ORION SERVICE DIGEST

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ORION

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FRONT COVER It is fitting that the Orion should be accompanied in flight by the veteran P-2 Neptune on the cover of this introductory issue of the **Orion Service Digest.** During a continuous production run of more than 16 years, Lockheed has produced more than 1,000 Neptunes. It is now the Orion's turn to take the baton in the ASW race, and continue what has been a long—almost traditional—Navy-Lockheed association in producing ASW aircraft.

BACK COVER Before deliveries of the Orion for operational duties began, the Navy undertook its own extensive aircraft evaluation and test program. Last April, five Orions were delivered to the Naval Air Test Center (NATC) at the Patuxent River Naval Air Station in Maryland, and they were assigned to three facilities: Weapons Systems Test, Service Test, and Flight Test. A sixth aircraft was assigned to the Naval Weapons Evaluation Facility (NWEF) in Albuquerque, New Mexico, where some special weapons tests were conducted.

Forming a back drop to the insignia, is the constellation of Orion. According to Greek mythology **Orion** was, rather appropriately, the son of **Neptune** and a mighty hunter. He was placed among the stars by the goddess Diana where, with the aid of some vivid imagination, he can be discerned as a giant with a girdle, sword, and lion's skin, brandishing a large club before Taurus the bull. The constellation of Taurus encompasses the asterism of the Pleiades, a group of stars representing seven nymphs who were daughters of Atlas. There are many mythological stories involving Orion and the Pleiades, but we thought it was interesting that one of the nymphs was named **Electra.**

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LOCKHEED SERVICE DIGEST
BURBANK, CALIFORNIA, U.S.A.

It was about 8 years ago that the initial issue of our first service magazine, the Lockheed Field Service Digest, appeared. At that time its stated purpose was "to convey timely and accurate service information that will lead to increasingly successful and efficient Constellation operations." The sustained enthusiastic response to this publication, which eventually encompassed the Electra along with the many versions of the Connie, leads us to believe that we are in fact accomplishing the task that was set before us.

With the introduction of a new Navy patrol model — the P-3 Orion — the Lockheed-California Company's Customer Service Division feels an obligation to those charged with its maintenance and operation, and wishes to provide in the Orion Service Digest a separate medium for: interchange of service information, description of helpful maintenance techniques, and presentation of both general and specific technical articles of lasting interest. We hope that this and the succeeding issues of the Digest — which we intend to publish on a two-monthly schedule — will enhance the Orion's effectiveness and efficiency in carrying out Fleet assignments.

We think that through our support of the Orion, Lockheed most tangibly supports a share of the present defense effort, a responsibility as awesome as that borne by any military establishment in history.

Neil M. Harrison, Manager

Customer Service Division

ORION

FOREWORD AND ACKNOWLEDGEMENT

The production problems of this first issue of a new magazine were made particularly difficult by the scope of its subject matter. It was proposed at the outset that we would provide something of interest for everyone concerned with the maintenance and operation of the Orion. While accomplishing this task we also endeavored to tell a story which would be understandable to anyone having some basic aeronautical knowledge. Although the specialist will possibly find herein some sections of particular interest to him, our aim is that he and others will read the complete story of the Orion's development and gain a better understanding of the complete airplane. We hope that the story is interesting enough that this aim will be achieved.

We drew frequently on the good offices of many people in compiling these notes. W. R. Gordon, Orion Project Engineer, and the engineers on his staff provided some basic information, and they and many other individuals reviewed the subsequent preliminary manuscripts — fifty copies in all — which were distributed to Lockheed people and departments concerned with such diverse activities as design, flying operations, research, sales, legal — to name a few. The final result we believe to be technically accurate, and constitutes as far as possible a cross section of views at Lockheed. Inevitably though, the article also reflects the influence of the thoughts and writing styles of the Editors. We mention this by way of explanation for those people who have reviewed our preliminary drafts, contributed comments (of all kinds), and suggested changes which may or may not have been implemented. The following alphabetized list contains the names of those consultants and contributors to whom we are principally indebted:

J. J. Barcellona	J. H. Henning	E. G. Mellon	P. Scelsi
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E. J. Gagnon	R. Lochridge	H. A. Putney	S. D. Wright
R. F. Goldman	J. F. McDonald	Bob Ray	F. Wyche
W. R. Gordon	C. Malkow	D. T. Ross	W. H. Wynholds

It is probable that we have overlooked some persons who justifiably should be included in the above list. Indeed, the manuscripts were circulated throughout many offices, where corrections were made anonymously — to these unknown contributors, we are no less indebted.

It is perhaps not usual or journalistic protocol to credit those who are responsible for the very existence of a magazine, but in this instance it is appropriate. The production of the *Orion Digest* would not have been possible without the encouragement and patience of Mr. Neil Harrison and Mr. Ray Richards of the Customer Service Division.

Roy Blay, Editor

Don Wadsworth, Asst. Editor

part one

HISTORY and GENERAL DESCRIPTION

ON A WARM July day in 1937, the latest in a long line of commercial transports took to the air on its maiden flight from the flying strip behind the Lockheed plant at Burbank. This airplane, the Model 14 Super Electra, was destined for a remarkable future, but not exclusively as a fast 14-place airliner — as its designers had conceived it. It was but two years before Europe was to be plunged into the second World War. In June 1938 — less than a year after the first flight of the Model 14 — the British Air Ministry signed a contract for 250 patrol bombers developed from the Model 14 design and to be called the Hudson.

The Hudson was the first American warplane to fight in World War II and, eventually, nearly 3000 were built for the Allied air forces. These airplanes distinguished themseves in many roles. In particular, the Hudson did yeoman service as a coastal patrol bomber and, in this capacity, it proved its ability to sink U-boats. Thus did Lockheed first enter the field of anti-submarine warfare, and incidentally a Hudson became the first aircraft in history to capture a submarine. This occurred in 1942 when it bombed and strafed a U-boat into submission and circled it until surface craft came along to take the sub in tow.

Historically interesting and pertinent to this discussion, the U. S. Navy's first land-based patrol planes were twenty Hudsons, which were acquired in 1941 and given the Navy designation PBO-1.

Experience with the Hudson was put to good use in the design of the Vega Ventura, which was developed from the Model 18 Lodestar — another commercial transport. Larger, faster, and more heavily armed than the Hudson, the Ventura first flew in July 1940 and, like its predecessor, distinguished itself as an extremely adaptable combat aircraft. Battling submarines was of course only one of the tasks allotted to the Hudsons and Venturas, but they were achieving some spectacular successes.

Developed from the Ventura, the U.S. Navy's PV-1 was a direct result of these successes and for the first time an airplane was designed specifically for the purpose of combatting submarines. It played a major role in halting undersea attacks, particularly in the shipping lanes off the American coast. Towards the end of the war the series that had begun with the Model

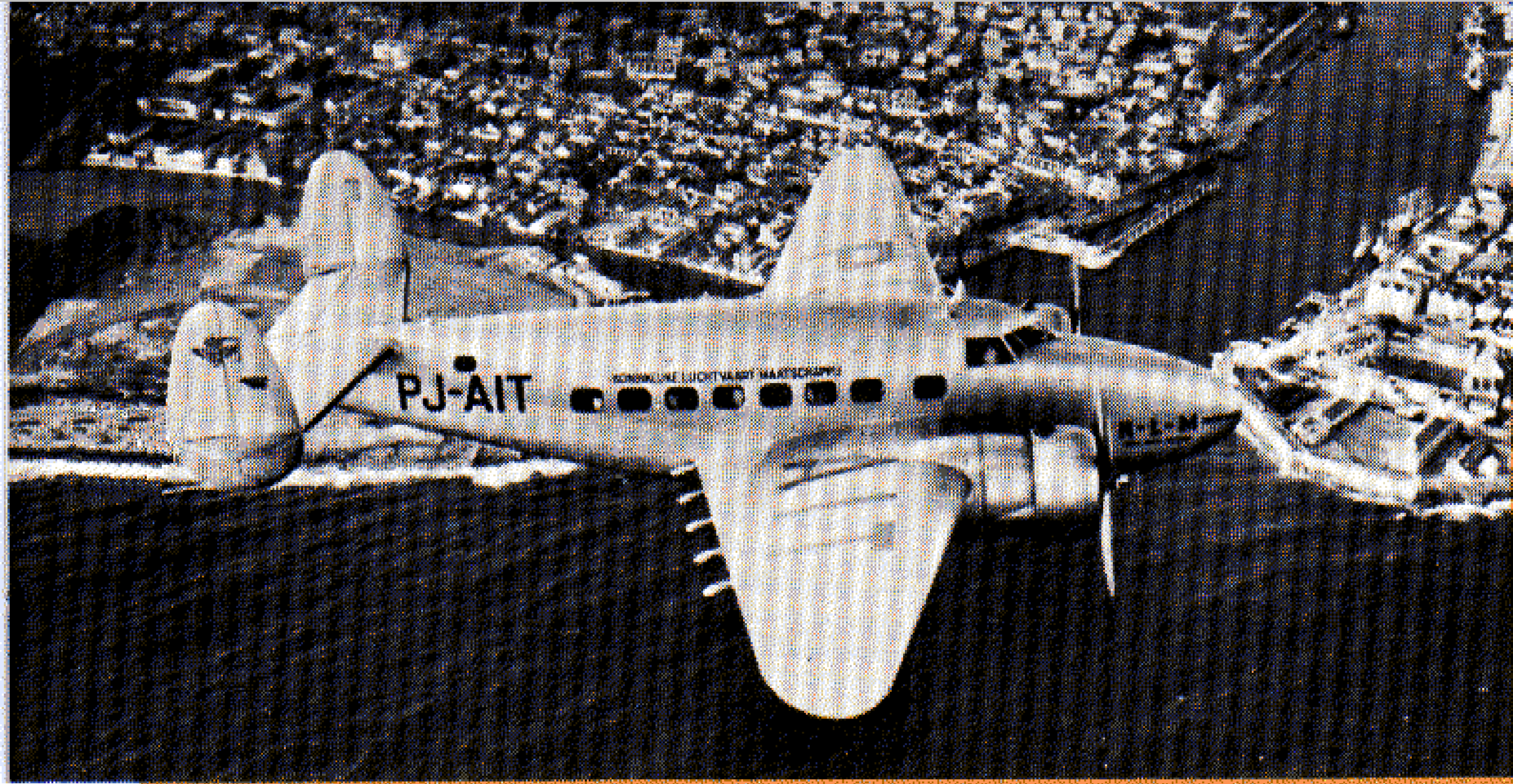


Figure 1 Model 14 Super Electra

Figure 2 PBO-1 Hudson

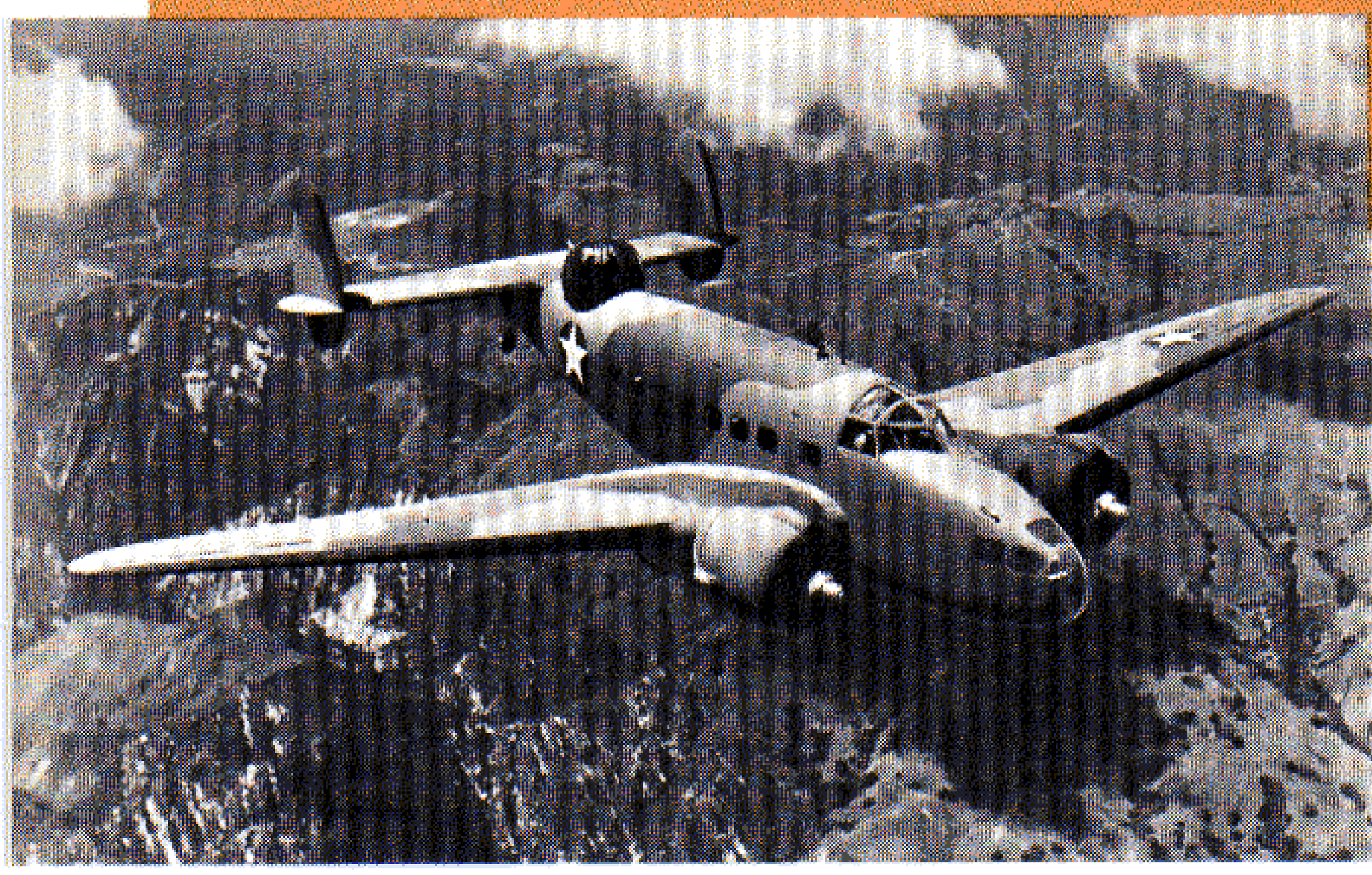
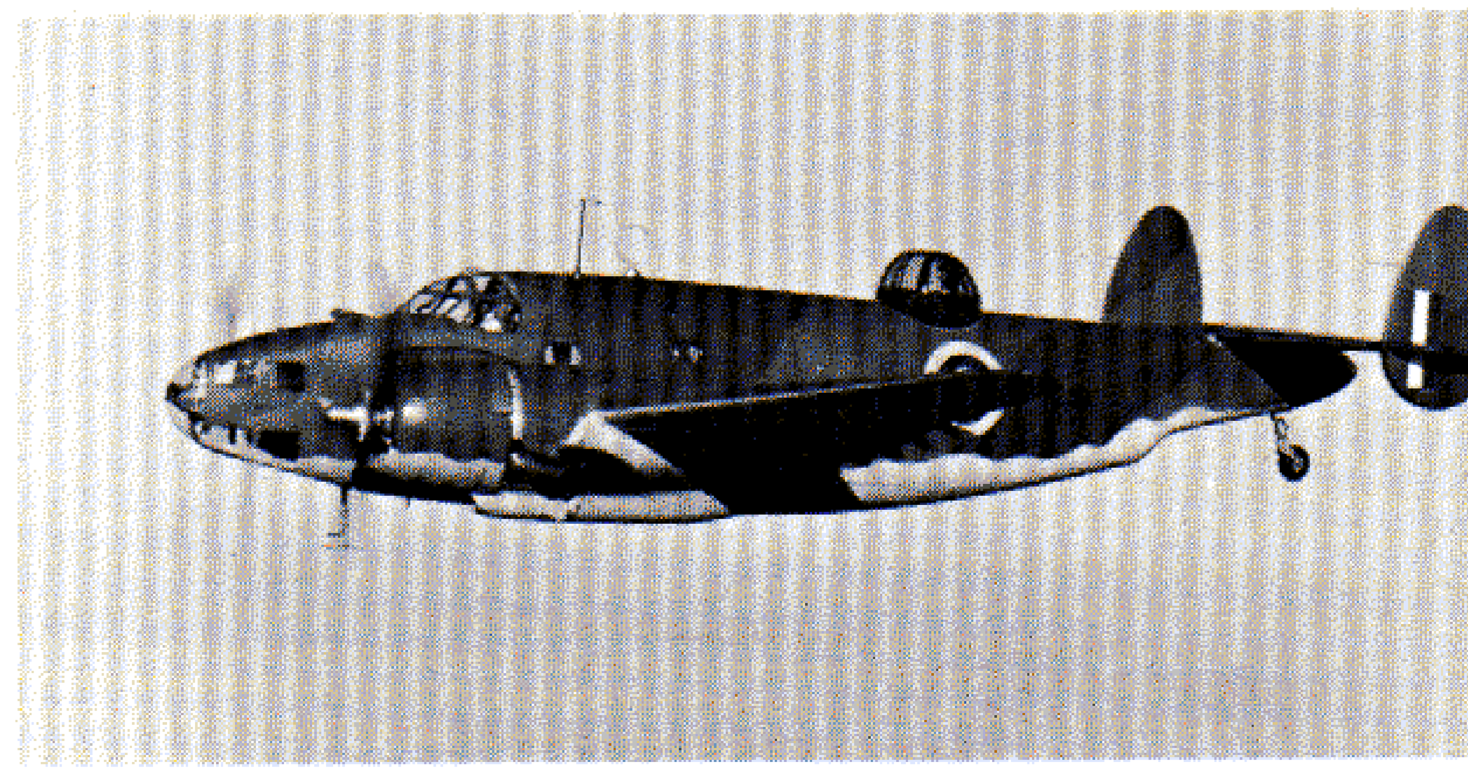


Figure 3 Vega Ventura



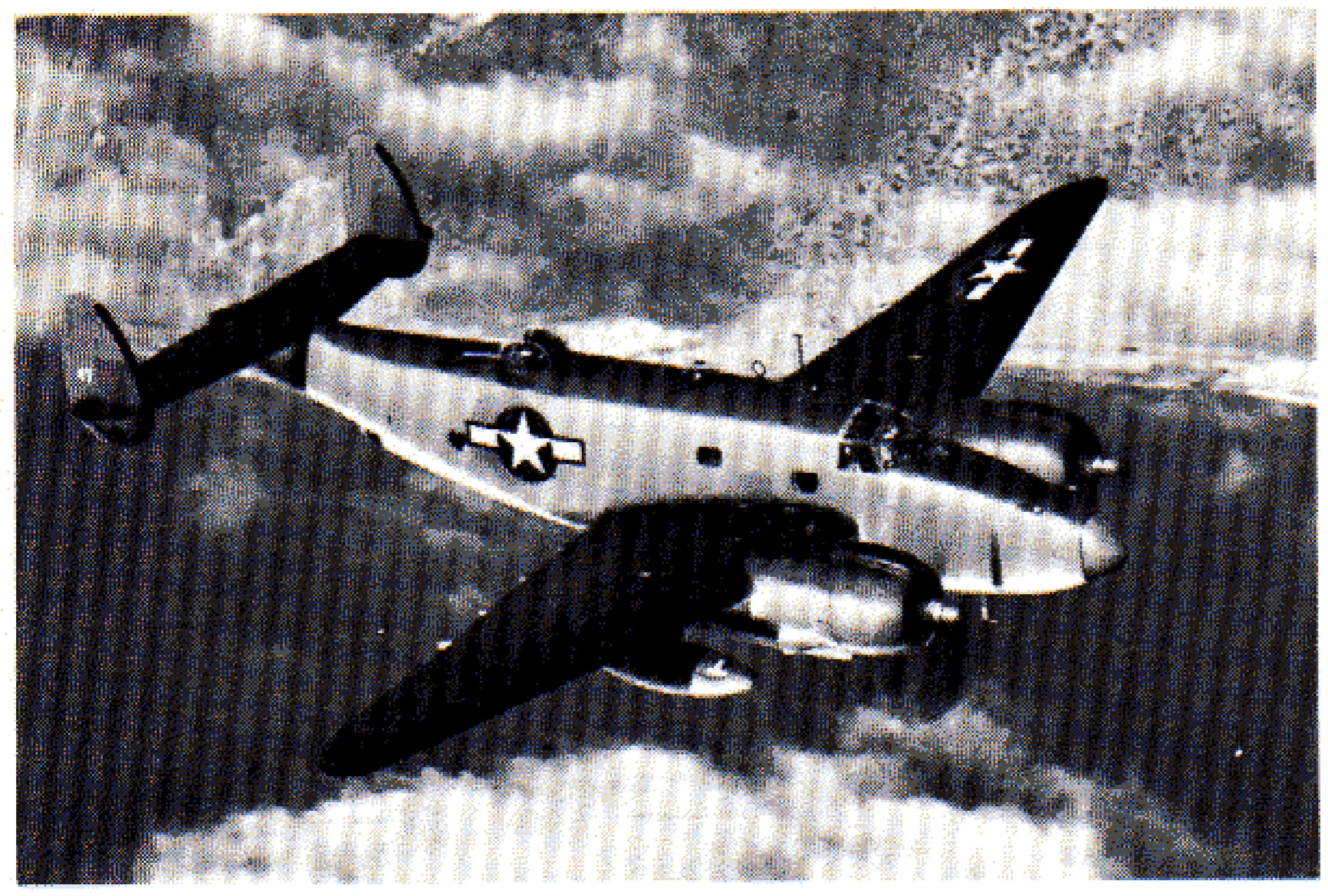


Figure 4 PV-1

14 evolved into the PV-2 Harpoon, but by that time the Battle of the Atlantic had been won.

It is interesting to recall some of the phases of anti-submarine warfare in World War II when the enemy submarine fleet wrought havoc in the shipping supply lines from America to Britain. Despite all Allied efforts, it was autumn 1942 before the output of Anglo-American shipyards began to exceed the rate of sinkings due to U-boats, and even then the shipping losses were still increasing.

However, earlier than this, in the spring of 1942, U-boat commanders returning to their bases on the French Atlantic coast, were reporting some strange occurrences. While on the surface, recharging their batteries at night, they had been suddenly floodlit with what seemed like pinpoint accuracy by the searchlight of a plane and bombed. Up to now anti-submarine patrol bombers had been handicapped by their inability to detect their quarry, but the U-boats were now faced with an electronic target-detecting device small enough to be carried by an airplane. Although initially successful, this first use of airborne radar was quickly counteracted by equipping the U-boats with receivers that gave warning when the submarines were in an attacking airplane's radar beam.

A year later, the most important of further counter-measures by the Allies included the introduction of long range bombers capable of patrolling in mid-Atlantic, where convoys of ships had previously proved extremely vulnerable to U-boat attacks due to lack of air cover. Moreover, these aircraft, and those patrolling the approaches to the submarine bases in the Bay of Biscay, were equipped with a new type of radar which was imperceptible to the U-boats' equipment and enabled the aircraft to locate enemy submarines on the surface without revealing their own approach. It was not until this phase in anti-submarine warfare was reached that the command of the Atlantic supply routes was established, thus setting the stage for a decisive invasion of Western Europe.

This is a measure of the importance of the long-range anti-submarine aircraft. But, future wars are never fought under the same rules as the last. The above historical facts do, however, serve to emphasize one important point. The fight against submarines is not a battle in which the weapons are established; it is a scientific race and we at Lockheed are part of it. Further, it is fairly certain that a future war will not allow one side the necessary time to gain a technological ascendancy if they do not have this advantage in the beginning.

Had World War II been prolonged, the Battle of the Atlantic would almost certainly have entered a new phase. U-boats were being developed with the ability to travel as fast under water as on the surface, and faster than most merchant ships. These sub-

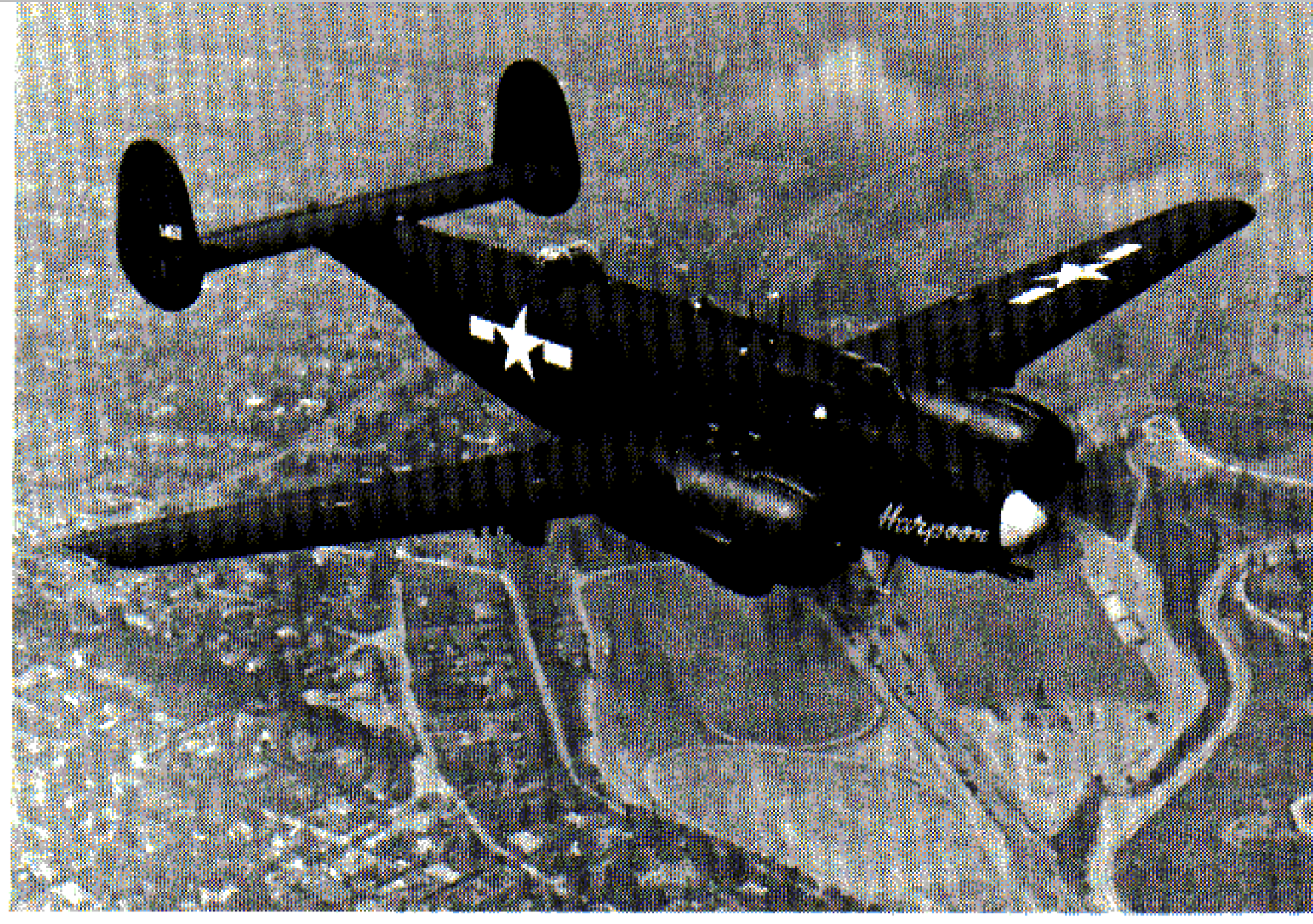


Figure 5 PV-2 Harpoon

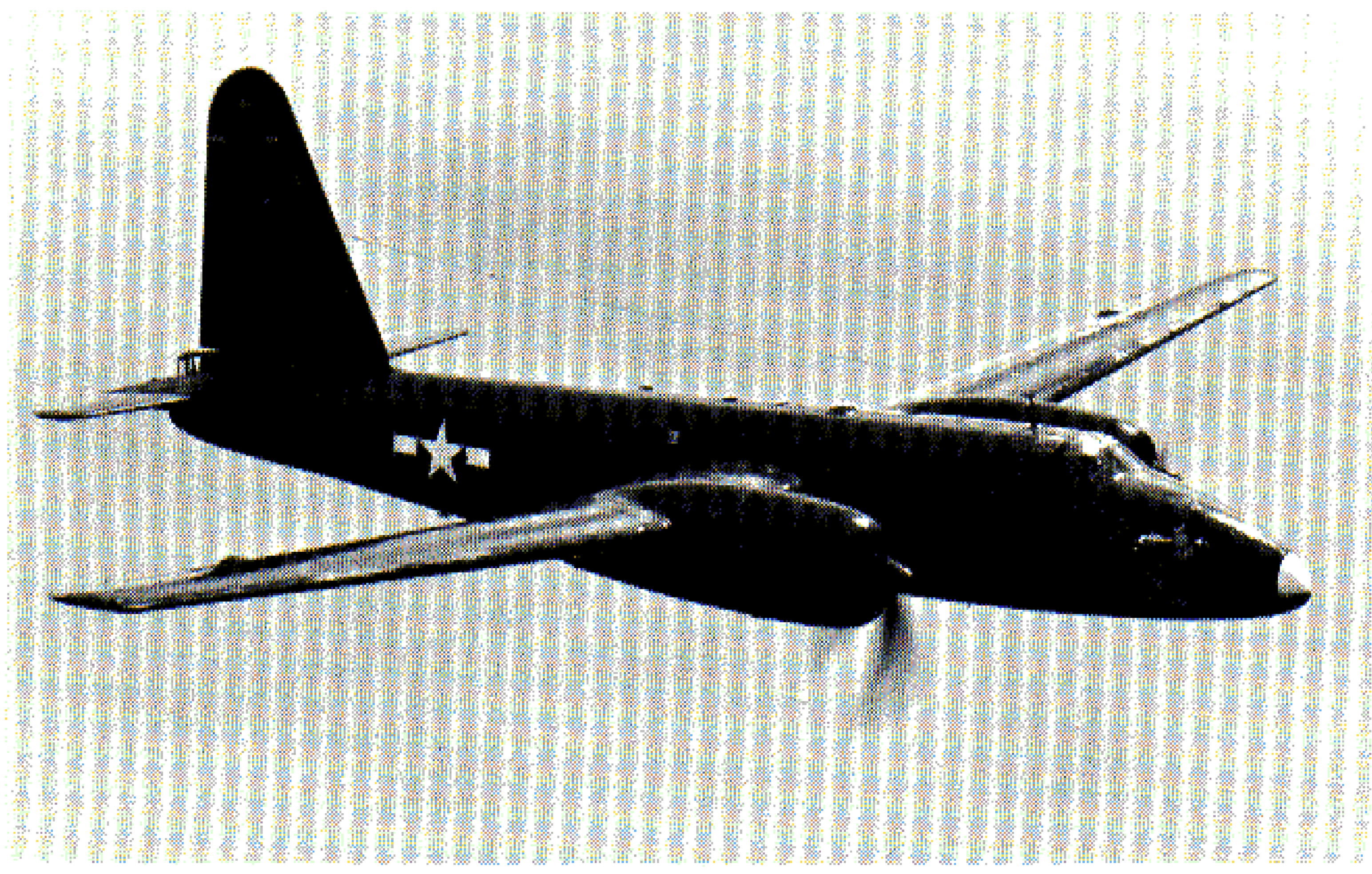


Figure 6 P-2A Neptune

Figure 7 P-2H Neptune

marines also had the ability to stay submerged for prolonged periods, and a new device — the schnorkel — would have permitted them to cruise indefinitely without surfacing. Most of these later developments have since been improved upon and incorporated in the latest post war submarines of all nations. The atomic-powered submarine has also become a reality.

Conceived during the war, the P-2 Neptune and its many variants placed Lockheed in the forefront of post war development of aircraft and electronic devices to counter any new submarine menace. The main requirements set forth in the original U.S. Navy specification for the P-2 were a longer range, a slower landing speed, and a greater armament load than any ASW aircraft up to this time. The P-2 Neptune met those rather exacting requirements and, today, about one thousand Neptunes serve many free-world governments.

In the subsequent fifteen years of P-2 development, there has been an astonishing increase in the quantity and complexity of electronic devices designed to locate and kill submarines. The existing P-2 airframe has managed to accommodate each new development in this field, but this process is no longer feasible in the future. In this same fifteen-year period, aircraft design has advanced to the jet-age, and the performance of the long range ASW aircraft — even a P-2 with jets — could be improved upon. The specification of a P-2 replacement could be summed up simply as being a larger and faster aircraft, without sacrificing outstanding P-2 performance characteristics such as maneuverability, low level performance, and short field take-offs.

We began this introduction with the memorable first flight of a commercial airliner in 1937. In December 1957 — twenty years later — the latest in the same long line of Lockheed commercial transports took to the skies from Lockheed Air Terminal at Burbank. History repeats itself; this airliner, also named the Electra, was destined to become the basic airframe for the latest ASW aircraft — the Orion.

