plugged in, and all switches in their normal operating positions. These conditions are reflected in Supplement A, depicting all relays deenergized and the nose uplock switch (shown in the dc section) in its normal gear down position. This causes the ground operation dc bus relay to be deenergized, thereby connecting the aircraft battery (the only available power source) to the ground operation dc bus and applying power to the few ground services on this bus.

If ac power is not available on the aircraft, setting the engine start selector to any engine results in a ground being provided for the inverter power relay so that the inverter is started. The inverter then powers the TIT (turbine inlet temperature) indicators through the start essential ac bus.

Unlike the battery test circuit, the emergency engine circuit passes through a pair of normally closed contacts of the monitorable essential dc bus power sensing relay. Since this relay is energized whenever the monitorable essential dc bus is energized, operation of the inverter is prevented during normal starts when another source of ac power is available.

With external power available, use of the inverter is not required. When external power is plugged in, pins E and F of the external power receptacle are connected by means of a jumper wire in the external power plug (see Figure 23). Subsequently, the external power monitor relay is energized if it senses that the external power quality is acceptable. Also, the EXTERNAL PWR AVAILABLE light on the electrical control panel is illuminated. (Note that the light does not indicate that the power is acceptable.)

Setting the external power switch to ON* should complete the circuit from the battery and flight essential dc bus, through the deenergized ground operation bus relay and the ground operation dc bus, through the external power switch and pins F and E of the external power receptacle, and through the closed contacts A1 and A2 of the external power monitor relay to energize transfer relay no. 4. Another circuit from pin E is grounded through the amber EXT POWER IN USE indicator light adjacent to the external power receptacle (not shown on figures).

Closing the main contacts of transfer relay no. 4 enables 115-volt, 3-phase ac current from the external power source to energize the complete essential ac and dc buses via runaround relay no. 2, the essential ac bus relay no. 2, and the essential ac bus monitoring relay, the latter being grounded through the normally ON essential bus monitoring switch.

The monitorable essential dc bus is powered from transformer-rectifier no. 3, and it is now possible to trace a closed circuit from the BUS A CONT circuit breaker through the normally closed contacts of the A bus monitoring switch through connections H and O of the no. 2 generator control unit (ACR is deenergized) to energize coil 2B of transfer relay no. 2. Thus, external power is now directed through the deenergized transfer relay no. 6 and the closed contacts of transfer relay 2B to power main ac bus A. A similar circuit can be traced out from the BUS B CONT circuit breaker to energize coil 3B of transfer relay no. 3 and the main ac bus B.

Subsequently, the main dc bus and its extension are energized and the complete system is now powered from the external power source. Note that the essential bus relay no. 1 is energized when the main ac bus A is energized, so that the flight essential ac bus is now the only bus being powered by the runaround feeder system.

Another set of contacts of transfer relay no. 4 close to complete a circuit to the green EXTERNAL POWER ON indicator light on the overhead electrical control panel. Also, the three GEN OFF caution lights on the electric power system control panel and the ELEC POWER master caution light on the center instrument panel are illuminated as soon as the monitorable essential dc bus is energized. Power distribution arrangement is as shown on Figure 22k.

Involved as the foregoing description is, the whole operation, like all the transfer operations in the

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**Switch should not be put ON until external power is plugged in.*

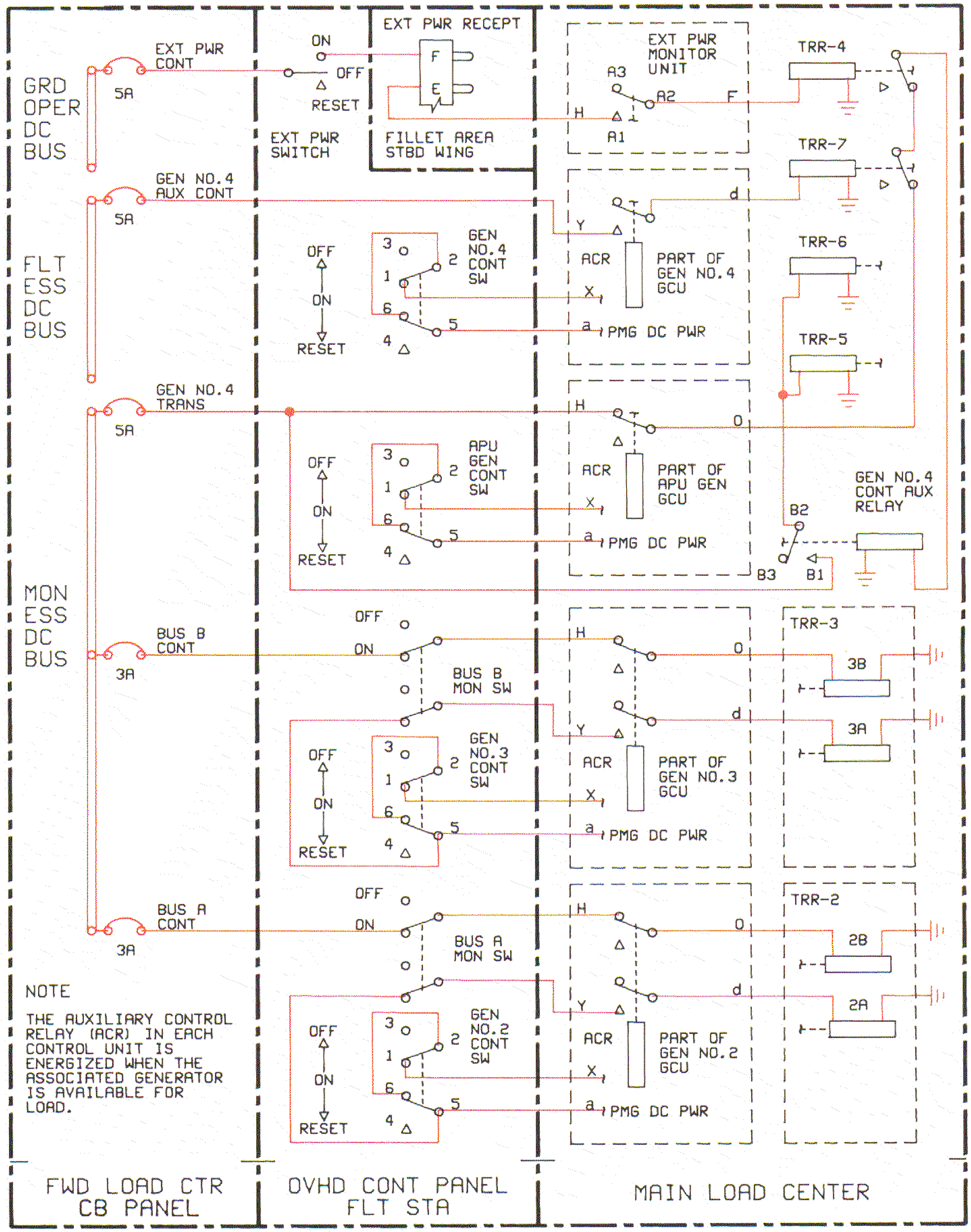


Figure 23. AC Power and Distribution Control

power system, is accomplished almost instantaneously in a fraction of a second. Note that external ground power cannot be selected to supply power to the system without battery power being available on the ground operation dc bus. Furthermore, if the nose landing gear is being cycled while the aircraft is on the ground, the ground operation dc bus relay circuit breaker on the flight essential dc bus should be opened to avoid losing external ground power each time the nose gear is retracted. In its up and locked position, the nose gear uplock switch disconnects the ground operation dc bus from the battery so that transfer relay no. 4 is deenergized.

Generator Control Switches There are four generator control switches, one for each of the four generators. Each switch has three positions. A switch guard holds the switch at the center ON position, and the guard has to be lifted in order to select OFF or RESET. Selecting either of the latter two switch positions achieves the same thing electrically, but selection of RESET is preferred during generator resetting operations because it is a momentary position; in other words, the switch automatically returns to ON when released. The generator control switch is designed to remain in the ON position at all times except for emergency or test purposes.

Shown adjacent to each generator control switch in Figure 23 is a section of the associated generator control unit (GCU). The complete circuitry of each GCU is not shown. Assuming that an engine has been started and the associated generator system is functioning correctly, dc power (rectified ac) from the permanent magnet generator (PMG) in the generator passes from pin connection 'a' in the GCU, through contacts 5, 6, 2, and 1 of the generator control switch, and back to pin connection X of the generator control unit. Subsequently, PMG control power from connection X energizes the auxiliary control relay (ACR), which is the final step in energizing the generator and signaling the main ac bus transfer system that the generator is available for load. This circuit is broken and the generator deenergized by setting the appropriate generator control switch to either OFF or RESET.

APU Generator – Power-On Sequence When the APU is up to normal operating speed and the APU generator control switch is positioned ON, the APU generator will be energized. However, at this time the output power of the APU generator is not connected to the bus system, because TRR-4 is still energized when external power is ON and supplying the bus system.

Setting the external power switch* to OFF will deenergize TRR-4 and connect the APU generator to the bus system as shown in Figure 22j. Both the external power indicator light adjacent to the external power receptacle and the EXTERNAL PWR AVAILABLE light in the flight station will go out. When the external power source is removed, the EXTERNAL PWR AVAILABLE light will also be extinguished.

