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ORION

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FRONT AND BACK COVERS Commissioned VP-108 on 1 July 1943, charter members of this squadron, now designated VP-28, joined their compatriots in the Pacific Theater during WW II flying PB4Y's. It is not surprising that the low level bombing techniques that they developed became standard procedure, for in a 5 month period they sank or damaged more than 200 ships while racking up 731 combat missions.

Following WW II the squadron was home-ported in Hawaii, re-designated VP-28 and equipped with PB4Y-2 "Privateers." During the Korean War, they were awarded the Korean Presidential Unit Citation for their patrol work in the Yellow Sea/Sea of Japan, and for their part in developing "flare-drop" techniques that proved amazingly effective in countering the "human sea" night attacks during the Korean conflict.

After 1952, they proudly returned to Hawaii with the well earned cognomen of "Hawaiian Warriors", and transitioned to P-2 Neptune's. For 11 years they deployed frequently to VP support facilities in Japan and Alaska; additionally, they were diverted periodically to the South Pacific to participate in nuclear tests and Australian exercises. The commendations of the Commanders of the Seventh Fleet, the Taiwan Patrol Force, Fleet Air Wing SIX, and the Captain Isbell Trophy for ASW Excellence attest to the quality of their work in this period.

Returning to Hawaii in 1963, the squadron transitioned to the P2V-7, served as practical consultants for visiting reserve squadrons, exchanged techniques with RAAF crews, then re-deployed to Japan and won further official commendations for their work in the Tonkin Gulf skirmish of 1964.

In the fall of that year they returned to Barber's Point, transitioned to the P-3 Orion and polished their skills with the new equipment while demonstrating the P-3's ASW capabilities in joint exercises with the RAAF and RNZAF in the spring and summer of 1965.

More recently, the Hawaiian Warriors deployed to Sangley Point in the Philippines where they flew over 8500 hours in the Vietnam combat zone in support of the Seventh Fleet Attack Carriers and "Operation Market Time".

In the fall of 1966, two crews deployed to Australia to participate in the largest maritime exercise in that nation's history, along with elements from New Zealand and the United Kingdom.

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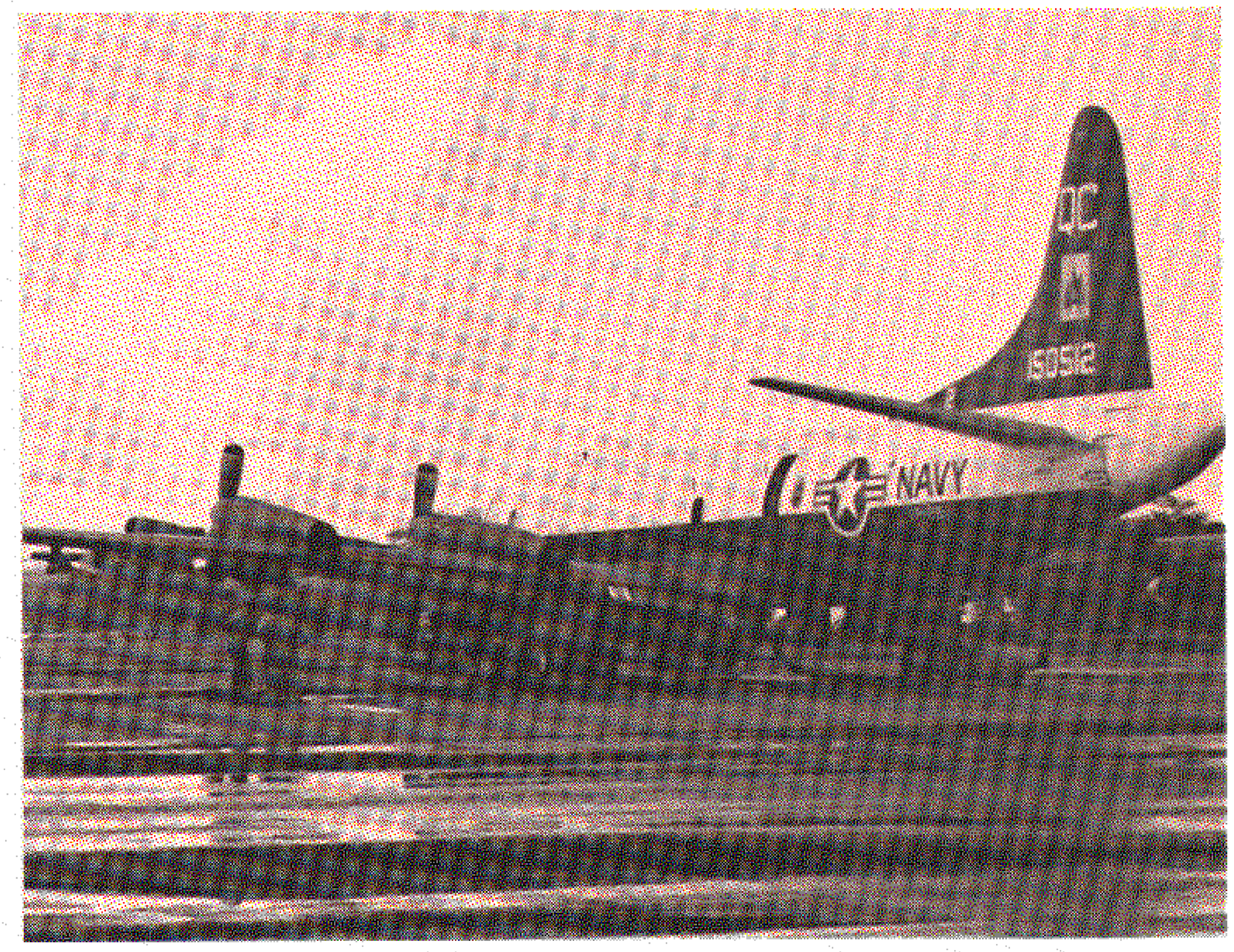


FOREWORD

This article follows on from ELECTRIC SYSTEM—PART ONE published in Issue 3 of the Orion Service Digest. Although some changes have been made in the basic system in the three years since the article appeared, the information in Issue 3 is largely applicable to today's system, and readers who are totally unfamiliar with the Orion can gain a valuable insight through reading PART ONE as a preface to PART TWO.

For their benefit we will mention here the principal changes that have made all or part of a few discussions in PART ONE obsolete.

1) The General Electric generator described in PART ONE has been supplanted by a Bendix generator (which is described in this article).

2) A fourth generating system has been incorporated. This system operates from a gas turbine Auxiliary Power Unit (APU), and it provides a power source that can be utilized as an alternative to either the No. 4 engine-driven generator or external power.

3) The 2-speed drive for No. 4 engine-driven generator has been deleted, and it is therefore necessary to utilize either the APU or external power to support buses during Low rpm engine operation. The latter change eliminates the need for the set procedures of engine speed shift decribed in PART ONE.

4) The addition of an inverter which can draw on battery power to maintain an uninterrupted power supply to the inertial navigator (ASN-42) makes it unnecessary to observe the engine starting procedure recommended in PART ONE.

The new generators and the added components—the APU and the ASN-42 inverter — are discussed, and we have completed the description of power distribution in PART TWO.

In order for this final part of our coverage of the P-3 Electrical System to serve as a fairly complete personal reference source on the subject, we have included generator-to-major-bus schematics from PART ONE, revised to reflect the present system. We do not plan to continue revising the Digest if further modifications are implemented, and, as always, personnel must consult the latest revision to the official NAVAIR manuals to find up-to-date information concerning this important and growing system.

The ORION Electrical Power System

PART TWO

FORTUNATELY FOR THOSE personnel directly concerned with operation and maintenance of the P-3 electrical system, the recently incorporated changes have not drastically altered the original basic design. In fact, the disparity between the original system and that depicted in this article is limited to additions or deletions that are of a minor nature individually, although collectively they constitute a major improvement of the P-3 ASW Weapons System.

BUS SUPPORT AND CONTROL PHILOSOPHY The power distribution system is divided into two principal transmission channels via the A and B Main buses, supported normally by No.s 2 and 3 generators respectively, with loads divided about equally between them. An elaborate automatic bus transfer system (described in OSD Issue 3) is provided to allow any available generator to support one or both channels for every conceivable combination of generator failures.

There is a less likely, but distinct, possibility that a fault at some point within one of the principal transmitting channels (rather than at the generator) could make it imperative to de-energize that channel. Accordingly, a manual Monitoring Switch is provided for each Main Bus which has the effect of isolating the bus from all generators. Although there is no specific monitoring switch for direct current, operation of both Main AC bus monitoring switches (A Bus and B Bus) removes power from the No.s 1 and 2 transformer-rectifiers, thereby de-energizing the Main DC Bus and its extensions.

Services are divided between the two main channels in such a way that loss of one bus would not ordinarily create a dangerous loss of services. Some services, however, are practically indispensable to every flight. In order to provide a special priority for these, they are collected on the Flight Essential buses, and a bypass arangement known as the Run Around System is provided that will sustain these buses even when one or both Main bus monitoring switches are "OFF."

As can be seen in Figure 1, the Flight Essential DC Bus has direct battery support plus transformer-rectifier No. 3 support (via Power Diode No. 2) 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 de-energized readily by operation of a monitoring switch.

Between the heavy loads of lesser importance (relegated to the Main Buses) and the extremely im-

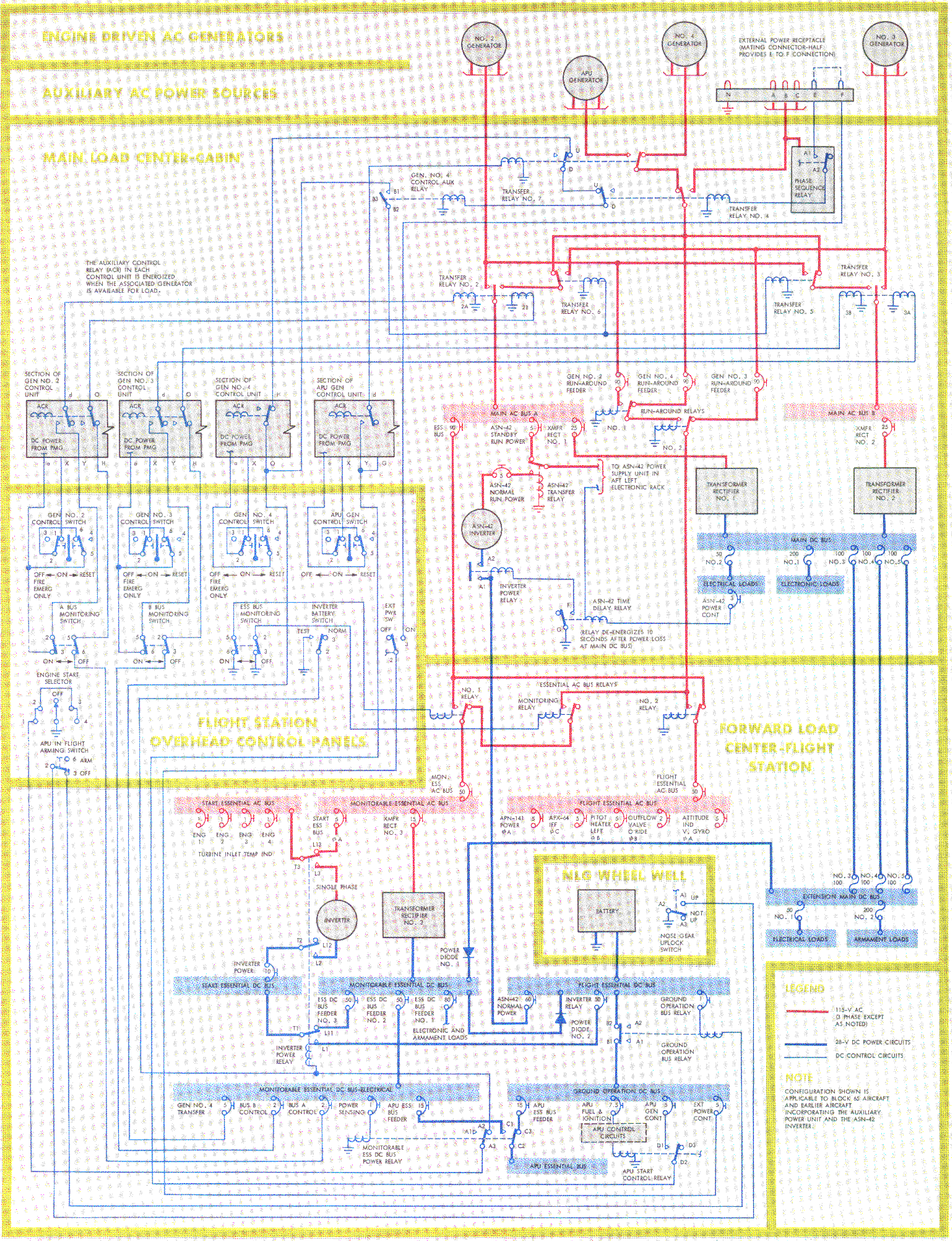


Figure 1 P-3 Orion Electric Power System — December 1966

portant services (supported by the Flight Essential buses) lies a middle group of services. These 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, and a separate monitoring switch is provided adjacent to the Main Bus monitoring switches. The Monitorable Essential AC Bus is normally supported by the Main AC Bus A, but it will automatically transfer to the run-around system if Bus A becomes de-energized, thus attaining the same capability of direct, all-generator support as the Main and Flight Essential AC buses enjoy. Turning the ESS BUS monitoring switch to "OFF" isolates the Monitorable Essential AC Bus from both sources.*

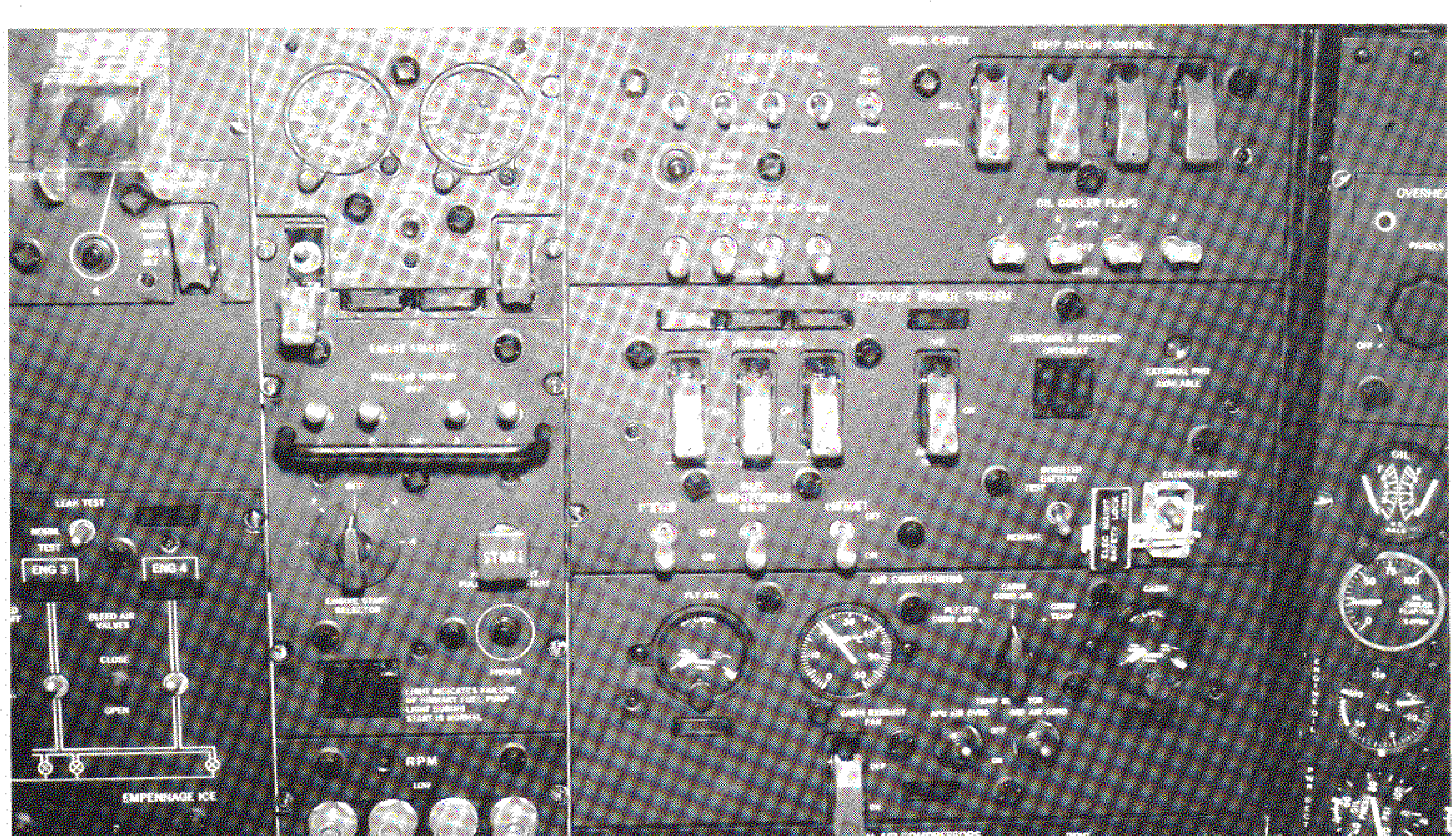
All three monitoring switches must be turned "OFF" to de-energize the Monitorable Essential DC Bus and its subsidiaries, for it is necessary to de-energize the power sources of all three transformer-rectifiers, Main AC Bus A and B plus the Monitorable Essential AC Bus. When this is done the Flight Essential 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 ensures that power is always available at the Flight Essential DC Bus, and other buses can be energized through relays as required.

If an engine is selected at the Engine Start Selector, battery power is extended to the Start Essential DC Bus and, through a small single-phase inverter, to the Start Essential AC Bus. On all configurations, lowering the landing gear automatically provides a further extension of battery power to the Ground Operation Bus; on aircraft furnished with an APU, operation of the APU IN-FLIGHT ARM switch performs the same function and the power is relayed to the APU Essential Bus automatically (assuming, as we are, that no other source of dc power is available on the aircraft).

Figure 2 depicts the basic bus support arrangement as it was shown in Digest Issue 3, Figure 1 revised to reflect the updated system now coming from production or as it is following the incorporation of P-3 Airframe Change No.s 110 and 122 on aircraft in service.

The normal ground operating configuration of the system is shown in Figure 2A. Note that the two-speed gear box has been removed from No. 4 generator so that engine-driven generator power is no longer available with engines selected to LOW rpm position. With engines selected to NORMAL for

**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 it supports. Air crew members should be doubly wary of inadvertently de-energizing this bus for, as proven in a recent happening, there are two controls in the flight station which serve the purpose. The bus feeder employs an isolated, multiple 50-A circuit breaker, located on the front panel of the Forward Load Center directly behind the copilot — an area commonly frequented by observers. The circuit breaker was inadvertently opened during a night approach, thus de-energizing all the related services including the flight station lights at a crucial moment. A spring loaded plastic guard is now fitted over the circuit breaker on new aircraft and will be retro-fit on operating aircraft (through AFC 150). In the interim all flight crew members should be apprised of the location and importance of this circuit breaker.*



Electrical
Control Panels
Flight Station
Overhead

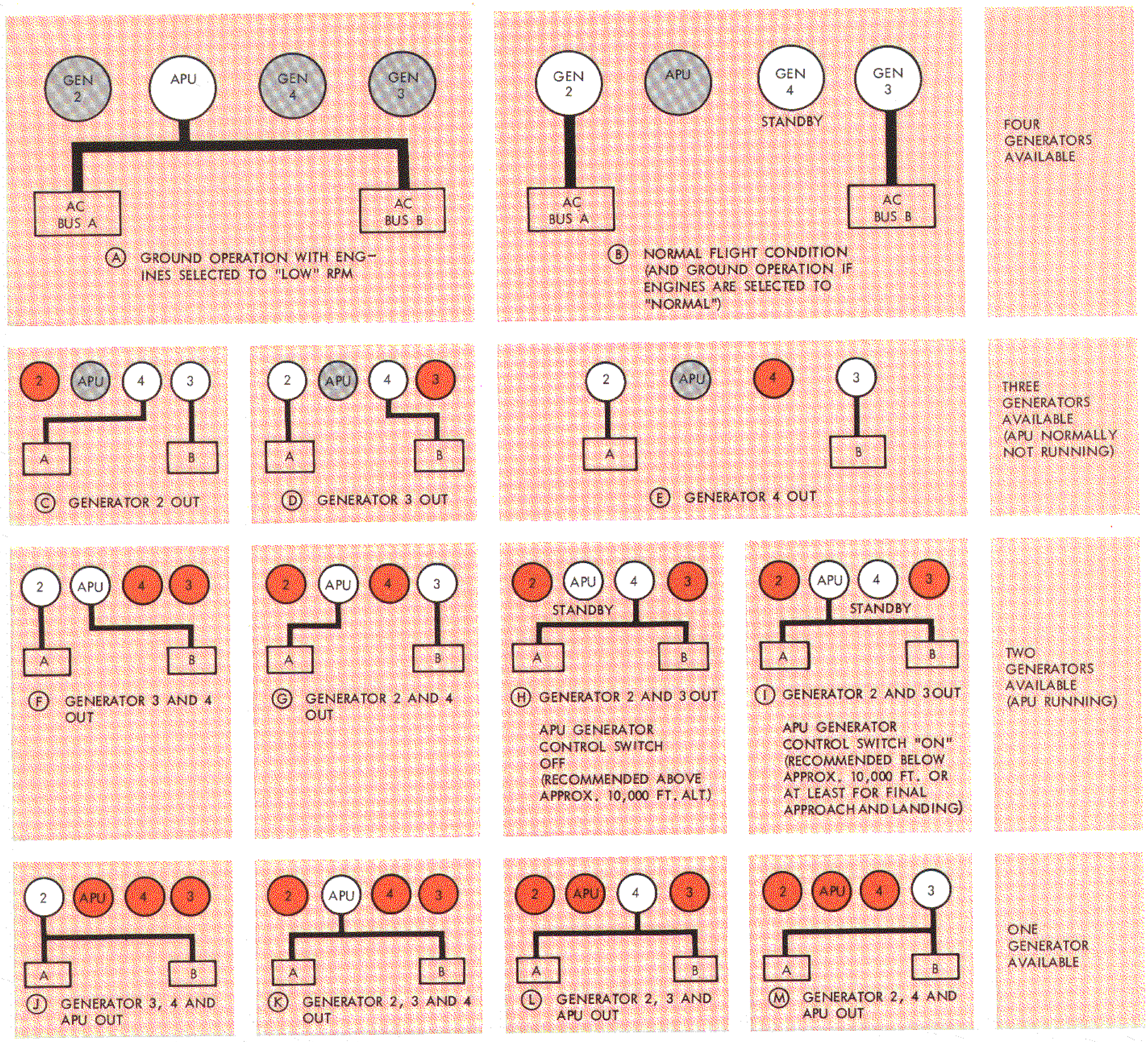


Figure 2 Updated Generator/Bus Support Diagram

either ground or flight operation, power distribution is the same as before, i.e., No. 2 generator energizes AC Bus A, No. 3 generator energizes AC Bus B and No. 4 is on "standby" duty. Under these normal conditions, the APU will be shut down. In fact, the P-3 NATOPS Flight Manual (NAVAIR 01-75PAA-1) directs that the APU not be used in flight unless two of the three engine-driven generators have failed. This normal situation is represented in Figure 2B.