Except for range, the performance requirements of a modern short/medium range airliner and those of an ASW aircraft are remarkably similar in many respects, and increasing the fuel capacity of the basic Electra airframe proved to be no great problem. With the basic airframe configuration established, the design of the P-3 Orion began in earnest — but now we are getting ahead of our story. We should, however, point out at this stage in the discussion that the Orion is by no means a modified Electra, a fact which will be apparent to the reader as this article progresses.

Figure 8
Model 188 Electra

Figure 9 P-3A Orion

ORION DESIGN DEVELOPMENT While the Electra was still getting its finishing touches before entering airline service, new concepts in the tactics of land based ASW aircraft were being formulated. To implement them a speedier and more spacious platform was needed, and, as before stated, neither quality could be obtained economically, and in adequate measure, from the P-2 airframe. Furthermore, due to the many changes it had undergone, the P-2 crew accommodations were less than optimum. There are, of course, many and more subtle factors, all of them embodied in the document issued by the Chief of Naval Operations in August 1957 as Type Specification No. 146; a requirement for a new land-based ASW patrol aircraft.

To the manufacturer who proposed to supply the requirement, Type Specification 146 also embodied some aspects in sore conflict with the airframe industries' hard economic facts of life. It was clearly impos-

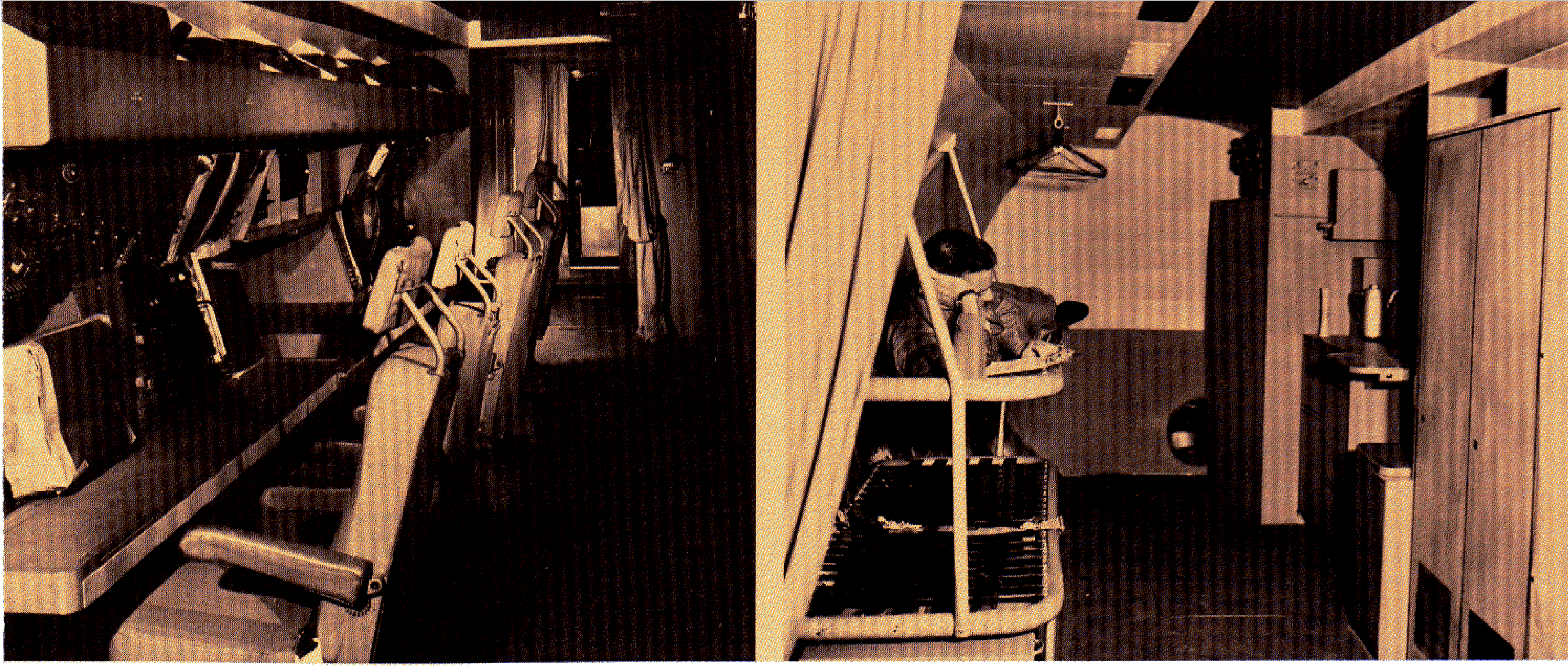


Figure 10 Orion Cabin Mock-up — Fore and Aft Views

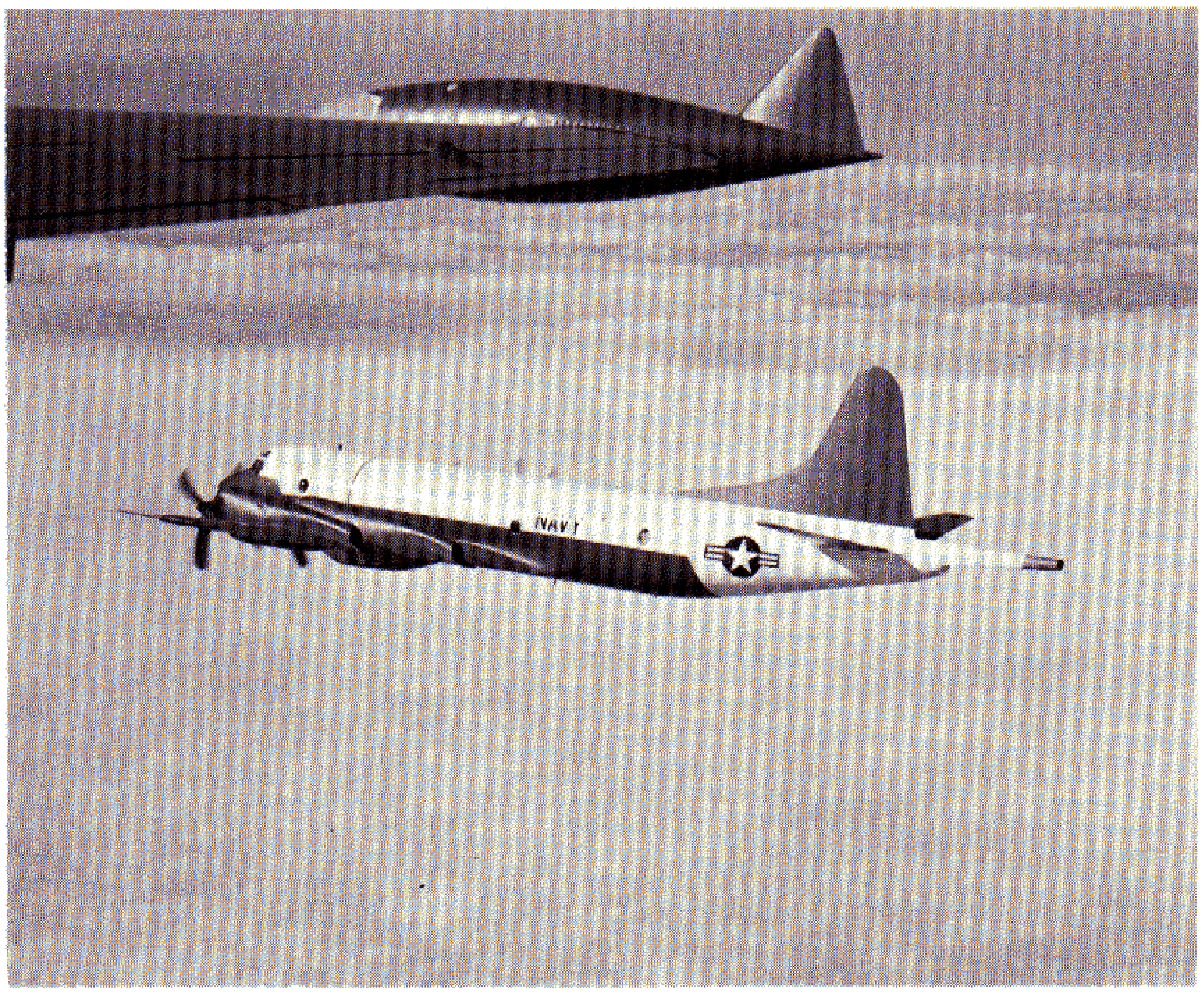


Figure 11 YP-3A — First Flight of Prototype

sible to build a fleet-worthy article and deliver it, when required, in such quantity, at so little cost, if the manufacturer began with just a clean sheet of paper and ambition. Consequently the several major aircraft companies who submitted proposals all tailored them around existing aircraft, and inevitably most of the proposals compromised some of the requirements of the type specification. Lockheed's proposal, based on our new Electra airframe, fulfilled all the requirements.

Two facts were especially advantageous to our proposal: A high percentage of the unique flying qualities required in the new airplane were already engineered and built into the Electra, and we could therefore use more existing tooling and draw on a larger fund of basic development and test data to save time and money than could our competitors. Secondly, Lockheed's long experience with ASW airplanes and techniques gave us a certain insight into the broad problem of this specialized field that was second to none.

Despite these advantages, the stringent requirements of Type Specification 146 were trying, and we did a great deal of soul searching before we deleted some 7 feet of the forward Electra fuselage to save weight. However, this portion of the fuselage was not required and its deletion also improved the aircraft's aerodynamic qualities.

Our proposal won for us a Research and Development Contract, and we constructed an engineering mockup (shown in Figure 10) of our proposed airplane. This was reviewed by a Mockup Inspection Board in September, 1958, and a number of detailed changes were agreed upon at that time. Thereafter, a pre-production contract was let, and work was begun on the "long lead-time" items such as forgings, complicated tooling and the like.

To ensure that new electronic systems were properly integrated and aboard when the new airplanes were ready for delivery, a flight testing vehicle was constructed by modifying an existing Electra airframe. Designated as YP-3A, this prototype made its first flight, on schedule, on the 25th of November 1959 (see Figure 11). We were pleased that, even at this early date, we were able to install production parts in many cases rather than parts which were merely representative of new design elements. Nearly all of the new design in the areas of power plant, armament, air conditioning, structure, and newly designed mechanical components were installed, tested, and developed on the YP-3A in addition to the electronic gear.

Naval Air Test Center (NATC) personnel made a preliminary assessment of the YP-3A in June 1961, and shortly thereafter they made two preliminary evaluations on production aircraft to determine the readiness of the aircraft for the Board of Inspection and Survey/Initial Trials Phase. Changes of a minor nature were recommended and the third and final evaluation was conducted by the NATC in March 1962. Subsequently, five aircraft were delivered to NATC, Patuxent River, with a sixth aircraft going to the Naval Weapons Evaluation Facility (NWEF) in Albuquerque. The BIS/ITP began on 16 April and ended officially on 16 June 1962. Finally, a post-BIS trials conference, held in Washington on 9 July 1962, established the delivery configuration of the aircraft.

As a contractor with a reputation for dependability to uphold, we take a great deal of satisfaction in noting that these trials were successfully completed on schedule — exactly as programmed almost four years earlier — and Squadron VP-8 took delivery of the first three aircraft in the now-established fleet configuration during the month of July 1962.

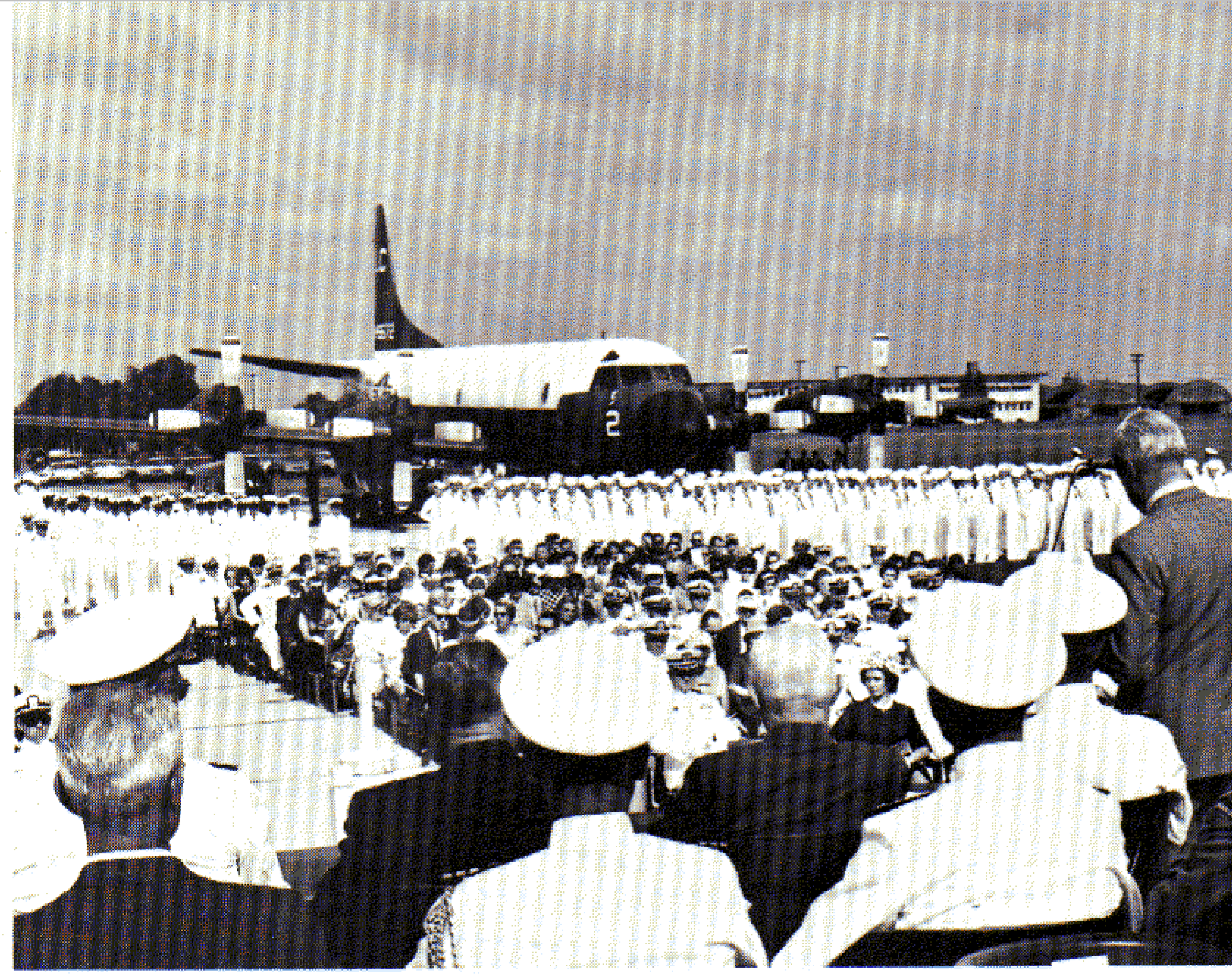


Figure 12 Fleet Introduction Ceremony — Courtlandt S. Gross, Lockheed board chairman, addresses Patrol Squadrons VP-8 and VP-44

Today, the Orion represents the ultimate in an ASW aircraft that Navy and Industry could devise, but the Bureau of Weapons and Lockheed are even now negotiating to further improve the capabilities of the P-3 and maintain its technological ascendancy.

P-2/P-3 COMPARISON

Though the P-3A is now in Fleet inventory, security still restricts us from publishing specific data on performance, electronics, and armament. We can, however, state that the P-3A is designed to get to an assigned area quicker, search out a more elusive needle in a bigger haystack, and hold on target longer than its predecessor.

Maintenance and operational features and the numerous improvements in equipment and crew facilities are less classified and equally interesting to maintenance and operating personnel. The latter part of this magazine is devoted to the layout and operation of the various major aircraft systems. For those who have worked on, or in, the P-2, and know the qualities which made up its character, the following resume will compare some of those qualities as they appear in the P-3 and point up some of the new features which make the P-3 a superior machine for the ASW mission.

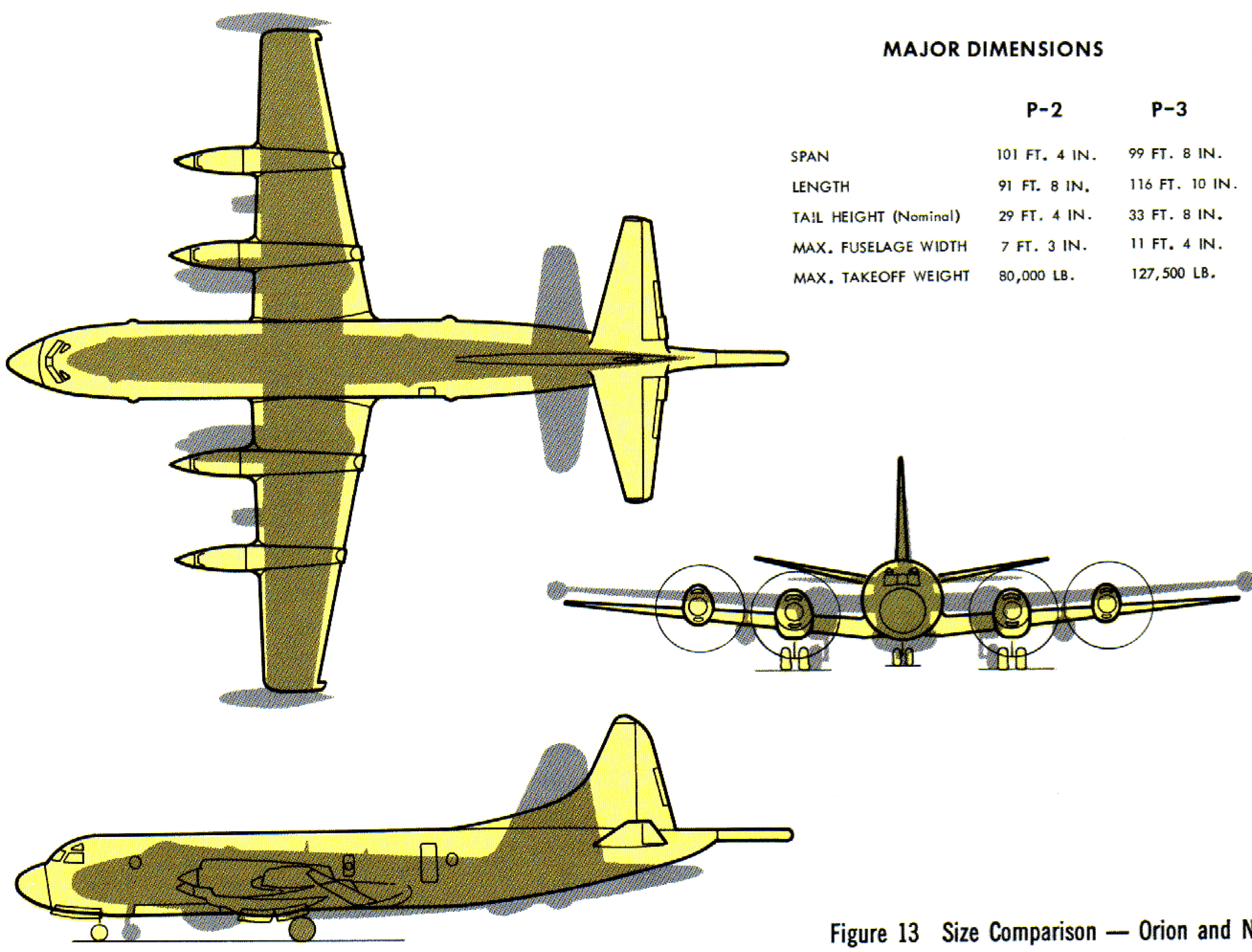
The most significant difference, of course, between the two airplanes is that, while the P-2 is basically a reciprocating-engined aircraft, the P-3 has turbo-jet engines which drive propellers. This raises the question: Why turbo props? Since the prop-jet has been classified by many as an interim airplane in the jet age, this might be an opportune time to answer this question.

The situation is actually analogous to the Electra — appropriately enough — for the prop-jet is still supreme on the short-haul airline routes. The comparison may seem surprising but, as previously pointed out, except for range, the requirements for both airplanes — one military and one commercial — are remarkably similar. A basic characteristic of pure-jet airplanes (including the later turbo-fan jets) is their dependance upon gaining high altitude for acceptable fuel economy—an obviously unacceptable drawback for ASW operations. On the other hand, two characteristics of the prop-jet aircraft are: fuel economy at low altitudes, and superlative airport performance, particularly in terms of short landings and take-offs. These are essential requirements of an ASW airplane and, with the present state of the art, they could not be achieved by using any other type of powerplant, that is, while still making a significant improvement over P-2 performance.

Figure 13 shows some interesting comparative dimensions of the P-2 and P-3 types. The increase in overall dimensions of the Orion is relatively small (wing span is actually less), so that ground handling should not present many more problems than previously, and existing hangar facilities can be used. In some instances, where the top of a hangar entrance will not clear the slightly higher tail of the P-3, sufficient tail clearance can be obtained by employing a special device to lift the aircraft's nose.

Floor space and cabin volume on the P-3 are vastly improved — a fact which will undoubtedly be appreciated by ex-P-2 crews who have spent much of their flying life climbing, crawling, and ducking walking through its confines. The small increase in overall fuselage dimensions is somewhat deceptive, for this small increase together with the change in the fuselage cross-section and the elimination of the Neptune's mid-wing center section, results in the Orion having almost 2½ times the floor area of the P-2 and no less than 3¼ times the volume above the floor. The more-than-ample elbow room on the present configuration allows flexibility for future evolution, and as new or improved ASW equipment becomes available, its installation need not entail "growing pains." Figure 15 shows the general arrangement within the cabin. See also Figures 71 and 72.

The next most important difference in the two aircraft will be especially noticeable to flight personnel and will contribute much to the efficiency of the new anti-submarine weapon. The pressurized air conditioned cabin will materially reduce crew fatigue on long missions, and the forced-air ventilation system for electronic equipment should promote a great deal more trouble-free operation than could be provided on the unpressurized P-2.



MAJOR DIMENSIONS

	P-2	P-3
SPAN	101 FT. 4 IN.	99 FT. 8 IN.
LENGTH	91 FT. 8 IN.	116 FT. 10 IN.
TAIL HEIGHT (Nominal)	29 FT. 4 IN.	33 FT. 8 IN.
MAX. FUSELAGE WIDTH	7 FT. 3 IN.	11 FT. 4 IN.
MAX. TAKEOFF WEIGHT	80,000 LB.	127,500 LB.

Figure 13 Size Comparison — Orion and Neptune

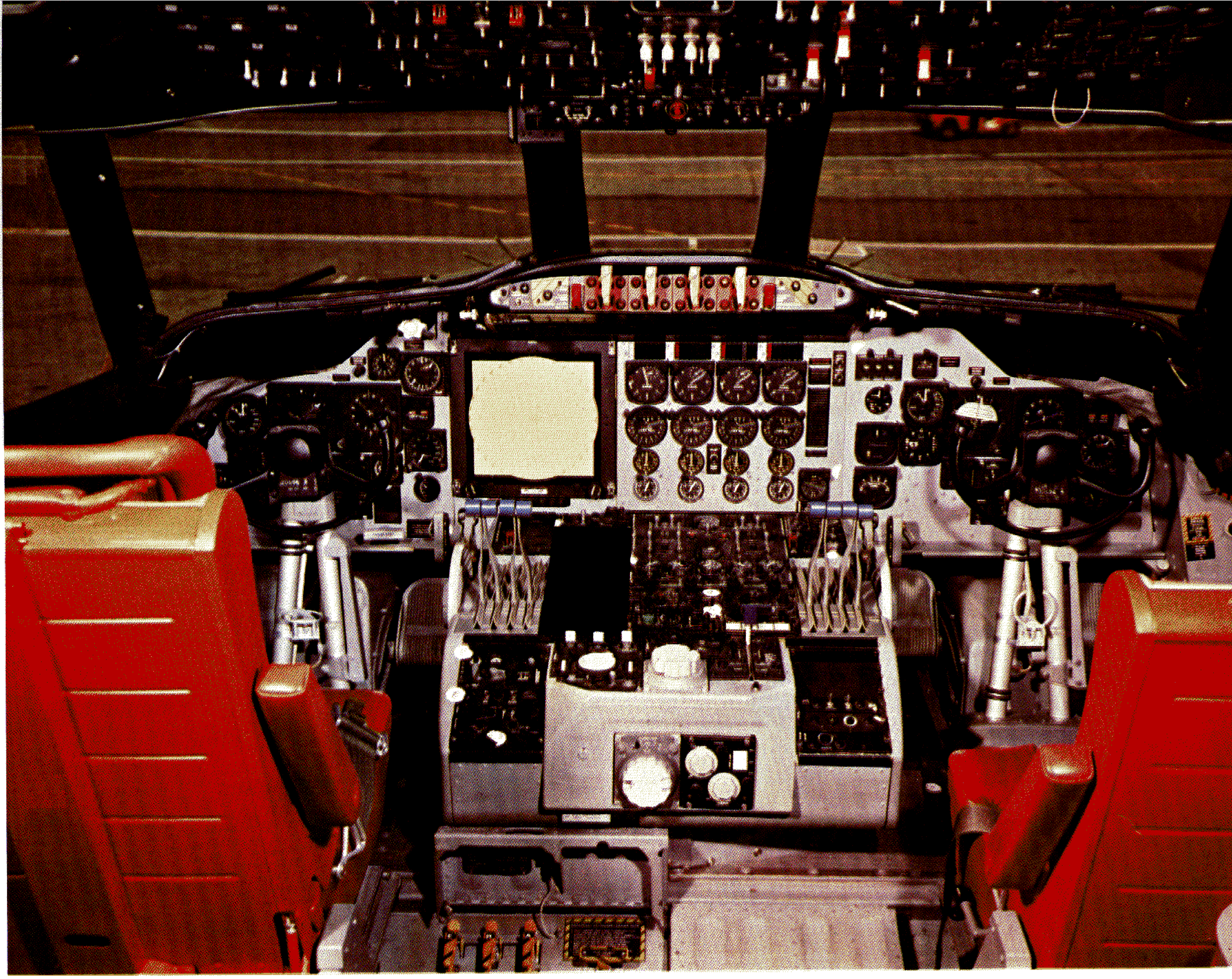


Figure 14 Orion Flight Station — Plane Captain's seat in center removed

The Flight Station is in marked contrast to that of the P-2 and is worthy of some special attention; a general view is shown in Figure 14. As in the case of the Electra, a special design team worked on the cockpit layout and the result is one of the most pleasing and functional flight stations of any aircraft.

The flight deck controls and instruments are arranged so that a pilot and copilot alone can carry out a tactical mission, but the Plane Captain, seated immediately aft of the control pedestal, will normally assume a share of the flight station duties. Thus, whereas the position of the Plane Captain was by necessity rather less than optimum on the P-2, he has now gained a well integrated position on the flight deck — a move of strategic importance. He is ideally situated to monitor engine instruments, annunciator and warning lights, cabin pressurization and air conditioning controls, and also serve as tactical observer.

This three-abreast crew arrangement is a direct result of maintaining the large fuselage diameter as far forward as possible and right up to the pilots station, where the rapid transition of the fuselage from the cylindrical form has many practical benefits, even if it gives the Orion a somewhat unartistic snub-nosed appearance. Another advantage stemming from the wide flight deck is the generous panel and pedestal space that it made available between the two pilots and, although not apparent in Figure 14, most of the controls on the large center overhead panels are within easy reach of all three crew members.

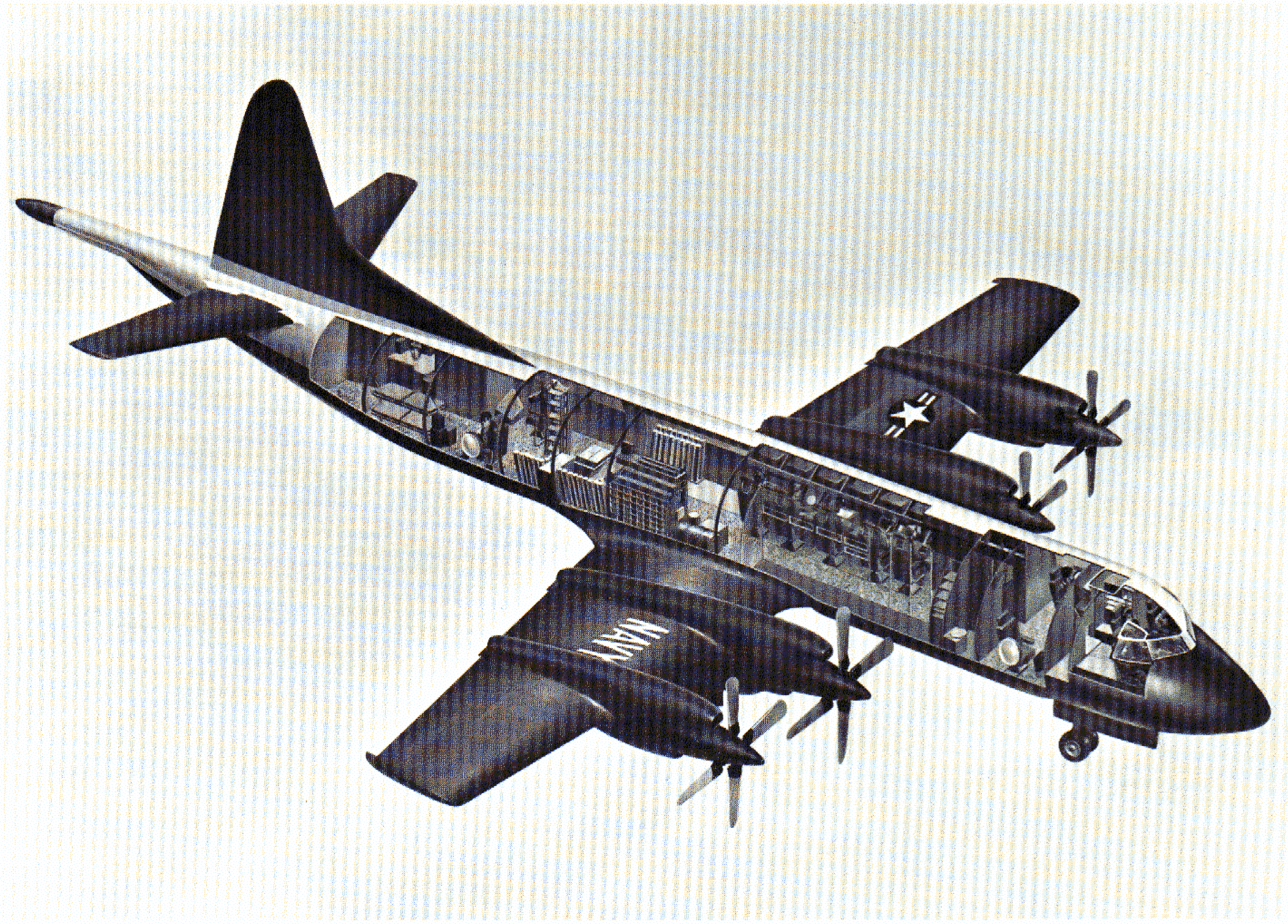


Figure 15 Orion Cabin Interior

While on this subject of accessibility of controls to crew members, certain controls are duplicated due to the wide cockpit arrangement. Landing gear selectors are provided either side of the center instrument panel, and it was also necessary to duplicate the power lever and elevator trim tab controls for the pilots. The power levers are appropriately named — each one performs the equivalent functions of several controls that are commonly used on a reciprocating engine. Using the P-2 reciprocating engine controls as an example, the power lever replaces the engine and prop-reversing throttles, the mixture control, and the propeller control lever. Moreover as a further aid to simplifying the operation of the power plant controls, the four power levers have been carefully designed to fit the average hand, for ease of combined operation.

P-3 engine instruments are of course quite different from those on the P-2; we might just mention that one of the most important instruments is now the turbine inlet temperature gauge (TIT), the purpose of which corresponds very roughly to that of the manifold pressure gauge in reciprocating engine practice. Another important engine instrument is the torquemeter which is calibrated directly in horsepower (at 100 percent rpm) rather than some less obvious indication of power output.

One panel, which is particularly interesting, is located just below the center windshield (see Figure 16). Most prominent on this panel are four handles — one per engine — which control the Engine Emergency Shutdown system. Pulling the appropriate shutdown handle sets in motion quite a series of events including blocking or deactivating everything that can feed or fan a nacelle fire, closing all ducts that might spread fire or fumes to other areas of the airplane, and lastly feathering of the related propeller. The most vital shutdown functions are done mechanically as well as electrically. The pilot who has serious engine or propeller trouble of almost any kind will find a speedy remedy amongst the multitude of functions performed by this system.