GENERATOR LOADING SEQUENCE

Before the engines are started, the aircraft's electrical equipment will be operating from either the APU generator or external ground power (most probably from the APU generator). Normal engine start procedures prescribe that the engine-driven generators' control switches be ON. The normal engine start sequence is 2, 1, 3, 4. Therefore, as soon as no. 2 engine has been started and its speed has accelerated to normal rpm, generator no. 2 will assume the electrical power requirements of the main ac bus A, the monitorable essential ac bus, and the flight essential bus. There will be a momentary power interruption to these buses as this transfer takes place. After no. 3 engine is started and its

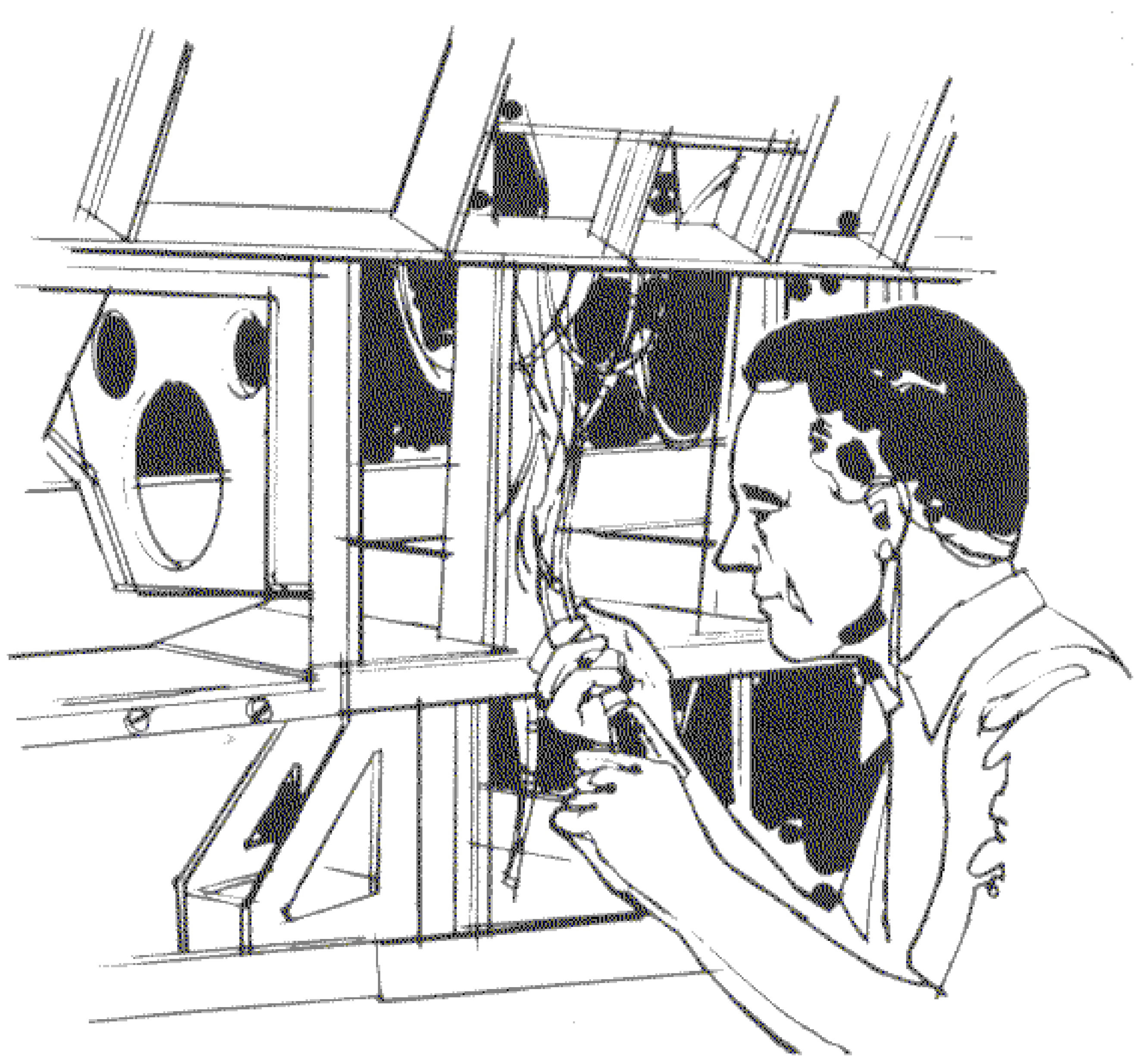
---

**It is important to set the external power switch to OFF before shutting off the external power cart or before disconnecting the external power plug. Following the correct procedure assures a clean fast transfer operation and, in particular, prevents repetitive transfers due to rocking the external power plug to facilitate its removal, a bad practice which is all too common.*

speed has accelerated to normal rpm, the loads of main ac bus B will transfer from the APU generator to generator no. 3. The main ac bus A, monitorable essential and flight essential buses will not be affected by this second power transfer.

When it is necessary to taxi to the fuel pit and/or to the high power turn-up area, the aircraft's electrical bus system will be subjected to several undesirable bus transfers and transients when, for example, the engines are shifted from high to low rpm for noise abatement and back to high rpm to move the aircraft up an incline, etc. The series of bus transfer transients which result from such shifting may be detrimental to certain avionic equipment such as inertial navigation systems and the central computer. Therefore, depending upon the circumstances encountered during taxi operations, it may be advisable to leave the generator no. 2, 3, and 4 control switches OFF during start and taxi operations. The aircraft's electrical bus system would then remain powered by the APU generator during the taxi operations.

When engine power is finally advanced to normal rpm for the last time before take-off, the generator no. 2 control switch can then be set in the ON position, followed by setting generator no. 3 and then generator no. 4 switches in the ON position. This will ensure that the avionic equipment will only be subjected to one power transfer transient i.e., from the APU generator to generator no. 2.



Shifting engine no. 2 to normal rpm with the no. 2 generator control switch in the ON position will energize the ACR in no. 2 generator control unit and energize generator no. 2. Subsequently, the runaround relay no. 1 is also energized, resulting in generator no. 2 taking over the runaround feeder system from the APU generator. At the same time, contacts H and O of the ACR in the no. 2 generator control unit open, deenergizing transfer relay no. 2 coil 2B (see Figure 23). ACR actuation also completes the circuit through relay contacts Y and d so that PMG control power from generator control unit contact 'a' is directed through the normally closed contacts of the A BUS monitoring switch and through the ACR to energize transfer relay coil 2A. Thus, generator no. 2 picks up main ac bus A, leaving the APU generator still supplying main ac bus B. The power distribution arrangement will be as shown in Figure 22h.

Similarly, if engine no. 3 is now set to NORMAL RPM, transfer relay no. 3 coil 3B is deenergized and coil 3A is energized so that generator no. 3 powers the main ac bus B, leaving the APU generator on standby. Action of transfer relays no. 2 and 3 extinguishes the appropriate GEN OFF caution light. If engine no. 4 is set to NORMAL RPM, generator no. 4 will automatically take over the standby duties from the APU generator. Since all generators are now energized, the ELEC POWER master caution light on the center instrument panel will go out. At this stage the APU should be shut down, at which time the power distribution arrangement will be as shown on Figure 22a.

As long as generator no. 4 is energized, contacts Y and d in the no. 4 generator control unit are closed, thereby energizing TRR-7 (see Figure 23). However, if generator no. 4 becomes deenergized for any reason, then the ACR in the no. 4 generator control unit will be deenergized, hence deenergizing TRR-7. A circuit is then completed from the GEN 4 TRANS circuit breaker on the monitorable essential dc bus through contacts H and O in the APU generator control unit and the closed contacts on the deenergized transfer relay no. 7, through the normally closed contacts on TRR-4 to energize the coil of the generator no. 4 auxiliary control relay.

Closing contacts B1 and B2 of this relay completes the circuit and energizes transfer relays no. 5 and 6. As long as generators no. 2 and 3 are both operating, power distribution is not affected. But if, for example, generator no. 3 is now deenergized, transfer relay no. 3 will actuate to connect generator no. 2 to the main ac bus B via the already energized transfer relay no. 5, as soon as TRR-3's coil 3B is energized. Thus generator no. 2 is enabled to supply power to both main ac buses. A similar action results if generator no. 2 is deenergized rather than generator no. 3, in which case both main ac buses would be supplied by generator no. 3 as shown in Figure 22f.

It has already been pointed out that when the system is operating under normal flight conditions, the only energized coils in the main ac bus transfer system are coils 2A and 3A. It can now be appreciated from Figure 31 that since these two coils are energized from the PMGs of generators no. 2 and 3, the system is actually independent of aircraft battery power for normal flight operation and emergency engine starting.

BUS MONITORING SWITCHES The three bus monitoring switches in Figure 31 are only used during an emergency. Action of the A BUS and B BUS monitoring switches is similar. Setting either switch to OFF breaks the circuits to both coils of the pertinent transfer relay (no. 2 or no. 3) so that the associated main ac bus is deenergized. Setting both the A BUS and B BUS switches to OFF will stop the power supplies to the no. 1 and 2 transformer-rectifiers and deenergize the main dc bus and its extension.

Setting the ESS BUS monitoring switch to OFF breaks the circuit to the essential ac bus monitoring relay and the essential ac bus relay no. 1 and consequently deenergizes the start and monitorable essential ac buses. Although labeled ESS BUS, the use of this monitoring switch alone will not affect the essential dc bus. Setting all three monitoring switches to OFF will, however, deenergize the monitorable essential dc bus because all three ac buses which power the transformer-rectifiers will be deenergized. In these circumstances, the flight essential ac bus would be the only remaining bus

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powered from a generator, assuming that at least one generator is operating. In addition, the battery-powered buses would be available.