It is interesting to note that the APU will assume the load of a failed inboard generator (about half the total aircraft load) provided the opposite inboard generator is the only remaining operational unit. However, if No. 4 is the only operative unit, the APU will automatically supersede No. 4 if it is put "on the line," in which case it will energize all buses and No. 4 serves only as a standby.*

**The standby roles can be reversed by placing the APU GEN CONT switch to OFF position. No. 4 generator now energizes all AC buses and the APU unit is the standby source. However, in this instance the APU does not automatically assume the load of a failed No. 4 generator and will result in a temporary power loss while the APU GEN. CONT. switch is being returned to ON position manually. For this reason the NATOPS Flight Manual recommends that if all buses are powered from a single source when flying below 10,000 ft., the APU is to be "ON" and No. 4 used as standby, particularly during final approach and landing.*

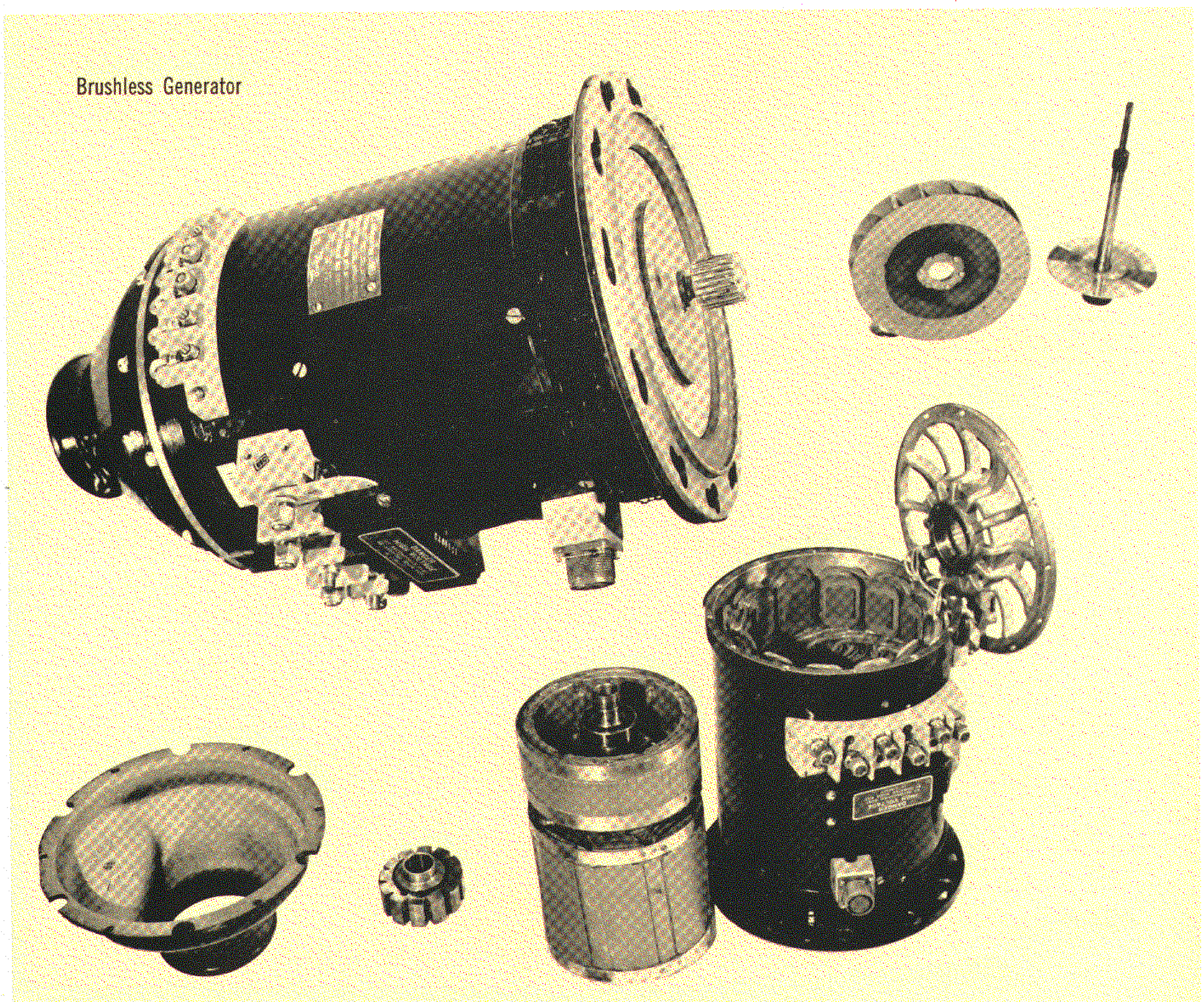
POWER GENERATION SYSTEM

The preceding discussion was concerned primarily with the electrical power system as a whole and pointed out the more obvious changes now included in production. Not mentioned previously but of equal importance from the standpoint of increased reliability, is the installation of the Bendix 28B95-15 Brushless Generator and the 21B18-2 Supervisory Panel. This advanced design generation system was initially incorporated on production Block 65 aircraft and retrofit is complete on virtually all aircraft in service.

The arrangement of the Flight Station control switches and of the warning lights is essentially the same before and after installation of the Bendix system. Also, each generator control unit still contains protective circuitry to sense system malfunctions and to de-energize and disconnect the generation system automatically if such malfunction occurs. Associated with the protective circuitry are four generator control switches and four yellow GEN OFF caution lights all of which are shown in Figure 3 on the center overhead electrical control panel. However, the APU GEN OFF light does not illuminate until the APU switch shown in Figure 4 on the AUXILIARY POWER UNIT control panel is placed in either ON or START position.

In addition, an ELEC POWER master caution light shown in Figure 5 is located on the center instrument panel where it is most likely to attract the attention of the flight crew. This master light is illuminated whenever No. 2, No. 3 or No. 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 engine-driven GEN OFF lights is illuminated. Subsequently, the master light can be extinguished

Brushless Generator



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.

The P-3 Bendix Brushless Generation System is relatively new but similar Bendix brushless systems have proven very reliable in other aircraft for several years. The high degree of success in service is due primarily to the absence of any physical electrical contact points — such as brushes or slip rings — that wear rapidly and produce metal and carbon particles that tend to contaminate and deteriorate other portions of the generator. Then too, the specially developed, high dielectric strength, epoxy material utilized to impregnate the stator windings practically fills all voids thus providing excellent mechanical stability and heat transfer. This material is also impervious to solvents, oils, and dilute acids. To a lesser degree the blast air cooling of the drive bearing through the hollow center shaft contributes to the extended service life of the generator.

The three engine-driven generating systems and the APU generating system are identical, except for the air blast adapter, and the discussion in the following text 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 as those given for the General Electric unit in Digest Issue 3. As explained later the APU generator load capacity varies with the operational environment of its turbine drive.

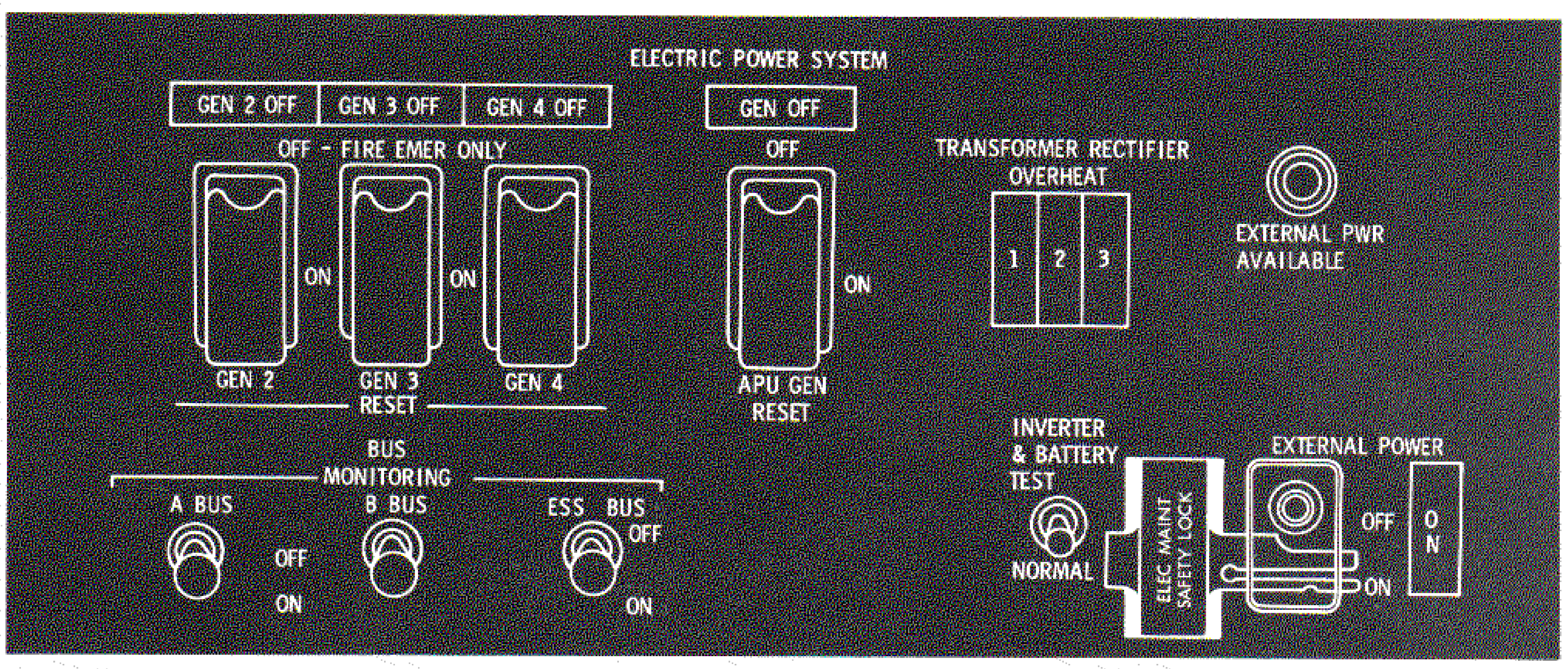


Figure 3
Generator
Control Panel

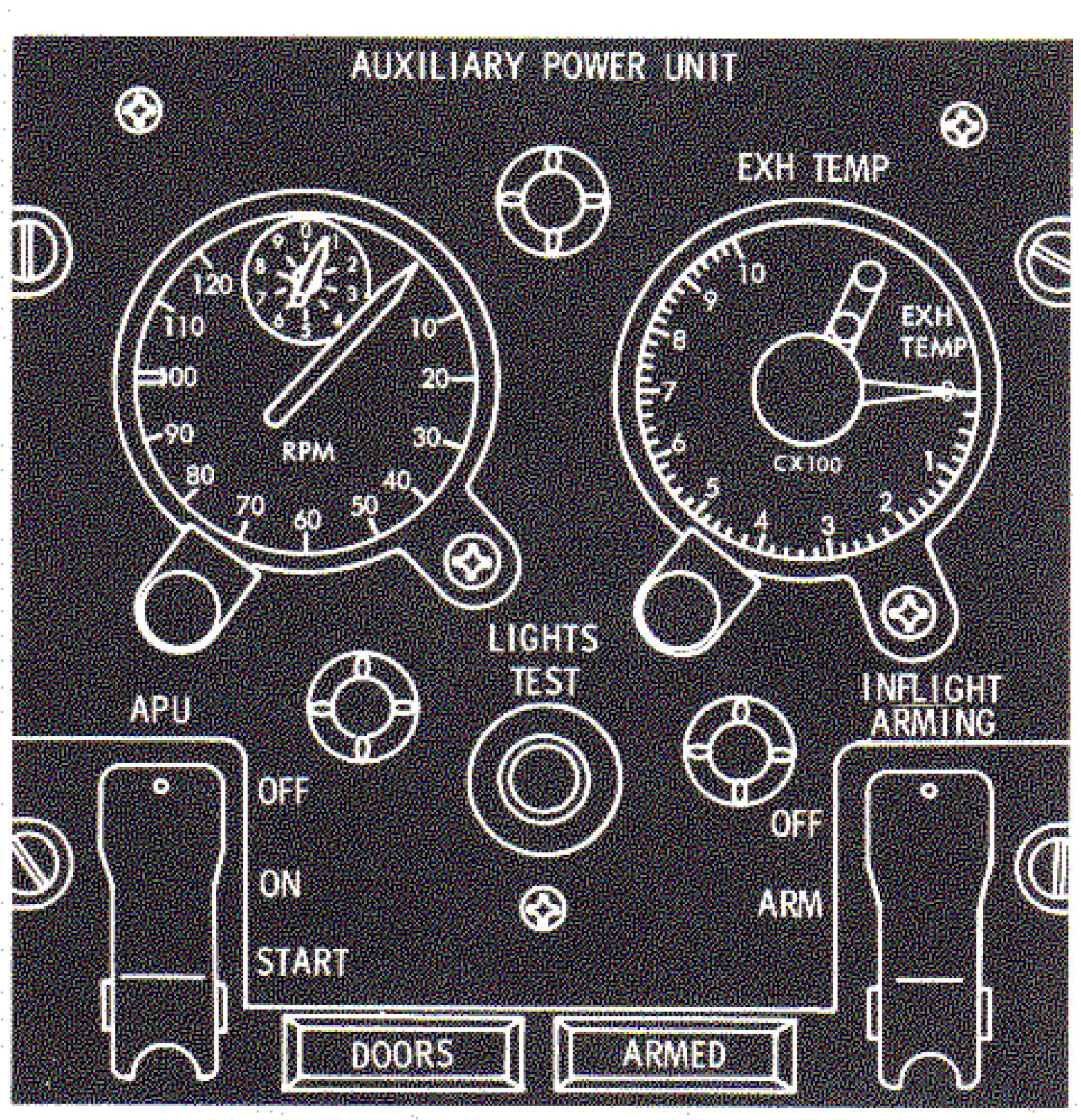


Figure 4
Auxiliary Power Unit Control Panel

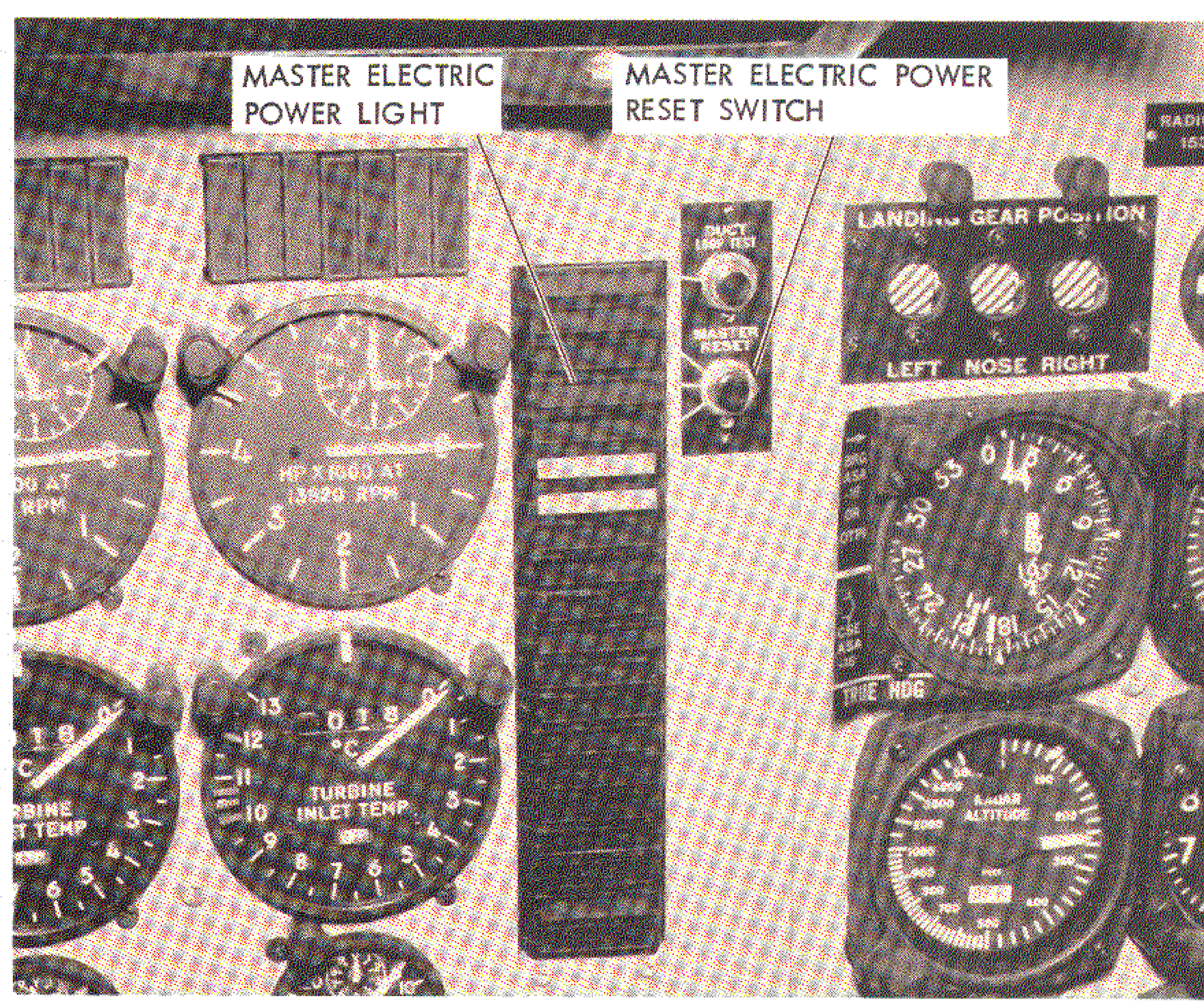


Figure 5
Center Instrument Panel

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 (SEE TEXT)	ENERGIZES LOCK OUT RELAY (LOR)
DPR	DIFFERENTIAL PROTECTION RELAY	WHEN FEEDER FAULT IS SENSED	BY REMOVING PMG & BUS POWER. (SEE FEEDER FAULT RESET DISCUSSION IN TEXT.)	ENERGIZES DLR, LOR DE-ENERGIZES ACR & GCR
GCR	GENERATOR CONTROL RELAY	3-SEC. 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 (SEE TEXT)	DE-ENERGIZES ULR, ACR, AND GCR
ULR	UNDERVOLTAGE LOCKOUT RELAY	3-SECONDS AFTER UNDER-VOLTAGE IS SENSED	BY UNDER-VOLTAGE RESET PROCEDURES (SEE TEXT)	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.

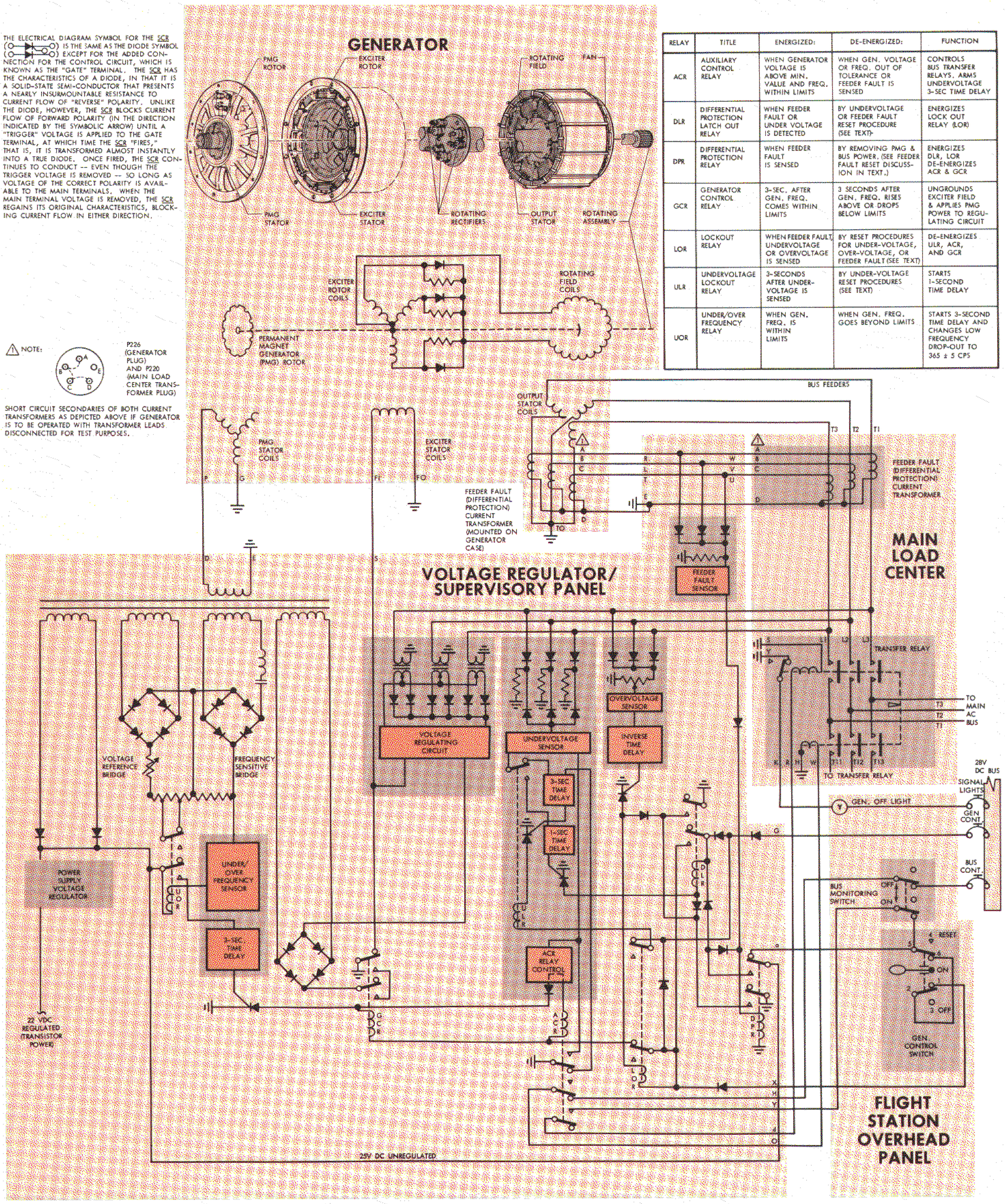


Figure 6 Simplified Generating System Circuit — Typical

The operating principles of the generating system are shown in Figure 6. 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 centertap common return line) but only two windings are utilized in the P-3 to produce a single-phase, 39-V, 600-cycle 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 three-phase rotor coils. Each of the exciter coil 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-V 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 portion of the generator.

The foregoing rather simplified explanation of generator operation describes only the method by which power is produced and omits all reference to the following control and protective functions provided by the PMG-powered voltage regulator/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. Lock out 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 7. This is accomplished by sensing any small voltage variation of the 3-phase output and utilizing 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. Even though the load on one phase of the generator is as much as one third higher or lower than the others, output voltage will not vary more than approximately five volts between the phases.