Conveniently placed on the same panel as the Engine Shutdown handles are the fire warning lights and the controls for a 2-shot HRD (High Rate Discharge) fire extinguishing system. A few words about this system are in order as there is no equivalent on the P-2. Briefly, there are two identical systems for the port and starboard engines, and each system comprises two electrically-discharged spherical bottles of Bromotriflouromethane (Bromotri for short) located in each inboard nacelle. This extinguishing agent is essentially non-toxic and non-corrosive, and the full contents of one bottle (about 10.5 lb) is expelled by a 600-psi nitrogen charge into all three fire zones of the selected engine in about one second or less after the button is pushed. The discharge button for each engine is located under the related Emergency Shutdown handle, which necessitates that the engine be shut down prior to an extinguishment. The 2-bottle per side arrangement provides a 100% reserve, permitting a second shot if necessary.

Visibility from the flight station, always a design problem on large pressurized airplanes, was outstanding on the Electra and is further improved on the P-3. We could not duplicate the rearward and straight-down viewing capability which the P-2H bubble type "green house" provided (due to cabin pressurization, the necessary pane thickness would have been structurally and optically unacceptable), but the wrap-around windshields in combination with the Orion's snub nose reveal a wide and near-vertical panorama. This is a convenient point perhaps to leave the flight station and draw attention to the four observers' stations in the main cabin which are fitted with convex windows (see Figure 17). Since the range of vision from each of these windows is more than hemispheric, the overall "watch" on the P-3 should be very effective.

The brief system descriptions given in Part Two of this article, will bring out many other differences between the old and the new ASW aircraft, but we have selected some of the more important ones below:

1. The prime electric system on the P-2 is 28-volt direct current, with inverters supplying the required frequency-controlled alternating current. In contrast, all electric power on the P-3, excluding the power obtained from a small battery, is generated as high-voltage alternating current and the necessary direct current power is derived from simple transformer-rectifiers.

   We might also add that the P-3's large power output ac system (any one of three generators will supply all the aircraft loads except under icing conditions) has had a far reaching effect upon all the aircraft's functional systems and represents a new concept in aircraft design.

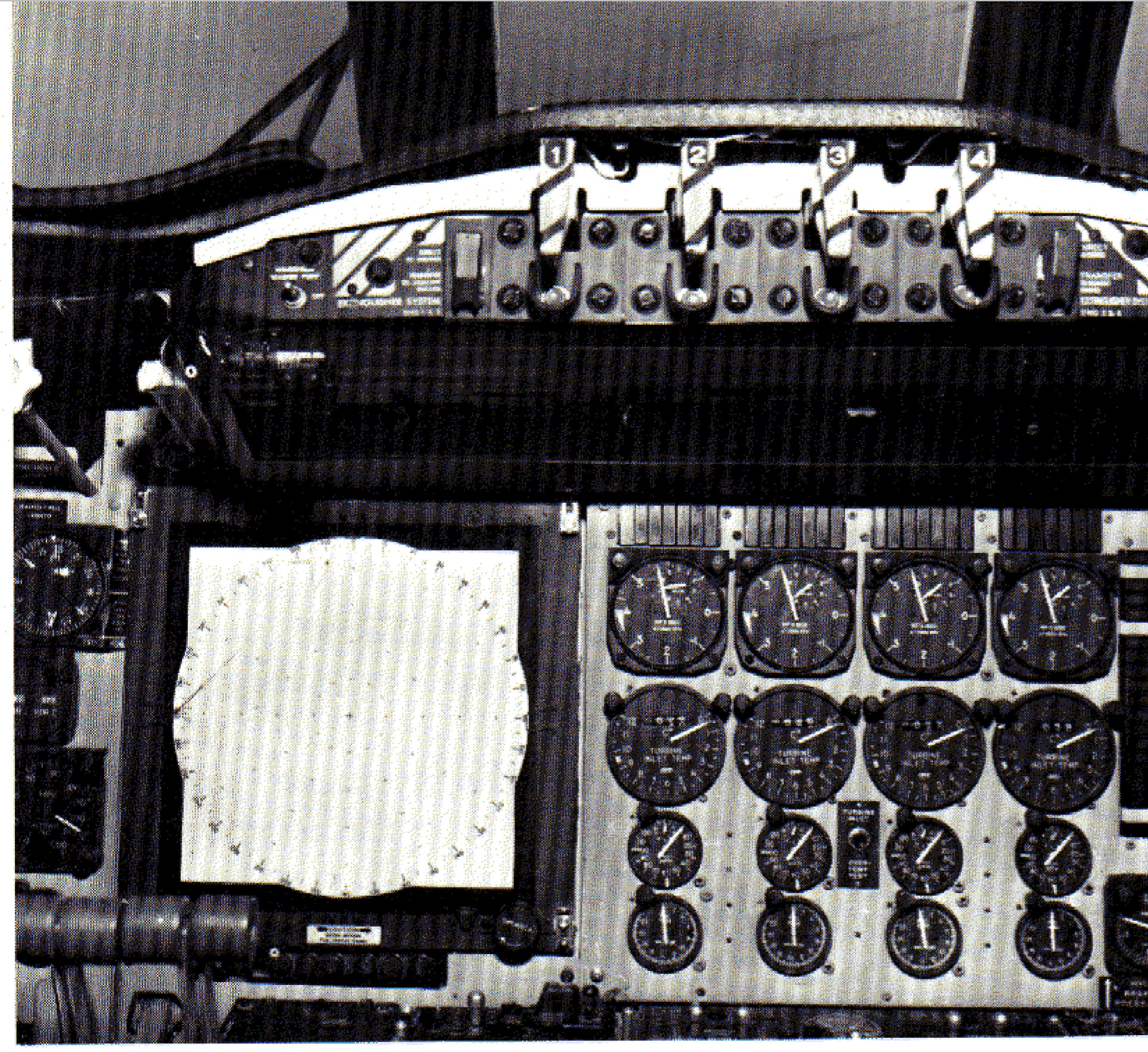


Figure 16 Engine Instruments and Emergency Shutdown Handles

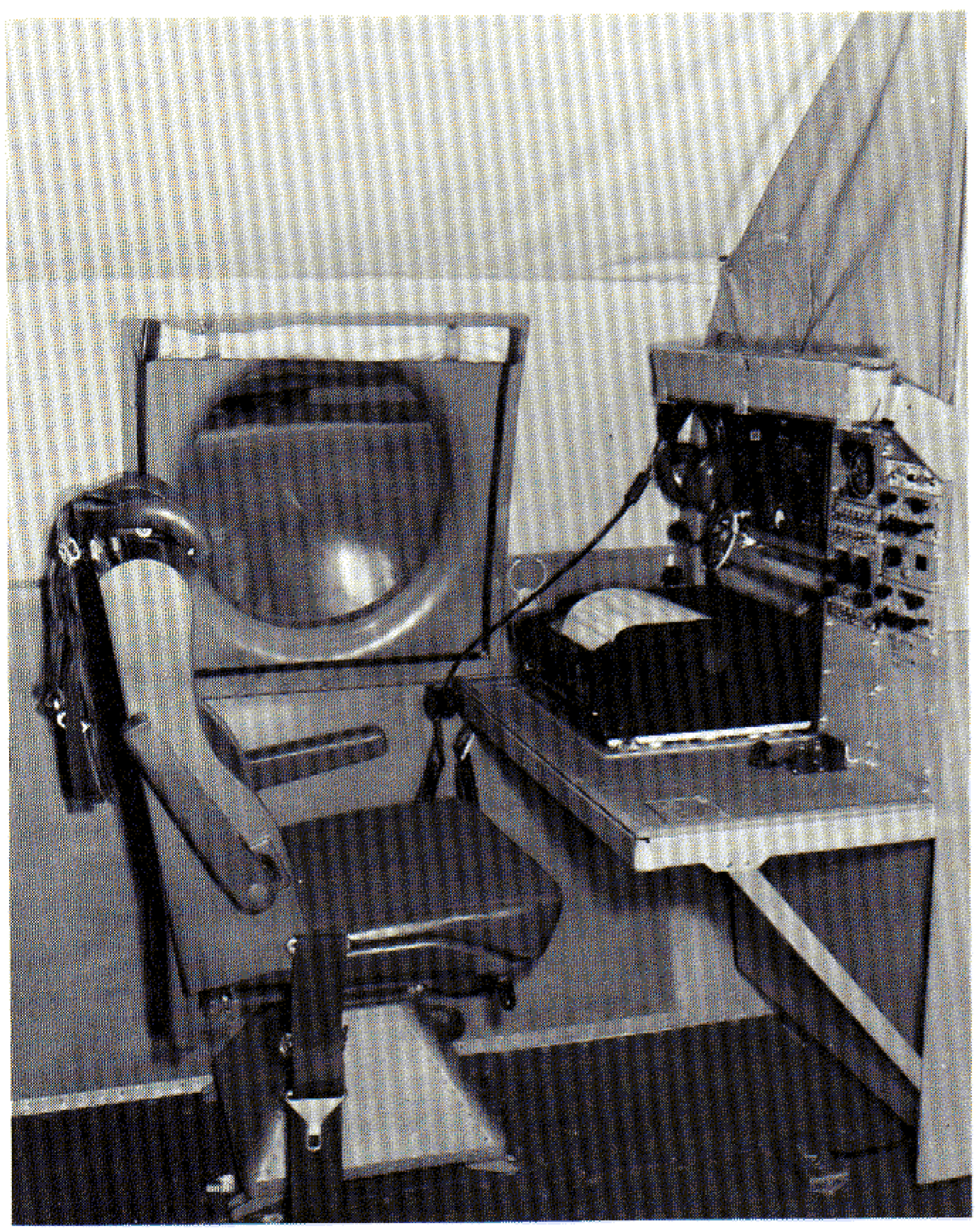


Figure 17 Observer/Radio Operator Station

2. The hydraulic system is quite similar to that of the Electra, which thousands of hours of operations have proven to be a very reliable one. The layout is also similar to that of the P-2, but differs in one important respect: the hydraulic pumps are electrically driven and are located in the fuselage rather than being mounted on and

directly driven by the engines. There are many advantages stemming from this change from the conventional design practice of using engine-driven pumps. The most significant perhaps is that two engines, even three in some instances, can be shut down and the hydraulic system would be unaffected; the pump electric motors are integrated with the electrical power transfer system in such a way that all hydraulic services are available so long as any single engine generator is operating.

3. Flight controls on the Neptune are largely manually-operated, the pilot forces being reduced by the use of servo-acting tabs installed on each control surface. In normal operation on the P-3, the pilot forces are reduced by hydraulic boosters, which are carefully engineered to provide this pilot assistance without sacrificing the normal control "feel" that is so essential for instinctive flying. There are no varicams or spoilers on the Orion, but there is an intriguing device on each elevator called a force link tab, which will be described in a future issue of the *Digest.*
4. An early design consideration of the Electra, which the P-3 inherits, was to make all 3 landing gears of the "free fall" type. This capability was not entirely possible on the Neptune, where the nose gear extends forward, but on the P-3 all of the hydraulically operated landing gears extend down and aft. In an emergency the uplocks can be released mechanically, and gravity and air loads are sufficient to extend all gears and lock them in the down position. We might also mention that the dual wheels on each landing gear make blowouts less hazardous on the P-3 and a fusible plug will deflate a MLG tire automatically if the wheel is overheated by excessive braking. There is little chance of damage resulting if a blown out casing or one with loose tread is retracted into the wheel well, for the main wheels are automatically braked gently to rest when "gear up" is selected.

FLIGHT CHARACTERISTICS

The way in which an aircraft responds to its power and flight controls is probably the most vital aspect of any flying machine, and we can think of no better recommendation than to state that, in this respect the Orion is little changed from the Electra. As the manufacturer, we might perhaps be prejudiced, but our opinion of the Electra is also shared by many experienced airline pilots, and we feel sure that Navy pilots will also recognize these same desirable handling qualities in the Orion.

We have already mentioned that hydraulic boosters are used to assist each primary flight control. It should be noted that the boosters are duplicated and that a manually-operated boost control shift is provided for each primary control so that the pilot can dispense with any or all boosters and revert to pure manual control if necessary. Flying in "BOOST OFF," the pilot has a better mechanical advantage over the control surfaces to compensate for the loss of hydraulic power assistance, but since the total throw of the surfaces is necessarily less, "BOOST OFF" maneuvers must be a little less sprightly.

One significant feature of the Orion is its unique response to power changes, due to the combination

of power plant, propeller, and wing. Since the prop and turbine turn at constant speed throughout the range from full power to full reverse, there is no lag in response due to a change in rpm. The power-loading is low in comparison to most large propeller powered aircraft, and acceleration is correspondingly high.

"NORMAL" engine speed (nominally 13,820 rpm, but varying slightly with different operating conditions) is used at all times, except that "LOW" (72.5%) speed may be selected for use during start and low speed taxi operations to obtain fine incremental thrust control and quieter operation.

The power plants' negative thrust characteristics are particularly pleasing to transitioning pilots, especially those with only turbo-jet experience. The turbo-prop offers excellent braking capabilities which are fully exploited on the Orion.

Propeller braking is especially advantageous for the ASW mission. Patrol craft must carry a heavy fuel load aloft, and consequently they may be expected to land heavier more often. If a high-speed final approach is necessitated due to high landing weight, the very speed that tends to make for a longer-than-normal rollout makes the Orion's wide propeller blades a more effective brake when they are brought into their nearly "flat" ground operating range. At the same time the propellers spoil the wing lift, and the wheel brakes become effective early in the landing roll without need of a separate spoiler system such as most large turbo-jets require. The net result is that the P-3 can, if necessary, land at the maximum gross take-off weight, which is about twice the P-2's maximum landing weight.* And we have demonstrated that at maximum design landing weight the airplane can be landed safely on a 5000 ft runway *using propeller braking only*. Of course, use of the multiple-disc Bendix brakes on the main gear wheels will substantially shorten the roll-out.

In concluding this section, we might also add that the control forces under all flight conditions are moderate with the change in control force per g being almost linear for all configurations. There are no apparent control force reversals or compressibility effects up to the maximum Mach number of 0.711.

**It is always preferable to lighten the load if possible, for unusually high landing weights obviously make hard landings more likely and increase the possibility of the aircraft sustaining severe structural damage.*

MAINTENANCE ASPECTS

During the half-century since Wilbur and Orville closed the bicycle shop, aircraft designing has grown to be a profession requiring ever more formal education, and the designer has had ever less time to gain experience in practical mechanics. Some of the resulting designs fostered a conviction among maintenance people that aircraft designers believed their machinery would never wear out or break down, knew nothing of the human anatomy or of its limitations, and thought that two or more mechanics could occupy the same space simultaneously.

Happily, the trend has been reversed in recent years; ease of servicing and maintenance has received more and more attention on successive aircraft — mostly in detail design. On the Electra, "maintainability" became a primary design objective and had a major influence on the basic layout of both this airplane and also the Orion. This perhaps was to be expected for, in the highly competitive commercial transport field, the time an aircraft spends on the ground is measured directly as unearned dollars and cents, and can be the deciding factor as to whether or not an airline is going to stay in business. Much of the basic thought that was put into the Electra design, and is now paying dividends for the airlines that operate them, has been inherited by the P-3, and the Navy airplane has also benefited from the subsequent three or four years of airline service evaluation.

It was apparent at the outset of the Electra design that much more of the functional equipment would have to be placed in the fuselage than had been usual in previous commercial ventures. The relatively short-span wings dictated that all available space in the wing box beam would have to be used for fuel storage. However, even though the fuselage location of components was partly a forced decision, there was the advantage that many of the units would be contained in an air conditioned environment. At the same time this decision also lent itself to the service center concept of design, which dictates that various systems be logically separated and properly grouped from the viewpoints of specialized equipment and trade skills.

Although the Electra's functional systems have undergone much redesign and reorientation for use on the P-3, the service center concept has been retained, and the result is that the cognizant Navy ratings or system specialists can work simultaneously without interference. The several work areas are located and planned for convenient access (without stepladders and aero-stands in most cases) and those items requiring the most attention are the most accessible. Figure 18 shows the location of the various major work areas.

The hydraulic service center occupies the same position as on the Electra and is situated below the floor, immediately aft of the wing center section (see Figure 60). It is in a pressurized area and has two

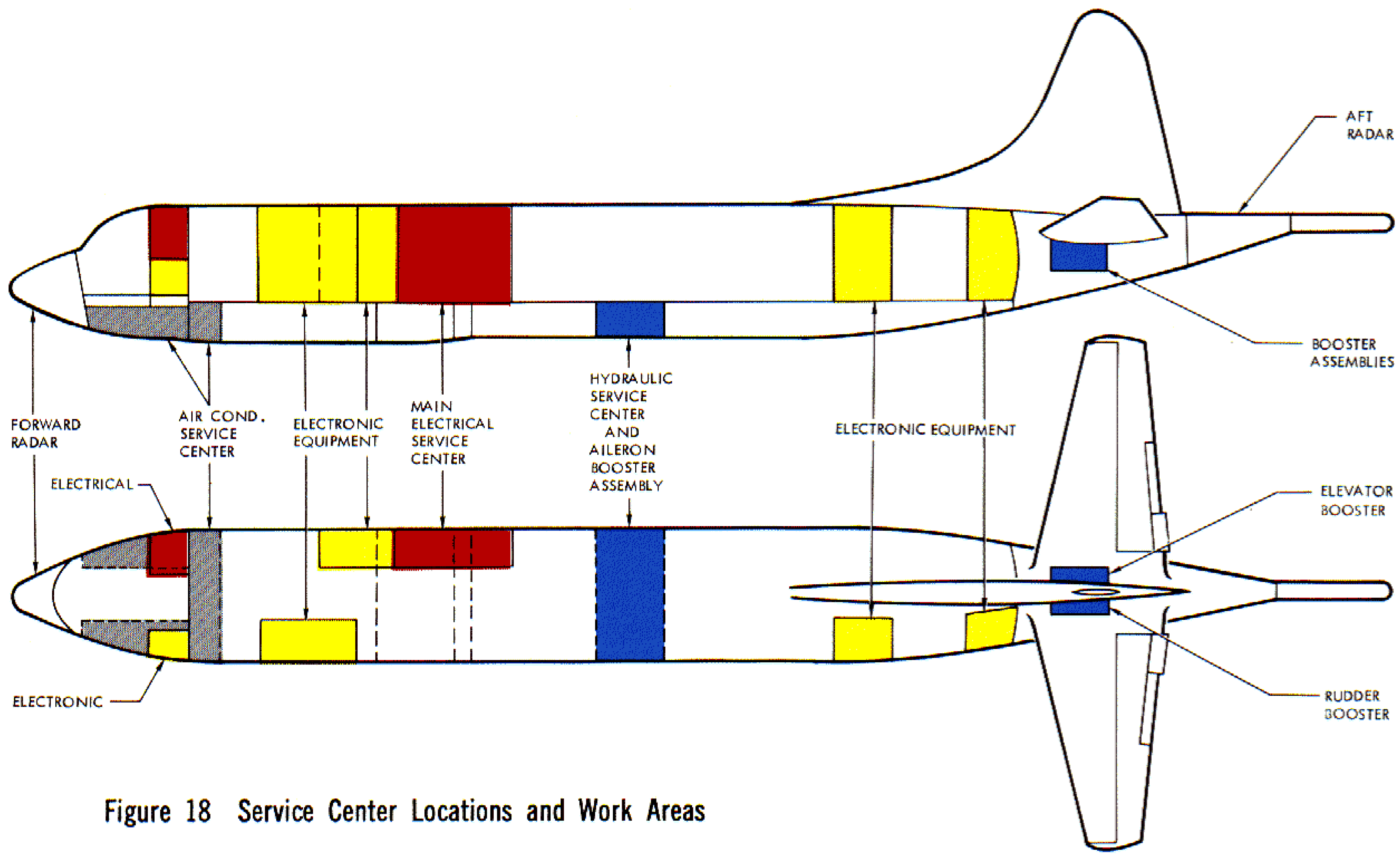


Figure 18 Service Center Locations and Work Areas

access doors making it accessible both from the ground and inside the aircraft. This area selection is logical since the aileron hydraulic booster assembly and wing flap hydraulic drive mechanisms have to be located centrally at the wing rear beam.

On the Electra, the main electrical service center occupies a position below the floor and forward of the wing center section. However, this space was not available on the Orion and, in any case, the ample room in the P-3 cabin offered an opportunity to provide a service center with even better accessibility and servicing features. The P-3's main electrical load center is located on the forward starboard side of the cabin. The components are arranged in racks within a paneled enclosure. A door is provided, allowing access to the inside of the electrical service center (see Figure 19), and the components are therefore readily accessible and can, if the situation should ever warrant it, be maintained in flight. Mounted on the racks are the various generator control system units, transformer-rectifiers, relays, and other items which compose the basic ac electrical power system. This also includes the main buses and circuit breakers for the principal circuits, and the main bus transfer relays.

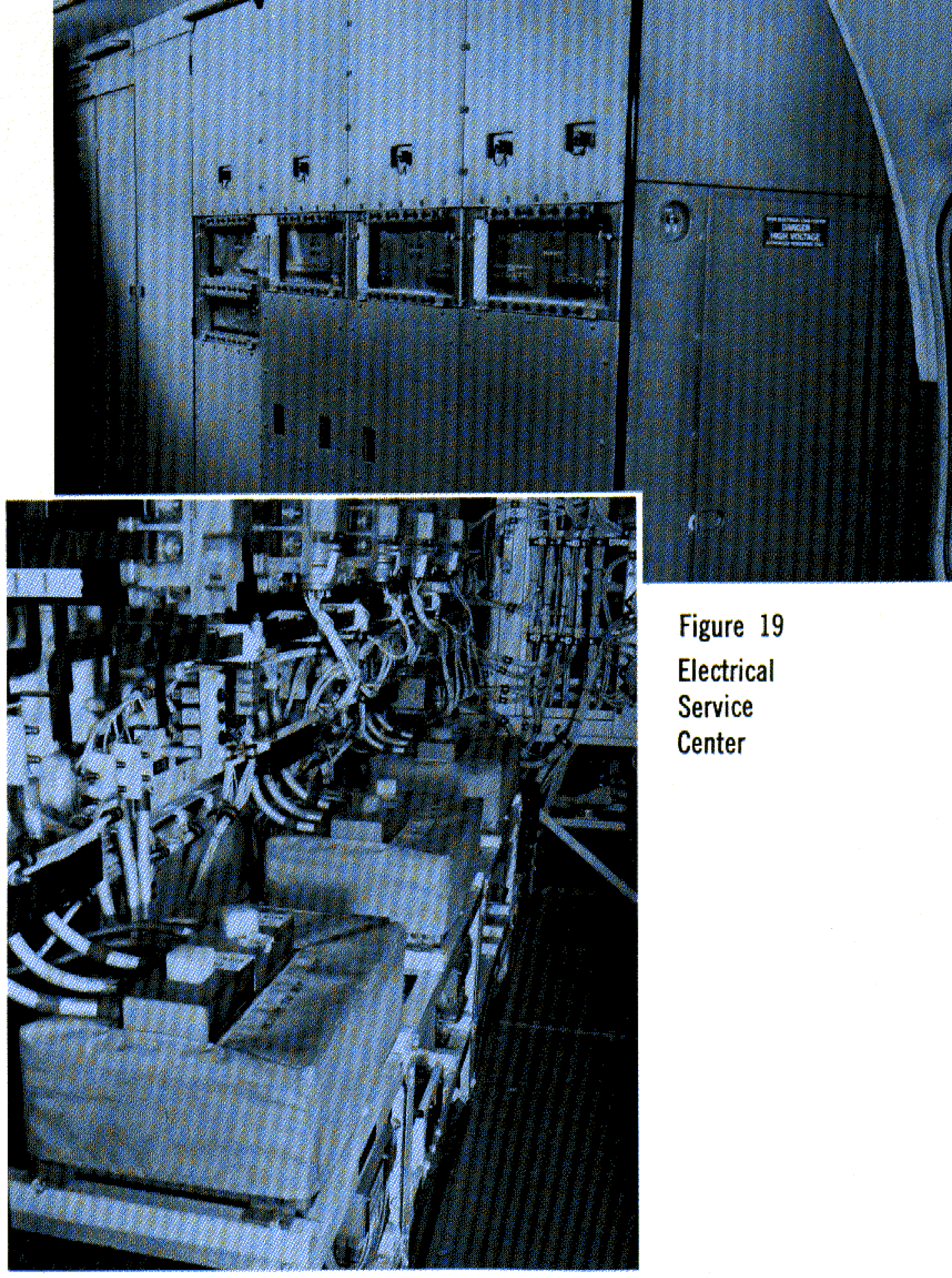


Figure 19 Electrical Service Center

To avoid running numerous feeder wires from the main service center to the flight station, an electrical sub center has been established in the aft starboard corner of the flight station. The essential ac and dc buses are located here together with their associated circuit breaker panels and relays. Other components include an inverter and a transformer-rectifier.

On the port side of the flight station is an electronic service center which contains equipment connected with radio and navigation. As is to be expected with an ASW aircraft, there are several other electronic service centers located in various parts of the cabin, and, as depicted in Figure 20, the equipment is arranged on shelves in cabinets with removable hinged doors. The electronic units are provided with power cables of sufficient length to allow their being pulled out for maintenance onto an attached tray which acts as an extension of the shelf, and is stowed in the aircraft when not in use.

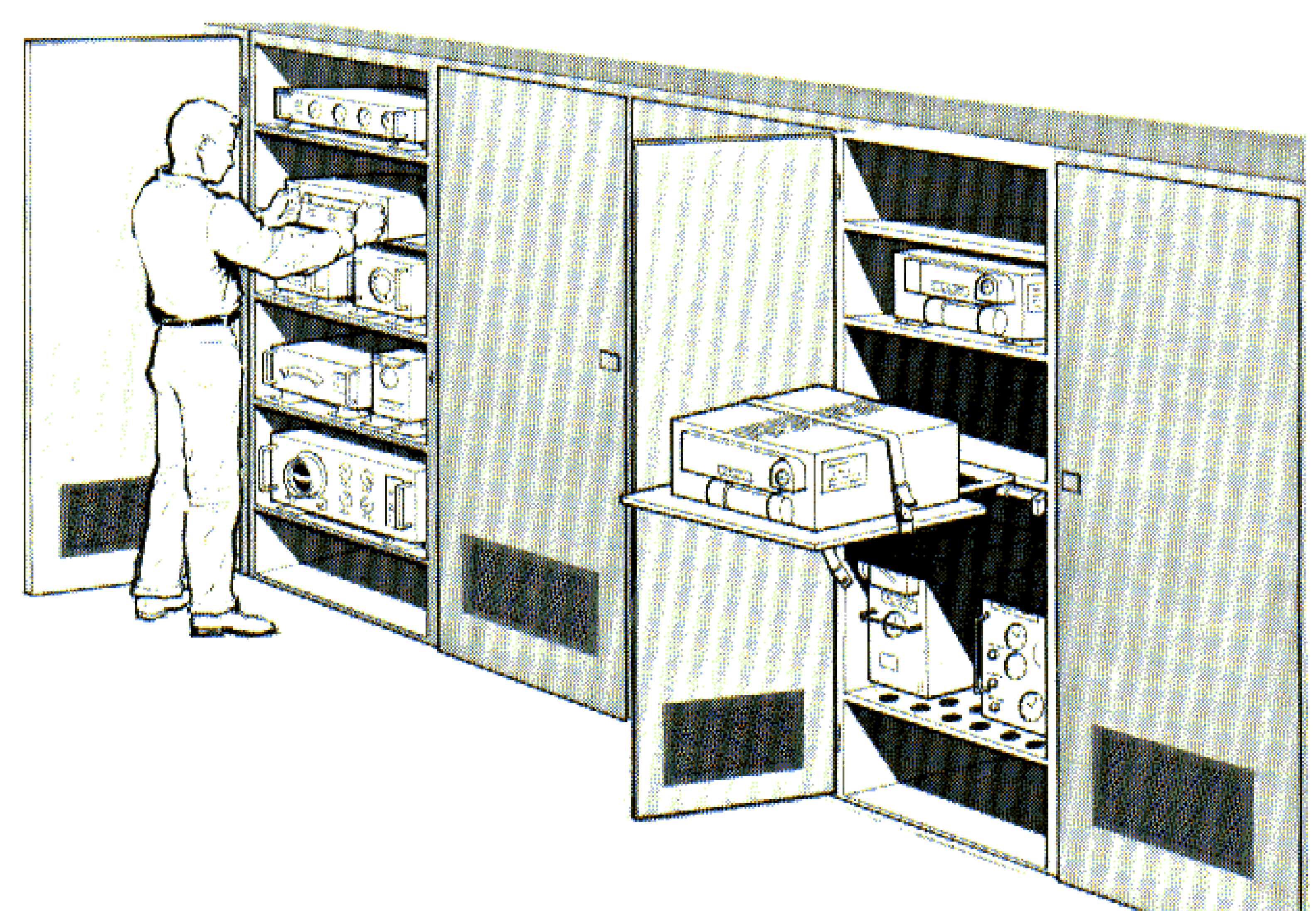


Figure 20 Typical Electronic Service Center

Due to the concentration of controls and equipment, the flight station on any aircraft often becomes a bottleneck during maintenance periods. The flight station design has received a great deal of attention to alleviate this problem. Hinging upward of the large nose radome, for example, gives access not only to the radar equipment but also to four pressure doors, which can be removed to gain access to the otherwise difficult-to-reach areas forward of the instrument panels and below the flight station floor. The latter area, incidentally, can also be reached from the nose wheel well by removing two panels, which are recessed to accept the nose wheels when the gear is retracted. The design of the windshield panels is also noteworthy. Panel replacement is not required very often, but it can be a troublesome and messy task if most of the work has to be accomplished inside the aircraft; the P-3 windshield panels are

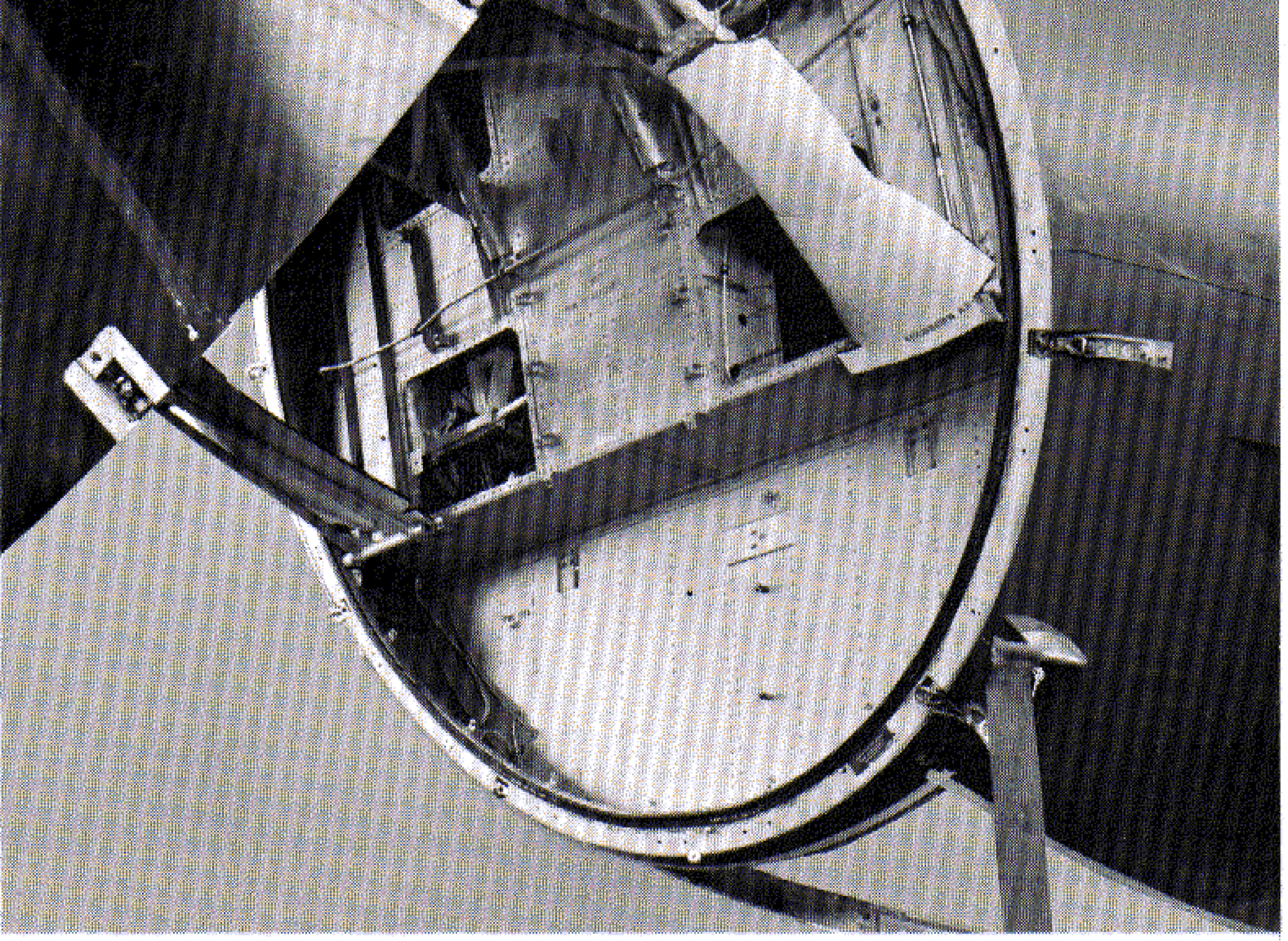


Figure 21 Forward Radome

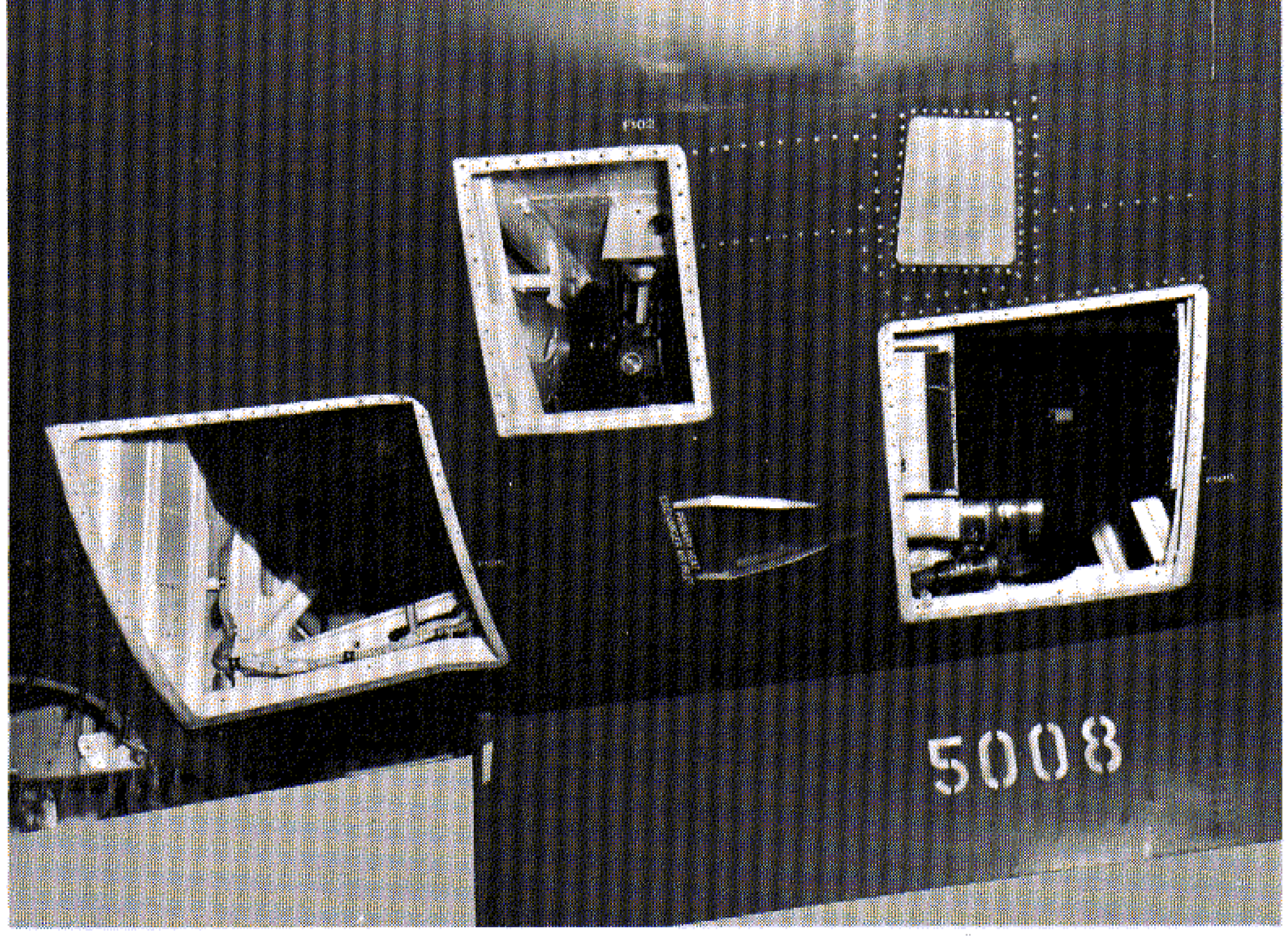


Figure 22 Air Conditioning Access Panels

designed to be installed from outside thus making the job easier to accomplish and avoiding flight station congestion.