ARMAMENT POWER CIRCUIT With the exception of the camera circuit breakers, all of the circuit breakers on the armament circuit breaker panel shown in Supplement A receive their primary power from the forward load center. The 115 Vac power is supplied from the ARMAMENT CKT BKR PANEL ϕA, ϕB, and ϕC circuit breakers located on the upper left-hand corner of the monitorable essential ac bus panel. Three-phase ac power is used principally for actuating the sonobuoy pressurized chute doors. Phase A also supplies the single phase ac requirements for the jettison programmer.

As shown in Supplement A, 28 Vdc is supplied from the ARMAMENT 1, 2, and 3 breakers on the extension main dc bus via the forward right-hand electronic rack terminals to the armament circuit breaker panel. The six camera circuit breakers on the armament circuit breaker panel are energized by electronics power feeder breakers on the main load center panels. The three ac circuit breakers are powered from the main ac bus A via ac electronics feeder no. 2. The three dc circuit breakers are powered from the main dc bus via the dc electronic power feeder no. 1. Both these feeders are subject to "shedding" during automatic load monitoring.

Note that the primary power breakers for T-414 CONTROL (special weapon's release and control) and the BOMB RACK LOCK PWR breakers, as well as one for emergency release (ARMAMENT JETTISON) are found on the monitorable essential dc bus extension (Supplement A) rather than on the main dc bus extension. This particular configuration helps ensure that power will be available in all but the most extreme cases (all ac generators or all monitoring switches OFF) for divesting the aircraft of its hot cargo should the need arise.

The electronic systems that provide basic communications (UHF, VHF, HF No. 1 and ICS) and navigation information (VOR, INS, and doppler radar) are powered by the monitorable essential ac bus and the monitorable essential dc bus, two power sources not so apt to be deenergized under adverse power conditions. Other systems less essential for safe flight such as HF No. 2, the search radar, and the ASW tactical gear are energized by the main ac bus A and/or the main dc bus.

RUNAROUND RELAY SYSTEM The runaround relay system is designed to provide the monitorable essential and flight essential ac buses with alternate sources of electrical power in the event of generator failure or loss of phase voltage. Relays with voltage-sensitive control circuits are incorporated in the various alternate power routes to transfer power to these buses. There are a total of five such relays (P/N BER-276) in the distribution system.

1. Runaround relay no. 1 (RAR-1)
2. Runaround relay no. 2 (RAR-2)
3. Essential ac bus relay no. 1 (EBR-1)
4. Essential ac bus relay no. 2 (EBR-2)
5. Essential ac bus monitoring relay (EBMR)

These relays become deenergized when the detected voltage on any one or more phases of the feeder line is less than 85±5 volts. For simplicity, only the runaround relay system and its associated bus/feeders are shown in Figure 24. The location of these relays in the distribution system is shown in Figure 5.

Four 3-phase circuit breakers provide protection for the line feeders for the various power paths between the essential ac buses and the power sources. These circuit breakers are shown in Figure 24.

1. Essential bus feeder (EBF)
2. Generator no. 2 runaround feeder (RAF-2)
3. Generator no. 3 runaround feeder (RAF-3)
4. Generator no. 4 runaround feeder (RAF-4)

These four feeders are protected by 90-ampere circuit breakers. Individual bus protection is also provided by a 15-ampere circuit breaker for the flight essential ac bus and a 50-ampere circuit breaker for the monitorable essential ac bus. All the relays shown in Figure 24 are depicted in the deenergized (power off) condition.

For normal operation and with correct voltages detected by the relay sensor circuits (which are connected to the respective power feeders), all relays will energize; i.e., relay contacts will be in the opposite position to that shown in Figure 24. If after being energized, any one or more phase voltages (of the feeder to which the sensor is connected) should drop to 85±5 volts, the relay will deenergize and connect its bus or downstream feeder to an alternate power source. The combination of feeder systems "alternates" may readily be determined from a study of Figure 24.

History of Runaround Relay-Sensor Circuit Initial service operation of the brushless generator system highlighted some incompatibility between it and the existing runaround relay control. This condition was the partial subject of AFC-114 which also authorized retrofit of in-service P-3s with the brushless type system.

Incompatibility between the brushless generator and the runaround relays was corrected by installing zener diodes in the ground-side circuitry of the BHR-138ARL relay coils, which effectively increased the dropout voltage of the relay coil to approximately 25 volts. This change was necessary because the earlier brushless-type generator had residual voltages of approximately 15 volts appearing at the output terminals after the generator field was deenergized. The residual voltage was sufficient to maintain some runaround relays energized, and hence prevent transfer of a bus when a generator went offline. The zener diodes were installed as an interim measure to correct this condition until a more permanent modification to the relays could be made.

Permanent modification to the runaround relays was the subject of AFC-161 which changed the coil dropout voltage and added a phase voltage sensing circuit. The original BHR-138ARL relay coil required that only one phase of the three-phase power be available to maintain the coil energized. Consequently, one or two phases could be lost, but the loss would not be detected and the bus would

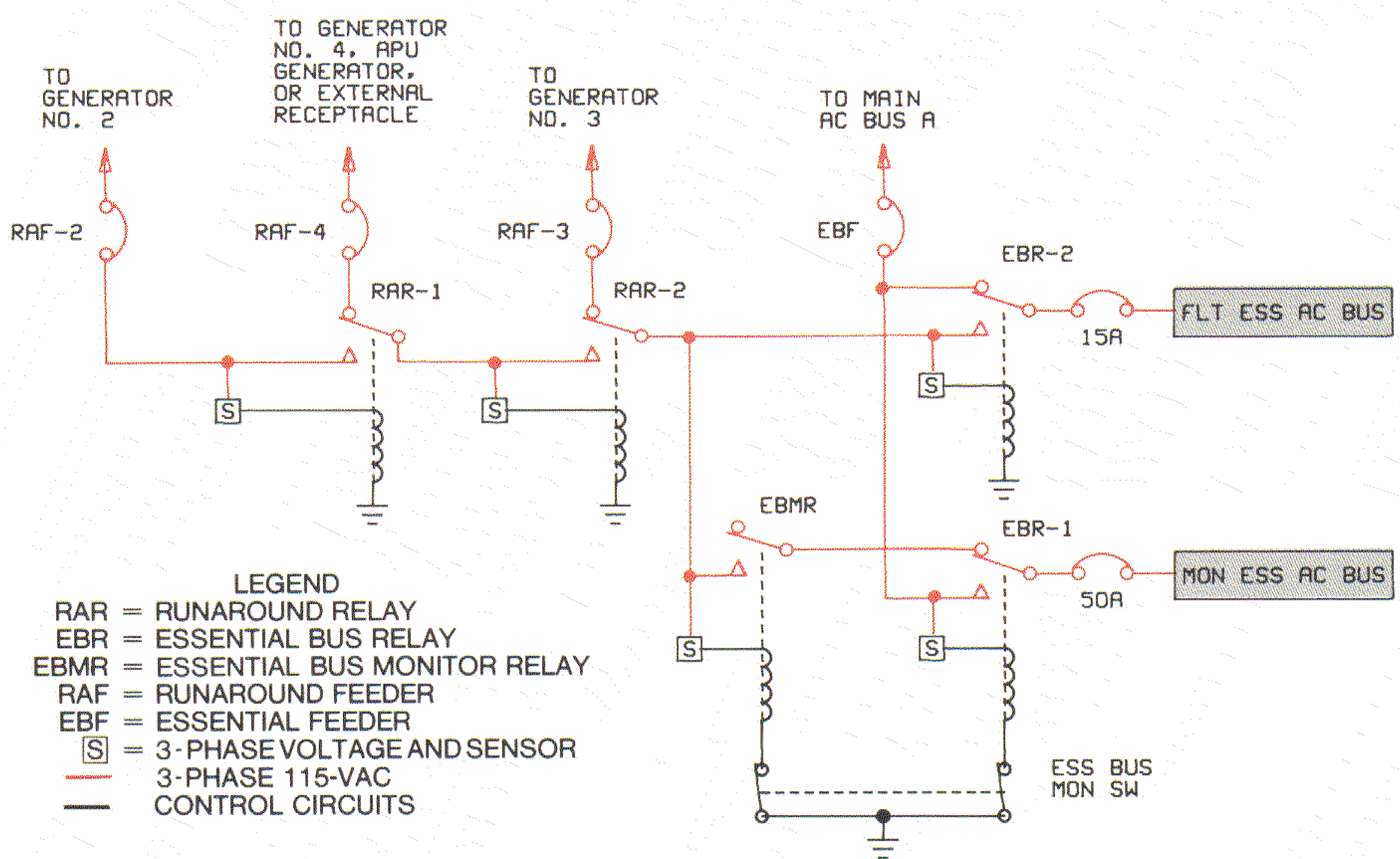


Figure 24. Runaround Relay System

not transfer. To correct this situation, a phase voltage sensing module was added piggyback fashion to the BHR-138ARL relay so that the relay coil would energize only when ac voltage was detected on all three phases. These BHR-138ARL relays, so modified (commonly referred to as *Texas towers)* were used for retrofit. Since these changes negated the original reason for the zener diodes, the diodes were removed. The production version of the relays with the sensor on the bottom is identified as BHR-276.

A number of quality control problems surfaced on the BHR-276 relays after their introduction into service. These problems necessitated rework of the relays, after which they were identified by a yellow dot, the part number remaining the same. Continuing problems after the yellow dot rework made it necessary to repackage the relays. The relays were repackaged by incorporation of AFC-202, then reidentified as BER-276. All these relays, together with their associated sensor circuitry are manufactured by Hartman.