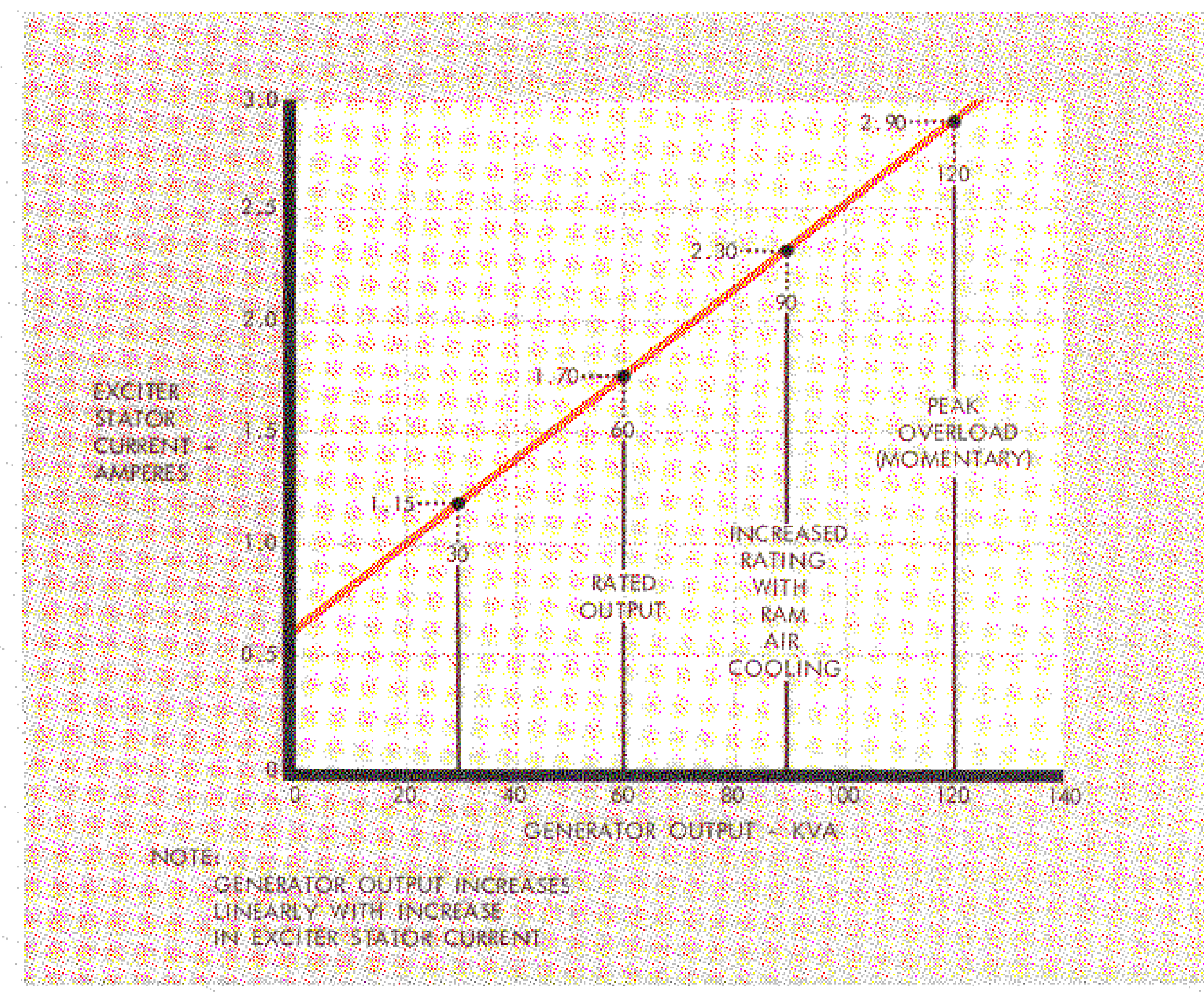
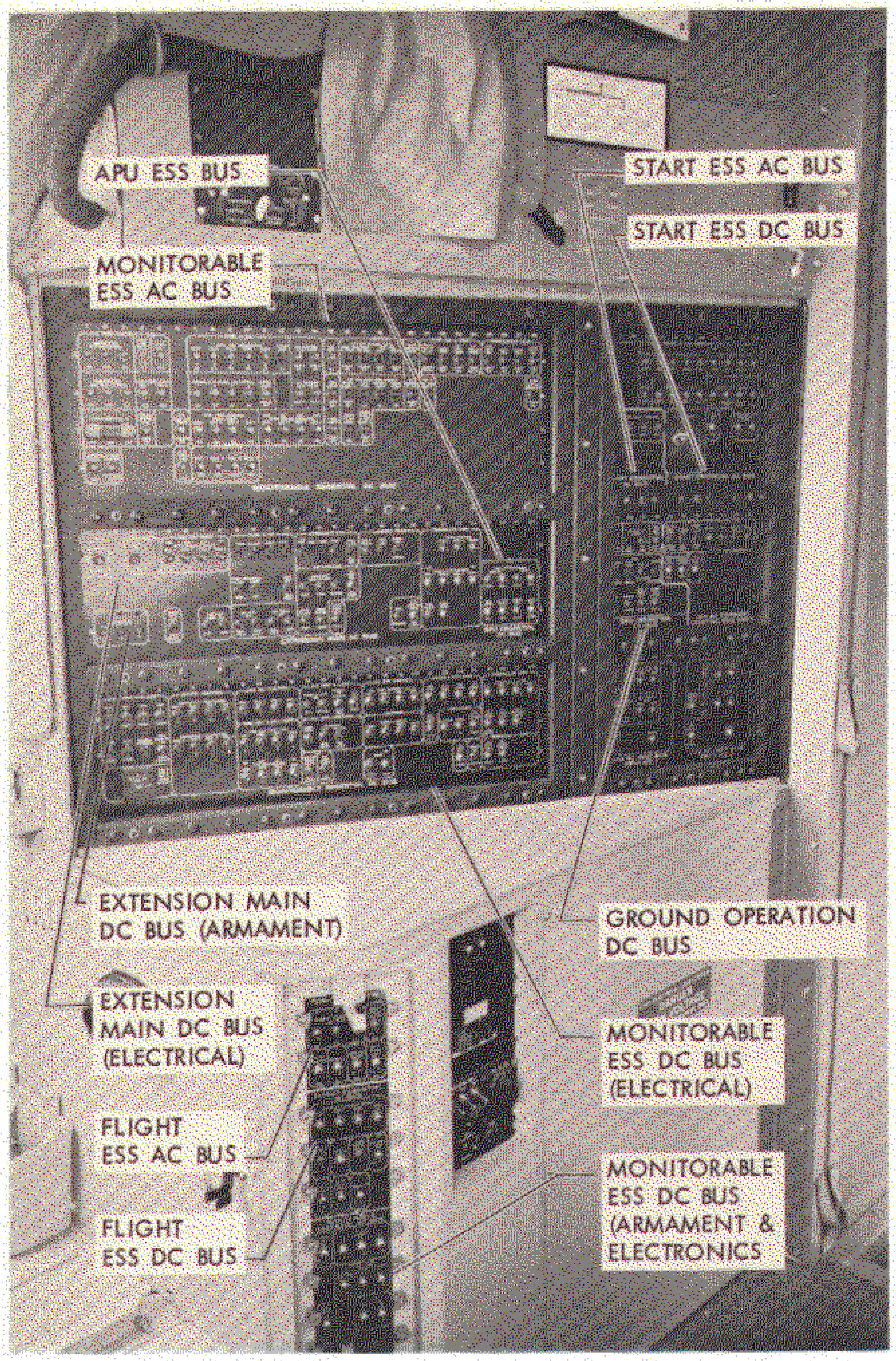


Figure 7 Graph showing Generator Output Power versus Exciter Stator Current

The undervoltage sensing and control circuit makes generator output available to a bus when the voltage rises to approximately 105V ac during the start cycle but does not de-energize and disconnect the generator feeders until one or more phases are reduced to 90 ±2 volts. The undervoltage sensing amplifier monitors the generator output through a 3-phase, half-wave diode rectifier and — in connection with the under/over frequency circuit—energizes the Auxiliary Control Relay (ACR) when voltage has built up to 105 V.

When the ACR is energized its contacts arm a timing circuit that will act automatically when one or more phases are reduced to 90 V. 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 approximately 4 seconds. The delay circuitry is intended primarily to allow time for corrective measures to occur — circuit breakers or current limiters to open — and thus remove the cause of the undervoltage.



Circuit Breaker Panel Location at Forward Load Center

If the cause of the undervoltage is removed and voltage rises to at least 105 V 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 re-instated. However, after a 4-second delay, under-voltage lockout occurs, the generator is de-energized, 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 selecting the generator control switch to OFF, opening and closing the appropriate GEN CONT circuit breaker, and then selecting the generator control switch to ON.

As explained in the "Feeder Fault" discussion, if the above procedure fails to restore a generator to operation, it is important that the generator control switch be selected to OFF and the GEN CONT circuit breaker be left in closed position for the remainder of the flight.

It should be noted that a second function is assigned to the undervoltage protection circuit — detection of an "open" circuit in one or more of the generator-to-Main Load Center feeders. 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 and the undervoltage sensor initiates the four second time delay which eventually de-energizes the generator.

An overvoltage tripped condition of the P-3 generator system is not likely to occur unless, of course, the voltage regulator should malfunction. 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 volt.

Operation of the comparison circuit initiates the inverse time delay start and 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 comparison circuit, a severe three-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, this circuit energizes relays that de-energize the generator and its loads transfer to another generator. Thereafter, the generator can be re-energized 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 (differential protection) is provided by two differential current transformers and a transistorized sensing circuit. 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 lock-out, this circuit is designed to detect a shorted feeder only. As explained in the "Undervoltage" discussion, an open feeder fault will be detected indirectly as an undervoltage condition.

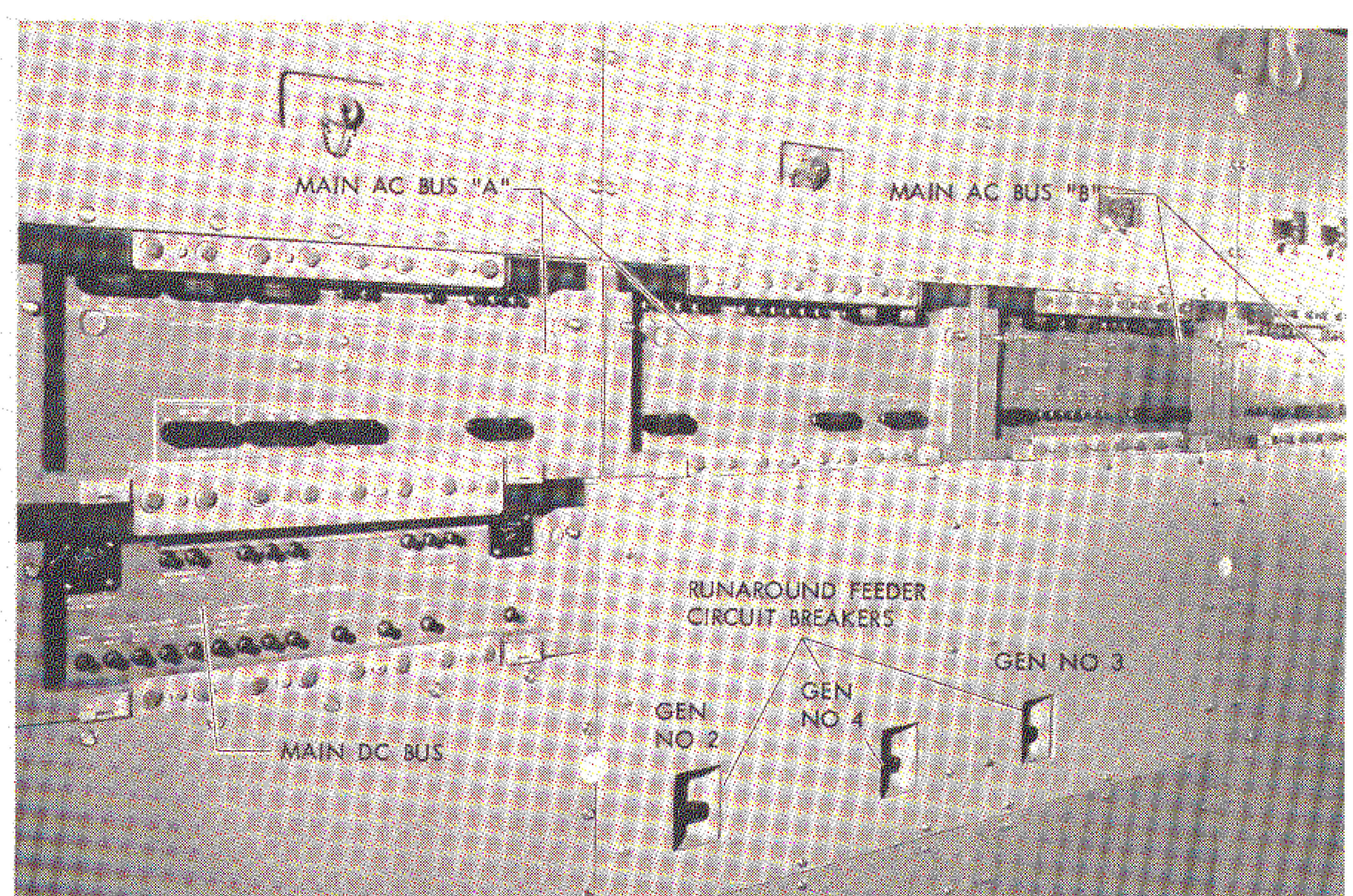
As shown in Figure 6, the generator-to-Main Load Center feeders pass through a three-circuit current transformer located in the Main Load Center. A second current transformer is a part of the generator and is mounted on the outer case adjacent to the output terminals with the neutral side of each phase 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 lock-out relays are energized. As the name implies, the lock-out 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 selected to OFF and the GEN CONT circuit breaker be 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 condition.

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 6 before operating the generator. This simple precaution will prevent excessive heat generation in the transformer iron core which may seriously damage or destroy the unit.

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 connection with the undervoltage circuit, it controls the Auxiliary Control Relay (ACR) thereby effecting a transfer of the associated bus to an available generator. The PMG frequency rather than the main generator frequency is sensed by the frequency monitoring circuits since the PMG is self-excited and has an output voltage even when the shaft is rotating at slower than normal speed, whereas the main gen-



Location of Circuit Breaker Panels at Main Load Center erator 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 their combined output inaugurates 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 CPS 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 CPS. At the completion of the time period a control transistor is turned on to energize the Generator Control Relay (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.

A generator overfrequency condition due, for example, to an overspeed propeller is sensed by the same circuits as those for underfrequency and will detect overfrequency and deactivate the generator at 435 ±5 CPS. 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 CPS.

As mentioned earlier, the P-3 generator has a unique, hollow-center 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 8). 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.

Engine torque is transmitted to the hollow rotor shaft via the torsion shaft that is equipped with a

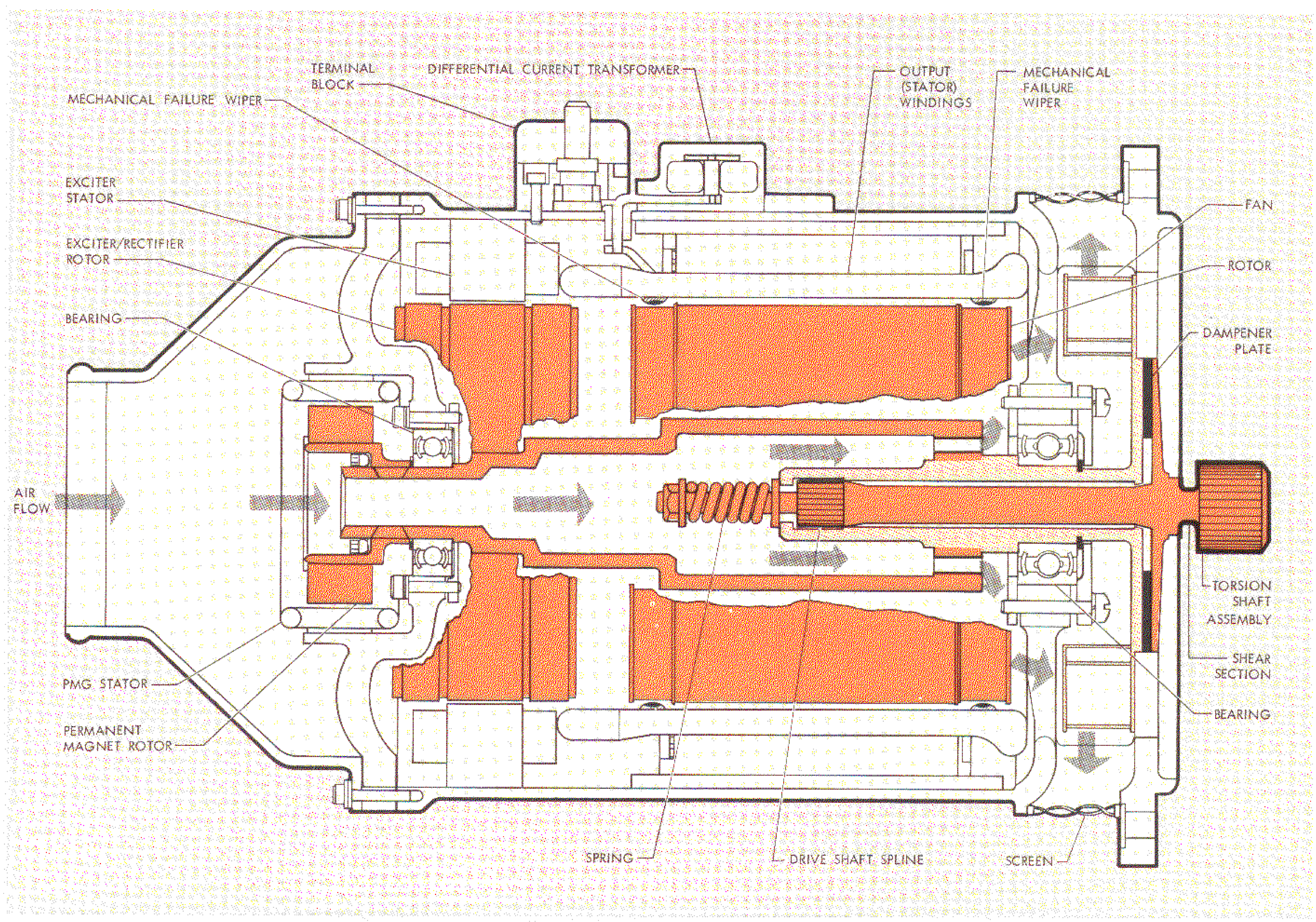


Figure 8 Generator Mechanical Construction with Details of Hollow Center Shaft

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 which 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 provides some tolerance for axial misalignment with the engine mount.

AUXILIARY POWER UNIT Although the Auxiliary Power Unit is to be covered in detail by a later issue of the Digest, a general description is necessary here to relate it to the current P-3 electrical system explained in this issue.

The Integral Start System (ISS) — generally referred to as the "APU" — was first envisioned as a 400 cycle AC ground power source with provisions for supplying pneumatic power both for engine starting and for ground air conditioning. In fact, part of Block 55 aircraft and all of Block 60 aircraft were delivered with these ground operating capabilities only.

Subsequent design changes broadened the scope of the APU to encompass in-flight operation to supply emergency electrical power and, as mentioned previously, these changes will eventually be incorporated on all aircraft in service.

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 since these factors determine to a great extent the maximum available horsepower rating of the turbine drive.

Airborne operation of the APU is limited to an altitude of 20,000 feet at an indicated air speed 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). The APU will not normally be running in flight but is to be started after two of the three engine-driven generators have failed.

As shown on Figure 11, the ACR contacts (of the APU regulator/supervisory panel) control transfer relay No. 7, and thus when the APU generator is energized it automatically replaces No. 4 on the bus.

Both the APU Essential DC Bus and the Ground Operation DC Bus must be energized for APU operation. Since the Ground Operation Bus is normally de-energized in flight by "gear up" position of the nose gear uplock switch (see Figure 1), an "APU Inflight Arm" switch has been incorporated on the center overhead panel. This switch de-energizes the Ground Operation Bus relay just as the NLG uplock switch does in its "gear not up" position, thereby connecting the Ground Operation Bus to the Flight Essential DC Bus. Power for the APU Essential Bus is generally supplied by the Monitorable Essential DC Bus, but it will be energized by the Ground Operation DC Bus (through the de-energized contacts of the Monitorable Essential DC Bus power sensing relay) if the battery is the only source of dc power available.

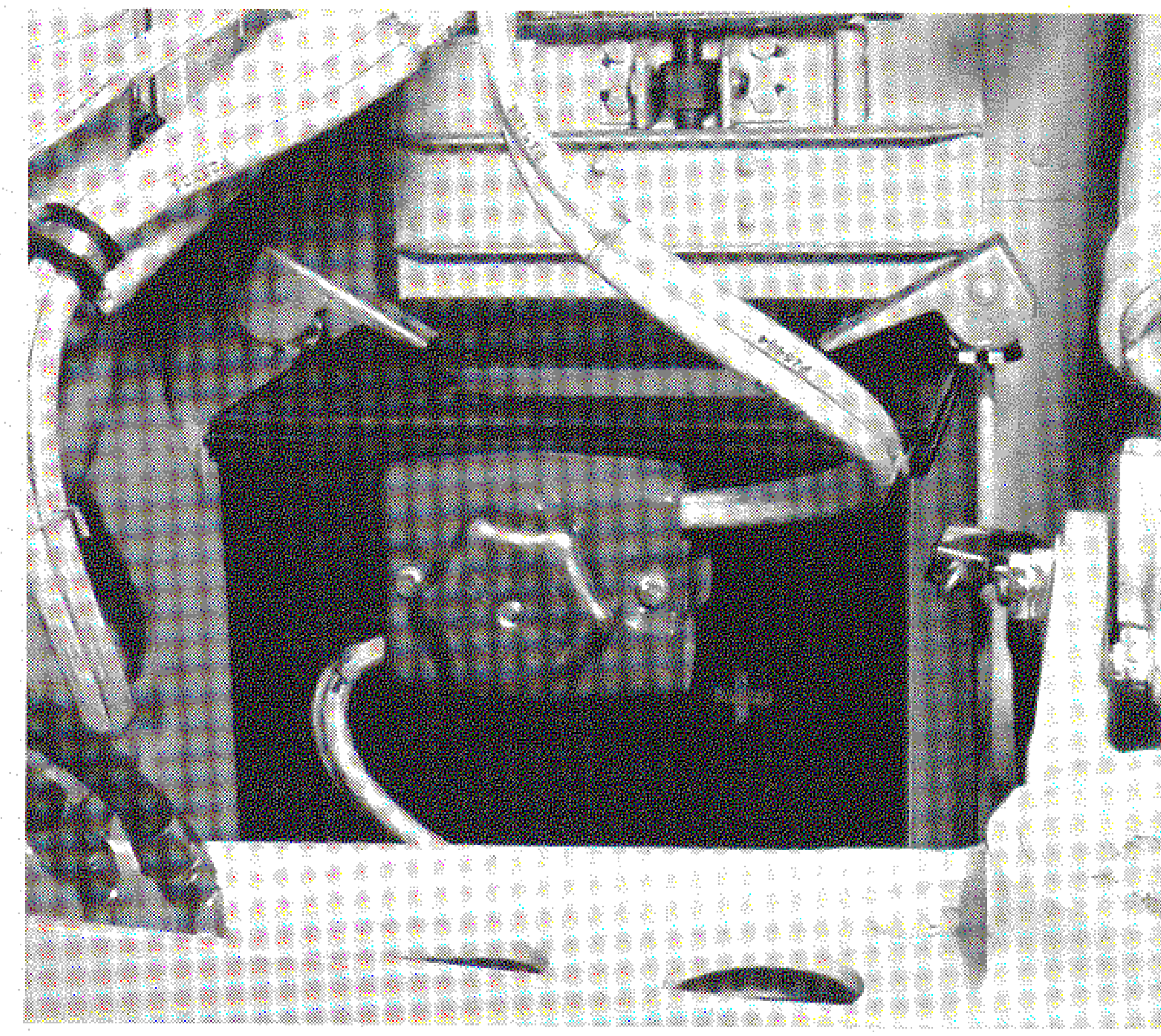


Figure 9 Battery Installation on P-3 Aircraft Equipped with APU

Since the APU turbine utilizes an electric starter, the 11 ampere-hour battery used on early aircraft is supplanted by one of 34 ampere-hour capacity to supply this increased load. The heavier battery (MS-18045-42) is now located at the aft end of the nose wheel well on a crank-operated elevator support to facilitate service and removal.