The air-conditioning equipment is located in the unpressurized areas on the outboard sides and aft of the nose wheel well. Although, by necessity, the air-conditioning components are not so ideally laid out as are the units in the hydraulic and electrical service centers, ample access can be gained from the nose wheel well and through a large number of access panels in the fuselage skin.

One maintenance area not mentioned so far is the unpressurized aft fuselage. The rudder and elevator booster assemblies, and other flight control components are located here, and they are accessible through a door in the lower fuselage skin. Farther aft, the radome and tail boom assembly is secured with six latches, and two rails resting on rollers allow the radome to be opened aft a distance of more than three feet.

We think the fuel system exemplifies the best in maintenance design, and ground maintenance should be simple and seldom of a time-consuming nature. There is little external fuel plumbing to leak — most of it is routed inside the tanks — and the wing designers have provided integral tanks which have very few skin joints and bottom wing cutouts. Many components are multi-purpose and are interchangeable as well, and most of the tank-mounted components are designed so that they can be removed and replaced in a few minutes — without defueling (see Figure 24).

Conventional "stiff knee" pins are provided for the landing gear, but there is also automatic protection in this respect in a positive ground-locking device consisting of a wedge which is interposed in each gear retracting mechanism when it is in the down position and the shock strut is compressed by the airplane weight. Each gear assembly, including the shock strut, retracting linkage, cylinder, wheels, and other equipment may be installed or removed as a complete unit (see Figure 25).

A word about in-flight servicing. As previously mentioned the majority of the hydraulic power system components, nearly all of the electrical power system components, and most of the electronic "black boxes" are within the cabin-pressure area and can be worked on in flight. This allows malfunctioning components to be located, and repaired in flight if such action is imperative. Insofar as the various electronic systems are concerned, parts may not only be repaired but actually replaced if the part is in the "In-flight Maintenance Kit." Step-by-step trouble shooting charts for the various electronic systems have been worked out, and these and some necessary trouble shooting equipment will be carried in the airplane to facilitate in-flight maintenance.

PERIODIC MAINTENANCE PROGRAM It is true to say that naval aircraft have steadily increased in complexity over the years, and it is probably safe to assume that this trend is going to continue. The Naval Aircraft Maintenance Organization has had to bear an ever-increasing share of the burden created by this trend and, recently, it seemed desirable to try a new approach to the problems of maintenance, so as to ensure better utilization on later aircraft such as the Orion.

Briefly, maintenance planning and management will continue to be the responsibility of the Aircraft Maintenance Officer of each squadron, but he will be backed by a more efficient and better organized maintenance system in which the aircraft manufacturer will assume a larger and well integrated role. Some of the major provisions and features of the new program are:

1. The introduction of a single document (Periodic Maintenance Requirements Manual) as the controlling directive at all levels of maintenance.

2. Use of engineered and proved maintenance instructions and requirements which will be kept current through periodic reviews by a designated Maintenance Engineering Review team.
3. Presentation of such requirements in a readily usable form to maintenance personnel.
4. Inauguration of a preplanned method of conducting scheduled maintenance, embodying enough flexibility for adaption to local operating and environmental conditions.

One significant change instigated by this new program is that maintenance will be scheduled primarily according to calendar intervals, rather than by flight or operation time as in the past. Another significant change from normal practice is the provision of Maintenance Requirements Cards, which will give comprehensive coverage of all tasks classified as periodic servicing and maintenance. The cards are provided in three separate decks: Preflight, Daily, and Calendar. The Preflight and Daily cards contain all minimum requirements for such inspections and the Calendar cards contain the minimum requirements for all calendar periodic maintenance, which, at the time of writing, is established at 90-day and 180-day inspections — the 180-day inspection being termed an "even calendar inspection" and coinciding with alternate 90-day calendar inspections. Odd and even calendar inspections will continue until the Periodic Aircraft-Rework (PAR) is due.

There are many advantages to be derived from the use of maintenance cards, and some significant ones which come quickly to mind are:

1. All the information that is required to accomplish scheduled maintenance tasks, including clarifying illustrations, is included on the cards.
2. The cards can be distributed to pertinent personnel and carried to the aircraft where the work is being accomplished.
3. The cards in each deck have been arranged so that the work of planning the various maintenance tasks in a sequence to avoid congestion in any one area, while still accomplishing the inspection in the shortest possible time with a minimum of personnel, has already been "built-into" the card system. The Calendar cards are necessarily more involved than the others and are used in conjunction with an "Odd" or "Even" Calendar inspection sequencing chart.
4. Locally established periodic maintenance requirements, not included on the published Maintenance Requirements Cards, can be easily added to blank cards supplied with each set.

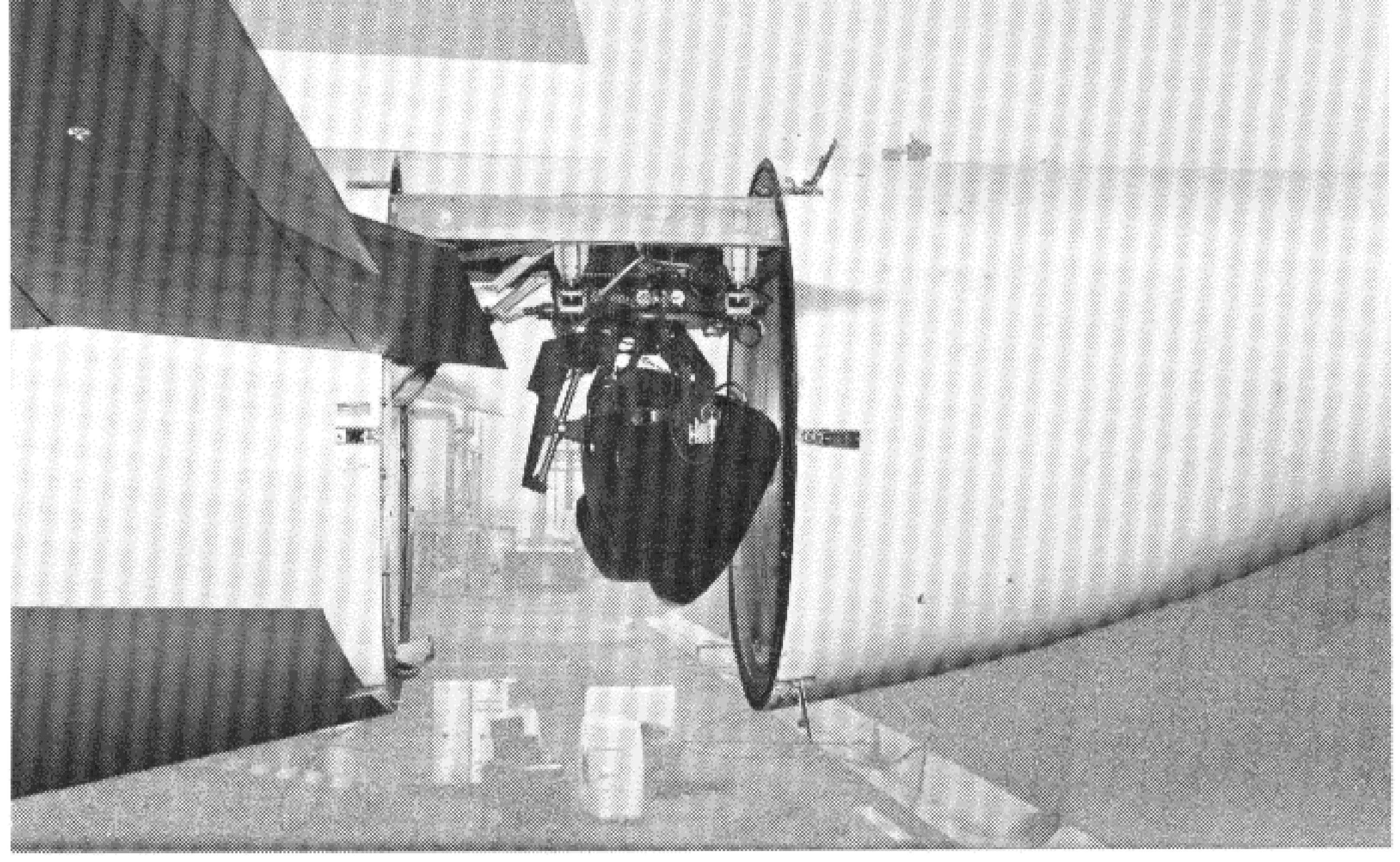


Figure 23 Aft Radome

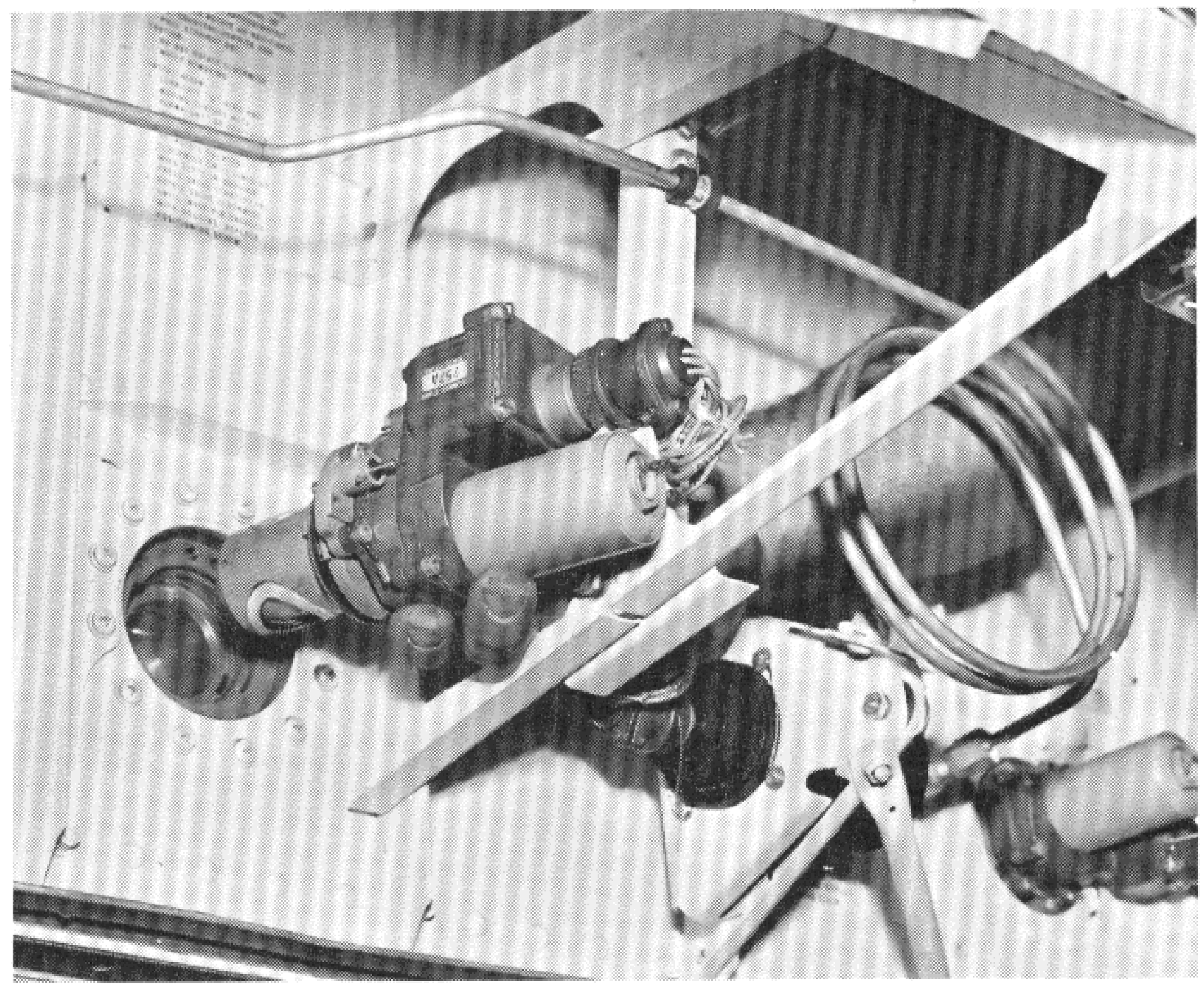


Figure 24 Removal of Fuel-feed System Valve

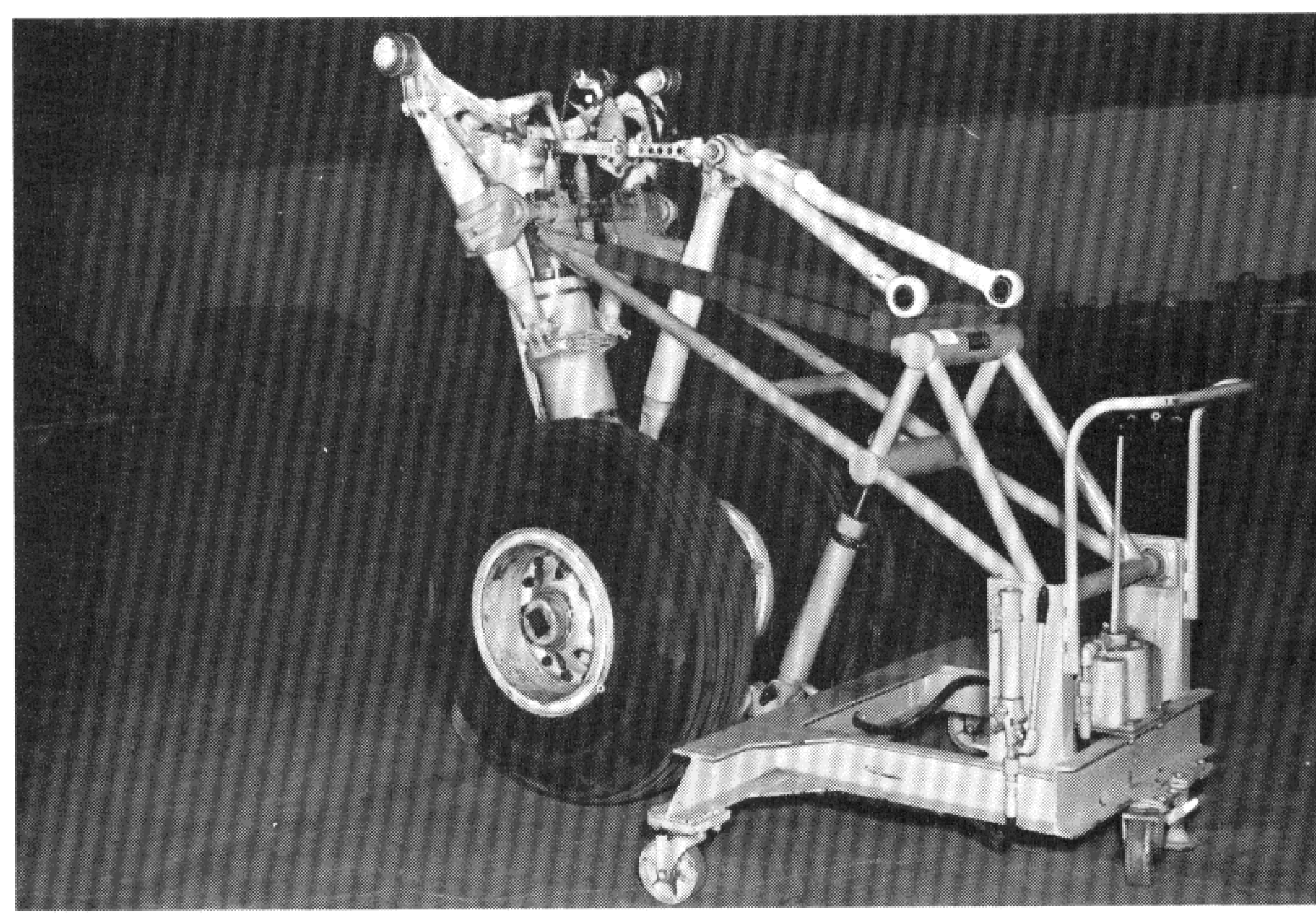


Figure 25 Landing Gear Assembly — Removed from Aircraft

There are many other noteworthy aspects of the new Periodic Maintenance Program, and no doubt there will be improvements and refinements as service time increases on the P-3. We feel sure, however, that this program, implemented on an airplane with well-designed maintenance characteristics, will set a new standard for mission or combat readiness.

part two AIRFRAME,

A word about the order and content of the following sections: The descriptions are general in nature and are presented in an order which we feel to be most suitable for the purposes of orientation, although the order does depart from the usual to some extent. The *airframe structure* discussion is first, as the structure can be discussed as a separate entity while familiarizing the reader with the basic aircraft layout. The *power plant* and those systems closely associated with the power plant, such as the *starter* and *fuel systems*, then follow, although it will be noticed that there are intervening discussions: the hot-air *wing anti-icing* is discussed in connection with the *starter system* because both use engine bleed air and have some common controls and manifolding, and the *empennage electric ice control* follows *wing anti-icing* because of their identity in purpose, although their method of achieving that purpose is quite different. The *electric system* comes next because — after the power plant — it is the prime power source for nearly all functions on the airplane. The exceptions are those functions which utilize engine power in the form of compressed air, and certain emergency functions such as manual operation of the flight controls and lowering of the landing gear. However, the subsequent discussions of the *hydraulic system*, with electrically-driven pumps, and the *flight controls*, which are normally hydraulically-assisted, follow in a logical sequence. The *air conditioning* discussion completes the description of what might be termed the functional systems on the Orion. The *electronics* and *armaments systems*—last but certainly not least—have received scant attention in this issue for two reasons: first, we desired an unclassified magazine to obtain the widest possible distribution and second, these systems have already been described in a classified edition of the Naval Aviation Electronics Digest (March, 1962 issue).

POWER PLANT, and SYSTEMS

AIRFRAME STRUCTURE

The basic structure of the P-3 Orion is closely related to, and is in some instances identical to the Electra airframe from which it was evolved. However, it would be entirely misleading to consider the P-3, structurally, as a modified version of its commercial predecessor.

Besides providing for weapon and detection equipment installations to transform the basic Electra airframe into an efficient operational weapon the redesign program called for a complete reassessment of the structure. Extensive noticeable changes, such as redesigning the flight station for increased visibility and shortening the front fuselage by several feet, were the result of this reassessment. Many major and detail changes, not so obvious outwardly, were included to meet the higher stress requirements of a Navy combat aircraft. In effect every part of the Electra structure was evaluated for its adequacy and strength to do the job and was only retained unchanged if it met this extensive evaluation.

Nevertheless, despite changes, the Orion inherits a family likeness to the Electra. Much more important, it also inherits the same basic design philosophy used in the development of the Electra, where extreme emphasis was placed on "fail safe" and "long fatigue-life" characteristics. It was decided at the outset of the P-3 design program to continue to conform to the fatigue and fail-safe requirements set down in the Civil Air Requirements, while still meeting the required flight, landing, and ground conditions of the Navy Specification MIL-A-8629.

A few words about fatigue and fail-safe construction would not be out of place here. For many years most design criteria have required that the structure be built to withstand at least 1½ times the largest ground and flight loads that the aircraft will ever be subjected to. These maximum service loads are also called the design limit loads and they vary according to the category of the aircraft, be it a transport, fighter, fully-aerobatic trainer, or in some other category. Pertinent to this discussion, we might add that the design limit maneuver load factor for the P-3 is 3g, and is based on military requirements, while the Electra has a 2½-g design limit maneuver load factor which is based on commercial requirements.

Up to about fifteen years ago, this requirement of building to 1½ times the design limit load was the primary consideration in ensuring the structural integrity of an aircraft. However, metal fatigue was already becoming a serious problem and it was apparent that future structural design requirements would have to include some special considerations regarding fatigue. The appearance of this phenomenon can be attributed in part to the steady increase in service lives of aircraft over the years and the large increases in aircraft performance. Stronger materials, especially aluminum alloys, were developed which kept pace with this progress, and indirectly these new alloys became perhaps the largest factor accounting for the present day prominence of fatigue criteria in aircraft structural design.

Aluminum alloys exist today that are about twice as strong as their pre-war counterparts, but they offer no improved resistance to fatigue; in fact, for all practical purposes, aluminum alloys suitable for aircraft all exhibit the same fatigue characteristics weight for weight. Thus we have a kind of paradox: today we could build an aircraft structure of thinner and therefore lighter materials than those of yesterday to do the same job from a static strength standpoint, but such a structure would be completely inadequate in regards to fatigue.

Thus in order to achieve a long and trouble-free service life from a modern structure such as the P-3 airframe, it is often necessary to reduce the stress levels

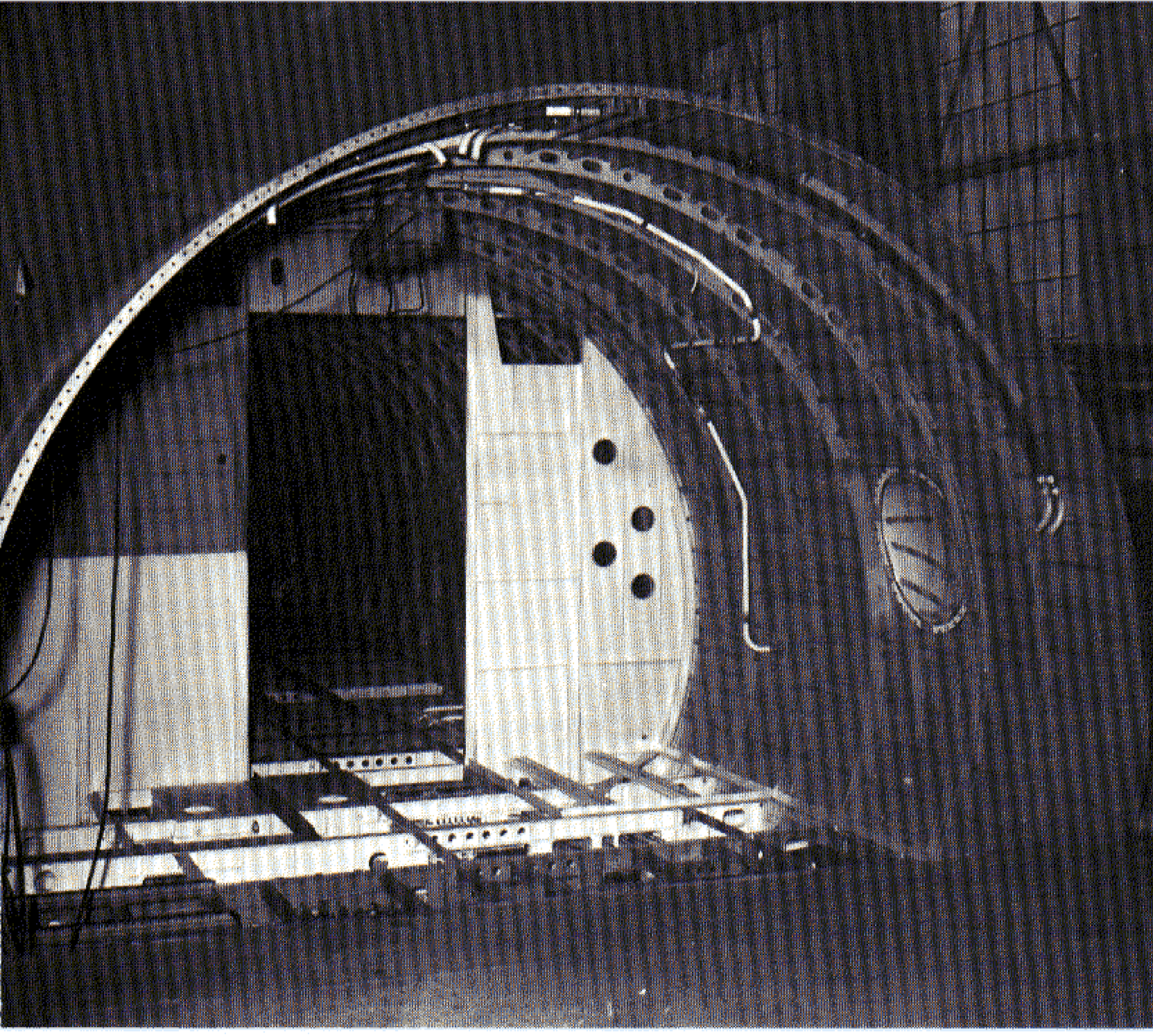


Figure 26 Basic Orion Fuselage in Final Assembly Station

allowed by the structural design requirements; in other words, the higher tensile strengths of these new alloys are not exploited. It is also necessary to pay much greater attention to detail design to avoid, as much as possible, those stress concentration areas that act as sources for fatigue damage.

In addition to providing for a long fatigue life in the P-3 structure, there is also provision for a high degree of tolerance to inadvertent or unpredictable damage. This provision is called the fail-safe concept of design and can be briefly stated as follows: "Any single structural failure occurring in flight must not result in loss of the aircraft through structural collapse, loss of control, flutter, or unmanageable change in aerodynamic characteristics."

Failure of a single element in the wing structure, for example, should not reduce the remaining structural load-carrying capability to a value which would cause collapse; or in the case of the fuselage under cabin pressure and flight loads, the failure should be confined to a local point enabling the airplane to retain sufficient structural integrity to complete its mission. The application of this philosophy to large structural elements on the P-3 will be apparent from the description given in this short article, but it should be noted that there are many detailed applications. For example, as a fail-safe provision against flutter occurring from a disconnected tab, each trim tab on each control surface is connected to its actuator by two control rods, either one of which is capable of carrying the load.

The Orion's structure exhibits a noticeable advance over previous aircraft designs, which in comparison had a far greater number of bolted and riveted joints. Extensive use is made of large structural elements; single-piece forgings are used for end attachments and other heavily stressed parts; and integral stiffening, by extruding, machining and chemical-milling processes, is used wherever practicable. In comparison to the older "bits and pieces" type of construction, these methods save weight, reduce complexity, and avoid building-in local areas of high stress known as "stress raisers." This latter consideration is particularly important in avoiding premature fatigue damage.

FUSELAGE STRUCTURE The fuselage is a semi-monocoque design, using sheet skin panels stiffened by circumferential rings and continuous longitudinal stringers, except where these are interrupted by cutouts for doors, windows, and access panels. Cutouts in a stressed shell are potential stress raisers since the structure adjacent to the openings has to carry a greater share of the load. However, the cutouts on the P-3 are stoutly framed so that stress levels around them are kept at the same safe low values as the rest of the structure.

The P-3 fuselage is circular in cross section for most of its length. Besides making an ideal pressure container, this configuration has additional advantages in design and manufacturing simplicity. Some deviations from the ideal cylindrical form are necessitated by the requirements of flight station visibility, streamlining, wing attachment, and stores accommodation in the bomb bay. In the center section region, the upper panels of the wing serve as a pressure deck and in effect, this pressure deck is extended forward to cover a fuel tank cell, the bomb bay, and the nose landing gear wheel well. The pressure deck and the cabin floor above it in these regions are supported by rugged beam and truss structures.