The development of a new sensor was authorized by ECP-836. These new sensors supersede the Hartman models and are supplied by the Leach Corporation. This new sensor module (which has pigtails for interconnection) is mounted on a bracket that will mate with the relay portion of the BER-276, BHR-276 or BRH-138ARL. All P-3C aircraft from SERNO 159883 (Lockheed Serial No. 5634) and up have this Hartman/Leach combination. The new sensor assembly is identified as 741751-101 and is shown in Figure 25. Figure 25 also shows the two Hartmen/Leach combinations that are located in the main load center. The other three are located in the forward load center. The new Leach sensor may be used to replace a failed sensor portion of the BHR-276 or BER-276 relays. In this respect, the basic interconnection schematic of this replacement together with a BHR-138ARL/Leach combination is shown on Figure 26.

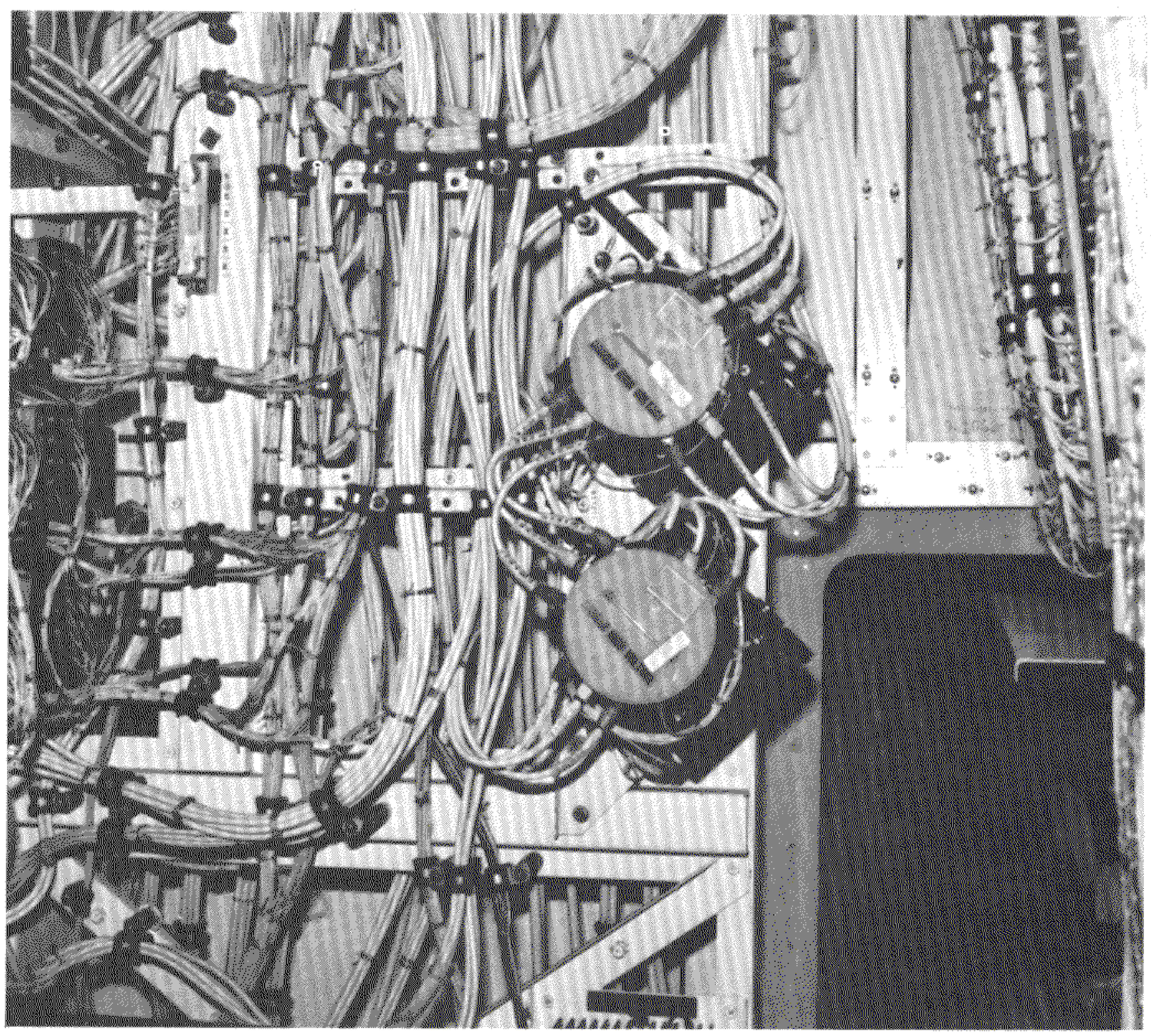


Figure 25. Hartman/Leach Combination of Runaround Relay

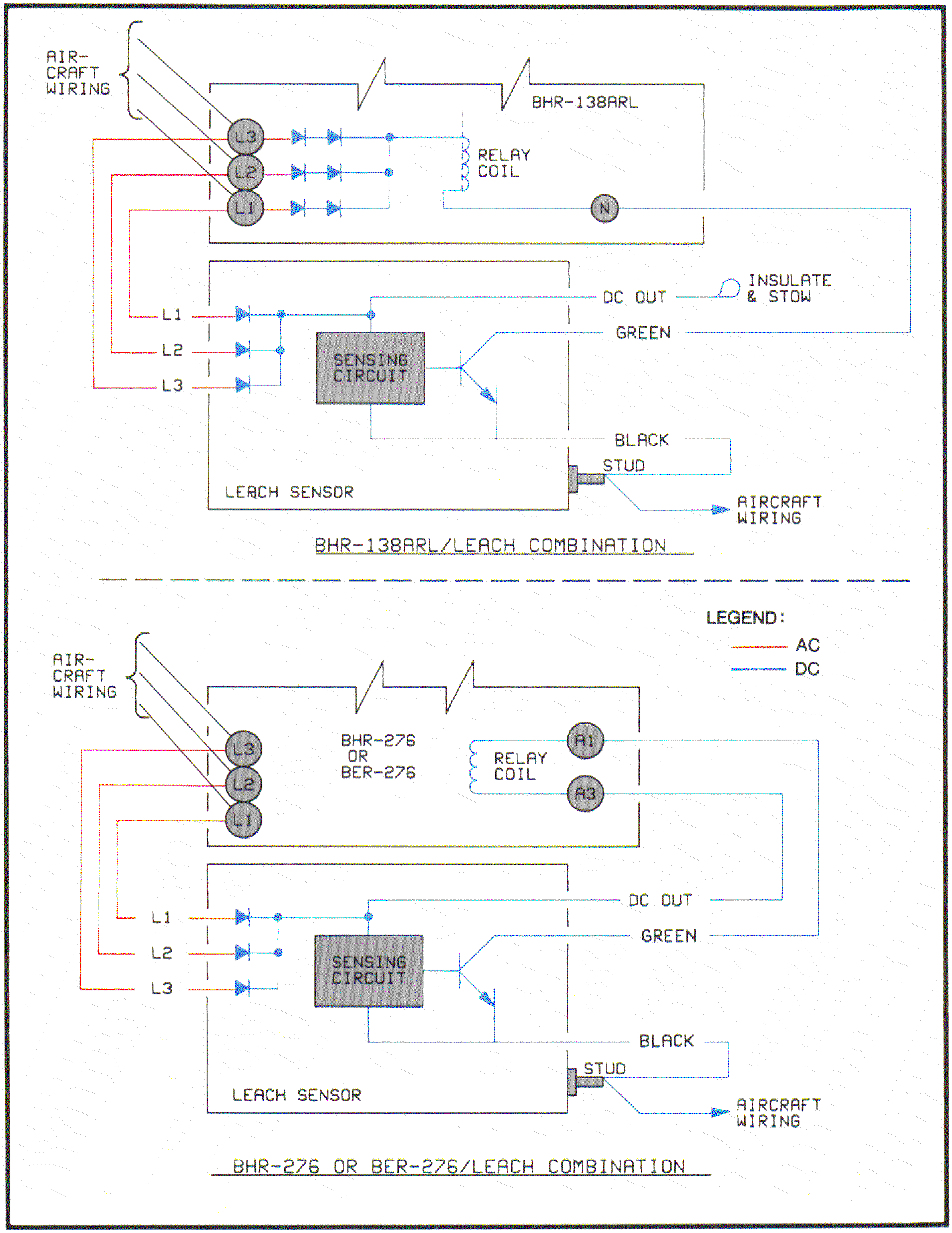


Figure 26. BHR-138ARL/Leach Combination and BHR-276 or BER-276/Leach Combination

LOAD MONITORING AND AUTOMATIC LOAD SHEDDING The basic transfer system design and the predetermined plan are based on the aircraft requirements and the output available from the generators. As mentioned previously, each generator has a nominal nameplate rating of 60 kva, but is capable of continuous operation at 90 kva during flight. Thus, with one generator on standby, the system capacity is actually that of two generators and totals 120 kva nominal rating and 180 kva continuous overload rating. During icing conditions a single generator cannot supply the total power requirement for the aircraft. Should this situation occur, a control circuit will automatically reduce the power load by deenergizing control relays to loads considered nonessential. This action will reduce the total power requirement to approximately 86 kva, which is within the capability of a single generator.