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 source is available. Note, however, that the APU loads are only supported by the battery while none of the transformer rectifiers are operating.

The ASN-42 inverter connected to the Flight Essential DC Bus on Figure 1 was described in Orion Digest Issue 12 in connection with the Inertial Navigation System.

The inverter was installed for the specific purpose of supplying the power-sensitive ASN-42 with 3-phase ac that is essentially independent of transients — due to heavy starting loads and bus transfers — which formerly disturbed the Inertial Navigation System.

At first glance it would appear that this inverter will quickly deplete the battery charge if transformer-rectifier power is not available from either the Monitorable Essential DC Bus or the Main DC Bus through one or both of the power diodes. This is not the case however, since the Main DC Bus energizes the ASN-42 Time Delay (10-second dropout) relay and its contacts in turn energize the ASN-42 Inverter Power relay. This arrangement ensures that the battery-supported Flight Essential DC Bus will continue to energize the inverter for a short period (up to 10 seconds) after Main DC Bus power is interrupted. Thereafter, the inverter will stop and cannot be restarted until power is restored to the Main DC Bus.

POWER CONTROL AND DISTRIBUTION

As explained earlier, the P-3 power generation circuitry is not drastically different for any of the aircraft manufactured to date. In fact, the changes discussed in connection with Figure 1 are mainly expansions of the basic circuit.

For those readers interested in greater detail of the control circuitry as well as distribution of power to the secondary dispersal points, the simplified circuitry of Figure 1 is included in Figure 11 (center fold). Also, the collective buses shown in Figure 1 are expanded in Figure 11 to reflect the latest aircraft configuration insofar as possible.

Note that Figure 11 depicts the distribution of all 115 V ac and 28 V dc power up to and including the circuit breakers that furnish power to each individual system and the lower-voltage circuits used for area illumination and panel lighting are also shown. In addition, Figure 11 depicts the extension of the Ground Operation DC Bus and the addition of a new bus (APU Essential Bus) which serves as an extension of either the Ground Operation Bus or the Monitorable Essential DC Bus for starting, control, and operation of the Integral Start System. The 115-V 400 cycle ac, the lower voltage lighting and the 28-V dc circuitry are distinguished by color to aid in circuit tracing.

No attempt has been made to point out the minor circuit differences that exist on a small number of individual aircraft. Rather than complicate the diagram in this manner, the schematic calls attention to the block number of the series of aircraft first incorporating a particular change in production as well as the P-3 Airframe Change (AFC) number providing for retrofit on earlier aircraft.

In each case the relays and controlling circuits, together with the current limiters and circuit breakers that control the energization of power buses, are shown to expedite trouble-shooting and aid in isolating bus failures as quickly as possible.

ARMAMENT POWER CIRCUITS With the exception of the Camera circuits, all of the circuit breakers on the Armament Circuit Breaker Panel shown in Figure 11 receive their primary power from the Forward Load Center. The 115 V AC power is supplied from the ARMAMENT CKT BKR PANEL ϕ A, ϕ B, and ϕ C breakers shown in Figure 12 on the upper L.H. corner of the Monitorable Essential AC Bus Panel. A fourth breaker — MSL PWR ϕ B — was added on Block 70 and subsequent aircraft to ensure adequate launching power for the AGM-12B "Bullpup" missile. The 3-phase ac power is used principally for actuating the Underwater Sound Service (USS) release doors and the sonobuoy chute doors. Phase A also supplies the single phase ac requirements for the Intervalometer and the Jettison Programmer.

As shown in Figure 11, 28 V dc is supplied from the ARMAMENT 1, 2, and 3 breakers on the Extension Main DC Bus via the forward RH electronic rack terminals to the Armament Circuit Breaker Panel. To reduce the possibility of an accidental or premature release of the search or kill stores, all of the release circuits with the exception of the "Bullpup" missile are powered through the following series-connected devices: MASTER CONT circuit breaker, PILOT'S MASTER ARM SW — or his SEARCH POWER SW — landing gear lever switch in "UP" position, "kill" or "search" power relay, and finally through the ARMAMENT POWER, SEARCH STORES or KILL STORES circuit breaker. The latter then applies power to the respective release circuits.*

The "Bullpup" missile release circuit is wired to allow its release with the landing gear either up or down in flight. However, the "Bullpup" cannot be released without first closing the ARMT PWR MAST CONT circuit breaker and placing the pilot's

**A spring-loaded test switch, labeled ARMT SAFETY CKT is installed on the upper rh corner of the armament circuit breaker panel. Since activating this switch to DISABLE position will bypass the landing gear lever switch, and possibly energize the release circuits, this test should not be made without first referring to the procedures given in current NAVAIR manuals.*

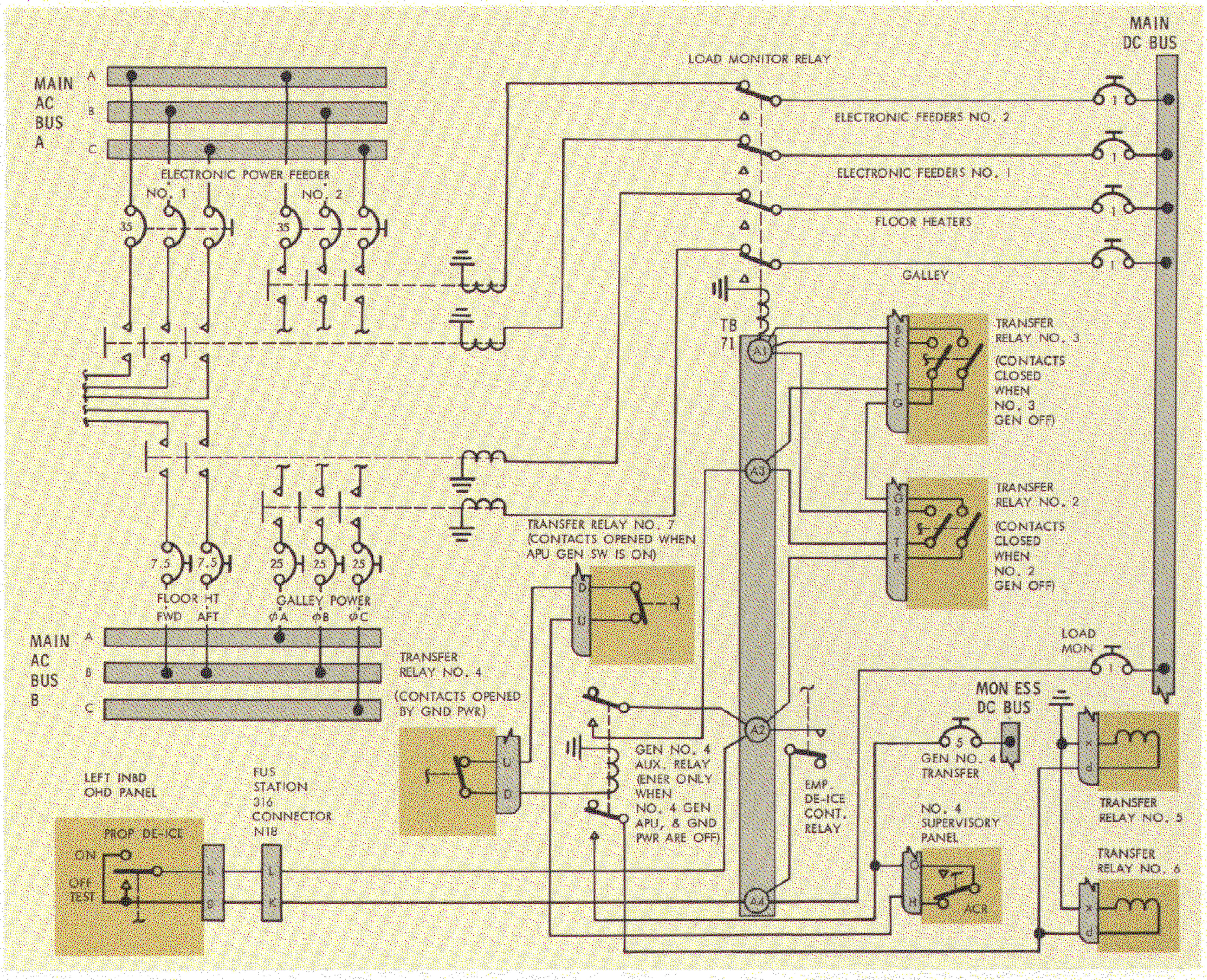


Figure 10 Automatic Monitoring Circuit

MASTER ARM switch to PILOT or PILOT-TAC position. Then the release circuit is completed through the main landing gear scissor switches as long as the weight of the aircraft is not supported by the gear.

The six Camera circuit breakers on the armament circuit breaker panel are energized by electronics power feeder breakers on the Main Load Center panels. Of the six camera breakers shown on Figure 12 only one, the DOOR AC breaker, is powered by ϕ A of the ELECTRONICS POWER FEEDER NO. 2 group on the Main AC Bus A panel. It should perhaps be noted that this circuit is subject to automatic monitoring in the event propeller or empennage deicing circuits are actuated while all buses are energized from a single power source (see Figure 10).

The remaining five Camera breakers are 28-V dc and are energized by ELECTRONICS POWER FEEDER NO. 1 on the Main DC Bus panel. They supply power to two day cameras and one night camera mounted on the bottom of the fuselage and to the photo-flash ejector system located on each side of the fuselage beneath the horizontal stabilizer.

Note that the primary power breakers for special weapon's release and control (T414) 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 (Figure 11) rather than the Extension Main DC Bus. This particular configuration helps ensure that power will be available in all but the most extreme case (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 elementary navigation information (AHRS, VOR, and DOPPLAR radar) are powered by the Monitorable Essential AC Bus and the Monitorable Essential DC Bus — two power sources not so apt to be de-energized under adverse power conditions. Other systems less essential for safe flight such as the No. 2 HF, the search radar, and the ASW tactical gear are energized by the Main AC Bus A and/or the Main DC Bus.

As depicted in Figure 11, the ELECTRONICS POWER FEEDER NO. 1 and NO. 2 circuit breakers are powered by the Main AC Bus A and are part of the automatically monitored loads mentioned previously. The FLOOR HT., FORE and AFT and GALLEY POWER, ϕ A, ϕ B, and ϕ C breakers — located on the Main AC Bus B panels — are also monitored by this circuit. All of these services will be suspended under one-generator power conditions if it is necessary to energize propeller and/or empennage deicing circuits.

Both the AC and the DC power for the electronic portion of the Aft Left Electronic circuit breaker panel are provided through breakers located on the Forward Right Electronic circuit breaker panel. This service is divided into two groups labeled AFT LOAD CENTER — MONITORED and AFT LOAD CENTER. The first group is controlled manually as a part of ESS Bus monitoring switch operation. The multiple 15-ampere AFT LOAD CENTER ac breaker is part of the automatically monitored circuit.

The Galley secondary power breakers — located on the Aft Electronic circuit breaker panel — are powered directly from the three 25-amp. GALLEY POWER Breakers on the Main AC Bus B panel and are also part of the automatically monitored loads.

ANTICIPATED MODIFICATIONS

As mentioned earlier, changes and improvements are a necessary adjunct to the modern aircraft. Although plans for their incorporation have not been finalized at the time of this writing, two areas in the Flight Essential category are being investigated by Lockheed and Navy engineers.

One area involves an alternate source of power for certain Flight Station lights and basic flight instruments which are now powered exclusively by the Monitorable Essential AC Bus.

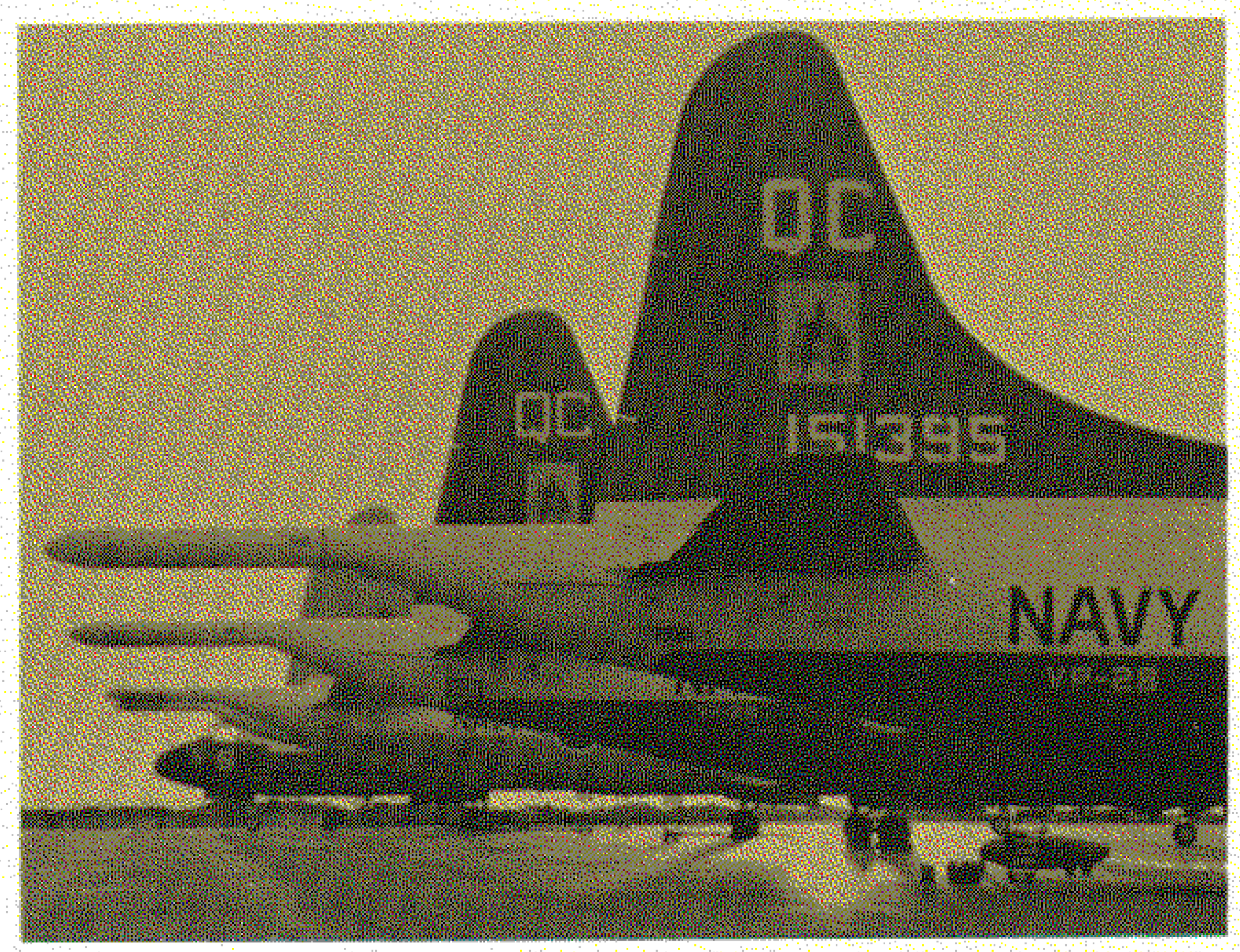
A second change under consideration includes provision for sensing the loss of *one* or *two* phases of the AC power supplied to the Essential buses in addition to the present practice of sensing the loss of all three phases. This study is directed primarily towards the relays that supply the Essential AC Buses and the Run-around circuits. The loss of any one phase to these circuits may de-energize essential loads — such as the Pilot's and Copilot's MM-4 Attitude Indicators — which could be vital to safe flight under certain circumstances.

EDITOR'S NOTE

In 1963, as an adjunct to Issue 3 of the Orion Service Digest, we offered wall-chart size reproductions of the principal illustration from our first Electric System article, a schematic which showed in simple form the P-3 power distribution system as it was originally designed and produced. These charts have been widely disseminated and have proven quite useful, for the system is one which affects a broad spectrum of maintenance and operating specialists, and it is difficult for most personnel to grasp and retain an accurate "working knowledge" of such a complex system without an aid of this type.

Copies of Figure 1 of this second Electric System article, reflecting the system configuration that is currently in production and as it will be on operating aircraft after modification, are available in 4-color wall chart size. Personnel desiring either or both wall charts should preferably request them from the Lockheed-California Company Service Representative at their activity. Otherwise, copies can be obtained by writing to the address given on the inside front cover of this magazine.

Integral Fuel Tank Maintenance



MOST INTEGRAL FUEL TANK maintenance is of the unscheduled variety, and is rather specialized work in which true proficiency is acquired through practice. Experienced tank-seal crews are not always available, especially while operating from deployed bases, and when the need for tank maintenance arises it is often necessary to assign personnel to the task who have little or no previous experience.

Working without the specialist's skills and equipment, inexperienced personnel are doubly handicapped, and a minor leak repair sometimes becomes a major maintenance problem under field conditions.

The difficulties attending most field repairs can be avoided if the personnel assigned have a general knowledge of P-3 wing structure, understand the properties of sealants and the particulars of preparing and applying them, and if they then adopt a careful, methodical approach in analyzing and resolving tank seal problems. It is the aim of this article to provide line-crewmen with a personal reference source of information summarizing tank-sealant repair data and emphasizing the principal points of care to exercise and methods to employ in restoring the integrity of integral fuel tanks.

INTEGRAL TANK STRUCTURE

The upper and lower wing skins each consist of nine (9) integrally stiffened planks and the front and rear box beam webs are the one-piece fore and aft tank walls. With the exception of the ribs used to secure the tank bulkheads and those used to support the wing flap, landing gear, and nacelle structure, the interior rib members are generally attached with "H" clips to the the wing top and bottom integral skin stiffeners. This arrangement minimizes the number of seams and fasteners leading to the tank exterior surfaces. All faying surfaces and fasteners are coated with uncured catalyzed sealant just prior to assembly. As described in detail later, many steps of the assembly process are deliberately redundant to ensure that every potential leak point is well covered. Reference at this time to Figure 1 through Figure 4 on the following pages may be helpful in understanding the general nature of the wing structure.

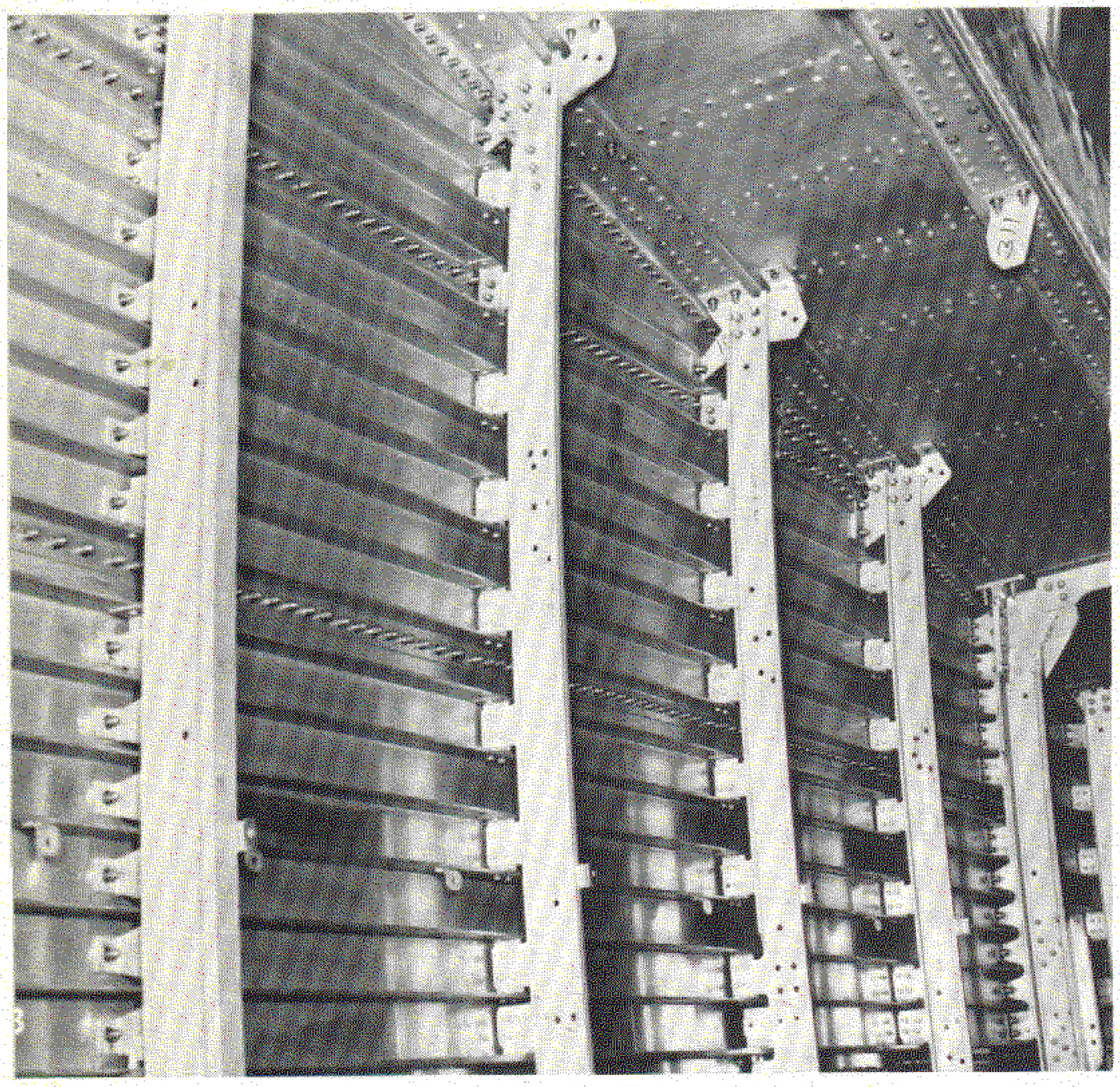


Figure 1
Typical Box Beam Web that Forms the Fore and Aft Walls of the Tanks. Except for those noted in the text, ribs are attached to wing plank risers by "H" clips shown here.