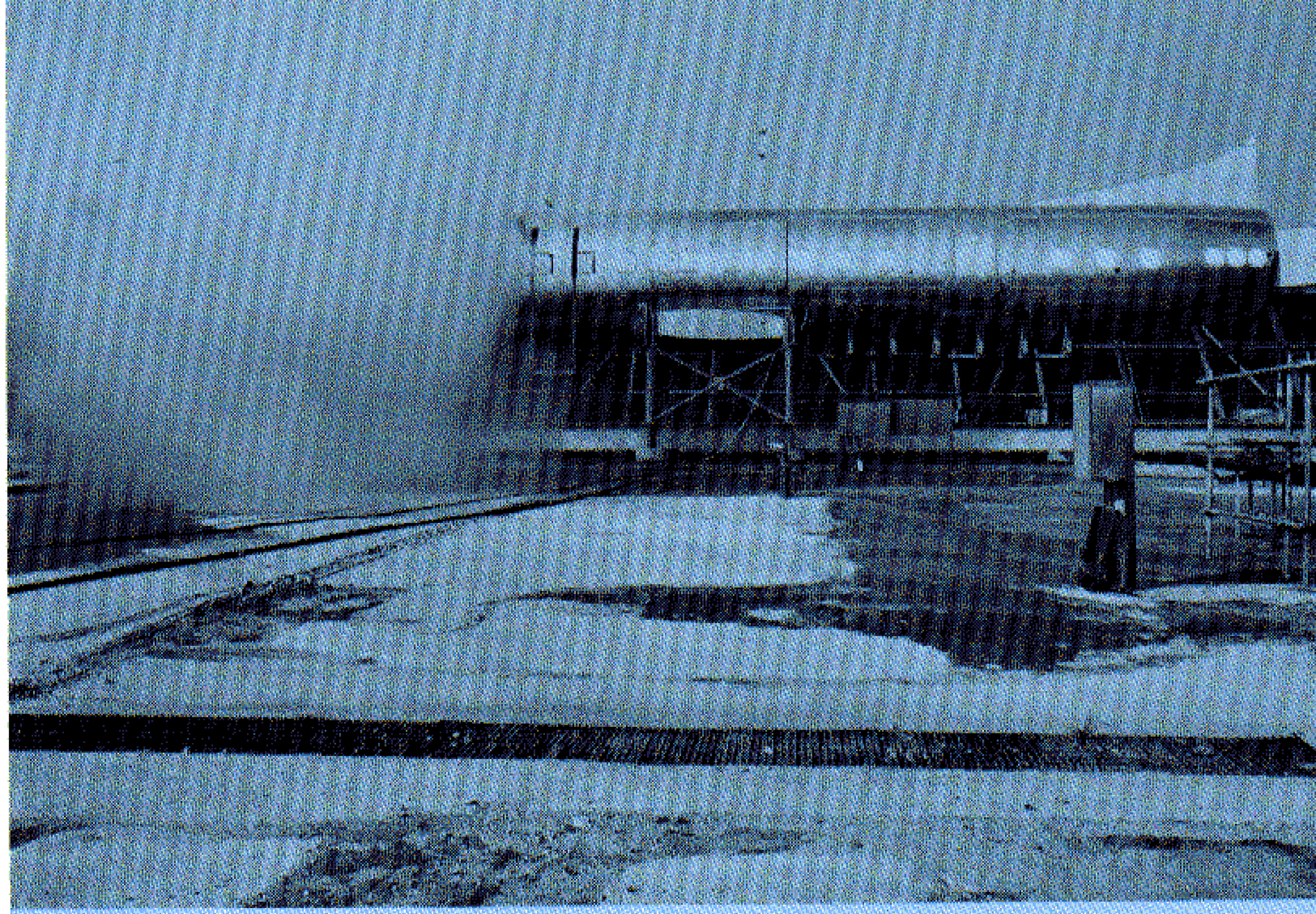
The pressure-containing fuselage skin material is either 2024-T3 or 2024-T42 alclad. This alloy was selected for its relatively high ductility and low crack-propagation rates; it follows that this alloy also has good fatigue and tear resistance qualities. The same material is generally used for all fuselage skins except in the nose and tail boom areas where detection equipment requires non-metallic materials.

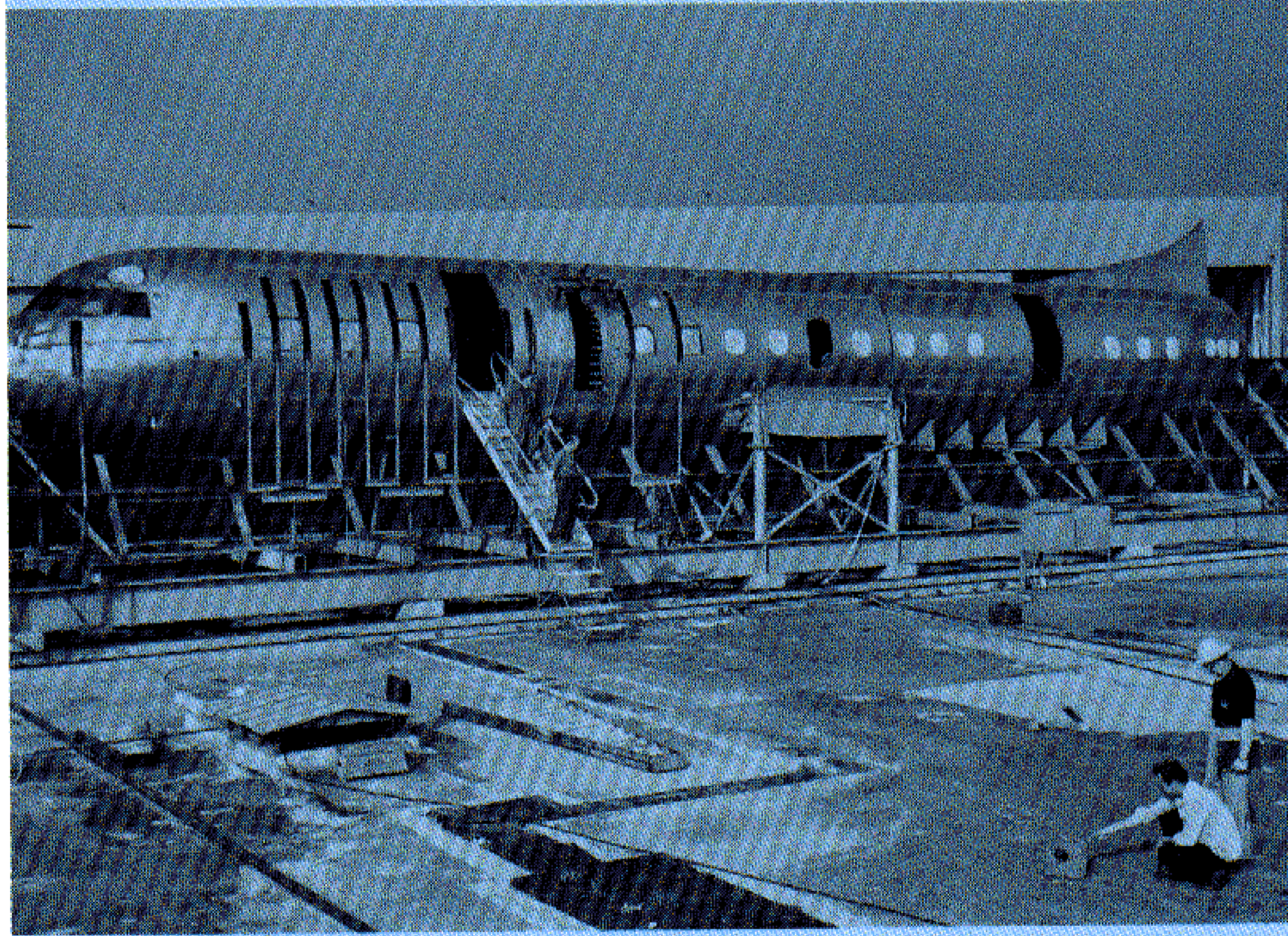
As suggested by the earlier discussion on fatigue, the most important criterion in the design of the fuselage structure concerns its resistance to rupture under pressurization loads. This means designing the fuselage so that cracks in the pressure hull are unlikely to occur during normal operation for the service life of the aircraft. It also means designing to ensure that cracks, which could occur during service from some abnormal cause, do not propagate and seriously impair the strength of the structure — a fail-safe concept of design.

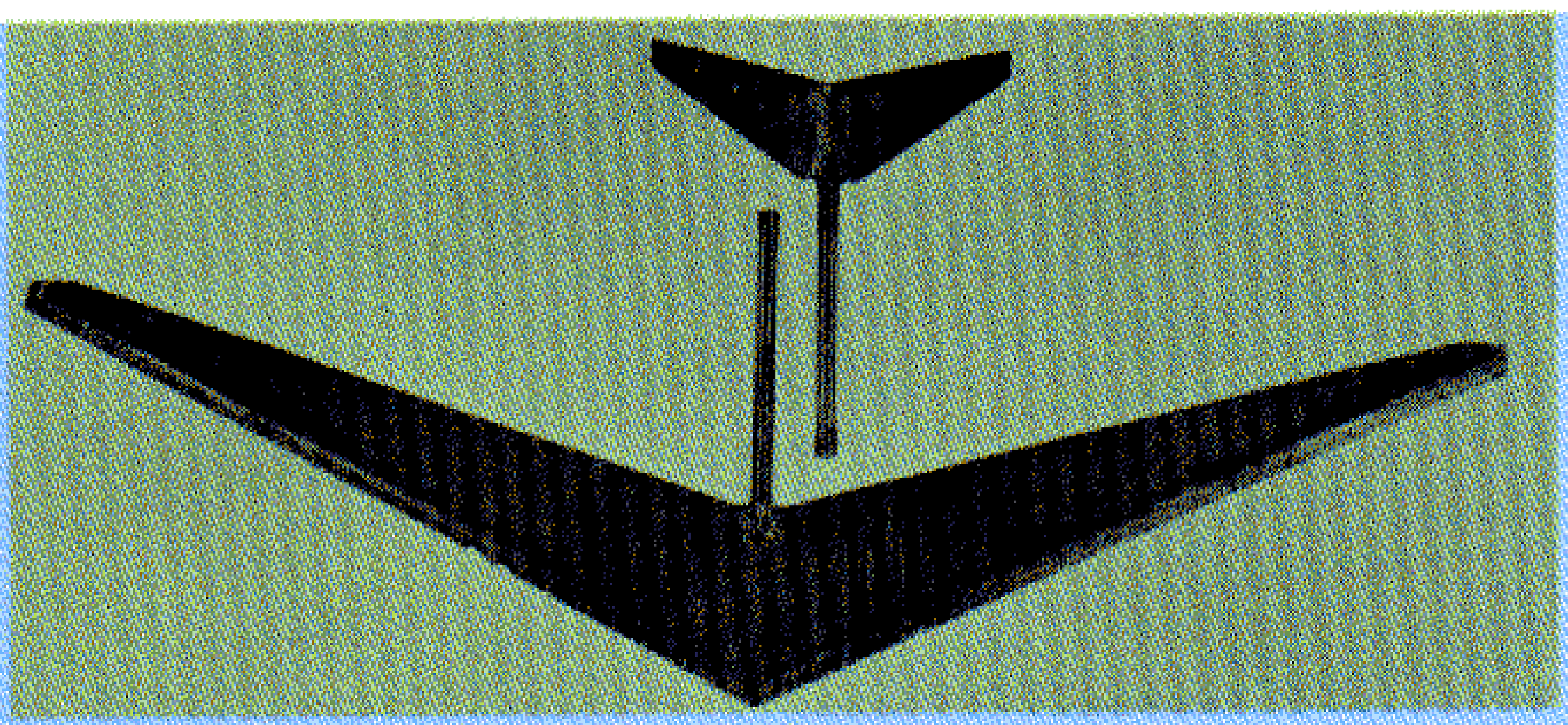
A complete production-type Electra fuselage was subjected to exhaustive tests to prove this concept and, since the P-3 fuselage is basically similar, these tests are directly applicable to the military airplane.

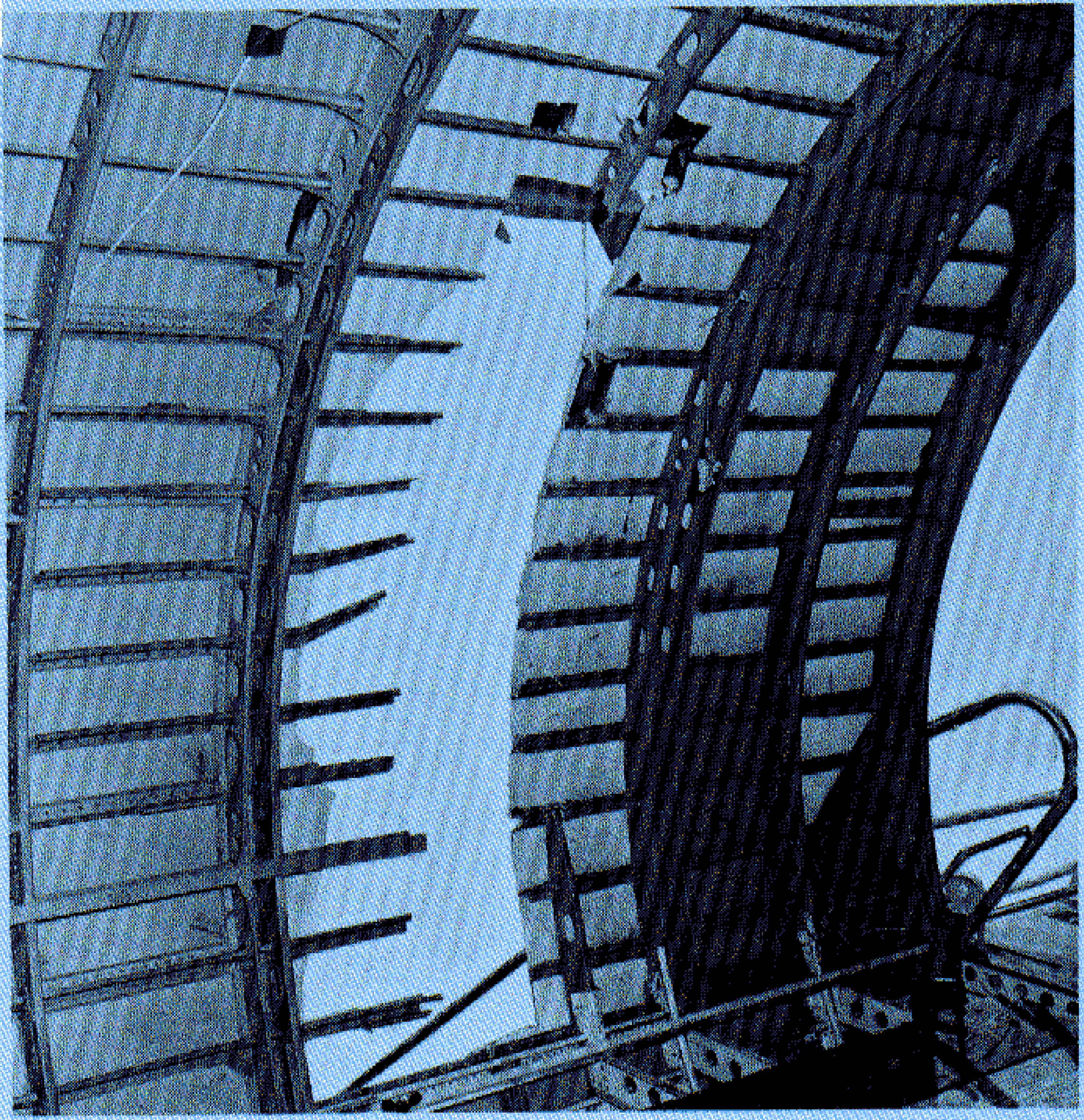
The Fuselage Fail-Safe Tests on the Electra were both realistic and spectacular. With the cabin sustaining full pressure, and with various flight maneuvering loads applied, the fuselage was subjected to a series of tests demonstrating its tolerance to damage, in which the structure was sawn through at various critical points, such as fuselage frames, wing to fuselage main rings, windshield posts, nose landing gear attachment forgings, and other selected structural members. Other tests in the fuselage fail-safe proving program simulated shell ruptures that might be caused by inadvertent damage, by catapulting spears through the pressurized fuselage. In all instances the fuselage ruptures were restricted to the local areas and the structure continued to carry the design load.

The program culminated in a rather drastic test to determine the effect of ripping a large hole in the fuselage shell structure, again while fully pressurized (see Figure 27). The initial cut was six feet high and one foot across at the top. For obvious reasons this major damage was inflicted in the plane of the propellers, although we hasten to add that in four years of Electra operation there have been no instances of in-flight damage occurring from propellers. However, in this final test, the expected rapid decompression resulted but the fuselage continued to carry full 1-g flight loads. This 1-g load was further increased to 125 percent to simulate mildly turbulent flight — without failure or the occurrence of further damage.


Instant of firing spears into pressurized fuselage


Damaged fuselage after firing — Note spear assembly in foreground


Close-up of typical spears and spear assemblies


Decompression damage as viewed from fuselage interior

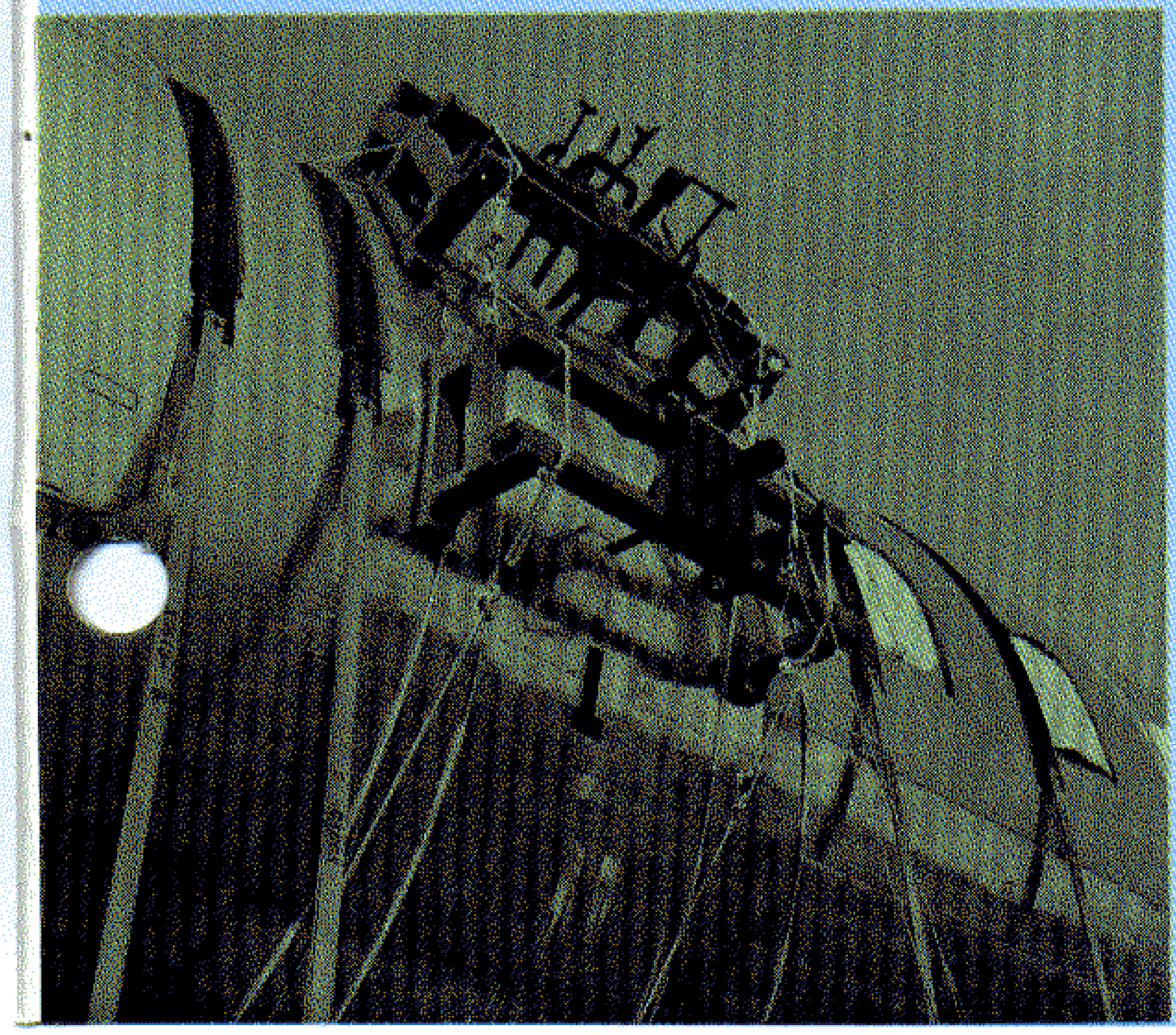


Figure 27 Electra Fuselage Fail-Safe Test

WING STRUCTURE Constructed of 7075-T6 aluminum alloy, the wing, from a structural viewpoint, consists primarily of a single-cell box beam, which is essentially continuous from one wing tip to the other, and which combines its structural and aerodynamic functions with that of fuel storage. The upper and lower surfaces of this spanwise box are made up of integrally stiffened planks, which are shot-peened to obtain the required curvature. The front and aft box sides or shear webs are of conventional plate and vertical angle stiffener construction; and T-section spar beam caps, located at the corners of the single-cell box, serve as primary attachment members for the box and also for the leading and trailing edges. The wing leading edge is of double-skin construction — the thin inner skin being beaded for stiffening and for channeling the hot air used for anti-icing (see the "Wing Anti-Icing" section).

The **P-3** wing is an excellent example of a design which avoids as far as possible stress raising irregularities in the primary structure and also conforms to fail-safe principles of construction. In most wings, the problem area from a fatigue viewpoint is the underside, where structural members sustain relatively high tension loads under flight-maneuvering and gust forces. In the more fatigue-critical inboard area of the **P-3** wing lower surface, cutouts are virtually non-existent except for an occasional small water drain; inner fuel tank access panels are located on the wing upper surface; and the main landing gears are retracted externally to the wing box beam into the inboard engine nacelles.

In any wing primary structure, it is preferable to avoid the use of chordwise joints, which interrupt the primary load paths. All the joints in the **P-3** wing box beam, with the exception of the wing/center section attachment, run spanwise and it will be noted that this design practice also lends itself to fail-safe principles of construction. This fact is perhaps made more apparent with the knowledge that the **P-3**

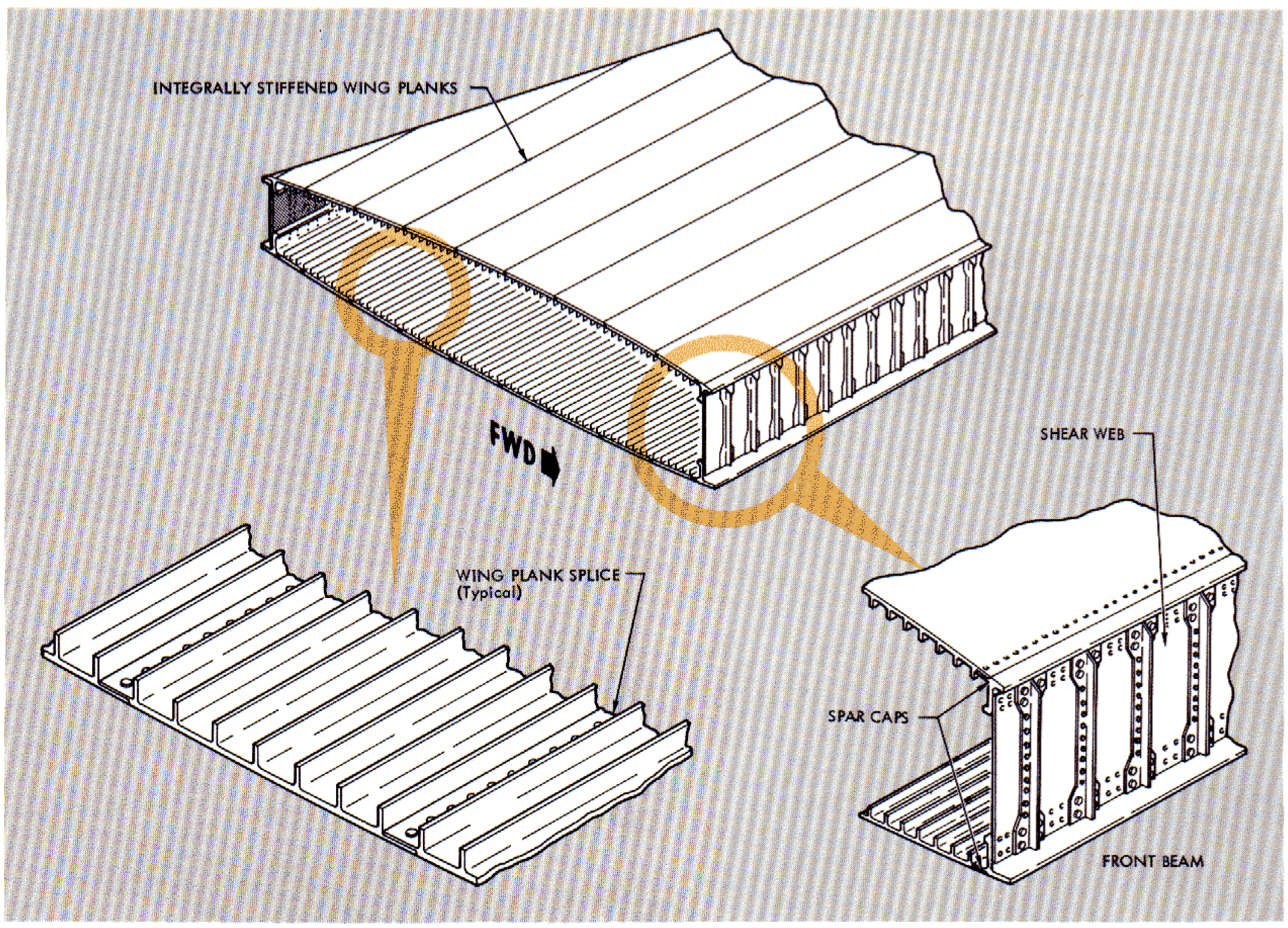
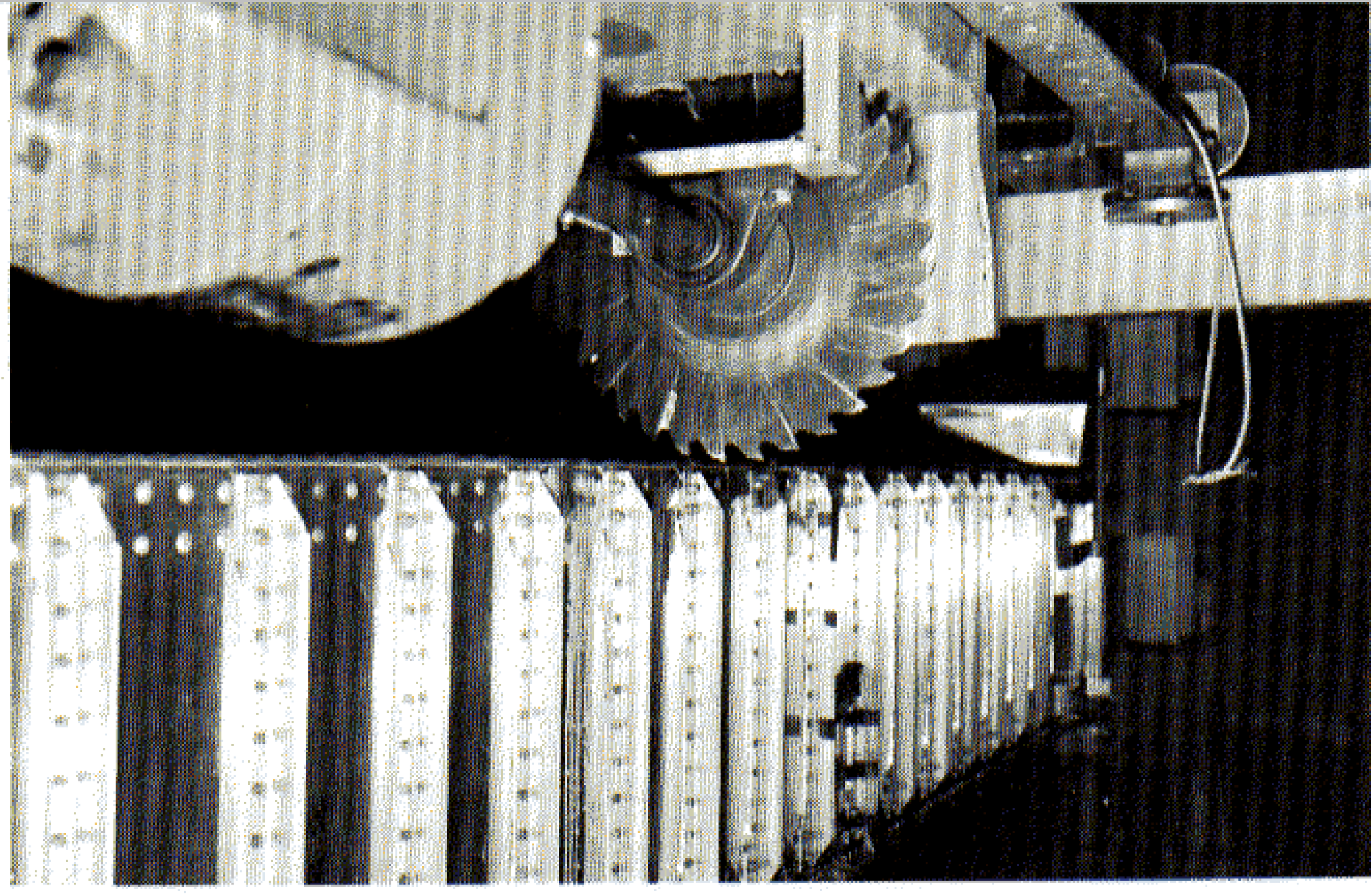
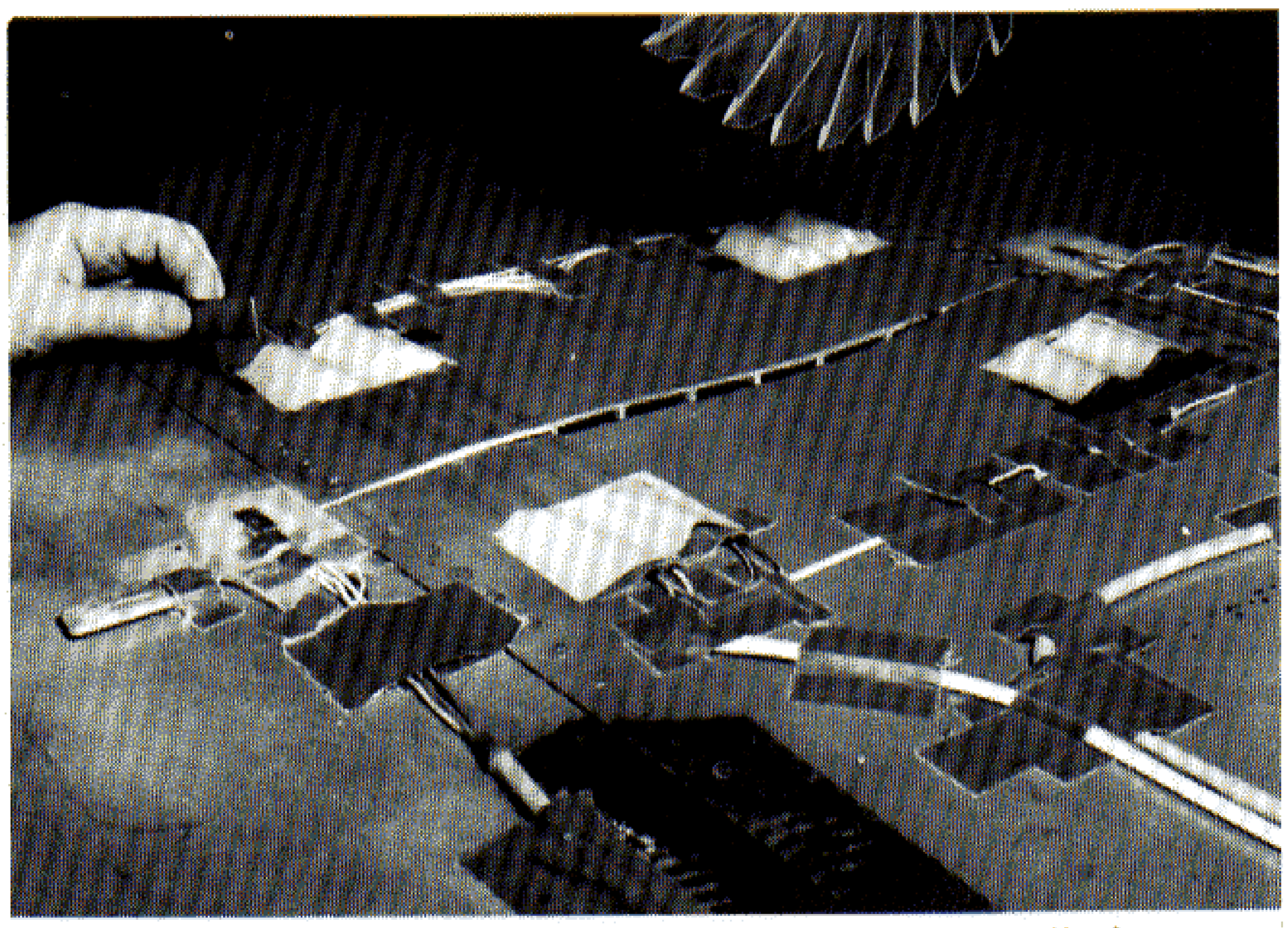


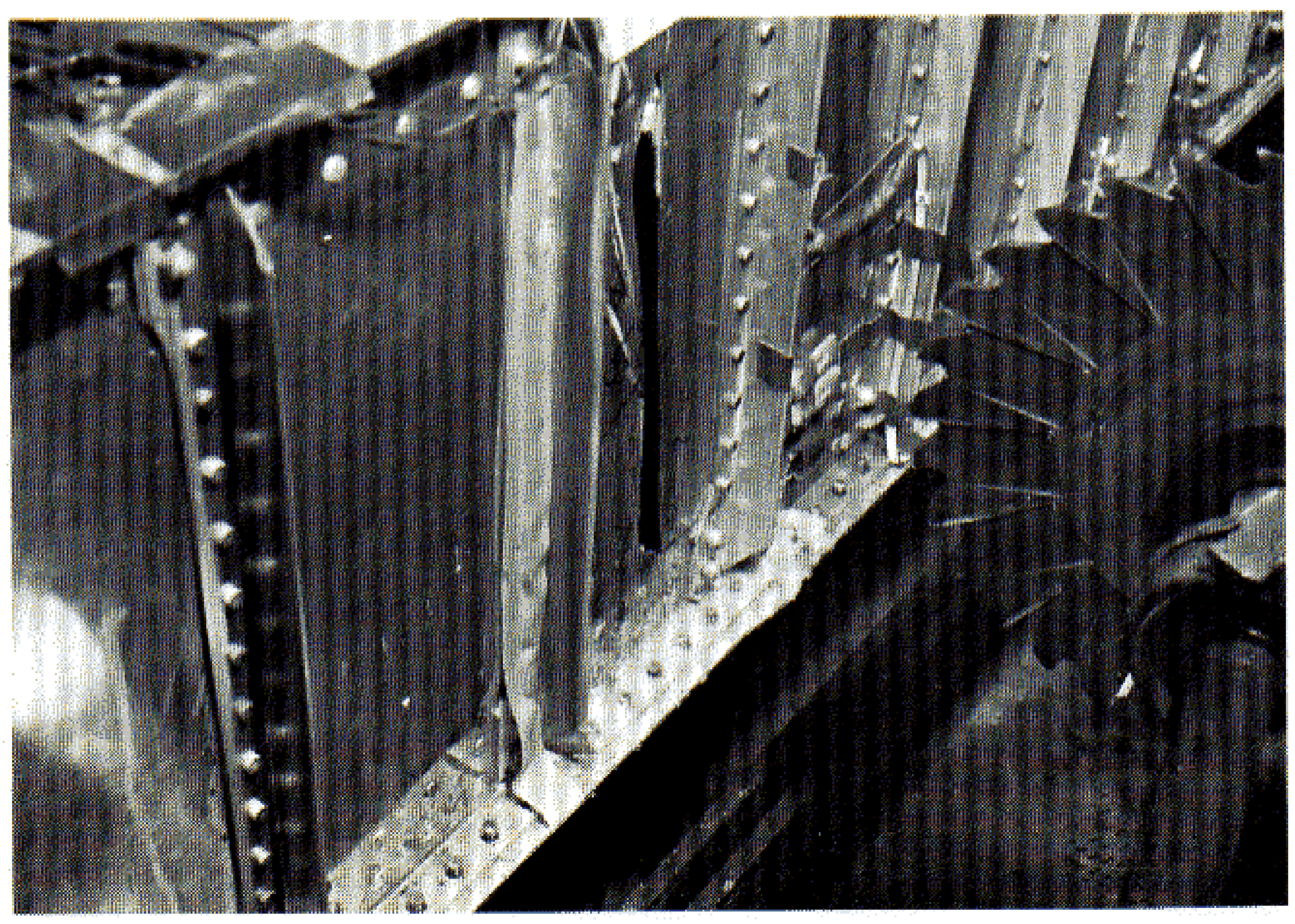
Figure 28 Wing Fail-Safe Design Details



Set-up for sawing beam cap



Wing plank saw cut, showing strain gauge installation



Saw cut in front beam web

Figure 29 Typical Electra Wing Fail-Safe Tests

wing has been designed so that a failure of any plank, shear web, or beam cap would not even reduce the wing strength below design limit load — it will be noted that the spanwise joints also fulfill the useful purpose of limiting the chordwise propagation of a crack in a failed primary member.