Figure 27 describes the sequence of events leading to the load shedding. It can be seen that during icing conditions with single engine-driven generator operation, the following loads are dropped:

- No. 1 and 3 ac electronic feeders
- No. 2 ac electronic feeder (monitored portion)
- No. 1 and 2 dc electronic feeders
- No. 3 dc electronic feeder (monitored portion)
- Side windshield defog
- Galley power
- Radiant floor heaters

If the extreme and very unlikely emergency situation should arise where the APU generator is the only source available (i.e., no. 2, 3 and 4 generators have failed) and an icing condition exists, then further automatic reduction of loads will occur if the aircraft is above 8000 feet altitude. Above this altitude the following additional loads will also be dropped:

- No. 1A hydraulic pump
- Empennage ice control heaters

Figure 28 shows the control circuitry through which automatic load shedding is accomplished.

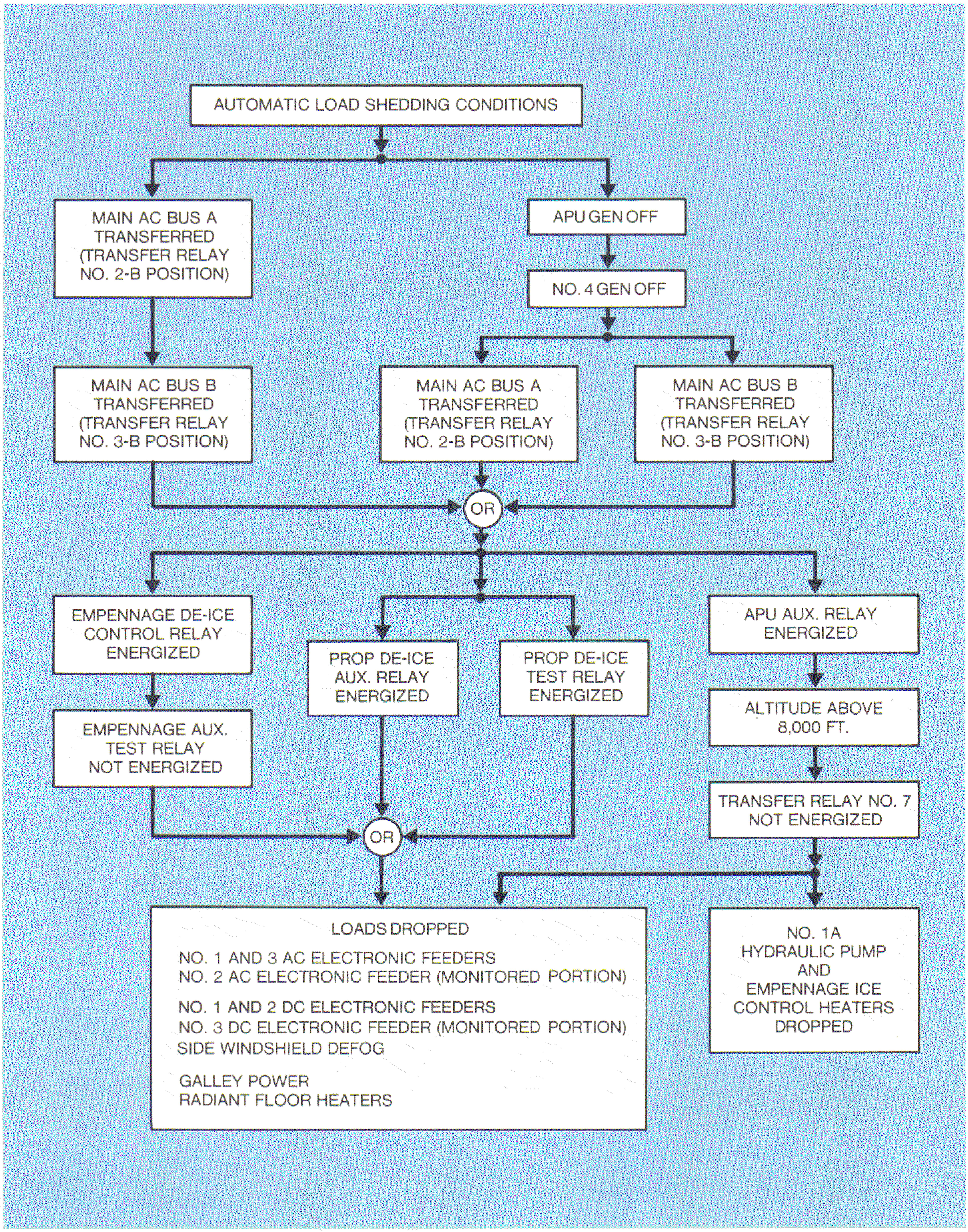
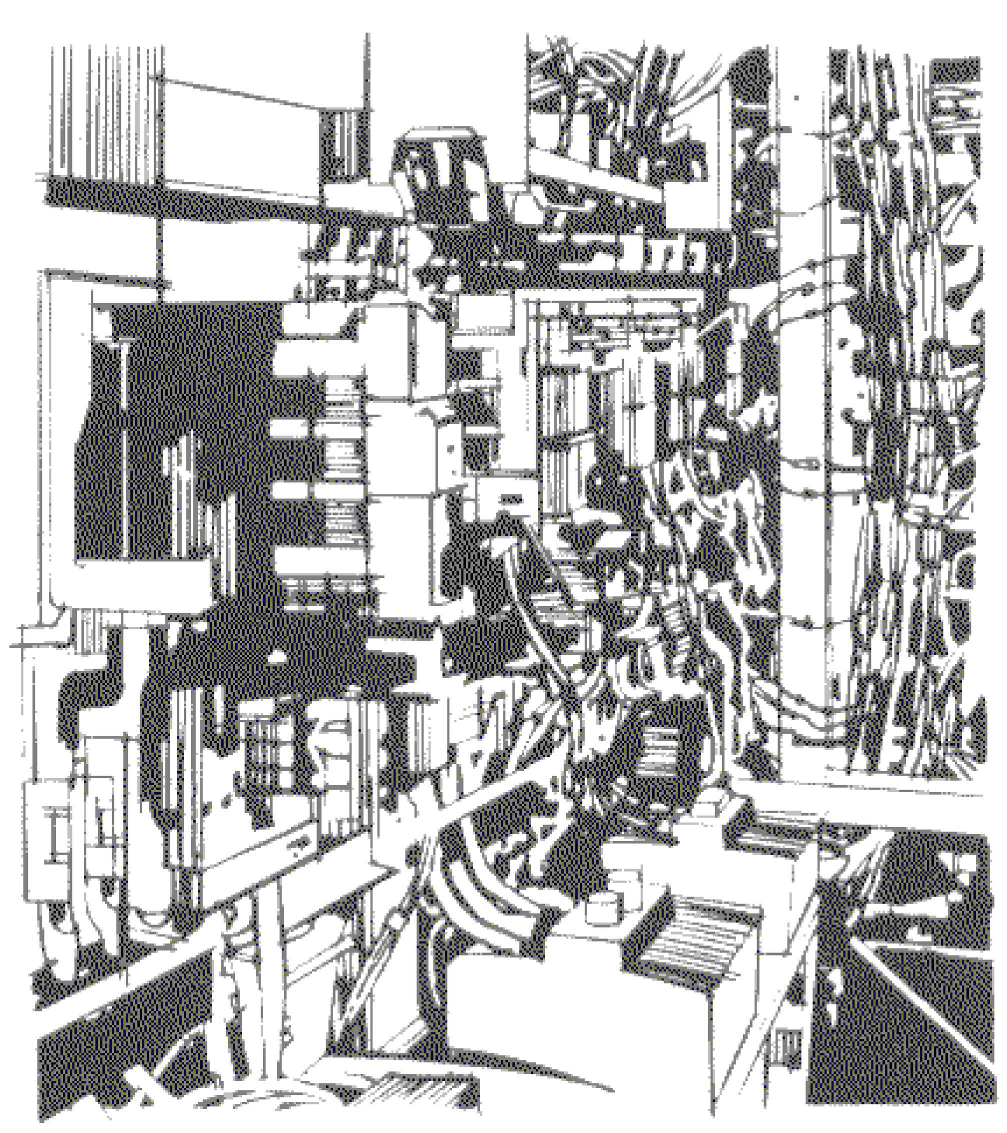


Figure 27. Automatic Load Shedding Arrangement

After automatic load shedding, the APU generator will be supplying a total load of 64.8 kva. Due to the limitation on the APU turbine horsepower output, this load of 64.8 kva can only be sustained up to 18,000 feet. Above this altitude and up to the maximum operating altitude of the APU of 20,000 feet, a further MANUAL monitoring of 5 kva will be required to prevent loss of the APU generator. It may be readily seen from a study of Figure 28 that the automatic opening of the empennage de-ice control relay circuit can be negated by placing the EMP DE-ICE MON SW in the override position. However, manual monitoring of other loads of equal magnitude would have to be made to compensate for the power required by the empennage heaters if this switch is used.

It may be puzzling to the reader, after studying Supplement A and Figure 28 as to the reason for the control of the data processing systems (AN/AYA-8) time delay relay. A study of Supplement A shows that it is downstream from monitorable relay no. 3 and ac power to it is therefore disconnected, and hence to logic units no. 1, 2 and 3 when load monitoring occurs. The coil side of the time delay relay is controlled from the same source as the no. 3 ac feeder monitor control relay (refer to Figure 28). In addition, a series/parallel arrangement of auxiliary contacts of TRR-2, TRR-7 and TRR-4 influences the control of this time delay relay. The reason, for what may appear at first glance a strange arrangement, is as follows.