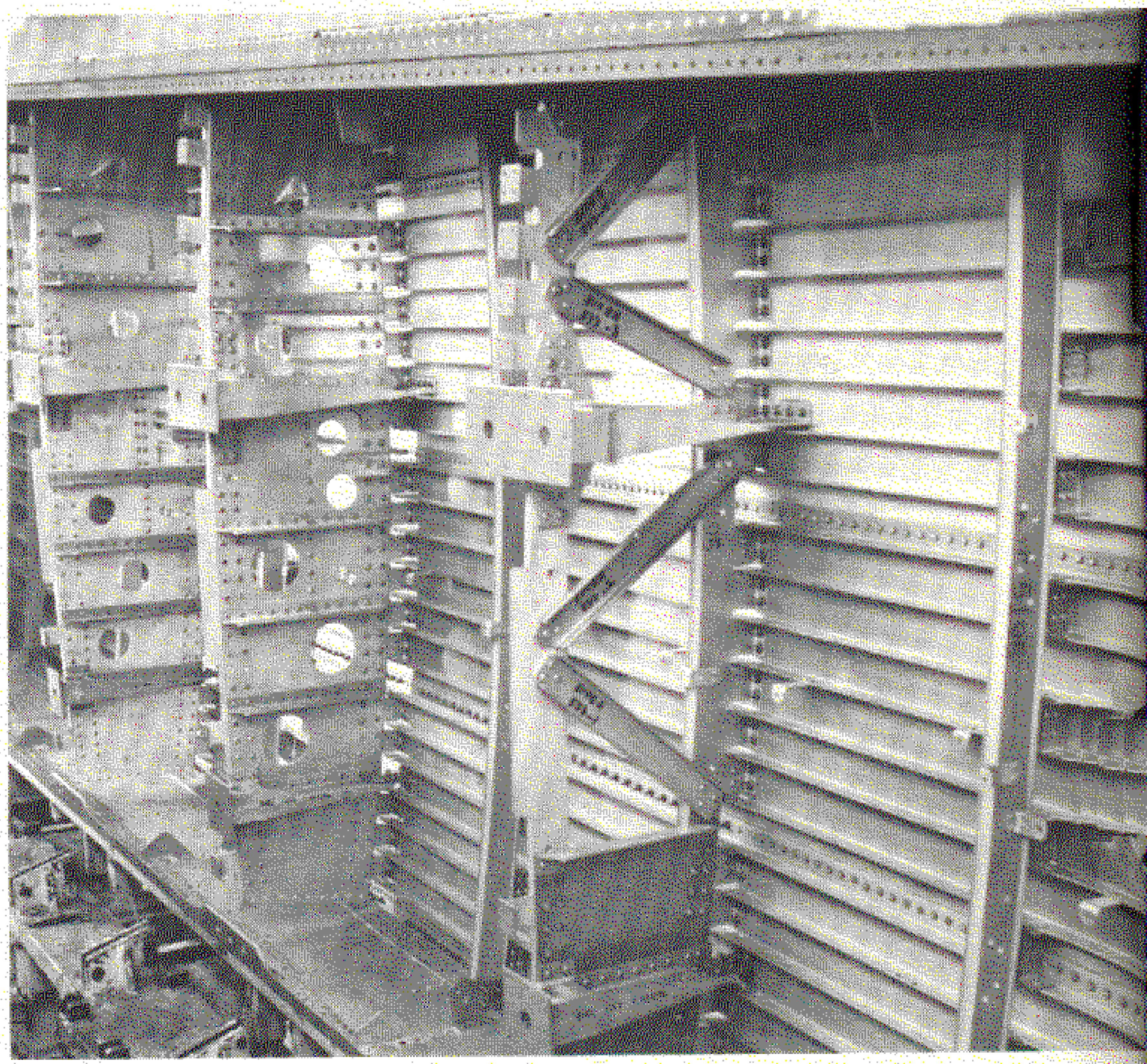


Figure 2 Wing Lower Surface Integrally Stiffened Planks Form the Bottom Surface of the Tanks. Wing ribs and tank bulkheads shown installed.

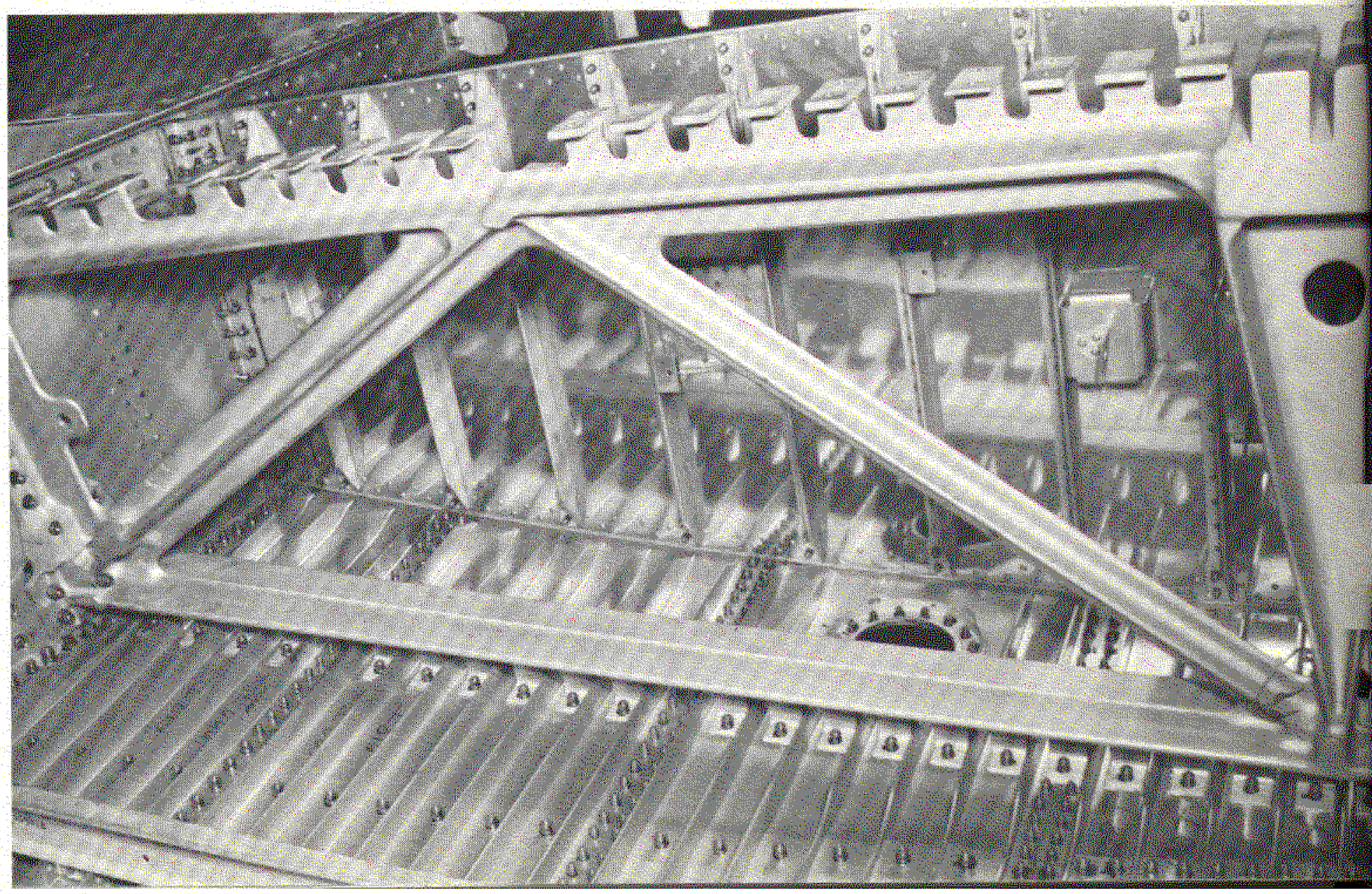


Figure 3
Main Landing Gear Rib and Tank Bulkhead

SEALING COMPOUNDS

Lockheed is currently using a single basic sealing compound, varying the viscosity and application time to suit specific purposes. This material is essentially a long-chain, polysulfide type polymer liquid rubber that cures by chemical reaction to the consistency of solid rubber when it is mixed with a catalyst accelerator in the correct proportion. The base material and the catalyst are always of contrasting colors. This provides a visual aid for the mixing operation for ease in determining the proper dispersion of the catalyst throughout the base material as evidenced by a uniform color.

Table I lists the sealing materials, the protective coatings, and the cleaners now in use at Lockheed for initial assembly work as well as quick repair kits, protective coatings, and cleaners used for field repair. These sealants, when correctly mixed and applied to a properly cleaned area, will provide a dependable, adequate seal. They can be used to repair any sealant installed by Lockheed, provided the deteriorated portion of the previously applied sealant is completely removed.

TYPES The MIL-S-8802 Class B-2 and A-2 materials have an application life of 1 to 3 hours. The Class B-2 is a heavy viscosity sealant used for injection and fillet sealing in voids, holes, and along structure seams and joints. The Class A-2 sealant is a brushable material used for sealing fasteners, such as rivets and bolts. The MIL-S-8802 Class B-½ and Class A-½ (LAC C-40-778, Types I and II) sealants are quick repair materials and have an application life of 15 to 45 minutes. Class B-½ is a heavy viscosity sealant and Class A-½ is brushable. The LAC C-40-778 Type III sealant can be used for either repair category, but has no military specification.

The MIL-S-8784 Class B and Class A (LAC C-40-769 Types I and II) materials have an application life of 1 to 3 hours. They are a low adhesion (2 lbs./inch max.) version of MIL-S-8802 and are used to seal contact surfaces of components which are not permanently installed.

The LAC C-40-777, Types I and II are extended work-life versions of MIL-S-8802 Class B-2 and Class A-2 but do not have a Military Specification number (see Table I). Type I has an application time of 10 hours and an assembly time of 20 hours. Type II has an application time of 24 hours and an assembly time of 80 hours. Both Type I and Type II are used only on faying surfaces, and chemical curing of these materials takes place within the required time subsequent to the exclusion of air during the assembly process. Since air interferes with the curing of LAC C-40-777, any uncured sealant at the edges of the faying surfaces (due to squeeze-out) must be completely removed to prevent its interfering with the proper curing of either fillet and/or brush-coat materials which are applied later.

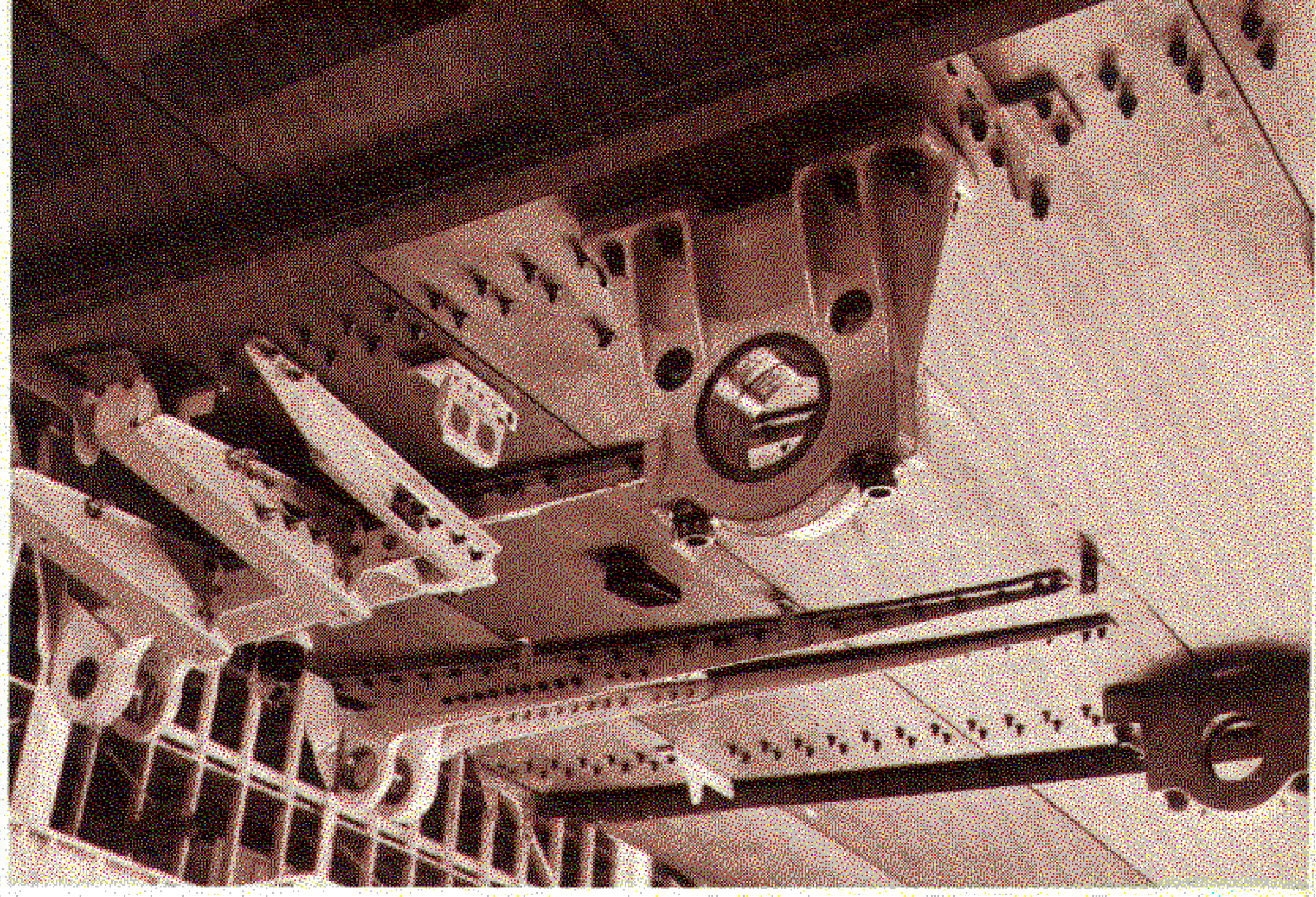


Figure 4 Landing Gear Attachment Structure is Faying Surface Sealed before Installation

The MIL-S-4383 (LAC 40-781) protective coating material is a Buna-N phenolic resin material which affords protection to the cured sealant and also provides protection of the metal surfaces from corrosion. Type I is brushable for touch-up and field repairs while Type II is used at the factory for the fill-and-drain application of the coating.

The LAC 40-668 corrosion preventive coating material used at Lockheed is a one-part air curing polyurethane polymer base material designed for either brush or spray application. The MIL-C-27725 coating used in service is a two-part polyurethane material which requires mixing before application and serves the same purpose as the LAC-40-668 material. These coatings are applied only to the bottom surfaces of the tank structure after the application of the MIL-S-4383 coating.

WARNING

Avoid all skin contact with MIL-C-27725 polyurethane coating during application. Chemicals used in its manufacture are poisonous and can be absorbed through the skin. Use precautionary measures such as protective hand cream, rubber or plastic gloves, aprons, and full-face, air-supplied respirator. Remove and launder all clothing contaminated by these chemicals as soon as possible. In case of accidental skin contact with polyurethane, wash the affected area immediately with soap and water. When applying polyurethane, ventilate the area as described under the "Safety Precautions" section of this article. When application is made by either brush or spray gun, wear an air-supplied respirator and cover all parts of the body.

PROTECTIVE COATING, LEAK DETECTORS, AND CLEANERS

MATERIAL DESCRIPTION	MATERIAL SPEC*	APPLICATION TIME	DRYING TIME	VENDORS	USEABLE MILITARY SPECIFICATIONS
COATING, CORROSION PREVENTIVE (1-PART POLYURETHANE MATERIAL). APPLIED TO WING LOWER STRUCTURE OVER THE LAC-40-781 COATING. (USED AT LOCKHEED)	LAC 40-668		2 HRS. AIR DRY AND 6 HRS. FORCE AIR DRY @ 110°F ± 10°F PLUS 48 HRS. @ 120°F ± 20°F AND 50% RELATIVE HUMIDITY	BRADLEY PAINT CO. NO. 58109 MAGNA COATING & CHEMICAL CORP. NO. 48-C-15	
COATING, CORROSION PREVENTIVE (2-PART POLYURETHANE COMPOUND). APPLIED TO WING LOWER STRUCTURE OVER THE MIL-S-4383 COATING (USED IN SERVICE)		5 HRS. IN TIGHTLY CLOSED CONTAINER	SEE DRYING TIME FOR LAC 40-668		MIL-C-27725
FILL-AND-DRAIN COVER COATING WITH HIGH FLASH SOLVENT (USED ONLY AT LOCKHEED).	LAC-40-781 TYPE II		30 MINUTES	3 M CO. **EC-776-HF-R PRODUCTS RESEARCH CO. **PR 1005-HF-R	MIL-S-4383
BRUSHABLE PROTECTIVE COATING FOR TOUCH-UP OR FIELD REPAIRS	LAC-40-781 TYPE I		2 HRS. @ 77°F (25°C) PLUS 6 HRS. @ 120°F (49°C)	3 M CO. **EC-776R PRODUCTS RESEARCH CO. **PR 1005R	MIL-S-4383
DICHLOROMETHANE TECHNICAL, USED FOR THINNING LAC-40-781				QUALIFIED PRODUCTS LIST	MIL-D-6998
LEAK DETECTOR, SOAP LIKE FLUID USED ON EXTERNAL SEAMS AND FASTENERS TO DETERMINE LEAKS WITH FUEL TANK UNDER 3 PSI AIR PRESSURE.	LAC C-31-215			TURCO PRODUCTS INC. TURCO 598	
LEAK TEST COMPOUND, NON-CORROSIVE BUBBLE SOLUTION USED FOR DETECTING LEAKS.					MIL-L-25567
CLEANERS, CHLORINATED TYPE USED AT FACTORY FOR CLEANING WAX TYPE CONTAMINANTS FROM TANK SURFACES TO BE SEALED.	LAC-32-337			TURCO PRODUCTS INC. NO. 657 DELCO CHEM. CORP. NO. 2083 LEEDER CHEMICAL CO. NO. 885	
DRY CLEANING SOLVENT, USED FOR LEAK CHECK AND GENERAL CLEANING AT FACTORY.	P.D. -680 TYPE II			QUALIFIED PRODUCTS LIST	
CLEANER, PETROLEUM BASE, USED AT THE FACTORY FOR REMOVING GREASE AND OIL FROM TANK SURFACES TO BE SEALED.	LAC-32-367			DELCO CHEM. CORP. NO. 2064 KELITE PROD. CO. KUL LEEDER CHEM. CO. NO. 500L	
METHYL ETHYL KETONE	TT-M-261			QUALIFIED PRODUCTS LIST	
AROMATIC NAPHTHA (USED IN CLEANING SOLVENT MIXTURE).	TT-N-97 TYPE I GRADE B				
ETHYL ACETATE (USED IN CLEANING SOLVENT MIXTURE).	TT-C-751				
ISOPROPYL ALCOHOL (USED IN CLEANING SOLVENT MIXTURE).	TT-I-735			FEDERAL STOCK NUMBER 6810-223-2726 (5 GAL.)	
RED DYE MIXED WITH JP-4 OR ISOPROPYL ALCOHOL FOR INJECTION LEAK DETECTION	DYE RED "O" (SOLVENT RED NO. 27)			FEDERAL STOCK NO. 6820-559-3248	
FLUORESCENT DYE MIXED WITH JP-4 OR ALCOHOL FOR INJECTION LEAK DETECTION	ZYGLO ZL-2				

Table I Materials Used in Production Sealing and

SEALING MATERIALS

MATERIAL DESCRIPTION	LAC MATERIAL SPEC*	APPLICATION LIFE @ 77°F (25°) AND 50% RELATIVE HUMIDITY	CURE TIME @ 77°F (25°) AND 50% RELATIVE HUMIDITY	VENDORS	USEABLE MILITARY SPECIFICATIONS
SEALING COMPOUND (FILLET AND INJECTION) USED FOR FILLETING ALONG SEAMS AND JOINTS AND FOR FILLING GAPS AND VOIDS BY INJECTION WITH A PRESSURE GUN.	LAC C-40-775 TYPE I	1 TO 3 HOURS	48 HOURS	PRODUCTS RESEARCH CO. PR7301K(PR-1422B-2) COAST PROSEAL & MFG. CO. PROSEAL 890-B2 3M CO. EC-1675-B2 CHURCHILL CHEM. CORP. 3C-408-B2	MIL-S-8802 CLASS B-2
SEALING COMPOUND (BRUSHABLE) USED FOR SEALING RIVETS, BOLTS AND ALL FASTENERS.	LAC C-40-775 TYPE II	1 TO 3 HOURS	48 HOURS	PRODUCTS RESEARCH CO. PR 7401K(PR-1422A-2) COAST PROSEAL & MFG. CO. PROSEAL 890-A-2 3M CO. EC-1675-A-2 CHURCHILL CHEM. CORP. 3C-408-A-2	MIL-S-8802 CLASS A-2
SEALING COMPOUND (QUICK REPAIR FILLET) USED IN SERVICE REPAIRS FOR FILLETING ALONG SEAMS OR JOINTS AND FOR FILLING GAPS OR VOIDS.	LAC C-40-778 TYPE I	15 TO 45 MINUTES	12 HOURS	PRODUCTS RESEARCH CO. PR5601K(PR-1422B-1/2) 3M CO. EC-1675-B-1/2	MIL-S-8802 CLASS B -1/2
SEALING COMPOUND (QUICK REPAIR, BRUSHABLE). USED IN SERVICE FOR ALL MINOR REPAIRS TO SEALANT COATING OVER RIVETS AND FASTENERS.	LAC C-40-778 TYPE II	15 TO 45 MINUTES	12 HOURS	PRODUCTS RESEARCH CO. PR5701K(PR-1422A-1/2) 3M CO. EC-1675-A-1/2	MIL-S-8802 CLASS A -1/2
SEALING COMPOUND (QUICK REPAIR, BRUSHABLE OR FILLET). USED IN SERVICE FOR MINOR LEAKS OF ALL TYPES.	LAC C-40-778 TYPE III	15 TO 45 MINUTES	24 HOURS	PRODUCTS RESEARCH CO. PR5801(PR-1435)	
SEALING COMPOUND (FAYING SURFACE). USED IN PRODUCTION ASSEMBLY, APPLIED TO ALL FAYING SURFACES (PRIOR TO INSTALLING FASTENERS) TO PREVENT SEAM LEAKS AND ALSO DETER CORROSION.	LAC C-40-777 TYPE I (FOR SMALL ASS'Y) TYPE II (FOR LARGE ASS'Y)	10 HOURS APPLICATION TIME AND 20 HOURS ASSEMBLY TIME 24 HOURS APPLICATION TIME AND 80 HOURS ASSEMBLY TIME	14 DAYS 6 DAYS @ 77°F PLUS 24 HRS. @ 120°F OR 3 DAYS @ 77°F PLUS 48 HRS. @ 120°F	PRODUCTS RESEARCH CO. PR7801K(PR-1431, TYPE I) PR7901K (PR-1431, TYPE II)	NONE CURED SEALANTS CONFORM TO CURED MIL-S-8802 REQUIREMENTS
SEALING COMPOUND (LOW ADHESION) APPLIED TO CONTACT SURFACES OF SYSTEM COMPONENTS WHICH ARE NOT PERMANENTLY INSTALLED.	LAC C-40-769 TYPE I	1 TO 3 HOURS	24 HOURS	PRODUCTS RESEARCH CO. PR-1301HT-K(PR-1301, CLASS B) COAST PROSEAL & MFG. CO. PROSEAL 712	MIL-S-8784 CLASS B
SEALING COMPOUND (BRUSHABLE, LOW ADHESION). USED FOR PURPOSES GIVEN ABOVE.	LAC C-40-769 TYPE II	1 TO 3 HOURS	24 HOURS	PRODUCTS RESEARCH CO. PR1301BT-K(PR-1301, CLASS A)	MIL-S-8784 CLASS A
PETROLATUM, USED ON EXPOSED AREA OF ACCESS DOOR SEALS TO PREVENT SEIZURE.	VV-P-236				

*KITS OF SEALANT RECEIVED FROM STOCK MAY HAVE CHANGE LETTERS SUCH AS "A", "B", "C", ETC., AFTER THE BASIC SPEC. NO. MERELY TO REFLECT THE LATEST REVISION TO THE SPECIFICATION BUT DO NOT SIGNIFY A DIFFERENCE IN THE COMPOUND FROM A SERVICE STANDPOINT.

**THE LETTER "R" AFTER THE NUMBER INDICATES THAT THE SEALANT HAS BEEN DYED RED FOR EASIER IDENTIFICATION OF REPAIRED AREAS.