Wing Fail-Safe Tests. As in the case of the fuselage, this basic wing fail-safe concept was proved rather dramatically in a series of tests on the Electra wing (see Figure 29). Planks at mid-chord and adjacent to the spar caps were completely severed by saw cuts; and beam caps and shear webs were similarly tested. In every case the structure continued to support full limit load, which was 25 percent greater than that specified by the FAA requirements. In no instance did cracks propagate beyond the saw cut, and no significant change occurred in overall wing deflections as a result of severing any individual structural member.

P-3 STRUCTURAL STATIC AND FATIGUE TESTS Up to now we have only mentioned tests, previously carried out on the Electra airframe, which proved the basic fail-safe design philosophy. These tests can also be applied to the P-3 since both airplanes employ similar methods of construction. In order to further prove the structural integrity of the Orion, it was necessary to conduct a comprehensive series of static and fatigue tests. The static tests were carried out on a complete P-3 airframe allotted special serial number 9998. Although this airframe has never left the ground, the flight loads it has been subjected to will probably never be experienced by another P-3 in service (see Figure 30).

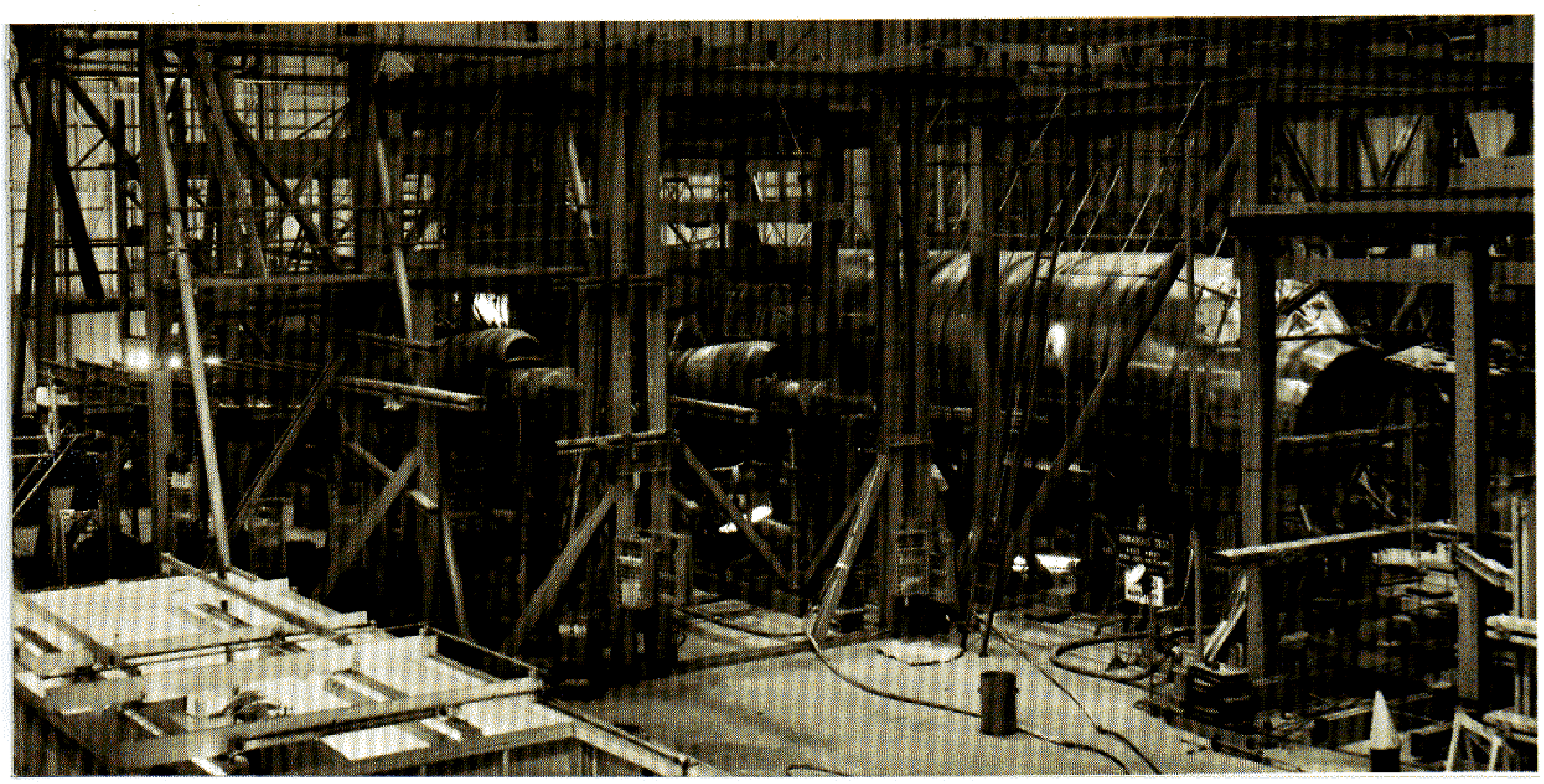


Figure 30 General View of Static Test Set-up for Orion Airframe — Serial Number 9998

The static structural tests on number 9998 were conducted to ultimate loads which were 1½ times those expected to be encountered within the **P-3's** operating limits. Figures 31, 32, and 33 show typical tests carried out on the wing, which are explained in the accompanying captions. These wing tests were three of six major tests, each of which simulated a certain flight condition producing the maximum stress on different portions of the wing. Similar tests were carried out on the fuselage, engine nacelles, and other areas of the structure. All these static tests, totalling about 100, have been successfully concluded. As final proof of the static strength of the structure, the major components of serial number 9998—wings, fuselage, vertical and horizontal tails, engine nacelles, control surfaces, and also the flight control systems—will all be subjected to loads, in excess of the ultimate loads, until failure occurs. At the time of writing, this "destruction" program is almost complete.

The second phase of the test program will commence shortly. Another complete wing, main landing gear, and nacelle will undergo fatigue testing to ensure that the Orion will in fact have the prolonged operational life for which it was designed. Varying loads, duplicating actual operating conditions, will be applied repeatedly until a satisfactory service life has

Figure 31 Orion Wing Deflected Up 47 inches During "Positive High Angle of Attack" Test

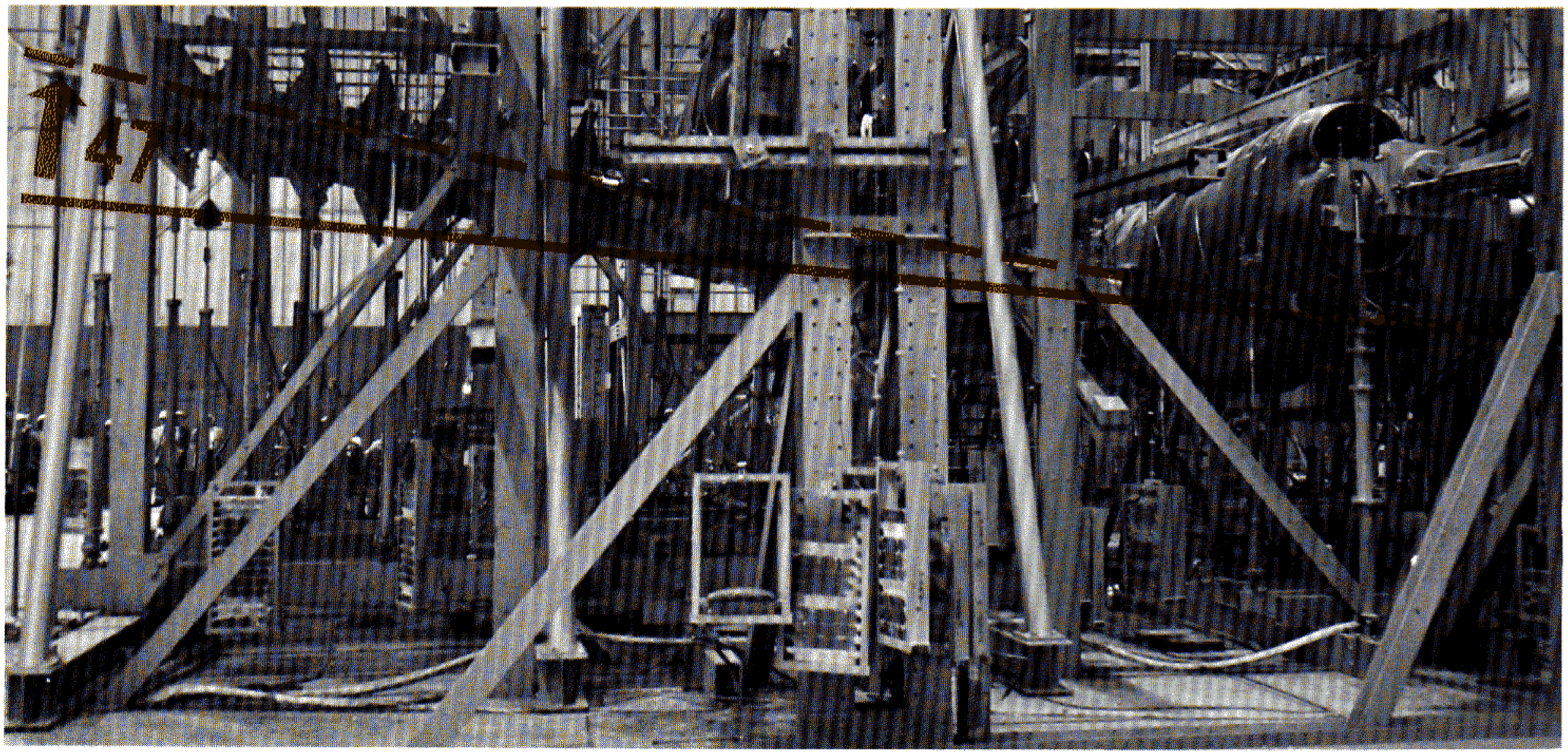
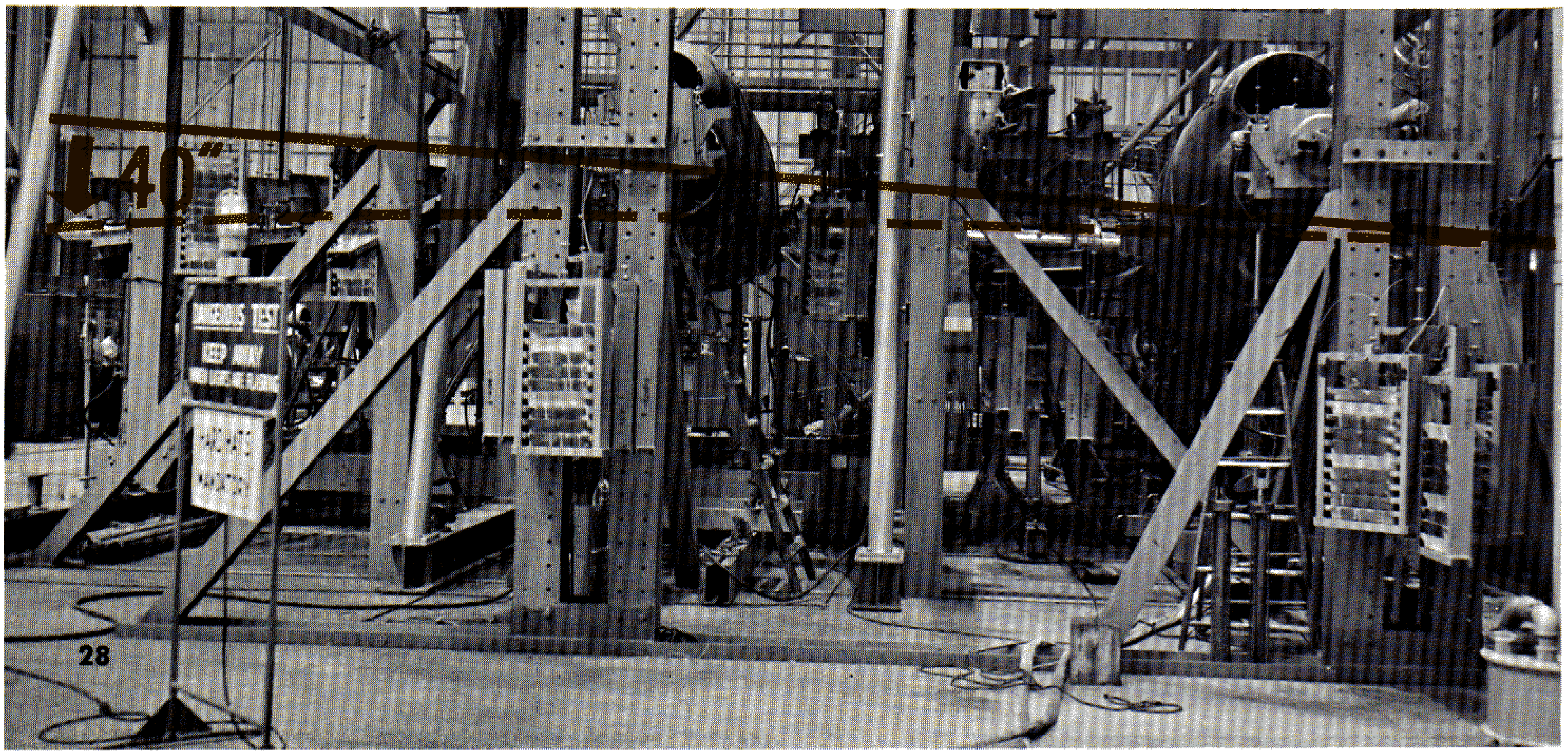


Figure 32 Orion Wing Deflected Down 40 inches During "Dynamic Taxi with Full Fuel" Test



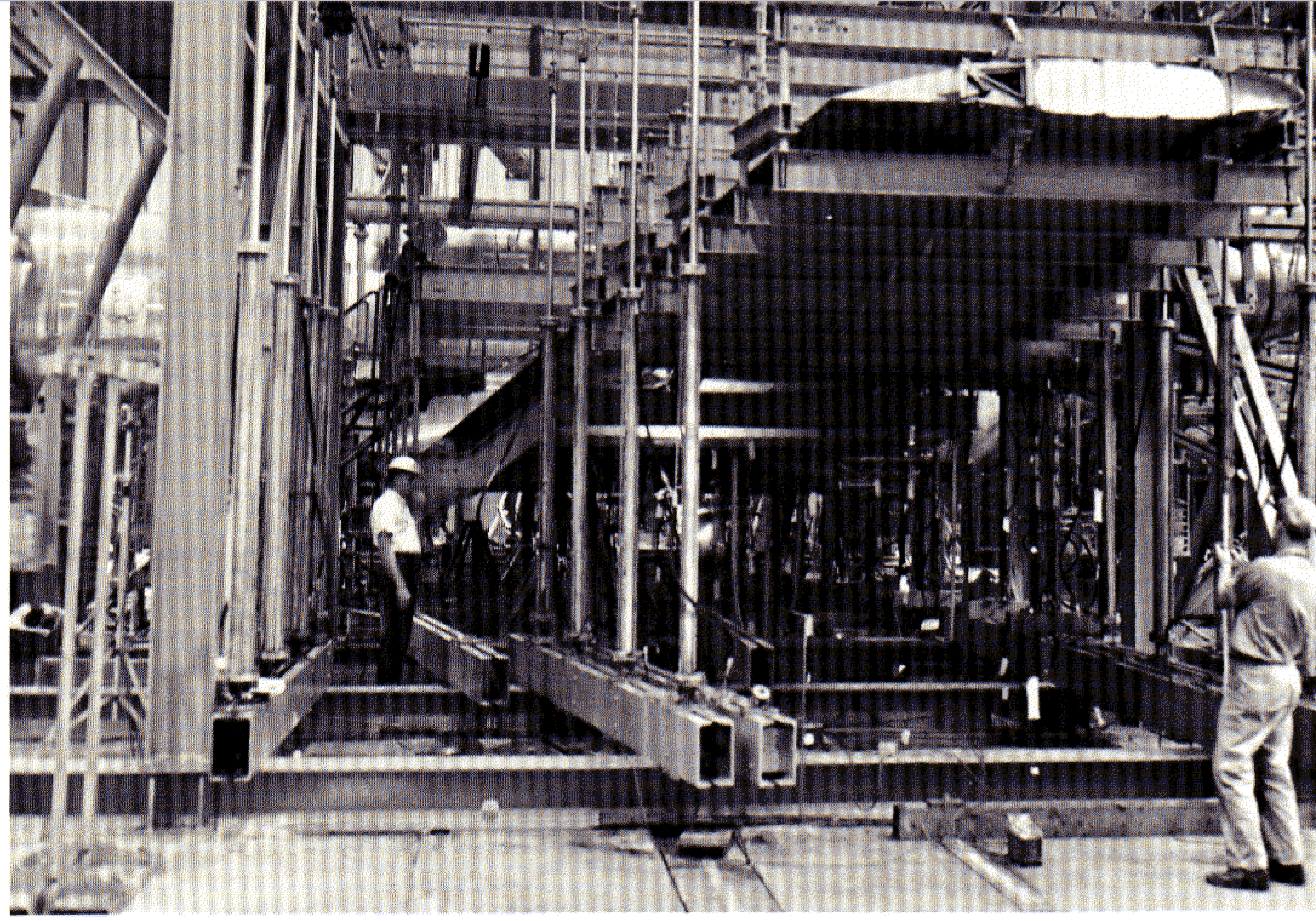


Figure 33 Orion Wing Subjected to Torsion Loads During "Rolling Pullout" Test

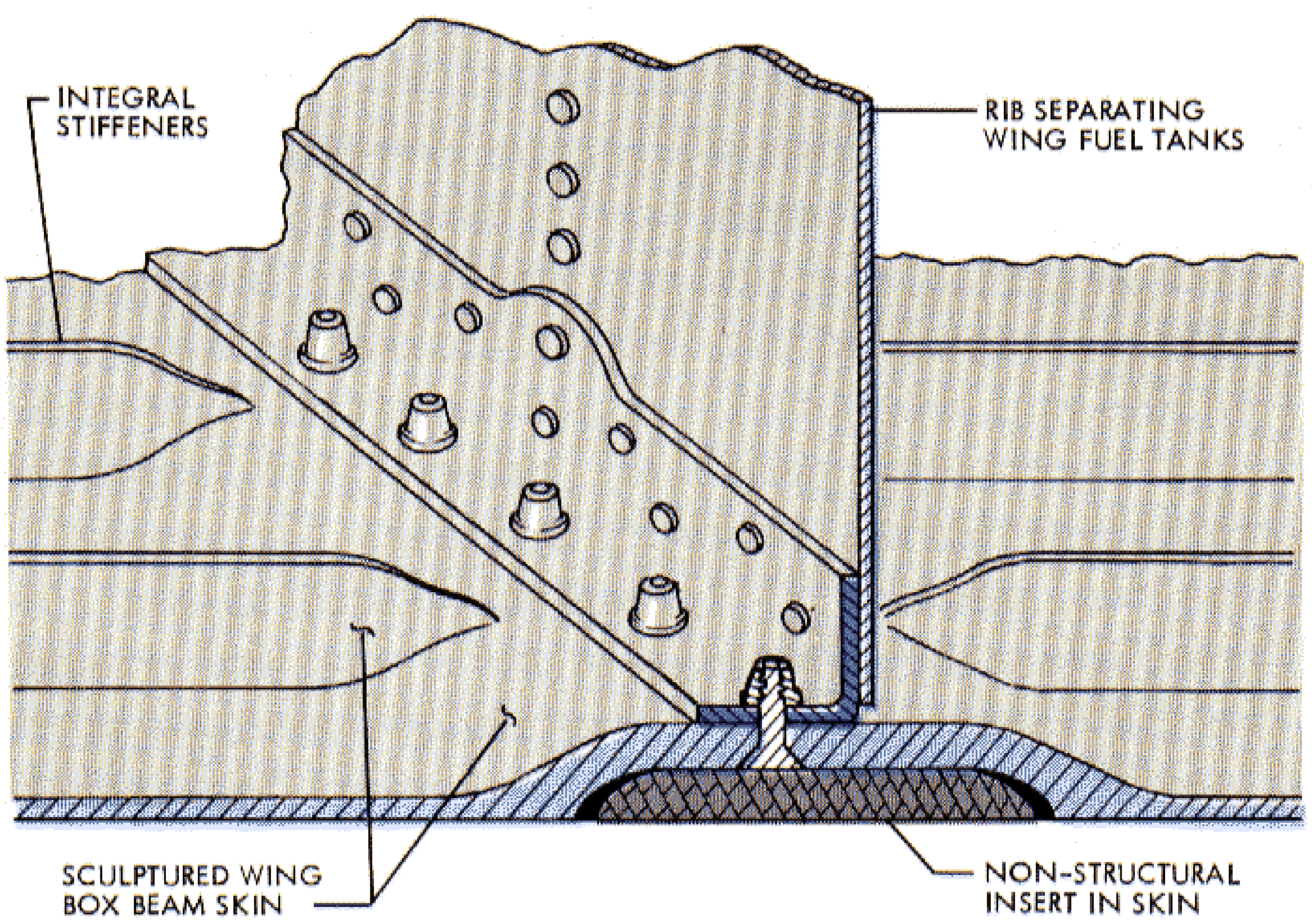


Figure 34 Wing Structure — Detail at Wing Tank Compartmental Rib

been demonstrated. This spectrum-type fatigue testing is programmed to investigate structural endurance of the airframe well ahead of any P-3 in service.

Also included in the fatigue testing program, and now in progress, is a series of tests on an outboard nacelle wing installation with engine and engine mount structure attached. Loads are being applied to this assembly simulating all phases of the airplane's flight and landing operations including the effects of propeller loads during power variations. Later on in this series of fatigue tests, critical portions of the engine support system will be deliberately severed to demonstrate the fail-safe integrity of the installation.

The complete P-3 structural testing program, taken in conjunction with the fail-safe tests discussed earlier, represents the most comprehensive testing Lockheed has performed on any airplane.

INTEGRAL FUEL TANKS In the past there has been a tendency to consider the design requirements of integral fuel tanks only after the wing structural details have been well established — a practice which makes for leaking tanks and the use of considerable quantities of sealing compound. From the first design stages the P-3 has been designed with both considerations in mind, and it should be noted that one basic requirement of a "leak-proof" fuel tank and a "fatigue-proof" wing is common to both concepts — the elimination of as many cutouts and attachment holes as possible. Fortunately, the integrally stiffened structure method of construction lends itself well to this design objective. The manufacturing advantage of machined "sculpturing" can be easily applied to producing flat surface contacts between the wing skin and the fuel tank end ribs, making a most effective fuel seal. In addition, the rib attachment area of the wing can be gradually increased in gauge thickness, by machining, to produce the optimum configuration from the structural and fatigue viewpoints (see Figure 34). This is in marked contrast to the older construction method of working with fixed-gauge materials and having to build up complicated pieces around stringers, and then having to seal them.

Faying surface sealing is used at all joints between mating surfaces in the fuel tank areas. Assembly is made while the sealing medium is wet, and is accomplished with interference type fasteners such as lock bolts rather than loose fitting screws. Further insurance against leaks is achieved by the use of fillet sealant after assembly.

Figure 35 Empennage — General View

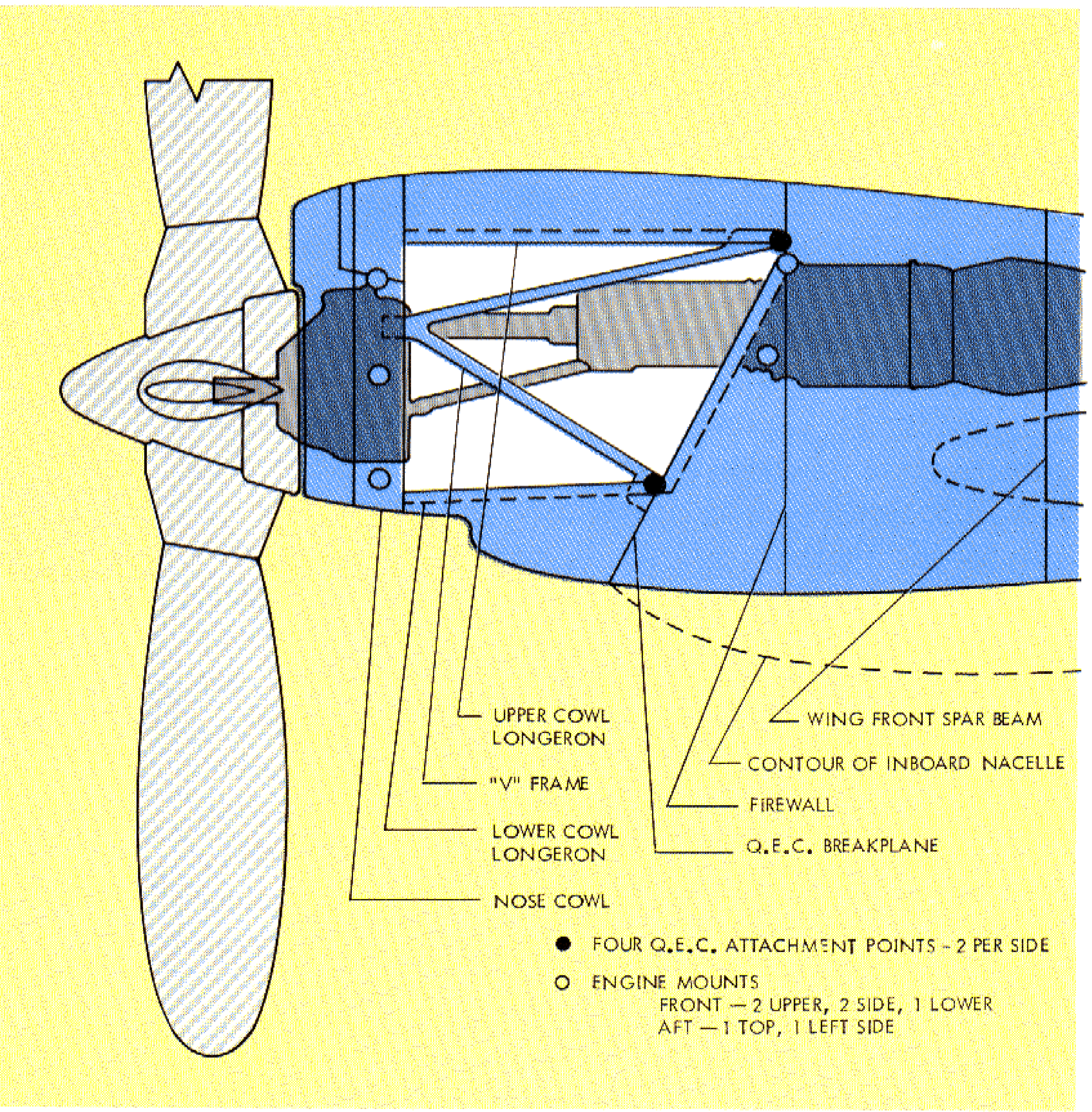


Figure 36 QEC Structure

THE EMPENNAGE is built as a single assembly which is tension bolted to the fuselage in the area of the aft pressure bulkhead. The same design concept used in the wing construction is also employed for the horizontal and vertical stabilizers; integrally-stiffened 7075-T6 panels are spliced spanwise to form the outer surfaces and chemical milling is employed to taper the thickness of the panels out towards the tips. In contrast to the Electra and the P-3 wing, the deicing of the empennage is accomplished electrically. The leading edges are built up as sandwiches of laminated glass cloth with the heating elements located near the outer surface and protected by an outer sheath of alclad.

ENGINE NACELLES Titanium and stainless steel, as well as aluminum, are used in the engine nacelle structure including the Q.E.C. A large power output from a relatively small engine, a high rate of propeller blade angle change, an almost instantaneous power response — all these characteristics combined result in extremely large torsional reactions to be absorbed by a rather slender nacelle.

The Q.E.C. primary structure consists of the nose cowl, two "V" frames with a connecting structural arch at the aft end, and top and bottom cowl panels. The side cowl panels, which provide access to the engine and accessories, are non-structural. The upper and lower cowl panels are made up of longerons, transverse frames, stringers and skin. The apexes of the two tubular "V" frames are bolted to the nose cowl while the other ends of the frames are attached to the upper and lower cowl panel longerons at the location of the four attachment points between the Q.E.C. and the wing nacelle structure. It will be noted that the Q.E.C. removal plane is actually canted away from the firewall in order to provide power plant interchangeability — the inboard nacelles being slightly bulged aft of this position to house the main landing gears.