Integration testing at the Lockheed test facility showed that the AN/AYA-8 DPS was susceptible



to malfunctions following transfer of power from one generator source to another. It was determined that the problem could best be resolved by the installation of a time delay relay subsequently authorized by AFC-291. This relay automatically senses that a power transfer from one generator to another has been initiated. Following this, the power is removed from the DPS logic units no. 1, 2 and 3 within 1.5 milliseconds and maintains power off for a period of 200 milliseconds, after which power is reapplied. This operation essentially restores power in the same manner as if the TACCO had manually operated his control switches. A study of the series/parallel arrangement of TRR-2, TRR-7 and TRR-4 auxiliary contacts illustrated in Figure 28 will show that all combinations of switching conditions are accommodated.

DC POWER SUPPLY AND DISTRIBUTION The three transformer-rectifiers used to supply 28-volt dc power are identical units. Except for a cooling blower powered from the nominal 117-volt input leads, the operation of the unit requires no moving parts. A 3-phase power transformer steps down the input voltage, and rectification is accomplished by silicon diodes. The resulting dc output is non-regulated; its magnitude is therefore only slightly affected by the applied load, and the output voltage varies from 29.5 volts under zero load conditions to about 26 volts at full load. However, the maximum figure is reduced in the Orion installation by ensuring that adequate dc loads (about ten percent of the nominal dc load) remain connected to be powered whenever the transformer-rectifiers are energized.

Each transformer-rectifier is provided with a load meter shunt in the ground return lead to permit checking the percentage of load on the unit. (The load meters are actually graduated from 0 to 1.0 rather than 0 to 100.) The load meters for transformer-rectifiers no. 1 and 2 are located on the main dc bus circuit breaker panel (Figure 11), and the load meter for the no. 3 unit is on the monitorable essential dc bus on the forward load center circuit breaker panel.

Three transformer-rectifier overheat lights (one for each unit) are located on the electrical control panel. They will illuminate whenever the temperature of a transformer-rectifier exceeds a certain maximum value. A transformer-rectifier can be

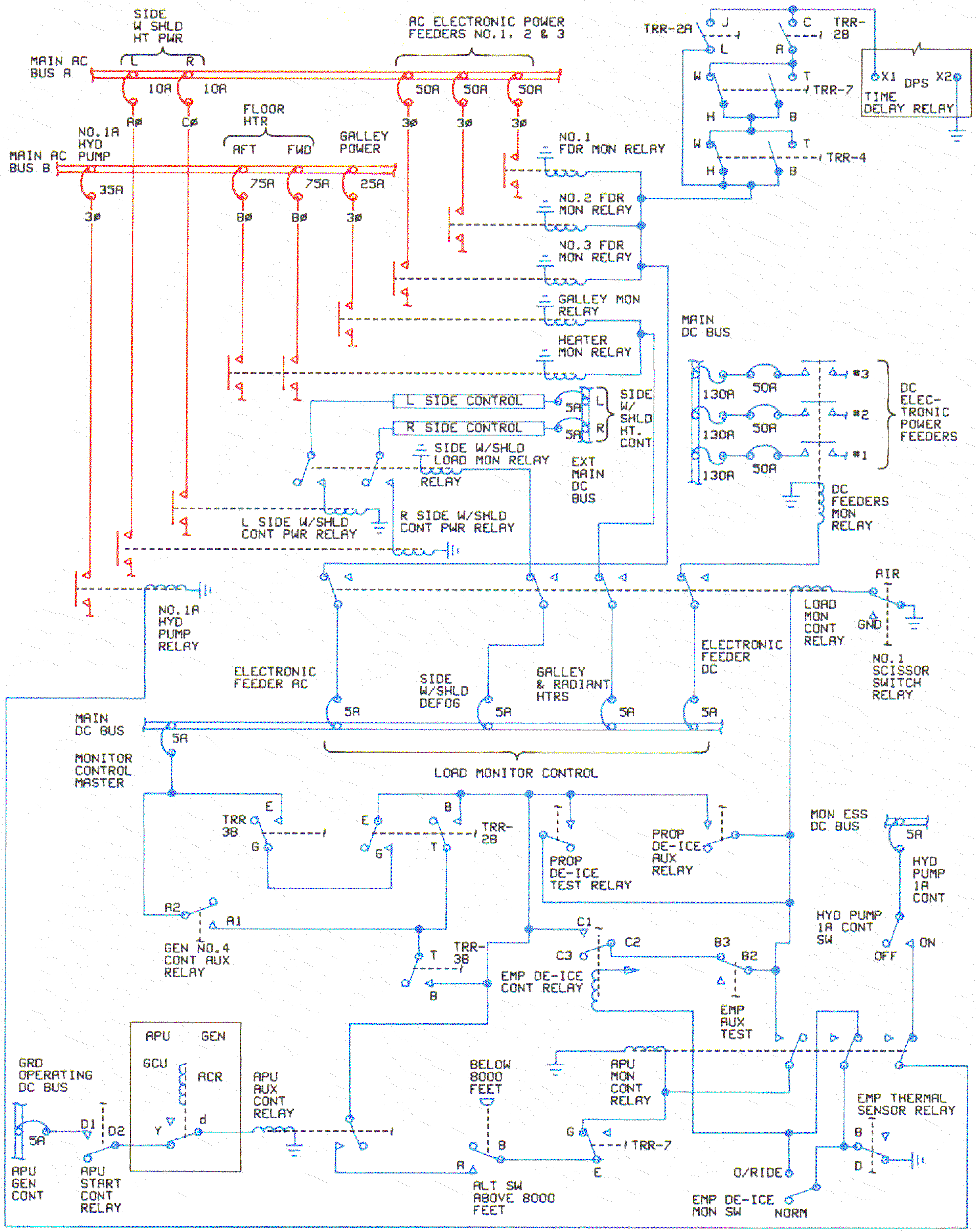


Figure 28. Automatic Load Monitoring Circuitry

shut off by pulling the appropriate XMFR RECT circuit breaker (no. 1, 2 or 3) located on the circuit breaker panels of the main ac bus A, the main ac bus B, and the monitorable essential ac bus respectively. As mentioned previously, the ELEC POWER master caution light on the center instrument panel will illuminate any time that one of the transformer-rectifier overheat lights illuminates.

Returning now to the various schematics which comprise Figure 22, it can be seen that all three transformer-rectifiers are available as long as any one generator is supplying power to the three ac buses to which they are connected. Even in the unlikely set of circumstances where either main ac bus A or B should be deenergized, two transformer-rectifiers are still available and are adequate for all dc loads.

Both main buses would have to be deenergized in order to reduce the number of available transformer-rectifiers to one – transformer-rectifier no. 3, which ultimately would receive its power supply from any one generator via the runaround transfer system.

The basic dc power system is depicted in Figure 29. The principal dc buses and components are shown in color while the principal ac buses are depicted in gray to show the interconnections of the ac and dc power systems.

The main dc bus and the extension main dc bus carry most of the heavy dc loads and are powered by transformer-rectifiers no. 1 and 2 operating in parallel. The main dc bus is located in the main load center, and three dc power feeders connect

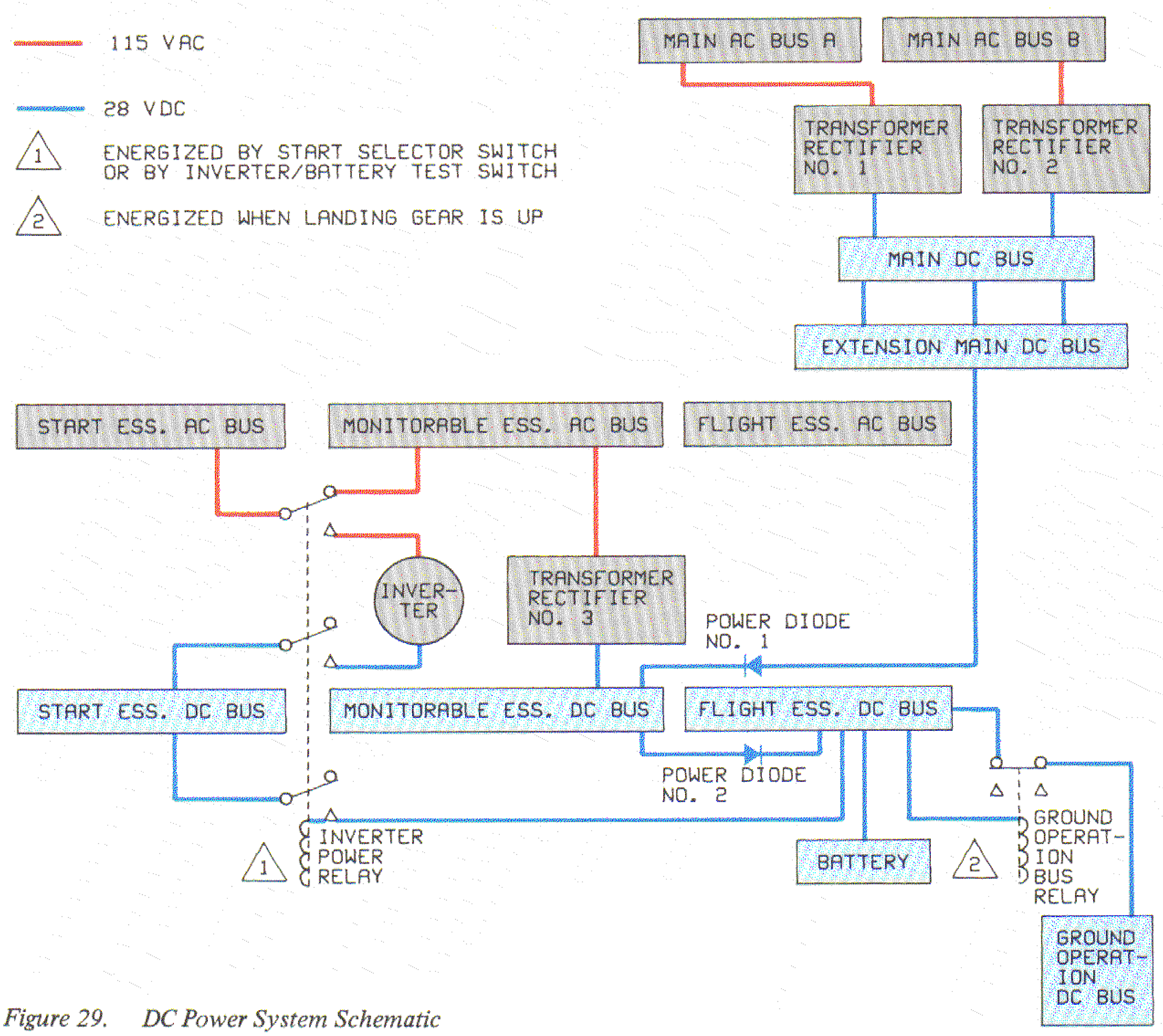


Figure 29. DC Power System Schematic

this bus to its extension in the flight station. The use of three feeders for this purpose is often queried, and the answer to the question warrants inclusion in this discussion.