MIXING The different brands of base sealing compounds included under the Military Specifications vary in color. The catalyst is of a contrasting color. A light colored base material and a dark colored catalyst is preferred because definite streaks of color are evident until it is thoroughly blended with the catalyst. At the factory where large quantities are used, the sealant is mixed by an automatic-metering, mechanical mixer. When this type of mixer is not available, the heavy fillet-type (Class B) sealant is mixed on a flat glass plate so that the thorough blending of the base and catalyst can be checked easily.

For service repairs, the sealant suppliers provide the correct proportions of base compound and catalyst in kit form — a kit consists of the catalyst container attached to the lid of the base-compound container. It is suggested that the ½-pint kit be kept in stock as this amount usually suffices for repairing the average leak. Good results are dependant on adherence to these basic mixing rules.

"DO'S AND DON'TS" WHEN MIXING SEALANTS

- DO mix all the catalyst and the base compound in the kit, regardless of how little sealant will be required.
- DO scrape all the catalyst into the base compound can.
- DO scrape all the base compound from the lid and from under the rim of the can into the mixture. This is a comparatively simple task if the rim is cut away with a household type can-opener as shown in Figure 5. Unless all the catalyst is added, the sealant will not cure properly and will not have adequate fuel resistance. If more than the recommended catalyst is added, the sealant will cure, but its flexibility and elongation properties will be seriously impaired.
- DO stir the mixture slowly (by hand, using a flat mixing paddle) for 3 to 6 minutes. Stirring the mixture rapidly will cause it to heat and will introduce air bubbles which may burst later and result in pinhole leaks.
- DO stir the mixture thoroughly until the catalyst and base compound are completely blended and free from a marbled appearance. All the mixture must be completely uniform in color.
- DON'T try to economize by mixing part of the catalyst and part of the base compound that comes with the kit. This will only result in an ineffective repair.
- DON'T intermix sealing materials supplied by different manufacturers.
- DON'T intermix different types supplied by the same manufacturer.

APPLICATION LIFE The period during which the mixture of the catalyst and base compound retains a consistency suitable to its particular use (for example, brushing, filleting, or injection sealing) is called *application life.*

The brush material is usable until brush marks no longer flow out when it is applied to rivets and bolts.

The fillet and injection materials are usable until the sealant becomes rubbery and sticks to the application gun rather than to the surface of the tank.

The application life of a sealant varies with the relative humidity, the ambient temperature, and the temperature of the mixture. Assuming the mixture is being used at an ambient temperature above 77° F (25° C) and 50% r.h. (relative humidity), the application life of the sealant is shorter than that listed in Table I; below 77° F (25° C) and 50% r.h., the application life is longer. The relative humidity has a distinct effect on the application life of the mixed sealant, but only within the range of 70° to 120° F (21° to 49° C). For each 15% increase in relative humidity over 50% at any temperature between 70° and 120° F, the application life of the mixed sealant

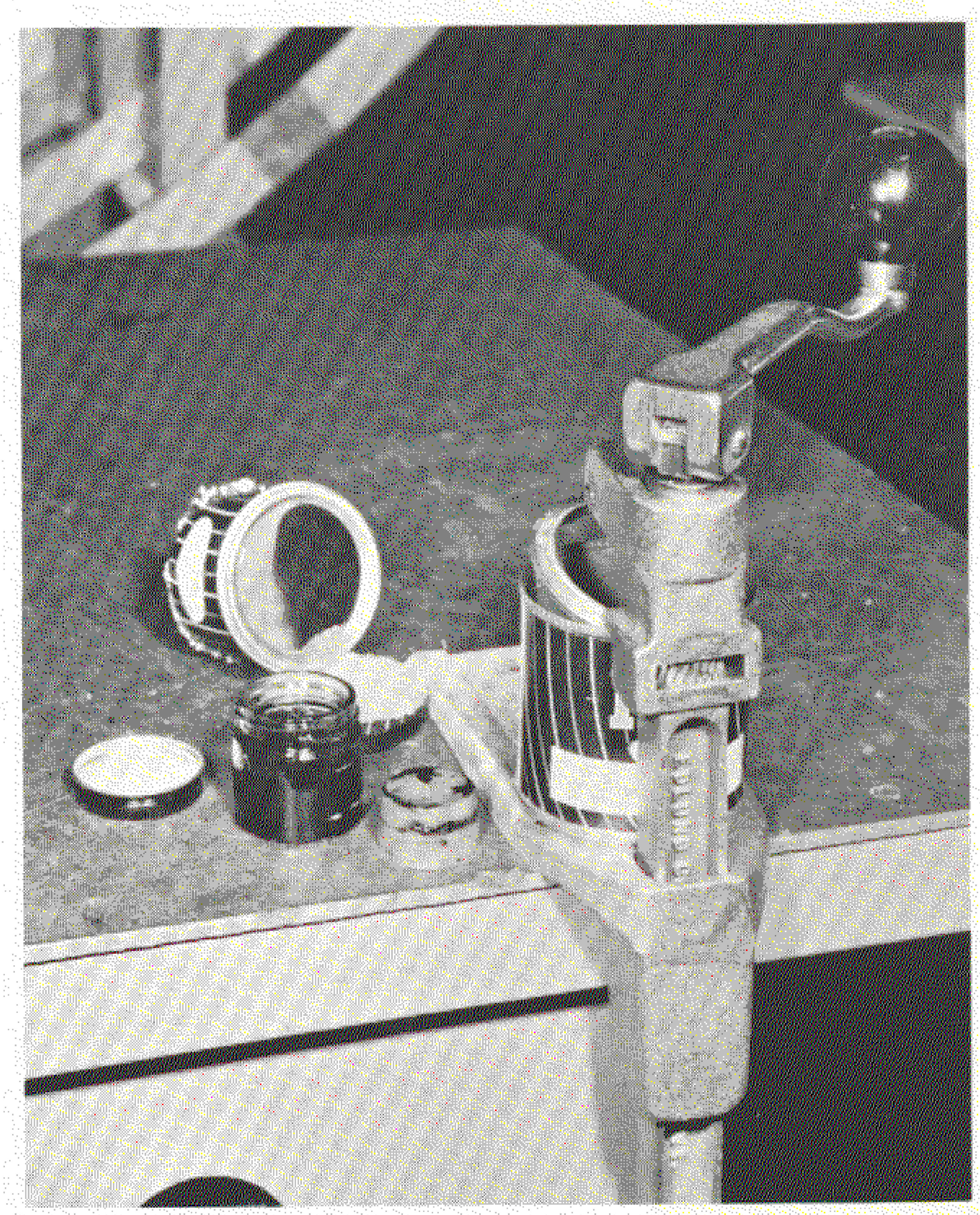


Figure 5 Remove Rim of Base Compound Container for Easy Access to Contents

is reduced by approximately one-half. Conversely, for each decrease of 15% r.h. under 50%, the application life is nearly doubled. The relationship of temperature, relative humidity, and application life is easier to understand if one keeps in mind that the sealant cures by chemical action; it does not harden through evaporation.

CURE TIME The length of time required for the sealant to set up after application is the *cure time.* This depends on the initial application life, the ambient temperature, temperature of the material, and the relative humidity. The time of cure is roughly about 10 times the application life provided the air temperature and relative humidity do not vary (see Table I). If, during the cure time, the air temperature is increased 12° F (6° C) over the 77° F (25° C), the sealant will cure in approximately one-half the time listed in Table I. Raising the temperature an additional 12° F to 101° F (38° C) will cure the sealant in about one-fourth the time listed in Table I. Below 65° F (18° C), the sealant will not cure, but will merely become tacky and remain in that state until exposed to higher temperatures. After exposure to suitable temperatures, the sealant will cure properly.

When a low ambient temperature delays or prevents curing or when accelerated curing is desirable, circulate filtered hot air through the tank until the sealant has cured.

STORAGE LIMITATIONS FOR KITS Most manufacturers specify a maximum of six months shelf life for an unopened container when stored at a temperature below 80° F (27° C). However, this time can be extended considerably if the kits are stored in an area maintained below 60° F. (Preferably at or near 40° F).

Naturally, the best practice is to use materials still current under the manufacturer's shelf-life specifications. Should an emergency arise in which an aircraft is considered unsafe for flight due to fuel leaks and currently dated kits are not available, we suggest this procedure:

1. Open the catalyst portion of the kit and check the contents for evidence of lumps or general hardening.
2. If the catalyst appears to be uniformly fluid, mix the sealant as directed and make a 2-inch wide by ⅛-inch thick test application to a properly cleaned aluminum surface.
3. Cure as outlined in Table I and check that the sealant attains a hard rubber-like surface. If the catalyst has lost its chemical properties the sealant will remain soft and tacky. Cut a 1-inch wide strip from the center of the test specimen and check for adhesion by pulling the sealant away from the metal. Continue to pull until the sealant pulls apart. Sealant with good adhesion qualities will pull apart before it pulls away from the metal strip.
4. If the results of Step 3 are normal, the remainder of the kits with the same batch number (stamped on the container) can reasonably be expected to serve their intended purpose.

PROTECTIVE COATINGS The factory is currently using red Buna-N phenolic resin liquid (LAC 40-781 Type II) in the fill-and-drain cover coat process. A deeper shade of red Buna-N for brush application is identified with an "R" following the vendor's number and is normally used for service repairs. These materials meet the requirements of MIL-S-4383.

The red color makes it easier to see the new coating as it is being applied and so aids in getting complete coverage. It also serves to identify areas that have been repaired.

If it is not possible to obtain the red Buna-N the original type may be dyed by dissolving approximately ¼ teaspoon of red MEK-soluble aniline rubber dye in 2 ounces of MEK (Methyl ethyl ketone). This mixture should then be poured into 2 quarts of MIL-S-4383 and mixed thoroughly. It is possible to purchase this dye (which must be soluble in MEK) in 1- or 2-ounce quantities from almost any chemical supply house.

In addition, a coating of MIL-C-27725 polyurethane material is generally applied to all the wing lower structure after MIL-S-4383 is thoroughly dried. It is applied by brush or spray in two applications; the first approximately .001 inch thick with a 2 hour air dry time followed by a second application approximately .003 inch thick, cured as noted in Table I.

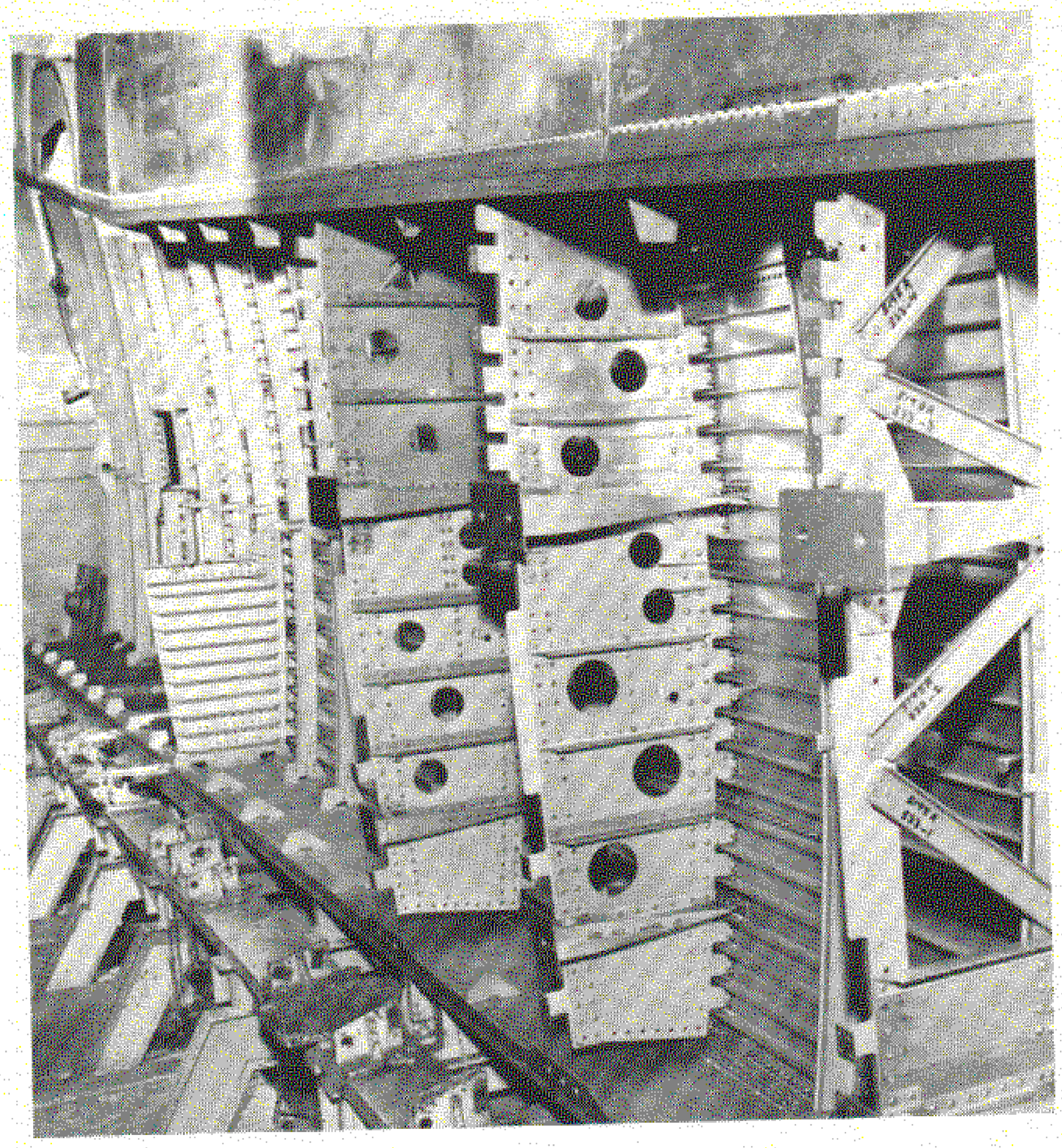


Figure 6 Faying Surface Sealant Applied to All Surfaces Mating with Skin Planks

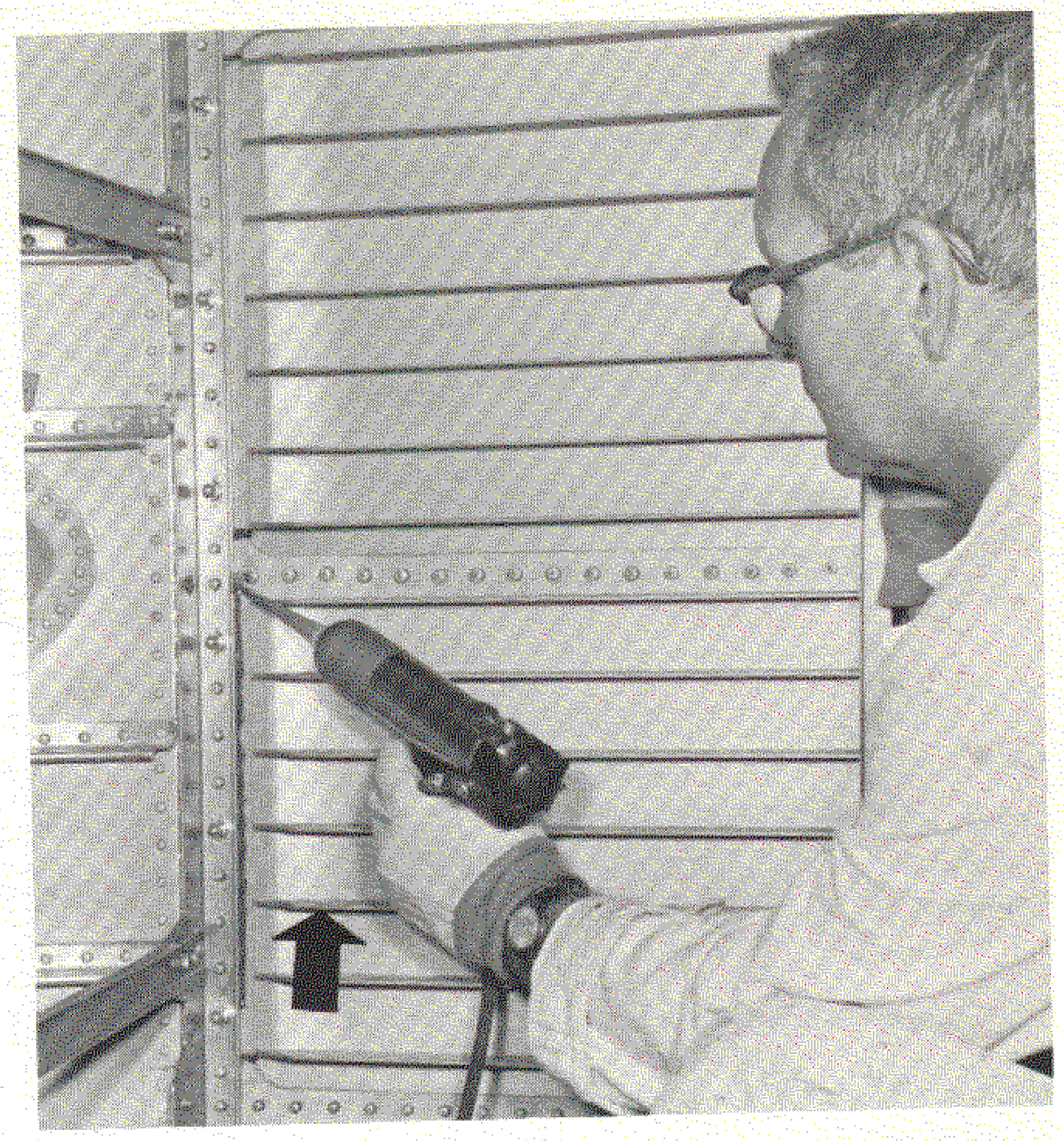


Figure 7 Application of Filleting Compound with Gun

TANK SEALING IN THE FACTORY

Chemical cleaning and degreasing of all interior fuel tank surfaces is a very important key to the successful application of sealing compounds. Production specifications require the removal of all grease, oil, adhesive residue, tape, organic finishes, pencil marks, and fingerprints before any sealing materials are applied.

Any foreign matter is first removed with brush, spray gun, or clean rags using LAC-32-337 cleaner or Methyl Ethyl Ketone (TT-M-261) and then the area is flushed with LAC-32-367 petroleum base cleaner to remove all traces of grease or oil. To avoid redeposit of oil or grease, the tank surface is wiped dry with clean soap-free rags and hot-air dried at 120° F to 140° F for a period of 6 hours before sealing operations start.

Faying surface sealant is utilized on all mating surfaces of the wing primary structure that forms the integral fuel tanks. These include all added doublers, angle clips, pump brackets, electrical and plumbing fittings, and other accessory equipment permanently mounted through the primary skin, rib, or web structure.

Any one of the following sealing compounds, LAC C-40-777, Type I or Type II, LAC C-40-775, Type I or LAC C-40-778, Type I, is used as a faying surface sealant. The compound is first applied to *one* mating surface and the desired thickness is obtained with the sealant comb shown in Figure 14. Then the parts are mated and fasteners installed. Naturally, the sealant used depends upon the total time that will be required to install all of the necessary fasteners.

As stated previously, curing time is directly related to ambient temperature and relative humidity and is considered when selecting the faying surface sealant from the following list:

LAC C-40-778 Type I — 15 minutes
LAC C-40-775 Type I — 2 hours
LAC C-40-777 Type I — 20 hours
LAC C-40-777 Type II — 80 hours

The time specified is that for 75° F at 50% relative humidity and is the maximum time that is allowed to elapse between the mixing operation and the completion of the assembly work.

All fasteners are installed with sealant applied under the countersunk heads and to the thread area of the Hi-Lok fasteners prior to installing the collars.

A sufficient quantity of sealant is applied to the faying surface and around the fasteners to ensure a full seal as evidenced by squeeze-out of the excess sealant. Where LAC C-40-777 sealants are used, the squeeze-out excess is removed prior to subsequent fillet or brush sealant application. Air interferes with the chemical curing action of this sealant making it necessary to remove the excess squeeze-out so that it will not interfere with the curing of the fillet and/or brush sealants applied later. Excess sealant

Figure 8 Brush Sealing over Fasteners

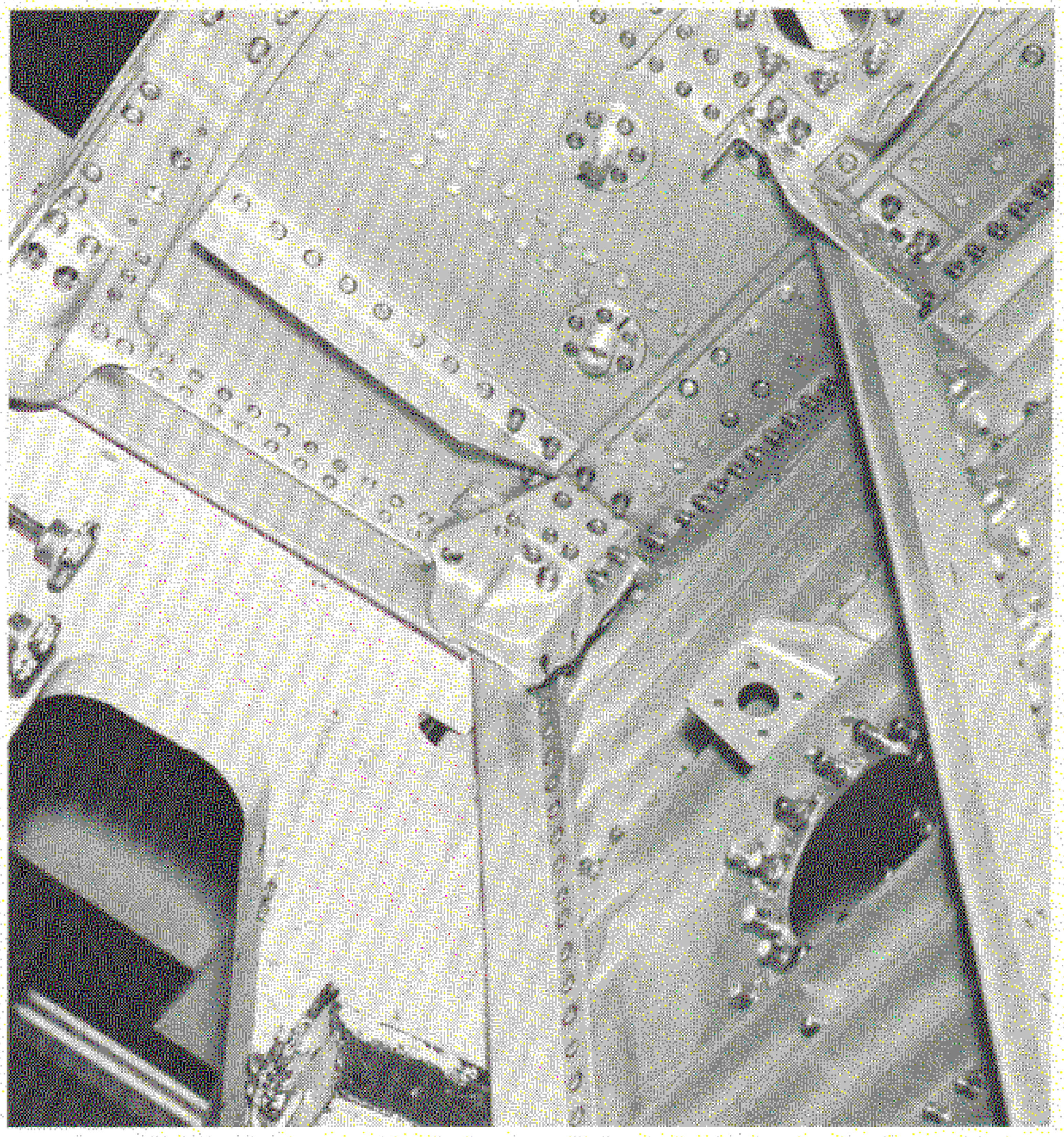


Figure 9 Corner Sealing

is removed with a non-metallic scraper or with a clean rag lightly dampened with LAC-32-337 cleaner.