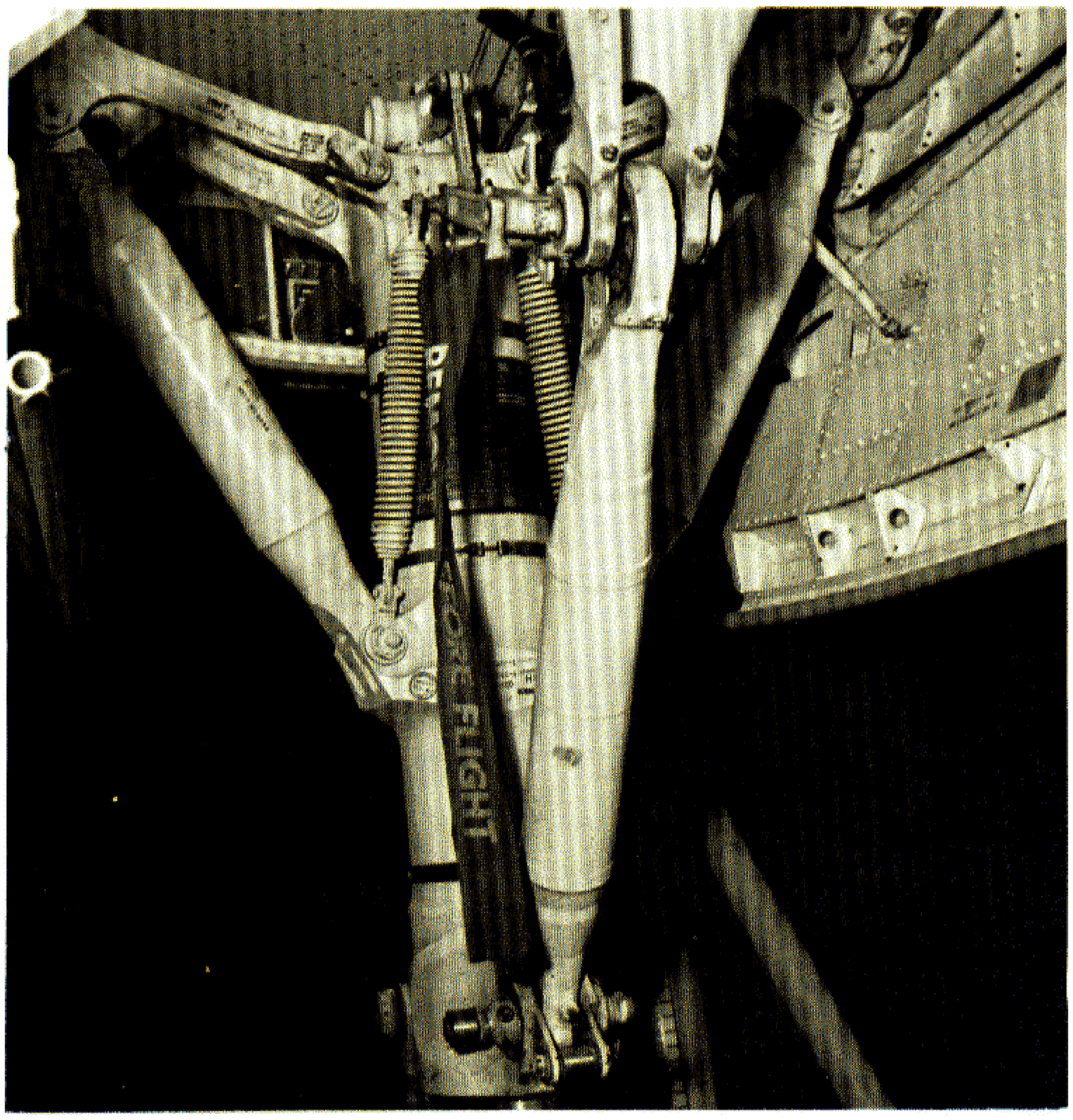
A total of seven mounts attach the engine to structure. The five forward mounts connect the engine reduction gear case to the nose cowl structure. The two rear mounts are attached to the compressor diffuser case on the aft section of the engine. The upper aft mount transmits vertical loads to a structural arch in the top cowl panel. The other aft mount is located on the left side and is designed to minimize lateral motion of the engine.

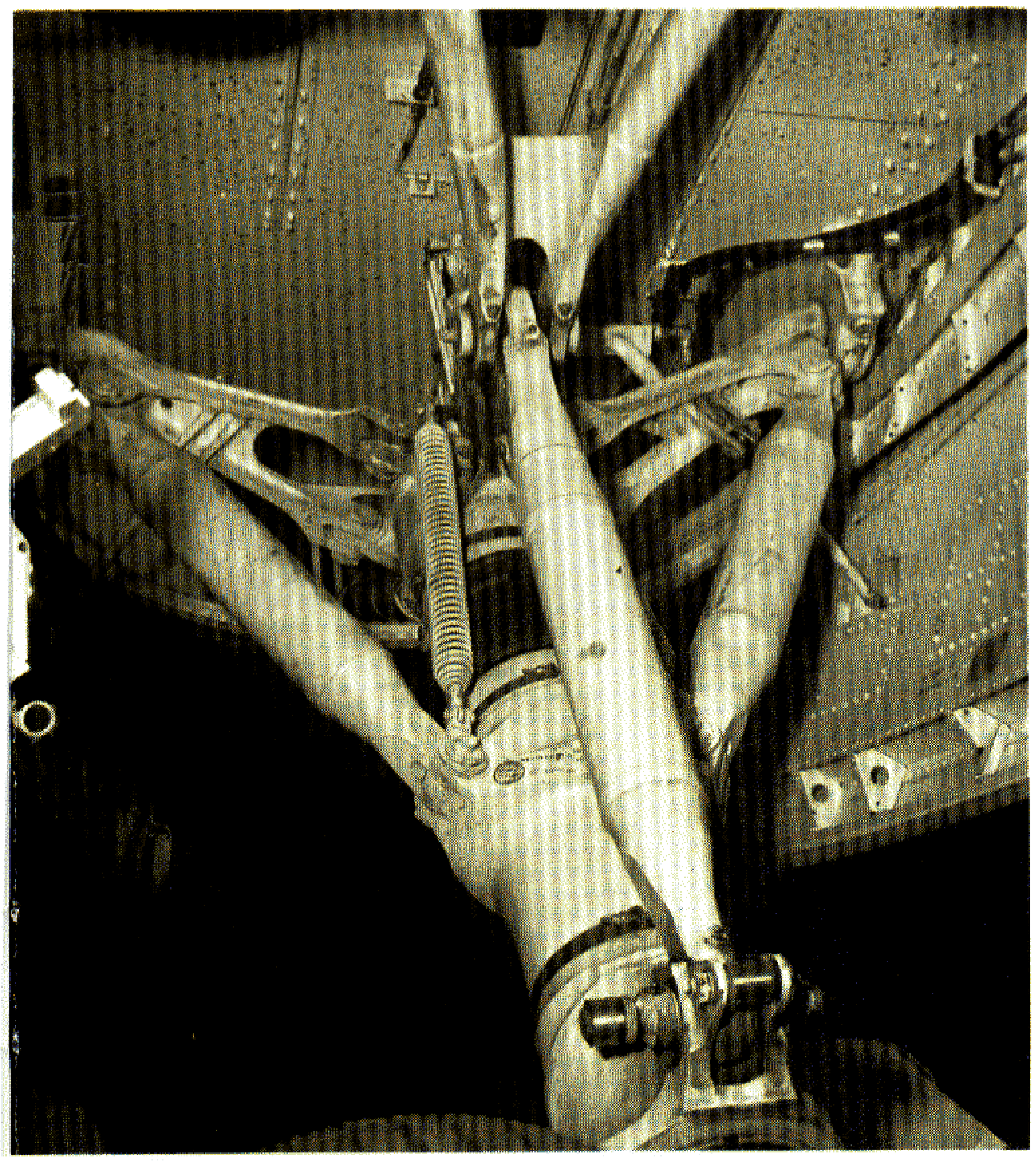
A vertical firewall of stainless steel with a flexible fire seal separates the hot section from the rest of the engine. A U-shaped stainless steel shroud extends aft from the firewall to the wing trailing edge to isolate the turbine section of the engine and the tailpipe from other areas of the nacelle and to afford a means of protecting the wing upper surface from excessive temperatures.

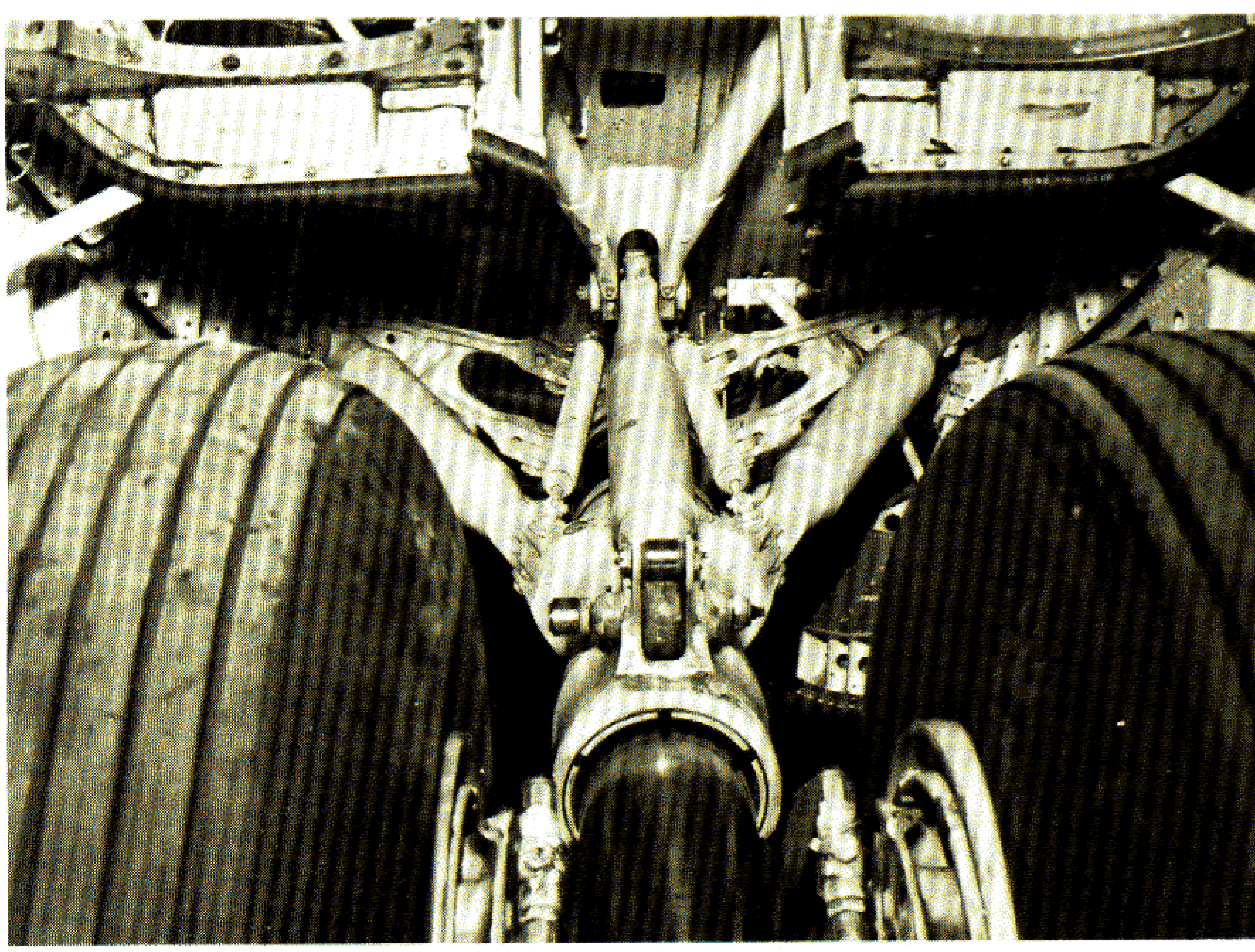
LANDING GEAR As mentioned previously, one of the primary considerations in the design of the landing gears was to ensure that the wheels could be lowered even in the event of a complete hydraulic system failure. All three gears may be extended by free fall in an emergency, and once the uplocks are opened, the gears extend, and are automatically locked in the down position by means of a simple tension spring arrangement. The hydraulic up latches can be unlocked manually and enough leverage is built into these mechanical over-rides to break loose any jammed latches.

Another primary design consideration was to ensure as far as humanly possible, that the gear would not be accidentally retracted on the ground. The geometry of the gear linkages has been engineered so that collapse of the gears is physically impossible with the airplane's weight upon them; the main struts lie over-center backward at a small angle and, similarly, the downlock (jury strut) arms and drag struts are also well over-center, so that the landing forces tend to keep the gears extended. In addition to this basic geometrical configuration, a positive locking device is provided which obstructs the gear retraction linkage when the aircraft's weight is on the gears.

Not the least of the interesting features of the main landing gear design is the surprisingly small amount of space taken up by the main gears in the retracted position. That the gears should be of relatively simple design and still remain at all times external to the wing structure is no small accomplishment; the operation of the drag strut eccentric bearing during the retraction cycle is particularly interesting.







'igure 37 MLG at the DOWN and at Two Partly-Retracted Positions

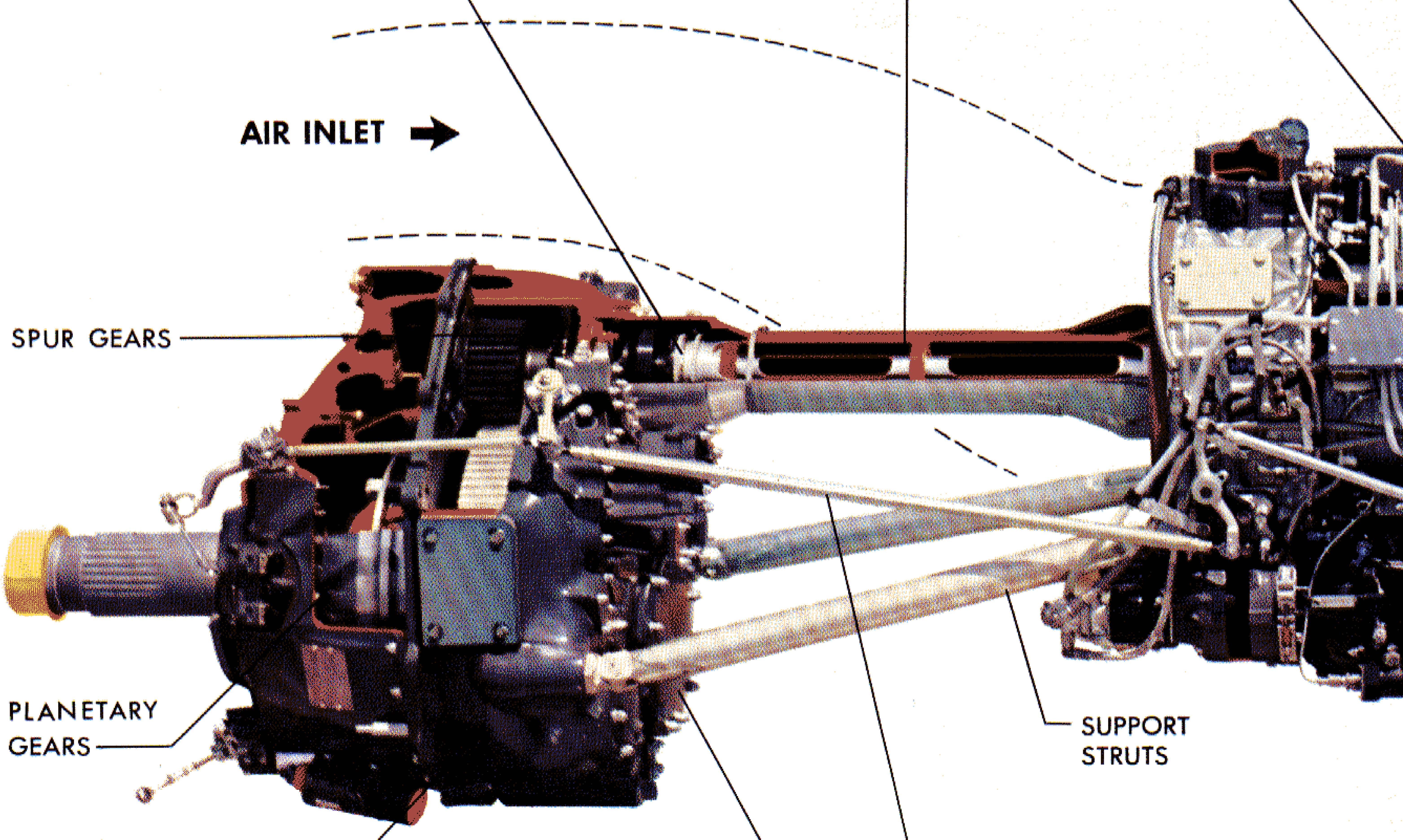
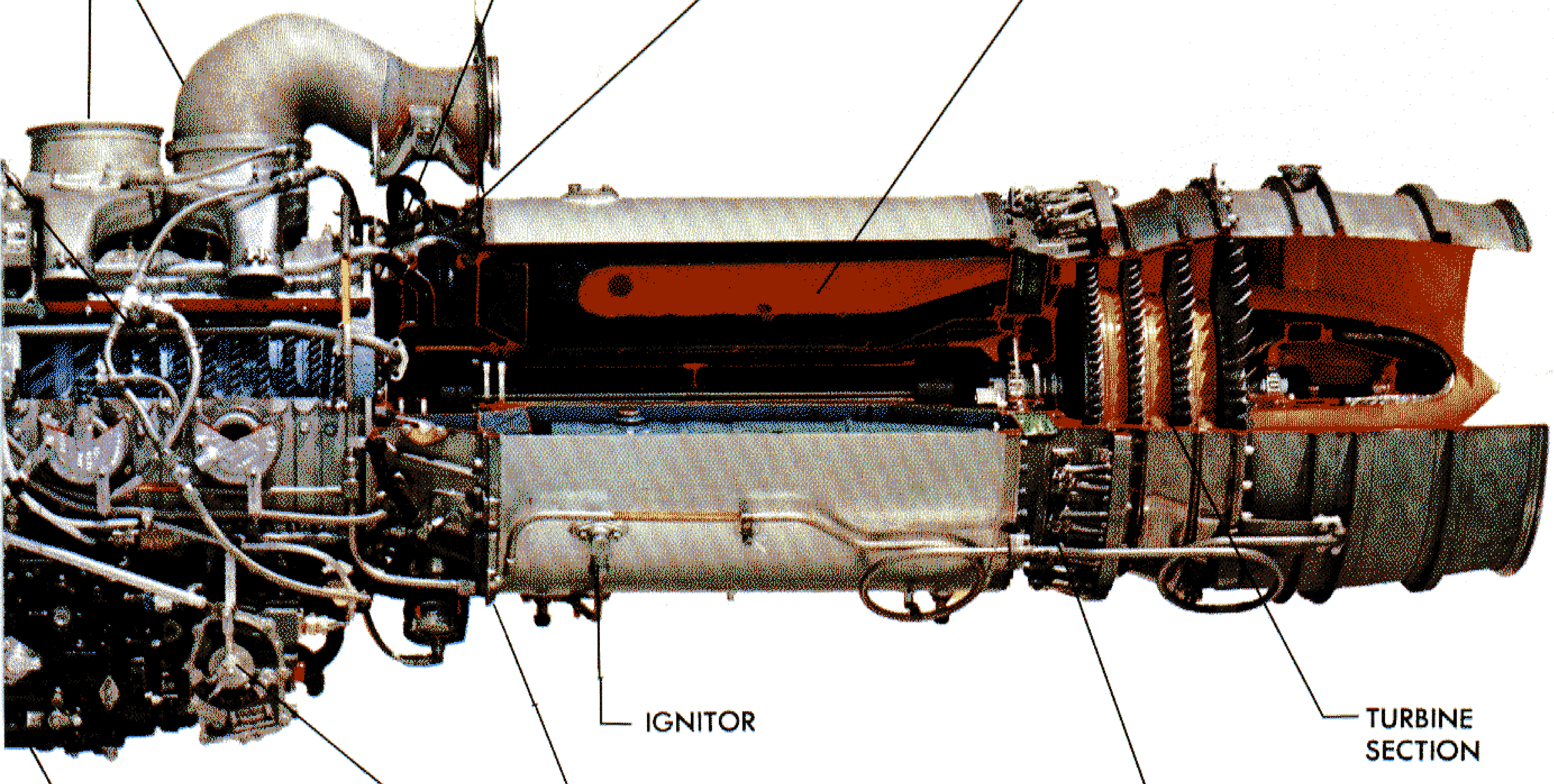


Figure 38 Allison T

POWER PLANT AND RELATED SYSTEMS

Lockheed has had considerable experience with the Allison turbo-prop engine, having done test work with it on Constellation airframes, and having since incorporated it into the design of three different production models. Installed on the C-130 it provides the power to transport enormous loads for parachute drops or for delivery to fields scattered around the world — fields that are in many cases considerably less than ideal. The Electra commercial airliner carries a slightly modified version of the basic engine, providing the air transport industry with a versatile machine which can operate economically, either as an "express" for route-sectors between principal cities, or as a "local" bringing jet-age transport to airports of limited size convenient to small population centers.

KLM, operating a long range version of the Electra, utilize a Hamilton Standard propeller with the Alli-



·bo-prop Engine. This demonstration engine does not have accessories or modifications for Orion installation.

son turbine. Both elements of this combination have been modified to better suit them for their new assignment as a power plant for the Orion.

The Propeller's hydro-mechanical operating principles need little explanation, being similar to those of the Hamilton Standard propeller used on the P-2. The Orion HS 54H60-77 propeller is completely self-contained (see Figure 39). The oil reservoir, the necessary pumps, and the governor and pitch-control components are all located within a control assembly mounted in the non-rotating afterbody of the propeller. The propeller blade cuffs and spinners are electrically heated for ice control.

ENGINE DESCRIPTION The general layout of the engine can be seen in Figure 38. Engine changes are "maintenance engineered," in that entire power plants can be stocked in QEC (Quick Engine Change) power plant packages with the propeller installed, rigged, and functionally tested. The engine shown in Figure 38 is stripped of engine driven accessories. Two accessories, a tachometer-generator and a starter, are common to all engines, regardless of the position in which the engine is mounted. No. 1 engine has only the two basic accessories, Nos. 2 & 3 engines have in addition a 60-kva generator and an engine driven compressor for cabin air conditioning, and the No. 4 engine has the basic accessories plus a 60-kva generator which is driven through a two speed gear box — the No. 4 generator is otherwise identical to the Nos. 2 & 3 generators.

Inasmuch as the Navy operates comparatively few turbo-prop aircraft, certain fundamental characteristics of this type of engine, and of the Allison T56-A-10W engine in particular, warrant a brief explanation in a general introductory article on the Orion.

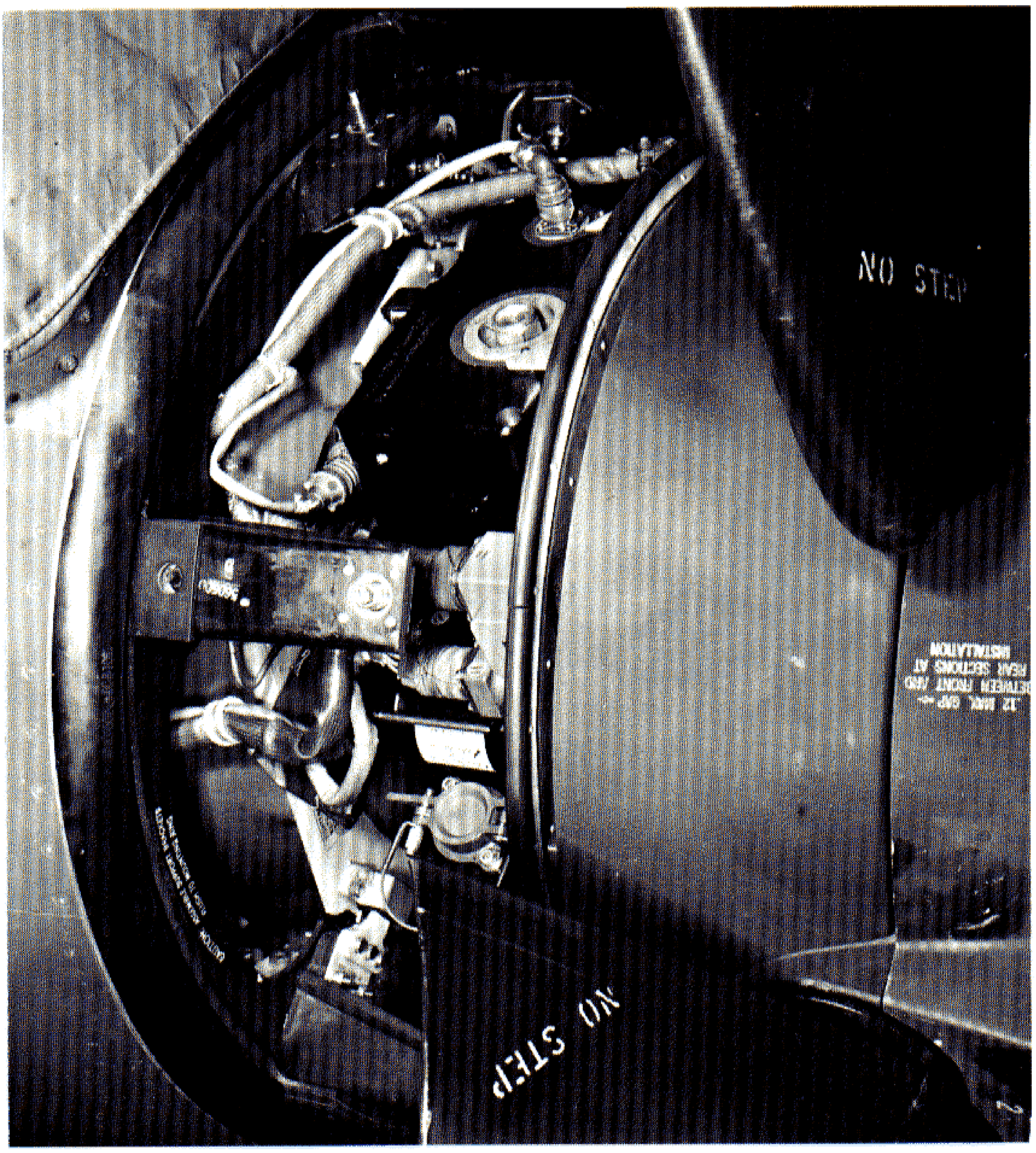


Figure 39 Propeller Control Assembly

The simple principles of power generation in this "single-spool" machine are shown in Figure 40. The horsepower figures given are approximately true take-off maximums for the engine. Note that the hot, high-speed gases develop about 10,000 hp in passage through the 4-stage turbine. About 6000 of this is needed to drive the 14-stage compressor, and the remainder, about 4,000 hp, is absorbed by the propeller to do useful work. The exhaust produces a jet thrust which is equivalent to about 7% of the maximum rated engine power at take-off — 4,500 ESHP (Equivalent Shaft Horse Power)* with water-alcohol power augmentation. Except for a limited operation to be discussed later, the compressor-turbine spool turns constantly at its optimum-efficiency speed (nominally 13,820 rpm), driving the propeller through a fairly long drive shaft and a two-stage reduction (13.54 to 1) gear-box at the propeller's optimum-efficiency speed (1,020 rpm).

Jet thrust at take-off is about 750 pounds. For the static (zero airspeed) condition, it is a fairly accurate rule of thumb to factor pounds of thrust by 2.5 to obtain equivalent horsepower. Thus 750 pounds divided by 2.5 equals 300. Take-off ESHP is the sum of 300 hp equivalent jet thrust plus 4200 hp contributed directly as SHP (Shaft Horse Power).

The Power Lever for the Allison engine is well and truly named for it affords a thrust control that coordinates all the functions which require separate controls on reciprocating engines with variable pitch propellers.

Each power lever drives a conventional cable system and a conventional swinging parallelogram linkage in the nacelle that allows for relative motion between engine and the airplane structure. There are two basic operating modes of propeller-engine control, one for Ground operation, and one for Flight operation. The system is rigged to a coordinator quadrant mounted on the engine power section which is indexed in degrees from 0° (full reverse power) to 90° (take-off power); 0° to 34° is the Ground operating range and 34° to 90° is the Flight operating range. The lever linkage has a "gate" which is rigged to correspond to the minimum flight power setting (34° on the coordinator index), and it is necessary for the pilot to deliberately lift the lever through the gate to enter the ground operating range. Figure 42 shows the arcs of the power lever controlling ranges as indicated at the coordinator index.

In the Flight Control Range the propeller functions as a sort of constant-speed aerodynamic governor for the engine, for it is not necessary to change engine speed to change the power output of the Allison turbine. The power control system has no air throttling action; a great deal more air passes through the engine at all times than is needed to completely burn the fuel. The power produced is dependent solely upon the amount of fuel supplied. The primary action instigated by advancing the power lever in Flight range is to reposition the fuel control to supply more fuel. The greater the fuel supply, the hotter the fire; the hotter the fire, the more the gases tend to expand, and due to the higher gas velocity, more power will be extracted from the gases by the turbine blades. This tends to accelerate the engine, of course, and the propeller takes independent and immediate action, increasing its blade angle at a rate as high as 13° per second if necessary, to absorb the power increase and maintain rated (100%) rpm.

In the Ground Operating Control Range (from 0° to 34° on the coordinator index), the mode of power control is considerably different. If the power lever is

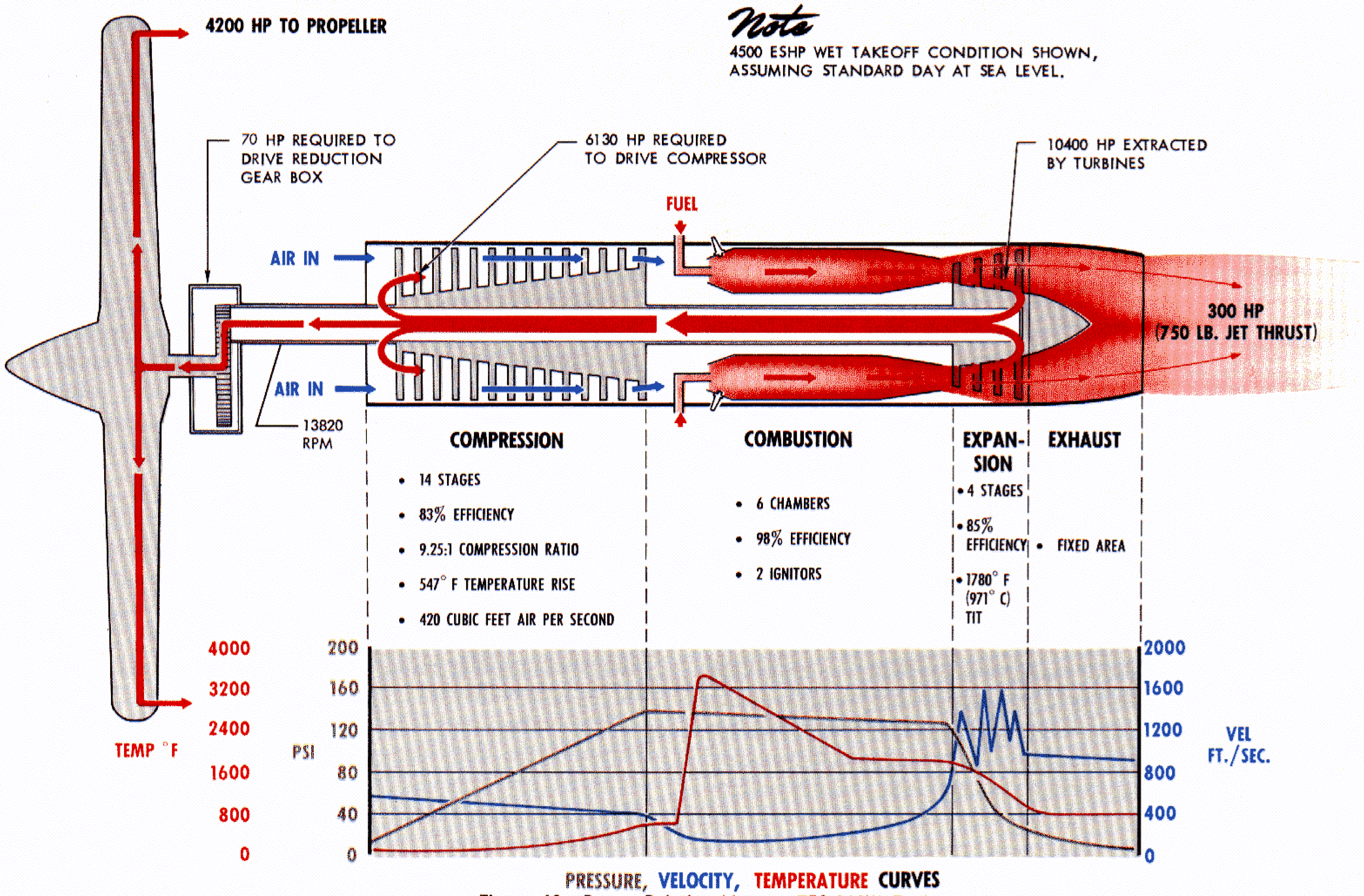


Figure 40 Power Relationships — T56-A10W Engine

moved forward in the Ground operating range, its primary effect is to move the propeller blades to a higher angle,* the engine tends to decelerate, and the fuel control provides the increased fuel flow necessary to maintain engine speed very near 100%.

Two Ground operating power lever positions are marked "START" and "GROUND IDLE". At "START", the propeller blade angle is such that the minimum resistance to turning is obtained and the starter load will therefore be least. At "GROUND IDLE", the propeller blade angle is such that enough reverse propeller thrust is obtained to offset the jet thrust produced by the exhaust. The above two thrust conditions hold true only when the aircraft has no forward motion.

The Ground operating range is commonly referred to as the "Beta Range" because the power produced in the Ground operating range is closely related to propeller pitch, and the aerodynamic symbol for propeller pitch is the Greek letter β (Beta).