The wire gauge of each of the three feeders is ample to supply the maximum load requirement of the extension main dc bus (about 55 amperes). Although the installation of just two feeder wires would have achieved the required safety factor of providing an alternate power supply feeder to the flight station bus, the use of three wires not only further improves the safety factor, it also provides a simple fail-safe circuit should a fault develop in one of the feeders. Each of the three feeders has an 80-ampere current limiter at either end of the wire run. If a fault-to-ground occurs in any one wire, both limiters of the faulted wire open so that the fault is effectively isolated (see Figure 30). This result cannot be achieved as simply with two wires, because circuit breakers and relays would have to be incorporated in the circuitry.

The extension main dc bus is connected through power diode no. 1 to the monitorable essential dc bus. The monitorable essential dc bus is also connected to its ac counterpart through transformer-rectifier no. 3. Since, under normal conditions, the start and flight essential buses are connected to the monitorable essential dc bus through the inverter power relay and through power diode no. 2 respectively, it follows that the entire essential dc bus is supported by all three transformer-rectifiers. The complete dc power and distribution system is shown on Supplement A.

The power diodes used in the dc system are hermetically sealed, high-voltage, silicon-rectifier cells. Power diode no. 1 prevents transformer-rectifier no. 3 from feeding the main dc buses, the object being to isolate the essential dc bus and its primary power supply should a malfunction occur elsewhere in the dc power system. Power diode no. 1 also has a secondary function; although it allows current to flow from the extension main dc bus to the monitorable essential dc bus, there is actually enough of a voltage drop across the diode to ensure that with all three transformer-rectifiers in operation, the monitorable essential dc bus will be supplied primarily by transformer-rectifier no. 3, with the other two transformer-rectifiers acting as standby power sources.

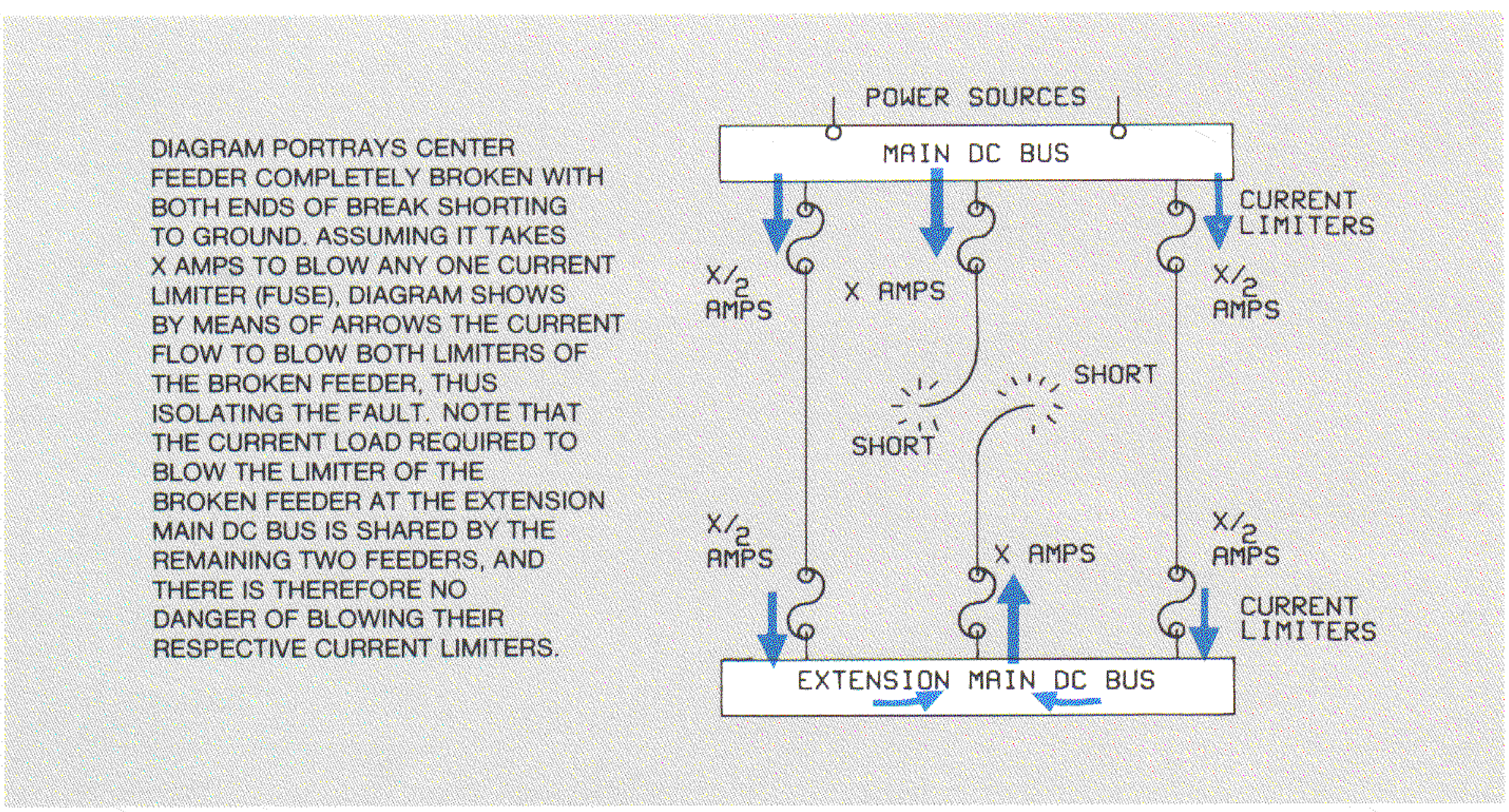


Figure 30. Fault Isolation in the Extension Main DC Bus Feeders

The battery is connected directly to the flight essential dc bus. Since the flight and monitorable essential dc buses are interconnected via power diode no. 2, the battery can be charged from any of the transformer-rectifiers, but is prevented from supplying power to the monitorable essential dc bus. Thus, the battery output is limited in order to perform the following functions:

1. Under emergency engine starting conditions (no generator power or external power sources available), the battery supplies the minimum power required during engine starting. In these circumstances the inverter power relay would be energized thus connecting the start essential dc bus to the flight essential dc bus. Operation of the inverter power relay would also supply battery power to the inverter which, in turn, would supply 115-volt, single-phase ac power to the start essential ac bus, thus energizing the turbine inlet temperature (TIT) indicators.

2. The battery provides a reserve source of power for certain ground operations. The ground operation dc bus relay is deenergized (as shown in Figure 29) when the nose landing gear is down, thus connecting the ground operation dc bus to the flight essential dc bus. Loads carried on the ground operation dc bus are not required in flight. They include the alternate power source for the engine oil quantity indicator and the external-powered hydraulic pump that powers the aircraft's hydraulic brakes.

3. Under extreme flight emergency conditions (such as a fire of unknown origin), it may be necessary to temporarily turn off all bus monitoring switches, thereby removing power from all ac buses except the flight essential ac bus. The battery would then supply power to the minimum dc loads that are essential to flight safety. These loads are carried on the flight essential dc bus and consist of the pilot's turn and slip indicator, flight station utility lights, propeller pitchlock reset, command bell, and certain dc power control circuits.

Considering all the services operated from the battery, most of them are of a momentary nature so that the average load on the battery at any time

is small. At present, battery loads amount to about one ampere during flight emergency (all generators and inverter off) and two amperes during ground towing (brake accumulator charged).

One component not described so far is the 100-volt-amperes inverter. It is actually a standard unit with 3-phase ac output available. However, only one of the phase output leads is used, which results in derating the inverter to 60 va. The 24-volt input from the battery powers a compound-wound dc motor that drives an alternator consisting of a 4-pole permanent magnet rotor rotating within a 3-phase stator. The motor and the alternator have a common drive shaft so that a centrifugal governor controlling the speed of the dc motor to 12,000 rpm also regulates the alternator/inverter output frequency to 400 Hz. Retraction of the OFF flags on the TIT gages indicates that the inverter is operating, assuming that only battery power is available on the aircraft.