Fillet sealing LAC C-40-775 or LAC C-40-778 sealant is applied to the edges of all seams, flanges, angles, gussets, doublers, and fittings with a fillet gun equipped with a ⅛-inch interchangeable nozzle opening. To ensure an even fillet along these places, the gun is held at a 45-degree angle and moved evenly along the seam in the direction in which the nozzle is pointing as depicted in Figure 7. Immediately after each charge of the fillet gun is applied, the mechanic uses a small aluminum spatula to force the sealant into the seams and joints, work out the air bubbles, and taper the edges.

Brush sealing When the fillet sealant has cured to a non-tacky condition, a brush coat of LAC C-40-775 Type II is applied over the fillets, seams, rivets, nuts, and bolts and it too is allowed to become tack-free. Then a second coat is applied and cured as denoted in Table I.

Injection sealing forces the air from all structural cavities at joggles, spacers, and fittings and replaces it with sealant. Sealant is injected with a high pressure injection gun until it emerges from all openings interconnected to the cavity.

Corner sealing All corner seals at bulkhead intersections are packed with faying surface sealant at the time the corner plates are installed.

Cover coats Following a visual inspection of the completely sealed wing, the tanks are filled with LAC 40-781, Type II. This liquid is allowed to stand 10 minutes and then removed. The fumes are evacuated by an overhead suction system for two hours, followed by warm forced-air drying at 120° F (49° C) for six hours. All areas not coated during the above fill operation (due to trapped air) are now brush coated with LAC-40-781 Type I to ensure complete coverage. This coating is used primarily to protect the exposed metal surfaces from corrosion.

After the LAC 40-781 coating is thoroughly dry, LAC 40-668 is applied to the bottom surface of the tank (upper surface of the wing lower structure including the beam caps and rib cap flanges) to inhibit corrosion which is similar to that in sump areas.

Soak checks The tanks are soak checked with Stoddard Solvent for 4 hours and after a no-leakage test is passed, the plumbing lines are installed. All mechanical seals and gaskets used with plumbing lines and other system components are checked by pressure-testing the tanks with air at 3 psi.

After the wings are attached to the airplane, a 6-hour fuel-soak check is made. When this check has been successfully completed, the tanks are filled with fuel to a specified level, and the aircraft is flown to test the tank sealing further. Finally, just prior to delivery, the tanks are given a 4-hour soak check on the ground after running the engines 15 minutes.

Figure 10 Wing Tank Bulkhead after Application of Sealant and Protective Coating

MAINTENANCE OF INTEGRAL TANKS— GENERAL

Failures of both the original and the repaired sealant are generally due to one of the following causes:

- Blisters
  These may be caused by air bubbles or cleaning solvents entrapped in the sealant. Expansion of the air in the blister at altitude plus the flexing of the wing structure or an extreme increase in temperature can rupture the blister and thus open a channel through the sealant.

- Ruptures
  Continual excessive flexing of the wing structure in flight, rough landings, or rapid taxiing over rough terrain with a heavy fuel load can cause ruptures in sealant.

- Voids or Omissions
  Leaks will result if sealant is omitted from difficult access areas or if it is not thoroughly worked into all voids along seams and joints.

- Poor Adhesion
  Sealant will not adhere to structure if applied over dirt, grease, soap film, oil film, or moisture trapped in seams and joints.

- Pinholes
  Brush sealant, if not thoroughly worked around each rivet or fastener, may break as the sealant cures and not be detected. In service, fuel will extract unmixed accelerator material from the sealant if the accelerator and base compound are not completely blended. This will occur sooner if the sealant is not cover coated adequately. Also, rapid mixing of accelerator and base compound can introduce small air bubbles into the sealant. The bubbles may rupture and cause pinhole leaks.

- Deterioration
  Improper proportions of base compound and accelerator can affect the quality of the sealant. Too much accelerator for the amount of base compound used results in loss of sealant flexibility at low temperatures. If too little accelerator is used, the sealant will not have the required resistance to fuel. The sealant will deteriorate and will appear chalky and powdery or will crack when flexed, even at room temperature.

- Dry Fuel Tanks
  When fuel tanks remain dry for extended periods, the sealant and the mechanical gaskets and seals will dry out and fuel leaks may result. For this reason, if an aircraft is to be parked outside for a few days, or if it is to be out of service for a prolonged period, each tank should contain at least 50 gallons of fuel. The fuel vapor will help to preserve the sealant that is not actually in contact with fuel.

- Dome Nuts
  Sealant failures that occur in the area of dome nuts are usually due to the installation of the wrong type screw. Long screws puncture the cap or rupture the sealant before the head is seated. Faulty screw threads or incorrect thread type or thread count can cause the nut to rotate and rupture the cap and sealant. Also screws that have been dipped in sealant — in contrast to coating only the underside of the head — may force the cap off the nut by hydraulic action.

INSPECTING AND RECORDING LEAKS Careful inspection in a well-lighted area is of prime importance. We recommend using leak inspection charts during the examination for recording the locations and types of leaks found. These charts are plan views of the lower surface of the center section and outer wing areas and show wing stations, major cutouts, and spars for reference purposes. A symbol, such as a circle or a square, is used to record the different classes of leaks described below. Charts can easily be made by the operator for each leak area involved.

It is particularly important from a safety standpoint to make a careful inspection for seeps and leaks in confined sections such as the areas forward of the front spar, aft of the rear spar, and in the nacelles.

TYPES OF LEAKS

A slow seep is a leak in which the fuel wets an area not over three-fourths of an inch in diameter. A slow seep should be wiped off and if it does not reappear within one hour it should merely be recorded and then inspected periodically.

A seep wets an area from three-fourths inch to one and one-half inches in diameter and recurs within one hour. This type of leak should be recorded and inspected frequently for increased activity. If it appears in an open area, repair is generally not required until the aircraft is temporarily removed from service for other maintenance which requires tank entry.

A heavy seep is one that increases to the point where it recurs immediately after being wiped off and spreads to an area from one and one-half inches to three inches in diameter but does not drip. It should be repaired if it occurs in a closed area or if the airplane is at a maintenance base.

A dripping leak is a continuous fuel leak which wets a limited area and then drips off the aircraft. We recommend repairing such a leak before the aircraft is released for flight.

A running leak is a continuous running of fuel caused by a definite break in the sealant and should be repaired before the aircraft is released for flight.

SAFETY PRECAUTIONS Improper use of materials and equipment in the fuel tanks could result in injury to personnel and damage to the aircraft. Therefore, Lockheed recommends conscientious observation of the following safety rules while investigating leaks and making repairs:

1. Be certain that the airplane is electrically grounded and that the fuel pumping gig is bonded to the aircraft.
2. Use only air motors that have been bonded to the aircraft for all drilling operations. If a vacuum cleaner is used to clean tank interiors, it too must be bonded to the aircraft and be of the air-driven type. Wear wing socks or gym shoes when working inside tanks.
3. Use only explosion-proof electrical equipment in the area.
4. Use only explosion-proof lights and flashlights inside the tank.
5. Have fire extinguishing equipment readily available.
6. Before entering a tank, circulate fresh, filtered air through the tanks for at least 30 minutes. A venturi-type air remover at the filler well and filtered air forced through the access panel in the wing lower surface will serve the purpose.

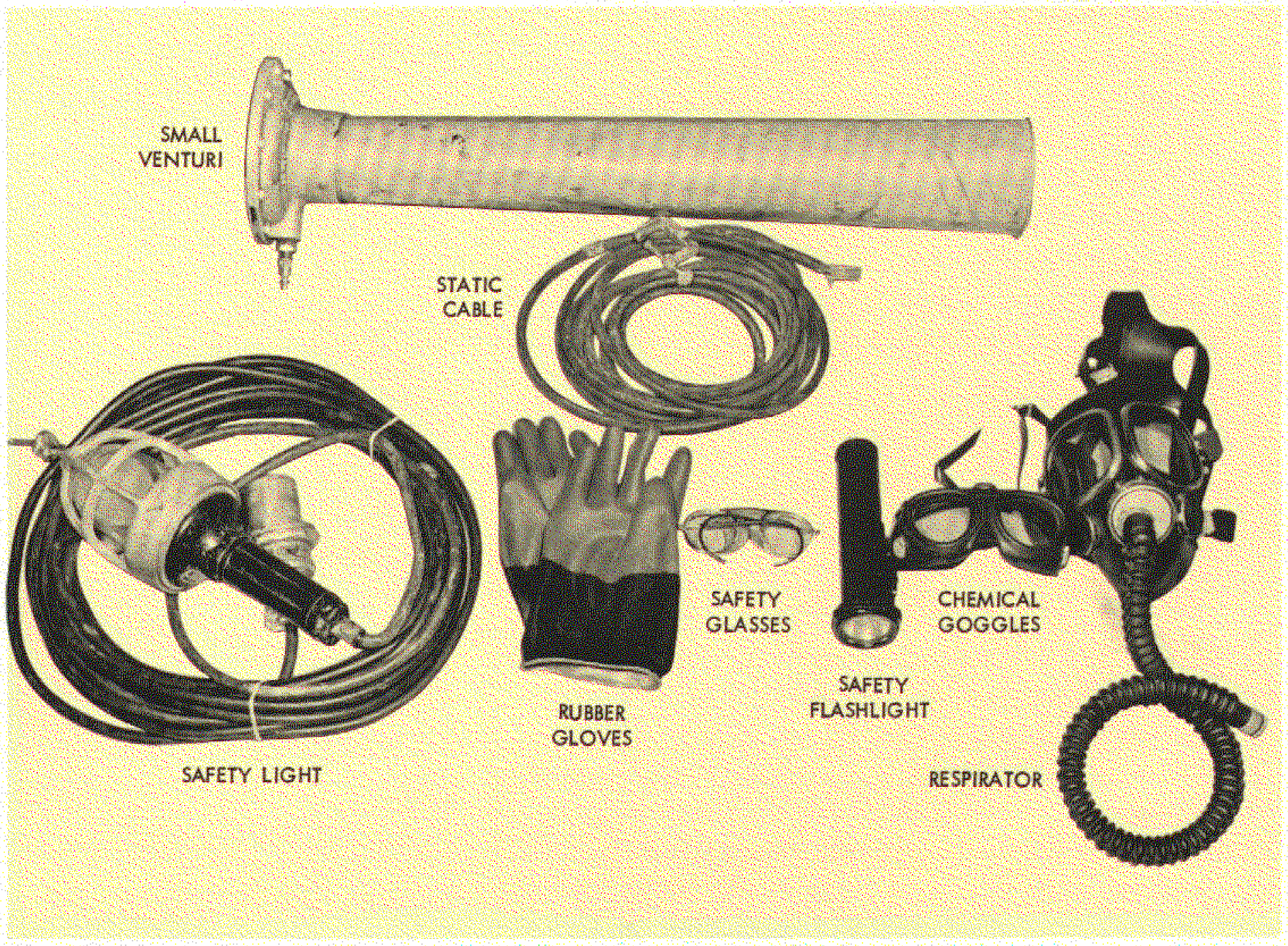
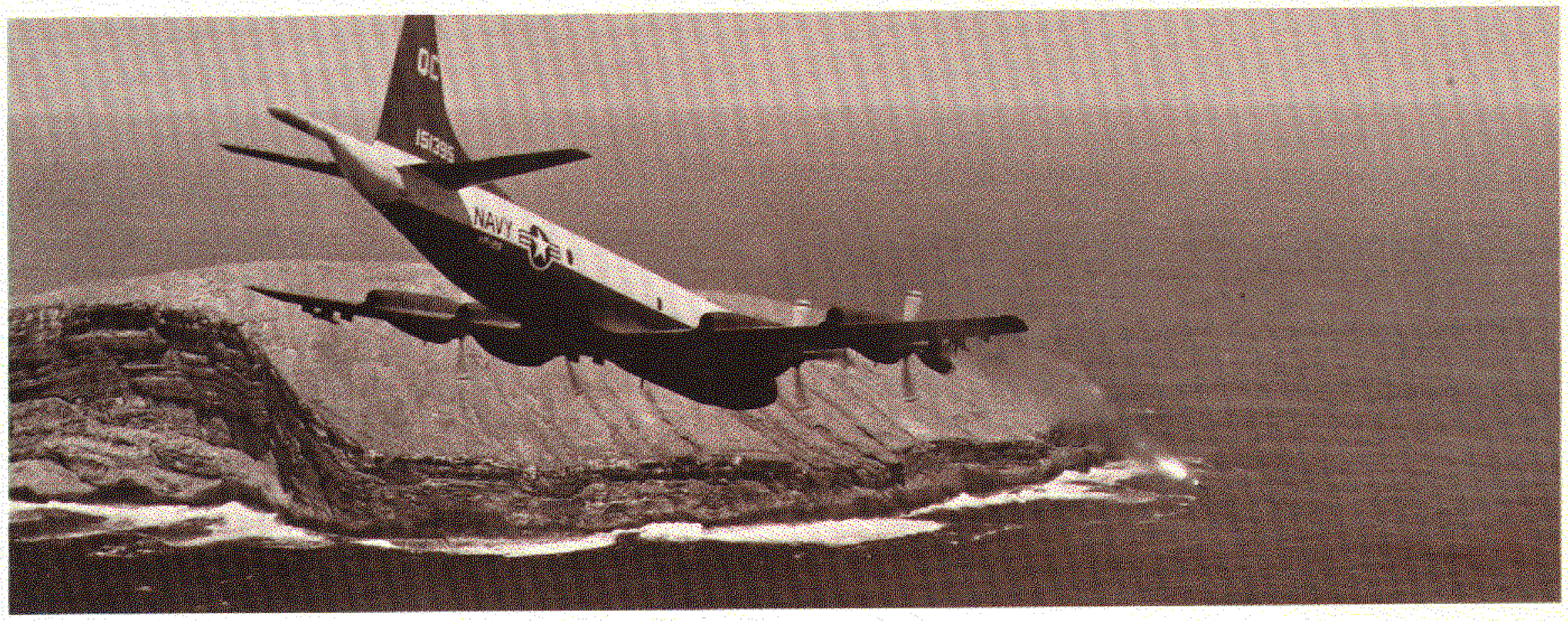


Figure 11
Typical Safety Equipment Used in Connection with Tank Sealing and Repair



The purging will be more effective if the residual fuel in the low spots in the tank is mopped up or removed with an air-driven vacuum cleaner (FSN 7910-632-9840 or equivalent) after the preliminary purging. *Supply fresh filtered air continuously while personnel are working in the tank.*

Air from a compressor should not be used unless it has passed through a filter that will remove all impurities, particularly water and oil. Otherwise, such impurities will be deposited in the tank and will prevent satisfactory adhesion of the sealant.

7. Station a man outside the fuel tank to be responsible for the safety of the man working inside. *Under no circumstances should a man be allowed to enter or remain inside a tank, even for a few minutes, without being in constant visual or oral contact with his "observer."*
8. Wear an air-supplied respirator in regions of high concentration of fumes.
9. Use clean, lint-free cotton rags and wear proper explosion-proof clothing free of exposed steel buttons or belt buckles when working inside the tanks.
10. Remove all loose items from pockets — especially the breast pocket—before entering the tank.

DETECTING LEAK SOURCES In the maintenance of integral fuel tanks there is one point which must be emphasized regardless of how elementary it may seem. That is *if you wish to fix a leak, you must first find the true source of the leak.* To do this, it is very important to be familiar with the wing structure and the possible leak channels such as the areas under doublers, along faying surfaces, end ribs, and the front and rear spar caps. Indiscriminate daubing of sealant at the leak exit point or by guesswork inside the tank will seldom, if ever, solve a leak problem.

The leak exit point of JP-4 or JP-5 fuel is sometimes difficult to determine especially when dealing with minor type leaks. Several methods have been developed for this purpose but one of the most effective is the "paper" test given here for use prior to defueling the tank. Wipe all fuel from the leak area and evaporate the fuel from crevices and seams with an air nozzle held approximately 1 inch from the surface. Move the "fuzzy" edge of a torn piece of absorbent

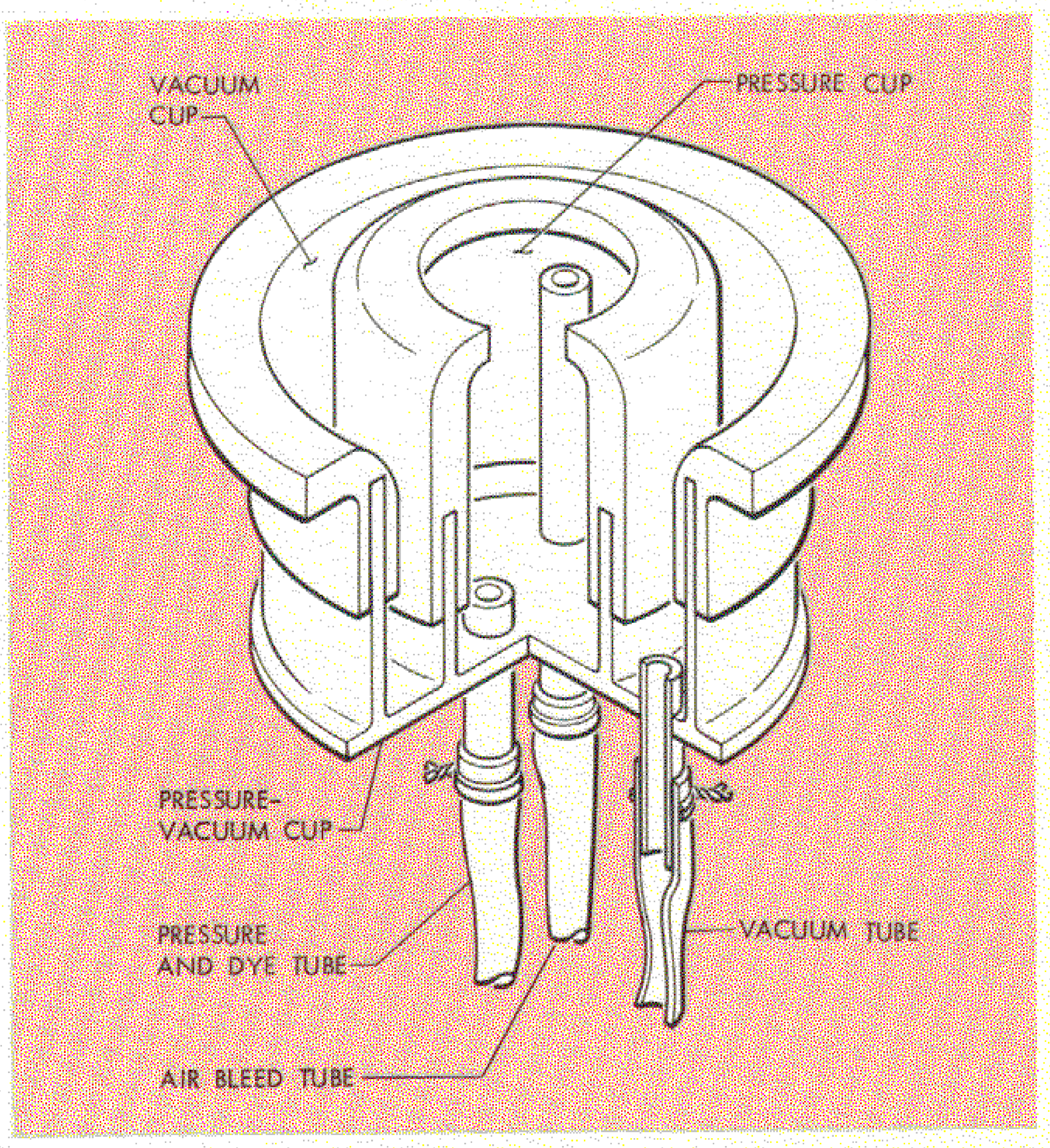


Figure 12 Low Pressure Pot Used for Locating Leak Entrance Point by Dye Injection Method

paper slowly over the suspect area and along the seams. The paper will absorb the fuel readily and give a good visual indication of the leak point. Mark the point carefully for future use and repeat as necessary to locate all leaks before defueling.

A complete leak path analysis should be conducted after defueling and purging the defective tank and before repairs are attempted. Observe all safety precautions during all steps of this procedure.

The first step upon entering the tank is to conduct a visual inspection of the sealant for breaks, tears, nicks or evidence of poor adhesion at or near the externally-marked exit points. Do not overlook the possibility of a leak due to structural damage rather than defective sealant. Once these are marked for repair, determine the entrance point or points for each externally marked leak. These may be at some distance from the exit point and can only be effectively repaired by resealing the entire leak path.

If the leak source has not been definitely established by visual inspection inside the tank, one of the simplest methods of leak entrance-point location is conducted in this manner: Apply non-corrosive leak detector fluid MIL-L-35567 over the suspect area inside the tank. Then while observing this area for bubbles, have an assistant direct air pressure from a hose (90 to 100 lbs. source) held not closer than one-half inch from the exit point. Continue the air application at the exit point while searching for multiple entrance sources. Locate and mark all leak entrance points inside the tank before making any repairs.

In case the leak entrance point cannot be located by the method just described it may be necessary to use the dye injection method for this purpose. This method involves the use of a low pressure pot — not to exceed 8 psi — of the type shown in Figure 12 filled with JP-4 or Isopropyl alcohol mixed with one of the dyes listed in Table I and applied to the leak exit point. Mix only enough dye in the solution to afford easy detection. If Zyglo Z L-2 fluorescent dye is used, a portable, explosion-proof Black light, FSN 6635-999-4172 or equivalent, should be used inside the tank for locating leaks.

Occasionally a leak will occur at a difficult access point where the ordinary detection methods prove to be impractical. In this case the experience and ingenuity of tank sealing personnel may be sorely taxed in finding its true source. It is suggested that a copy of Air Force T.O. 1-1-3 covering Preparation, Inspection and Repair of integral fuel tanks be obtained for reference, since this manual devotes an entire section to leak source analysis.

SEALANT REPAIR PROCEDURES

As stated in the preceding section, the leak source must be definitely found before it can be fixed. Also, the tank sealing specialist is reminded that all safety precautions previously outlined should be carefully observed.

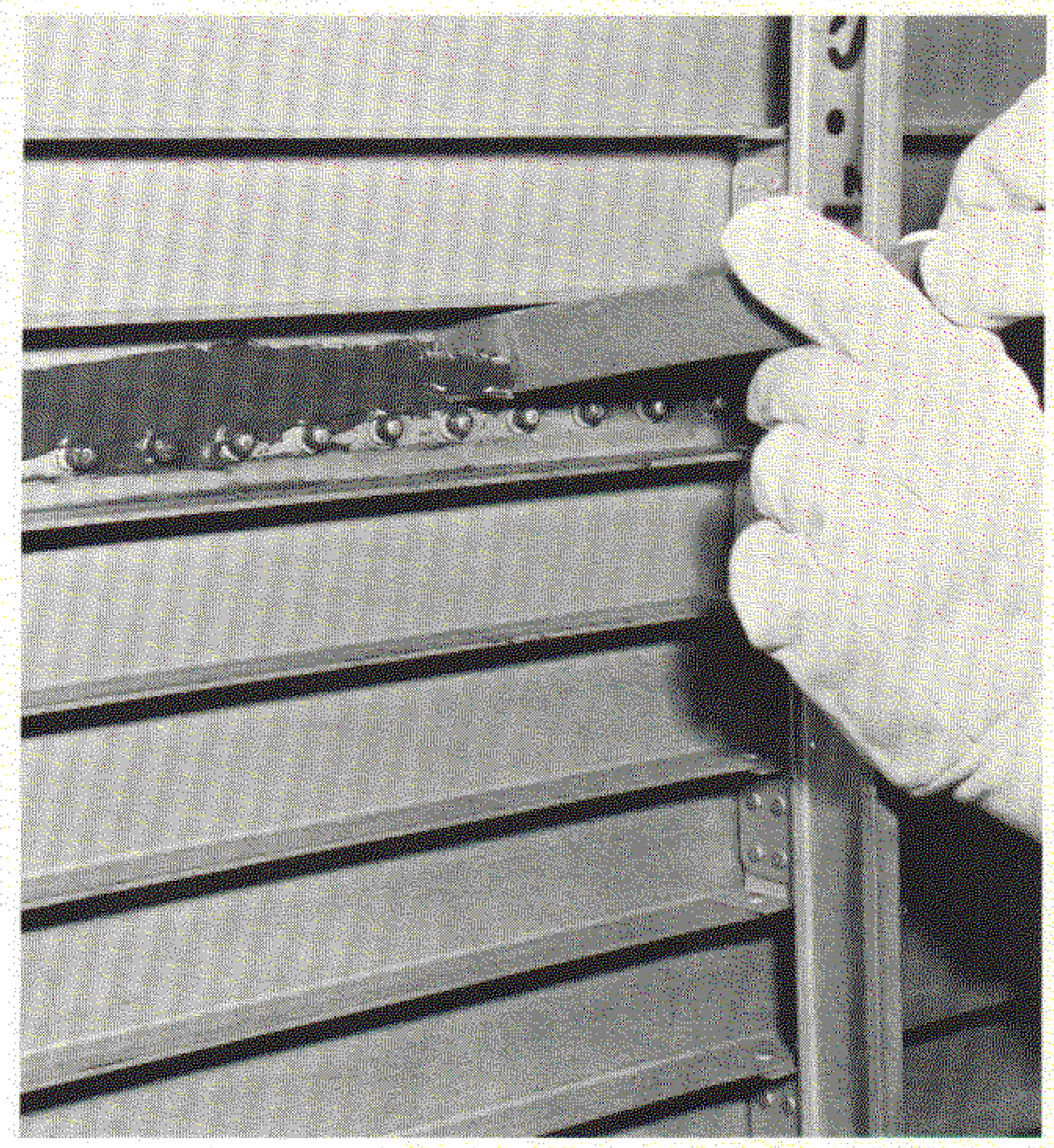


Figure 13 Removing Defective Sealant

EXTERNAL OR TEMPORARY REPAIRS In general all leaks should be permanently repaired inside the tank as soon after discovery as practicable. However, under certain circumstances and conditions, a temporary external repair may be made if it is considered safe to operate the aircraft until regularly scheduled maintenance is possible. The decision to make a temporary repair should be based on safety considerations as determined by the location of the leak exit and the amount of leakage. It is recommended that temporary repairs be kept to an absolute minimum and that such repairs be inspected frequently.

If circumstances indicate that a temporary external repair will be satisfactory, proceed as follows:

1. Clean the fuel tank exterior thoroughly in the leak exit area.
2. Apply a brush coat of MIL-S-4383 cover coating material at the exit point and surrounding area.
3. Allow to air-dry for 1 hour; then apply a second brush coat.

INTERNAL OR PERMANENT REPAIRS All internal repairs on sealant are permanent and should improve on the original sealant in the surrounding area.

1. Remove all deteriorated, blistered, or nonadhering sealant around the leak source. Deteriorated sealant is chalky in appearance and tends to crumble. Use only tools made from hardwood, red fiber, soft aluminum, or other material which will not scratch the metal, damage the MIL-C-554 chemical film or generate static electricity to remove the old sealant (see Figure 14).
2. Taper the edges of the good sealant around leak sources, such as pinholes, as shown in Figure 15. This is done so that the repair sealant can be forced into the cavity without entrapping air in the repair area.
3. Remove all leak detector fluid, dirt, grease, etc., in the area with clean, grease-free, lint-free rags dampened with clean solvent, preferably MEK (methyl ethyl ketone). Do not spill MEK or apply it too freely, as it will attack good sealant and cause new leaks. WIPE the area until it is free of MEK, and then rinse twice with the cleaner mixture cited in Table II. Wipe thoroughly after each mixture application and then allow the cleaner to evaporate until the area is completely dry. The important thing is that all foreign material and fluids must be completely removed. Do not apply the sealant over any moisture. Air should be forced through the leak exit point until any remaining fluid has been completely evaporated from the leak channel.

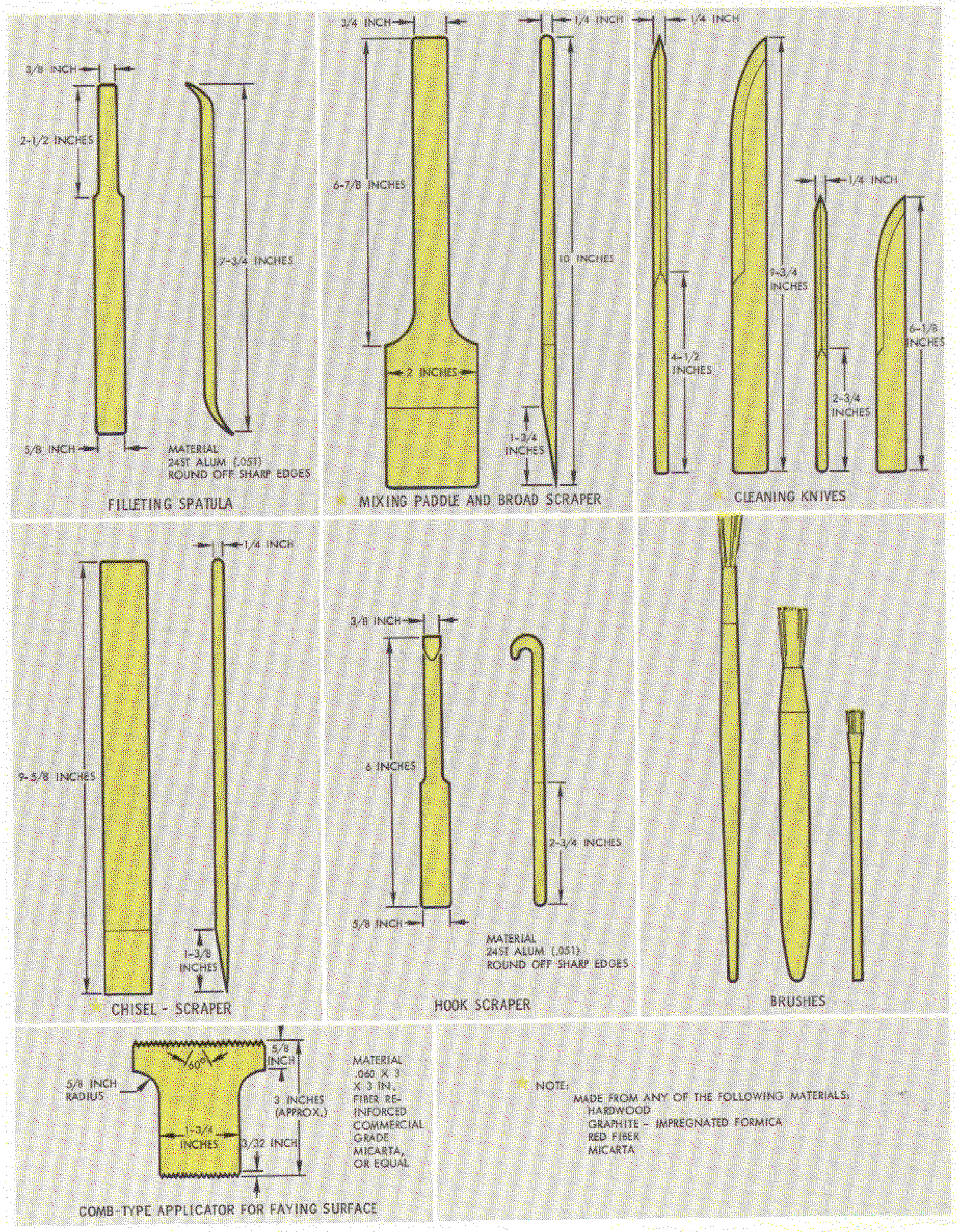


Figure 14
Hand Tools for Sealant Removal and Application

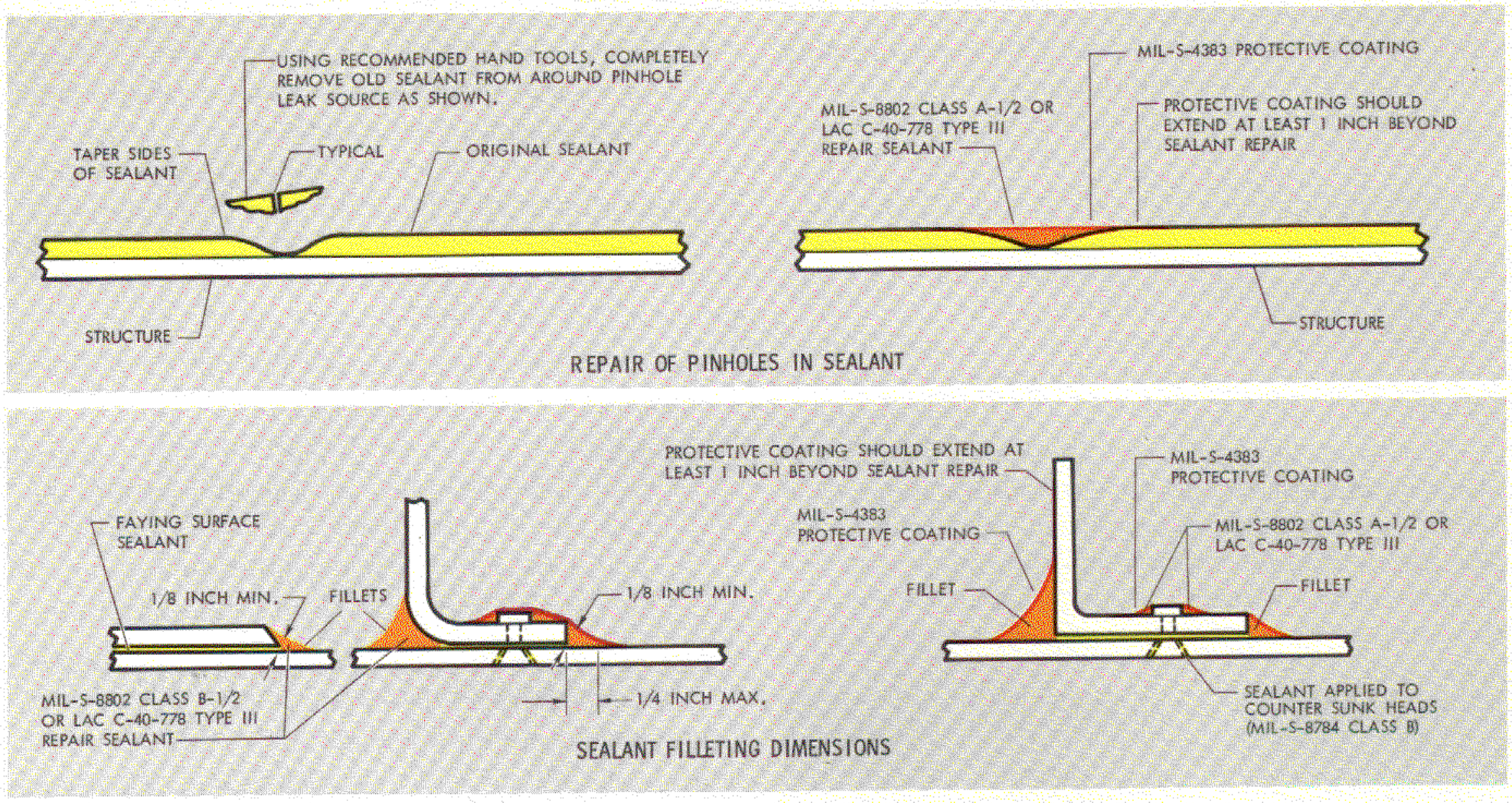


Figure 15 Typical Sealant Repairs

TABLE II

Aromatic Naphtha Type I Grade B TT-N-97	**5 parts**
Ethyl Acetate TT-E-751	**2 parts**
Methyl Ethyl Ketone TT-M-261	**2 parts**
Isopropyl Alcohol TT-I-735	**1 part**

4. Use quick repair sealant MIL-S-8802 Class A-½, Class B-½ or LAC C-40-778 Type III for service repairs. The ½-pint kit will suffice for most repairs.
5. Heat or cool base compound as required to maintain the temperature of the sealant at about 75° F.
6. Mix the accelerator with the base compound as described under "Sealing Compounds." Mix slowly to avoid whipping in air bubbles. Stir until the two materials are thoroughly blended. This should take approximately 5 minutes. It should be noted that mixed quick repair sealant has a short application life (see Table I) and should be applied immediately or the material will become too rubbery to adhere to the repair surface.
7. With a stiff bristle brush, apply a small amount of the quick repair brush material as an adhesion coat to the clean repair area. To ensure good adhesion, rub the material on the structure with a rotary scrubbing motion. For repairs requiring only brush material, immediately apply a second brush coat approximately 1/32-inch thick over the initial adhesion coat. Work the sealant in thoroughly so that no air will be entrapped.
8. For larger repairs requiring the quick repair fillet sealant, apply an adhesion coat of brush sealant as described in the preceding step. Allow a 15-minute air-drying period before applying the fillet sealant.
9. Use a spatula of the type depicted in Figure 14 to smooth the filleting material. The material must be worked into place to squeeze out any trapped air and then must be tapered out so that it fairs smoothly with the original sealant and the tank structure.
10. This final step applies to repairs made with both the brush and fillet quick repair sealants. When the quick repair sealant is no longer tacky, thoroughly cover the repair with a brush coat of MIL-S-4383 Buna-N protective coating. After a 15-minute air-drying period, apply a second brush coat. Both protective coats should overlap the original sealant and cover coat by at least 1 inch. Air-dry the fuel tank for 30 minutes before installing the access doors. Discard all unused accelerated sealant.
11. If the repair is in the lower area of the tank it should also be coated with MIL-C-27725 over the dry MIL-S-4383 coating. The protective coating must overlap the old application by at least 1 inch.
12. Before installing the access doors make one last check for tools or other foreign objects that

might have been left inside the tank. It is wise to count tools before and after repairing tank sealant.

13. Wipe off all fuel and leak detector so they will not be mistaken as evidence of new leaks, and fill the tank with fuel. A fuel soak check lasting 1 hour is adequate for test after repair, and a 15-minute engine run provides an adequate shake test.

ACCESS DOORS

The fuel tank access doors are part of the primary structure of the wing. As such, part of the shear loads carried by the integrally stiffened wing panels are also imposed on the access doors, causing them to flex to some extent. Unless the doors, seals, surrounding structure, and attaching hardware are maintained with

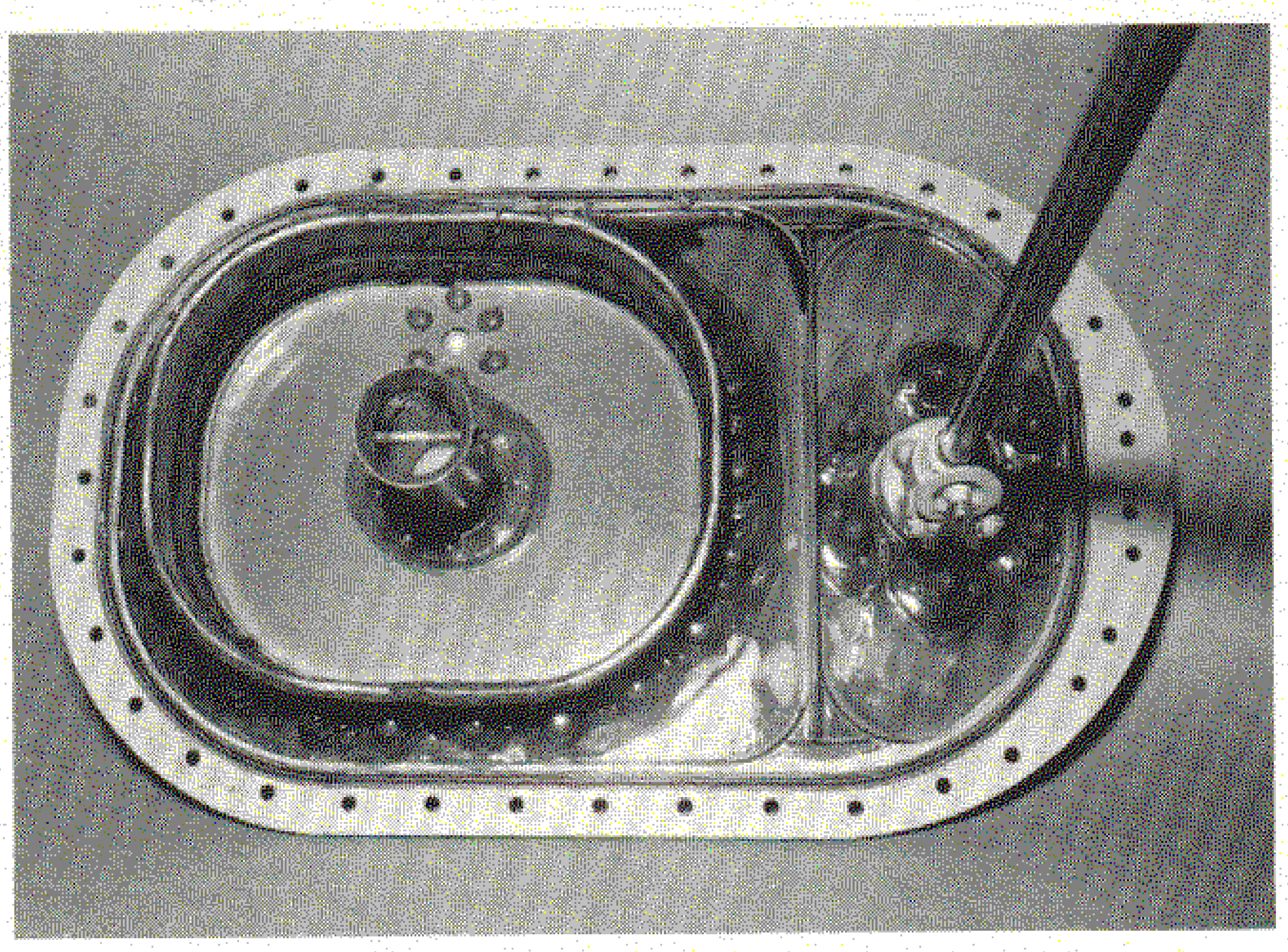


Figure 16 Access Door with Molded Seal in Place and Dome Nuts Properly Brush Coated with Sealant

care, this flexing will cause fuel leaks. For this reason a close manufacturing tolerance must be maintained between the door attaching holes and the relatively large number of attaching screws. Occasionally this close tolerance makes it difficult to install the screws. Consequently, the dome nuts can be forced away from the attaching surface (resulting in fuel leakage) when the screws are started into the dome nuts by force.

In an effort to reduce or eliminate leakage problems in this area, we have outlined some maintenance practices which will facilitate the effective sealing of doors.

REMOVAL AND INSPECTION OF ACCESS DOORS

1. Use an air-driven impact wrench with a correct size *Phillips* tip in good condition to remove access door screws. Some screws may be too tight to break loose with an impact wrench, in which case a large T-handle with the correct Phillips tip may be used. One man should hold the T-handle in alignment and apply pressure while another man turns the wrench to loosen the screw. If the recess on the screw head is stripped, use a small punch to make an indentation in the screw head on both sides of the recess. Then use a light hammer on a small punch in these indentations to rotate the screw.
2. Check the dome nuts for damage or separation from the attaching structure.
3. Inspect the sealant around the dome nuts for cracks, deterioration, or other defects and check that the Buna-N cover coat has been applied. Reseal and cover coat the dome nuts and the rest of the inside surface of the door as required.

INSTALLATION OF ACCESS DOOR SEAL Inspect the molded door seal for defects and if replacement is necessary, proceed as follows:

1. Select a seal that is free of storage deterioration checks and is even and smooth, particularly where the ends are joined together.
2. Remove the old seal from the door groove and thoroughly clean the door frame down to bare metal. Clean the door mating surface but do not remove protective coating unless it is damaged.
3. Lay the new seal in place in the groove and check for proper fit. If the seal is too long or too short (as evidenced by pulling at the corners or bunching), reject the seal.
4. The flat attaching surface of the door seal must be installed evenly in the groove. The following procedure is recommended: Remove the seal and wash the groove and the back of the seal with MEK. After the MEK has evaporated, apply a thin coating of Buna-N to the groove and to the flat side of the seal that contacts the groove. Also cover coat the door surface that contacts the door frame with a coating of Buna-N, allow to dry until tacky and then lay the seal in the groove. Roll the flat edges of the seal with a roller so that they do not project over the edges of the groove. If the edges of the seal are allowed to extend outside the groove, they tend to hold the door away from the frame and thus preclude a leakproof seal.

NOTE

A roller can be made either by bolting a handle to a cable pulley of the correct width or by bolting a suitable handle to two ¾-inch washers spaced the width of the groove. Run the roller back and forth so that the seal will not be stretched in one place and bunched up in another.

INSTALLATION OF ACCESS DOORS Before installing the access door, check that the contact surfaces of the door and the door frame are free of dirt, sand, oil, or sealant that would prevent an effective seal. The door frame should be cleaned to bare metal and should not be cover coated. Apply a thin coat of petrolatum (VV-P-236) to the exposed area of the seal just prior to positioning the door.

New screws of the correct specification should be used to reinstall access doors. If some old screws must be used, inspect them carefully for damaged threads, shanks, or stripped recesses. Damage of any nature is cause for rejection. Before installing the screws, check that they are the correct length for the particular application. If a chart showing screw lengths is not available, use a wire to determine the correct length screw to use in a specific dome nut.

Before placing the door in position, apply a light coating of LAC C-40-769 (MIL-S-8784) low adhesion sealant to the countersunk portion of each screw hole to inhibit corrosion. Do *not* use Buna-N, paint, or any other such material on the screws. A hand screw driver should be used to start the screw into the dome nut. Avoid striking the screwdriver with the hand or exerting undue pressure in an attempt to start the screw into the nut.

After the screws are started by hand, they may be tightened with a properly adjusted impact wrench or an air-driven screwdriver. Tighten the screws in a crisscross fashion so that the access door will be drawn evenly into place.

Special instructions If unusual difficulty is experienced in obtaining a leakproof access door, especially on the outer wing, the operator may use the method described below to effect a temporary repair until such time as a permanent repair can be made. This method is essentially the same as outlined above, except that low adhesion sealant LAC C-40-769 Type I is used between the contact surfaces in lieu of a seal. The door frame contact surface should be cleaned down to bare metal and the door surface cleaned down to the protective paint. Buna-N should not be applied to either surface. The low adhesion sealant should be applied the full width of the contact area on *one* surface only. The door should be installed and the screws tightened while the low adhesion sealant is still wet. The excess sealant that emerges around the access door should then be completely removed. The tank is not to be refueled for at least four hours after the door has been sealed in this manner.

This plan has been used in service with considerable success but should only be authorized when absolutely necessary as the door may be difficult to remove. When it is used, make certain that the aircraft records reflect this information.

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