RECENT MODIFICATIONS

GENERATOR A modified generator, Bendix 28B95-65A, is scheduled to be installed on production Orions late in 1978. The two modified areas are the drive end bearing and its support, and the coupling between the engine-driven gear box and the generator drive shaft. The drive end bearing is being replaced by a bearing with a higher loading capacity. It will be held in place with a spoke-type mount. On the generator drive shaft, the shape of the gear teeth has been modified, and a Vespel insert has been added to the coupling. This generator will be completely interchangeable with the -15D generator, i.e., the outer dimensions and electrical rating remain unchanged. In addition, the auxiliary (or third) bearing will function in the same manner.

GENERATOR SUPERVISORY PANEL A new supervisory panel has been installed on all P-3 aircraft, SERNO 160292 (Lockheed Serial No. 5655) and up, and may also be used for preferred spares. The new panel is identified as 21B18-5A. It is designed to eliminate certain functions and circuitry that are either redundant or of marginal value in the supervision of the P-3 electrical power system. The changes and deletions are as follows:

- Deletion of undervoltage lockout relay (ULR)
- Addition of ULR time-delay period to the differential protection latchout relay (DLR) time-delay period so that DLR time will be 4±1 seconds
- Deletion of the under/over frequency relay (UOR)
- Deletion of the UOR time delay
- No overfrequency protection required
- Underfrequency protection will work directly on the auxiliary control relay (ACR) and the generator control relay (GCR) circuits. Pickup will be 383±3 Hz. Dropout will be 367±3 Hz of the nominal 400 Hz. The permanent magnet generator (PMG) will be sensed for this function.
- Addition of an indicator to show when the feeder fault detection circuit has caused a protective "trip." This indicator is of the "eyebrow" type, mounted directly on the supervisory panel. It is intended for the use of ground crew when troubleshooting the system. It is mechanically latched and is reset by rotating a "collar" through 90 degrees.
- In addition to the aforementioned changes to the supervisory functions of the new panel, a modification to the voltage regulator portion has also been made. This consists of a diode and resistor connected in such a way so as to prevent inductive spikes from the generator field from affecting the field regulating transistor in the panel when the generator is switched off. There is such a protective resistor and diode arrangement within the generator itself, connected directly across the exciter field (see Figure 19). This arrangement is commonly known as the "flywheel" diode. Therefore, the objective of the additional, supervisory panel-installed diode arrangement is to provide backup to prevent a possible failure of the voltage regulator in the event of a generator flywheel diode failure.

Undervoltage Lockout Relay The elimination of the undervoltage lockout relay will not affect the control of the electrical system because this relay's contacts are not utilized. The new supervisory panel has fewer components, uses integrated circuits and is modularized to facilitate replacement of circuit functions. No unijunction transistors or silicon controlled rectifiers are in the new panel.

Overfrequency As mentioned previously, the operating speed of the P-3 engine is somewhere between 99 percent and 101 percent in the high (flight) power lever range and somewhere between 96 percent and 99 percent at low (ground idle) power range. The generator frequency will be somewhere between 394 Hz and 402 Hz in the flight range and somewhere between 383 Hz and 395 Hz during ground idle operation. The maximum excursion out of this speed range permitted by the engine overspeed protective devices is 109 percent. This can happen during landing where the engine is permitted to overspeed to a maximum of 109 percent before pitchlock occurs. Generator frequency at 109 percent engine speed would be approximately 432 Hz. The overfrequency protection circuitry of the earlier supervisory panel will deenergize the generator when the frequency exceeds 435 Hz. For the engine-driven generator to exceed this frequency, it would require failure of all the engine overspeed protective devices. Therefore, the function of the overfrequency protection circuitry of the supervisory panel was considered unnecessary and has been deleted from the new panel.

Voltage Regulator – Flywheel Diode One of the causes of supervisory panel failures may be directly attributable to a preceding failure of the generator flywheel diode. However, it does not always follow that a failure of the flywheel diode will automatically cause a supervisory panel failure. It will depend on the individual "switching" transistor in a particular panel. In other words, it does not always follow that a failed flywheel diode that has caused *one* supervisory panel to fail, will necessarily cause an immediate failure in its replacement. Therefore, it is imperative that a flywheel diode check be carried out every time a supervisory panel is replaced. This, unfortunately, is not always done. However, the additional protective diode installed on the supervisory panel, acting as a backup to the generator-installed diode, will increase the mean time between failures of the panel.

UTILIZATION EQUIPMENT Beginning at production aircraft SERNO 160290 (Lockheed Serial No. 5653) the following utilization equipment has been added, thereby bringing these aircraft to Update II configuration. Orion Service Digest, Issue 35 describes Update II equipment.

Armament An AN/AWG-19(V)1 Harpoon missile system has been installed to provide long-range, air-to-surface missile strike capability in P-3C aircraft. Harpoon missiles can be launched from the wing stores stations, from pylons containing GFE BRU-15/A racks and GFE Aero 1A adapters. In-flight selection, arming, and release of the missiles is controlled from a GFE Harpoon panel at the TACCO station.

Avionics An AN/AAS-36 Infrared Detecting Set (IRDS) has been installed to provide visual surveillance under low visibility weather conditions and during darkness. The IRDS sensor is installed in a retractable turret in the nose. The controls in the upper console of sensor station 3 have been rearranged to accommodate installation of the IRDS display, the display control panel, and the extend/retract control panel. The sensor station 3 upper console shelf structure and rack C3 have been revised and the existing equipment rearranged to accommodate the installation of the IRDS control-servomechanism and power supply-video converter. Aircraft equipped with IRDS are not equipped with the KA-74A forward camera.

Sonobuoy Reference System The P-3C weapon system submarine localization capability has been improved with the installation of a sonobuoy reference system. The 31-channel GFE AN/ARS-3 Sonobuoy Reference System (SRS) permits sonobuoy locations to be continuously monitored from a standoff course with greater accuracy than can be obtained with the "on top" system installed on earlier P-3 aircraft. The SRS receiver is installed in the aircraft cabin between racks F1 and F2.

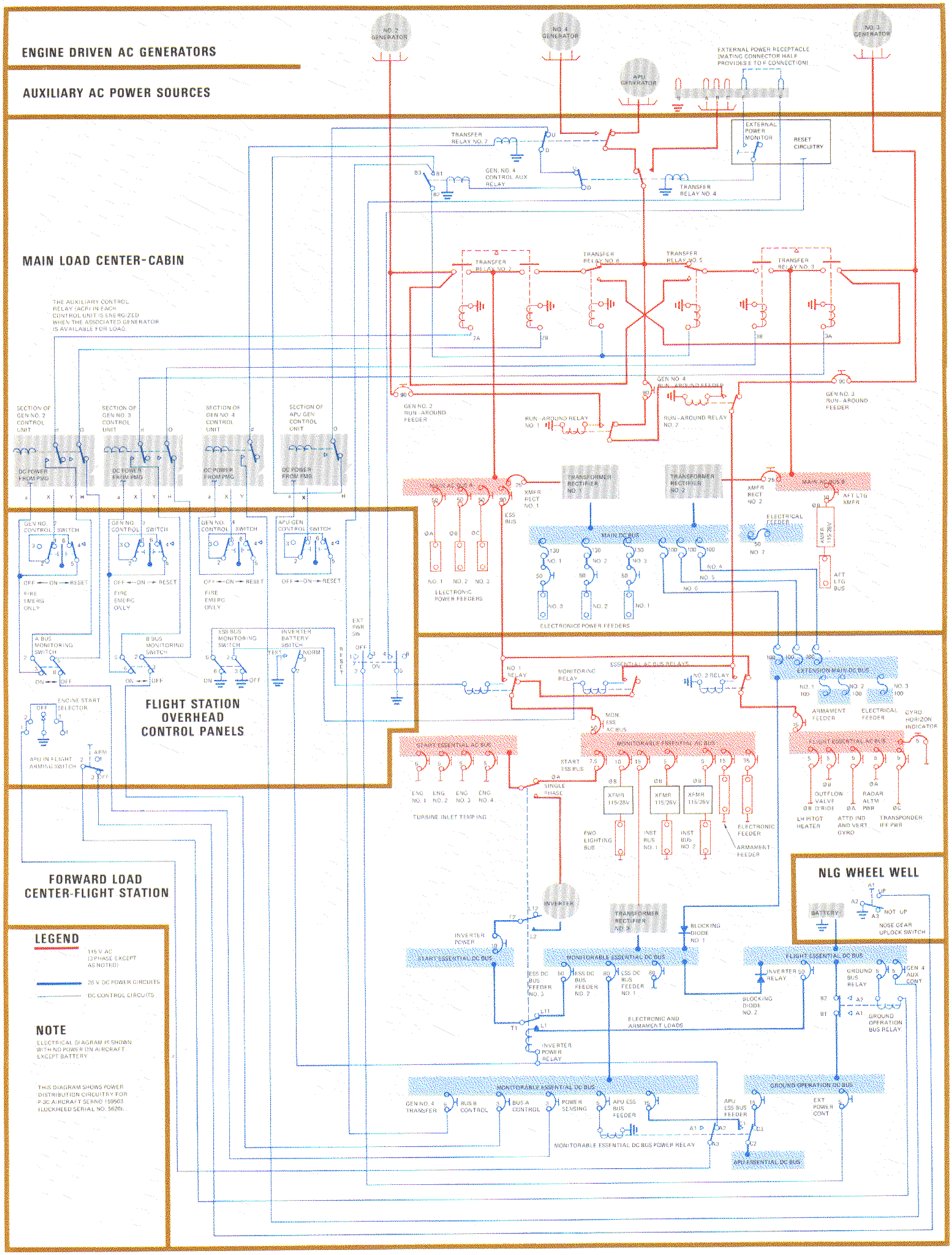


Figure 31. P-3C Electric Power Distribution System

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