If the airplane has an appreciable forward motion, the same small blade angles will give proportionally greater reverse thrust because of the angle at which the air meets the propeller. This is taken advantage of during landing to shorten the rollout. Immediately after touchdown, the power levers are brought back into the Ground operating range to "GROUND IDLE" position. So long as airspeed is high, it tends to "motor" the engines, furnishing a part of the torque required to drive the compressor sections, and the propellers become very effective drag brakes. Contrary to prop-reverse braking with reciprocating power plants, this reverse thrust is free in terms of fuel consumption. As the airspeed and the resultant reverse thrust decrease, the power levers are further retarded, increasing the reverse blade angle until in the last portion of the Ground operating range, the fuel flow is increased to supply enough reverse-thrust power to bring the airplane to a full stop.

Although the engine is considered to be constant-speed, it can be operated at 72.5% of Normal speed while the power lever is in the Ground operating range. This is known as "Low Ground Idle" speed, and the pilot must deliberately position a speed selector switch to "LOW" to induce the down-shift and obtain the benefit of quieter operation and better fuel economy for low speed taxi operation. The power lever continues to schedule propeller blade angle during "Low Ground Idle" operation just as it does during "Normal Ground Idle" operation, but the main fuel control is re-adjusted to maintain engine speed at approximately 10,000 rpm.

While the propeller is at or near the "Ground Idle" setting, it produces very little air blast. This is ideal for the ground crew, but the engine oil cooler would be starved of cooling air were it not for an augmentation system. This system is activated by fully opening the oil cooler flap. Bleed air, taken from the engine, is ejected aft through an augmentor rake assembly on the aft side of the oil cooler (see Figure 41). This draws sufficient cooling air through the oil cooler, even when the propeller is in reverse, for effective oil cooling.

An Engine Oil System, wholly contained in each QEC power plant package, employs an 8.65-usable-gallon tank which supplies two independent lubrication systems (reduction gear box and power section) on each engine. Each of these sections drives its own lubrication pump.

The oil is scavenged from these two areas and returned to the tank through a fuel heat exchanger, the oil cooler mentioned previously, and, on the inboard engines, an oil-to-oil heat exchanger. The latter component controls the lubrication system temperature of the engine driven compressors which are mounted on engines 2 and 3 only. Each engine has a single low oil pressure warning light, high oil temperature warning light, oil quantity indicator, and oil temperature indicator, but there is a separate oil pressure indicator for each of the two independent lubrication systems of each engine.

POWER CONTROL — MANUAL AND TEMPERATURE SENSITIVE The heat of the gases just downstream of the combustion chambers is the best measure of the gases' ability to do work or, to put it bluntly, to inflict overheat damage on the turbine blades. There are 18 dual-element thermocouples, spaced radially around the annular turbine entrance, to measure the turbine inlet temperature. The small dc potential generated by one element of each of these thermocouples furnishes a voltage signal which is suitably amplified for a Turbine Inlet Temperature (TIT) indicator on the pilot's center instrument panel. These four engine instrument gauges are calibrated in degrees Centigrade.

The thermocouple potential of the other elements is amplified and used as a reference signal in fuel controlling. This is a unique, interesting, and important system. As with all turbine engines, some rudimentary knowledge of the fuel controlling devices is a prerequisite to understanding the engine's abilities and limitations.

The fuel control on the T56 engine is a complex hydro-mechanical unit. Turbine inlet temperature is the major determining factor in the production of power, and the fuel control correlates power lever position and turbine inlet temperature by providing a specific volume fuel flow for a specific set of operating conditions.

Four signals are fed into the fuel control: power lever position, engine rpm, total ambient temperature, and total inlet air pressure (total temperature and pressure takes air speed into account). The adjusted flow from the fuel control is actually 120% of the amount normally required, the excess being trimmed off by a flow-divider known as a Temperature Datum (TD) valve, and by-passed back to be recirculated through the fuel control. The temperature datum valve has an electronic control which utilizes the T.I.T. thermocouple potential mentioned previously, but the valve will normally function on hydraulic principles alone. Thus the electronic control is not essential for normal engine operation, but it is a valuable backup for the fuel control.

The T.D. circuit constantly monitors the heat at the turbine entrance, compares it electrically to a signal derived from potentiometers which sense power lever position, and acts to "bias" the division of flow at the T.D. valve to correct discrepancies. The T.D. valve reacts quickly to correct momentary overshoots in flow from the main fuel control, and in the high power regime it can provide a constant correction factor if it is necessary to offset minor irregularities and malfunctions in the fuel control or the engine. Further, the T.D. system corrects automatically for variations in fuel density; a factor not taken into account by the fuel control.

The bias capabilities of the T.D. electronic control are limited according to the operating regimes as follows:

1. As the power lever is advanced from 66° to 90° (as measured on the coordinator index), T.I.T. is scheduled to increase from 760° to 971° C, and

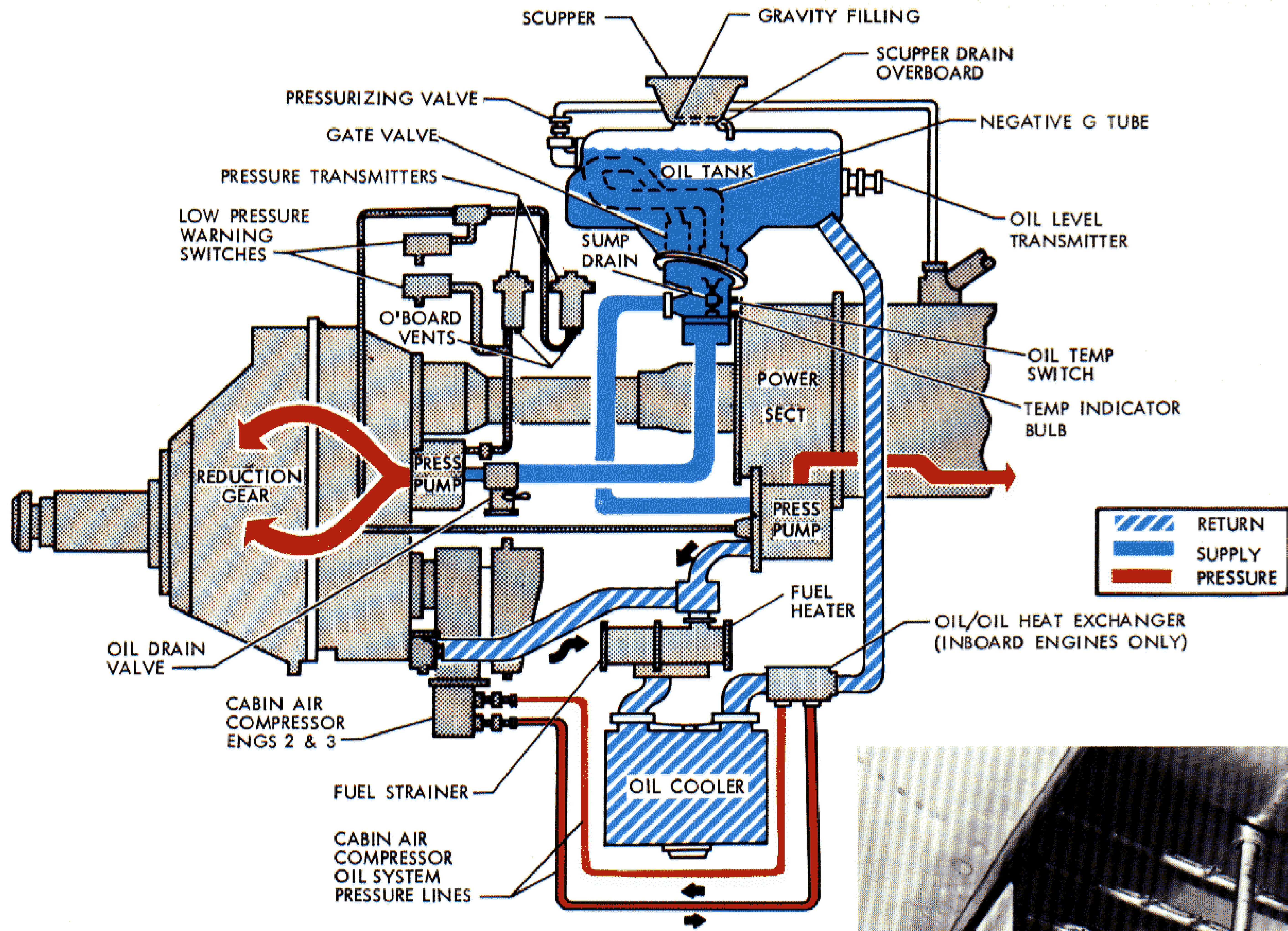
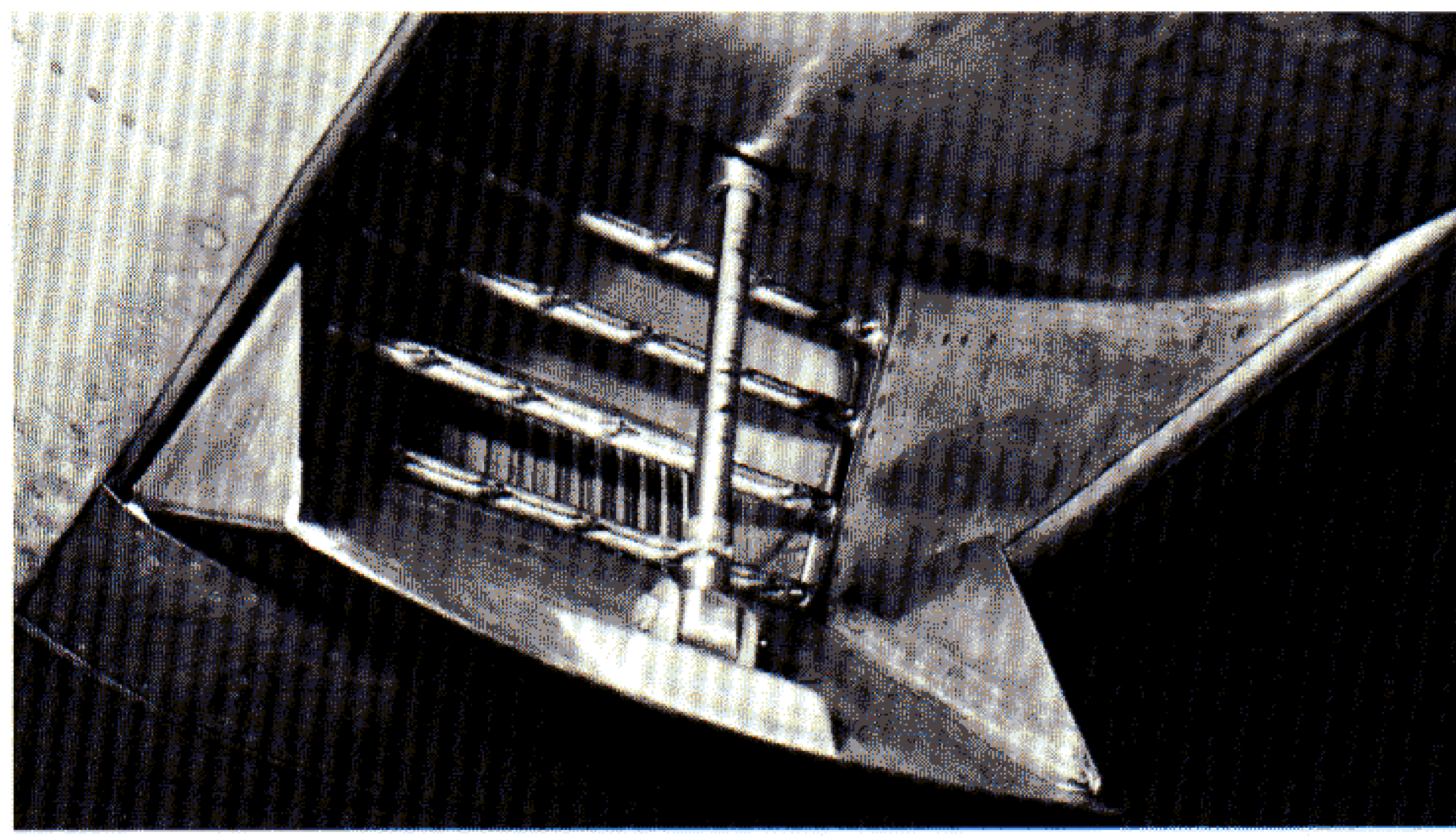


Figure 41 Engine Oil System Schematic and Jet-pump Type Cooling Augmenter



the T.D. valve can pass to the engine additional fuel from the 120% over-supply offered by the fuel control, or it can subtract as much as 2 gallons from each 6 gallons offered by the fuel control to maintain the temperature schedule. This range is denoted as the "Temperature Controlling Range" (see Figure 42).

2. From 0° to 66° (coordinator) is the "Temperature Limiting" range. In this range the T.D. valve cannot pass more than 100%. It can subtract as before, but only in the event the T.I.T. reaches 978° C while engine speed is more than 94%.

3. During engine start and when the engine is operating at Low Ground Idle speed (approximately 72.5% speed; 10,000 rpm) or at any speed less than 94% of Normal, a speed sensitive switch adds additional circuitry to the temperature datum control, enabling the valve to bypass as much as half of the nominal (100%) fuel flow if it is necessary in order to limit TIT to 830° C, (148° C less than the allowable temperature when the engine is operating at normal speed). This feature is of primary importance, for the weight flow of air through the turbine during start and Low Ground Idle operation is quite small in comparison to the flow at normal operating speed and a relatively minor error on the part of the main fuel control could seriously over heat the turbine blades.

The engine will operate, if necessary, through purely mechanical control. In case of electronic TD system malfunctions, the temperature datum control can be de-activated by turning a control switch in the flight station, but then there is no automatic protection against overheat and the crew must monitor the TIT gauges carefully to ensure that the turbine is not overheated.

(Cont. on next page)

POWER PLANT SAFETY DEVICES One of the basic differences between a reciprocating power plant and a turbo-prop is the vast difference in engine airflow, and hence, in the amount of power needed to compress this air. As explained previously, the high horsepower required to maintain the compressor "on speed" is turned to advantage on the Orion, for the wide-bladed propellers are very effective air brakes after touch-down when they are made to windmill in the air-stream and supply a part of the power to drive the compressors. This trait could be a hazard if these "airbrakes" were applied accidentally due to an engine failure, requiring that automatic safeguards be provided against such an eventuality. By referring to the power relationships diagram in Figure 40 and imagining engine and propeller failures of various kinds, it can be seen that the amount of drag which a failed engine could induce depends upon the location and nature of the failure.

When engine power is reduced, a constant speed propeller will reduce its blade angle in order to maintain governing speed. If the engine fails in flight, the propeller begins windmilling against the torsional drag of the defunct engine. The drag induced by a piston engine is relatively small in comparison to that which could result if the propeller of a turbo-prop attempts to drive the compressor without *any* aid from the turbine. This would be the worst case—the one in which the turbine blades are completely ineffective either because of blade damage or failure of the drive line between turbine and compressor. In this case the propeller attempts to supply the full 6000 hp required to drive the compressor at 100% rpm.

A simple flameout could not cause as much drag, for even though no heat is being added to the air in the combustion chambers, the air cycle would be undisturbed and the turbine blades would recover a great deal of the power expended by the compressor.

A second type of trouble — overspeed of engine or propeller — could originate in a number of ways, and both the engine and the propeller have separate protective devices in this respect.

Auto Feathering — TSS (Thrust Sensitive Signal). On take-off the yaw induced by a failed engine must be kept to an absolute minimum. For this reason the auto-feather system utilizes a Thrust Sensitive Signal device (schematized in Figure 42) that actually initiates the shutdown cycle *before* drag develops. Once the system is armed (by its manually operated arming switch and a power lever switch that actuates when the power lever is advanced past the 75° coordinator position) the high propeller thrust compresses Belleville springs under the propeller shaft thrust bearing and actually pulls the shaft forward about .10 inches. This motion holds a Thrust Sensitive Switch open. If propeller thrust decreases to about 500 lb., the Belleville springs will retract the shaft and the Thrust Sensitive Switch will close, causing the propeller to feather and the engine's fuel control valve to close.

NTS (Negative Torque System). Except for take-off, the propeller should be able to develop less than 500 lb thrust and, indeed, even a limited amount of negative thrust is desirable for certain operations. The NTS (Negative Torque System) affords constant protection against high drag due to engine failure in flight, and also allows limited use of the propeller as a flight speed brake. The system is immune to electrical malfunction, being a purely mechanical one. As shown in the Figure 42 schematic, a ring gear in the reduction gear box is spring-loaded aft, and it has a helical spline such that if the propeller transmits torque equivalent to about 375 hp in the reverse direction through the reduction gearing, the ring gear will move forward against its spring load, pushing a mechanical linkage which moves the propeller feathering valve toward feather position. Generally, reverse torque will be due to the propeller blade angle being too low in respect to the existing airspeed. As the propeller moves toward feather, the negative torque will be relieved, rpm will decrease momentarily, and the cycle will repeat until engine power is increased or until airspeed decreases to a level compatible with the engine power setting.

Decoupler. A final backup for the type of failure which would induce a severe negative torque is built into the reduction gear box-to-drive shaft coupling. If the NTS fails to relieve the situation at minus 375 hp, the drive shaft will decouple from the reduction gear box at minus 1500 hp, separating the propeller and gear box from the failed engine. Since the reduction gear box is self lubricated and the propeller is self governing and has it own control oil supply, this part of the power plant can continue on-speed operation, inducing a limited amount of drag.

Low Pitch Stops. The NTS system offers the primary safety when power is relatively low and speed is relatively high. If engine power should fail when the power lever is well forward in the Flight range, a hydraulically operated low-pitch stop (known as the Beta Follow-up) would probably be the first effective device to prevent the propeller from inducing a high drag, particularly if airspeed is relatively low. The propeller also has a conventional low-pitch stop, which is effective at all times while the propeller is

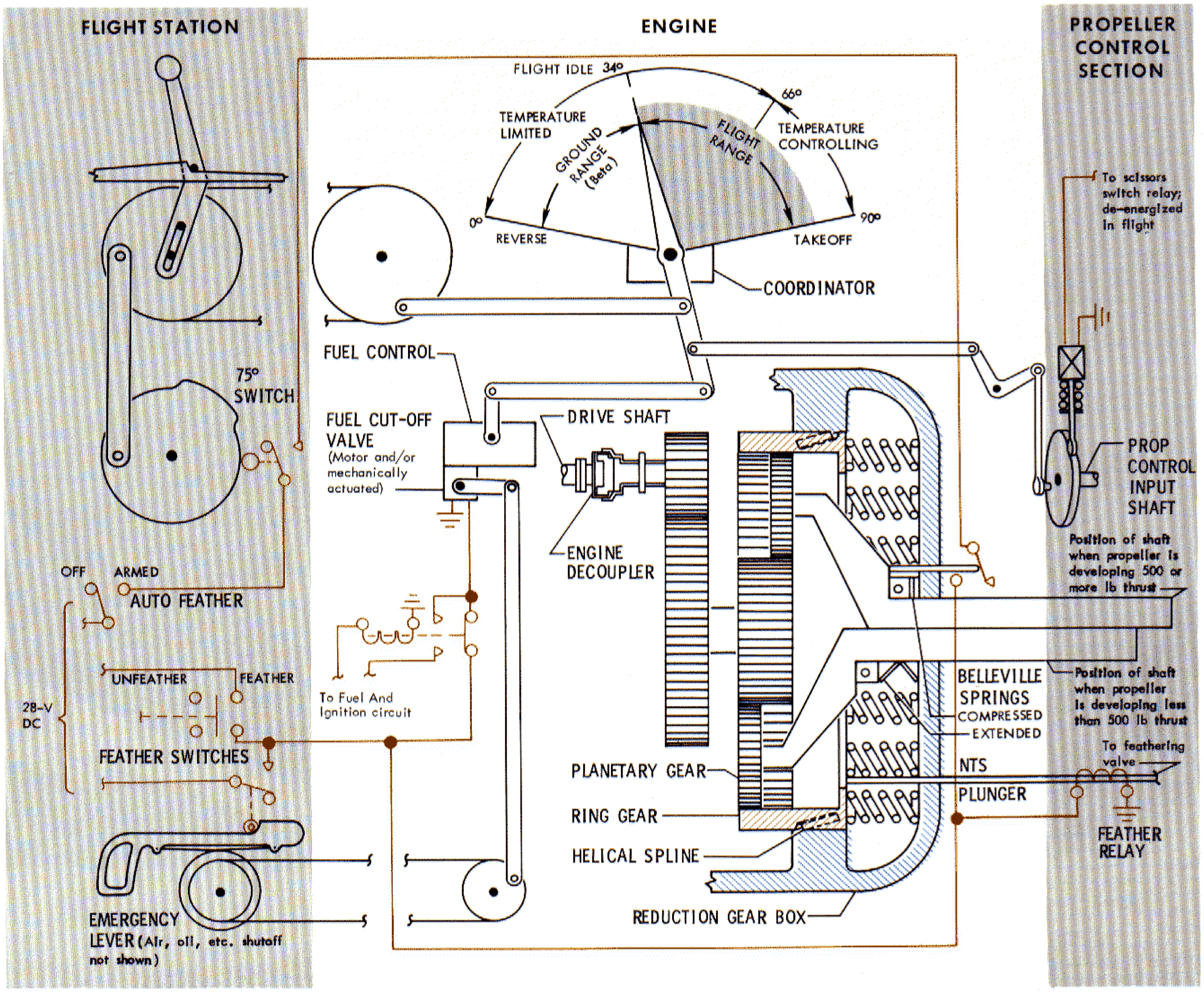


Figure 42 Schematic of Propeller and Engine Controls and Some Related Safety Devices

self-governing to prevent the prop from going to less than 13° while the power lever is in the flight range. This is a fixed position stop, whereas the Beta follow-up stop is actually adjusted by the power lever, following it up to prevent the propeller from going to a pitch setting that cannot possibly be correct in view of the high power being requested. With the power lever at take-off power, the Beta follow-up stop will prevent the propeller from going to less than 22° if the engine should fail.

If the Propeller Should Overspeed to 103%, or if propeller control oil pressure is lost, a pitch-lock mechanism will automatically lock the pitch control gears. With the pitch lock engaged, the propeller cannot go to a lower pitch, nor can it govern itself. The engine can sometimes be used for cruise after a pitch lock occurs by manipulating the power levers as necessary to maintain rated engine speed, but the engine should be shut down before entering the landing approach because the locked-in high pitch will be entirely incorrect for low air speed operation. The pitch lock does not prevent propeller feathering, and several factors ensure that feathering pressure will be available, even if the overspeed is due to partial loss of control oil, internal control valve leakage, or malfunction of the control oil pumps. First, the feathering pump is electrically operated, second, it draws oil from a lower strata of the oil reservoir than the normal mechanically driven pumps and, third, its output bypasses the control valving and goes directly to the "increase pitch" side of the pitch control piston.

Engine Overspeed Protection is furnished by a flyweight type governor (fuel topping governor) in the fuel control which restricts fuel flow if engine speed reaches 104% during Normal operation. When Low Ground Idle is selected, the fuel topping governor is readjusted and it serves as the basic fuel metering device to maintain 72.5% rpm operation.

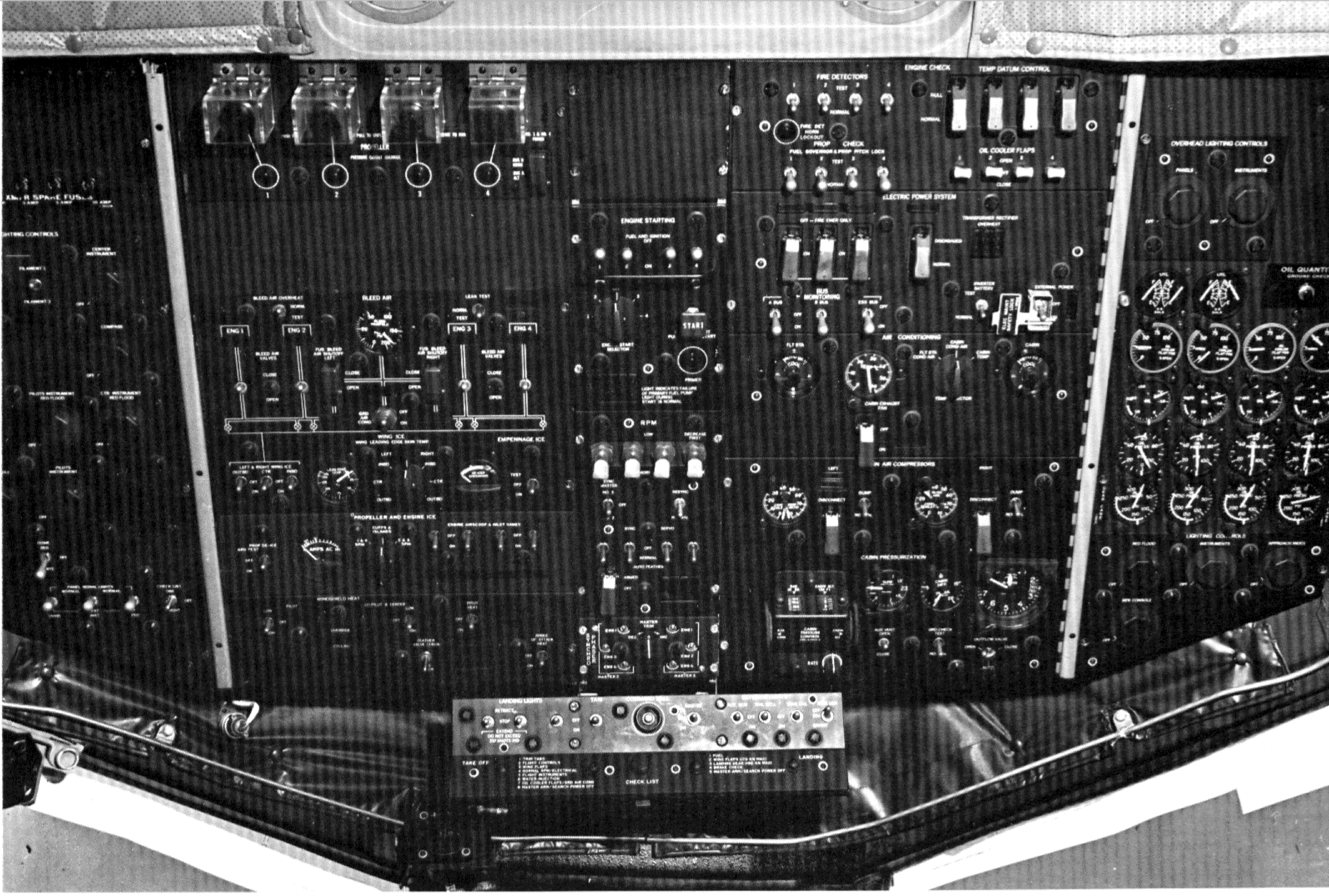


Figure 43 Flight Station Overhead Control Panels

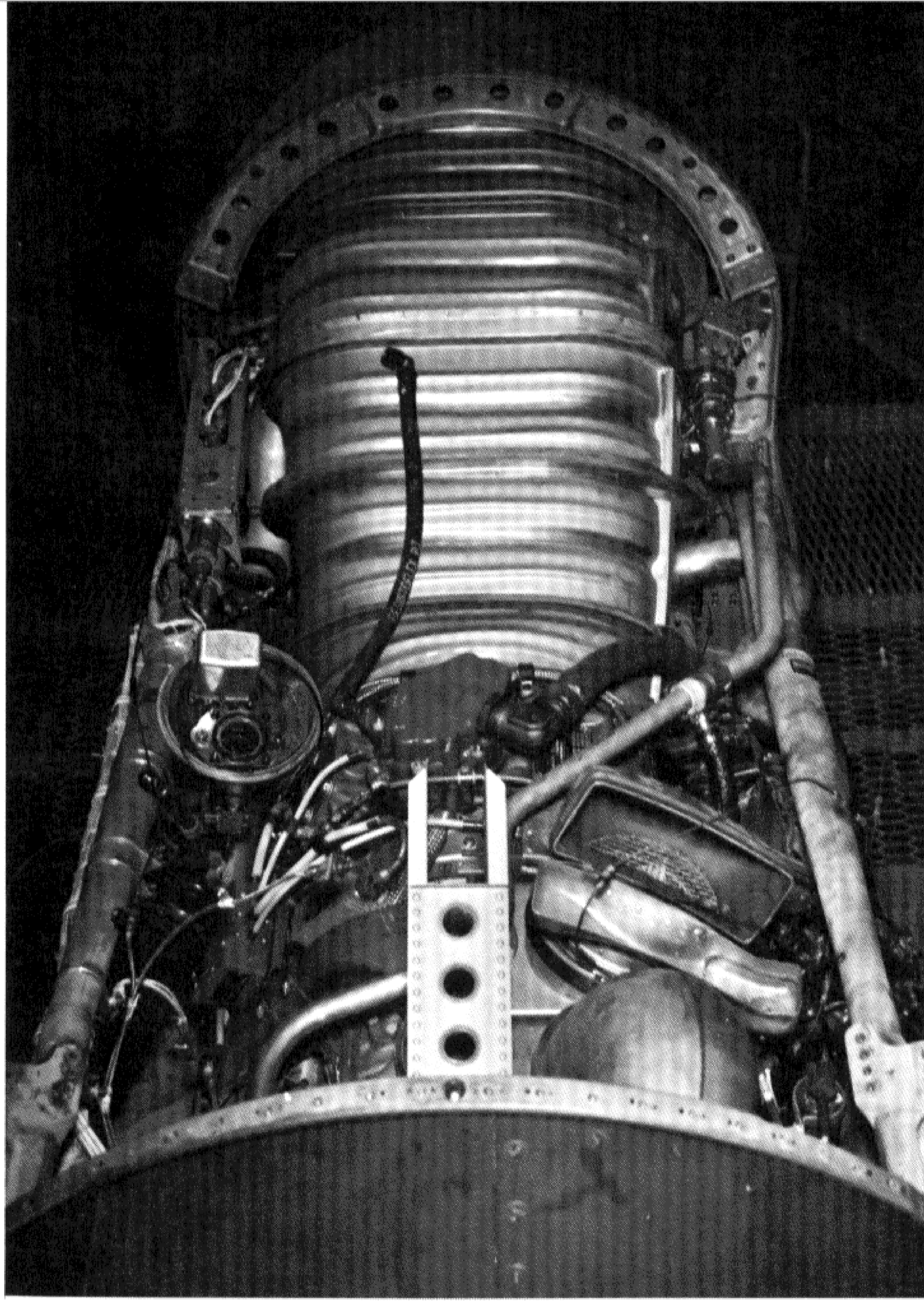
LOW GROUND IDLE As mentioned previously in connection with the ground operating control range, Low Ground Idle operation is a great deal quieter than Normal speed operation, and it saves fuel. An RPM switch for each engine is located on the center overhead panel in the flight station. Insofar as the engine and propeller are concerned, the only direct effect that the switch has is to readjust the fuel topping governor spring in the main fuel control when "LOW" is selected. However, at any time that engine speed is less than 94% of Normal speed, bleed valves on the 5th and 10th compressor stages open automatically and a great deal of air from the compressor is discharged over-board. This substantially decreases the amount of power needed to start the engine and also the amount of fuel expended to drive the compressor at Low Ground Idle speed after the engine is started.

THE ENGINE AIR INTAKE ANTI-ICING SYSTEM utilizes bleed air from the 14th stage of the engine compressor. The 14th stage air, which is more than 500° F above ambient temperature, supplies two sub-systems.

One sub-system routes air to be circulated through the hollow-walled air inlet scoop and thence through an integral circulating system in the walls of the engine air inlet duct.

The second sub-system serves to anti-ice various engine components in the inlet air path. A branch flow passes through the shroud covering the engine drive shaft, other branches through passages which warm compressor inlet components such as inlet air guide vanes, fuel control sensing probes and the like.

Each sub-system has a solenoid operated shutoff valve. These are open-when-de-energized type valves, ensuring that electrical power failure will not entail loss of anti-icing. To ensure that the two sub-systems are never used separately, the two valves for each engine are jointly energized from a single switch on the Ice Control Panel in the Flight Station. Further, a thermal switch is mounted downstream of each valve, and both of these switches must sense a satisfactory anti-icing air flow to illuminate a single advisory light adjacent to the engine's ice control switch.



BLEED AIR SYSTEMS
ENGINE START — WING ANTI-ICE

Hot, high pressure air from taps on the right side of each engine's 14th compressor stage is used for engine starting, wing anti-icing and, oddly enough, the cooling augmentors that ventilate the engine oil and air conditioning heat exchangers when ram air is not available. Engine air intake anti-icing (which also uses 14th stage air, but from separate taps) and the cooling augmentation systems are discussed elsewhere in connection with the power plant and air conditioning.

Each engine supplies its own air for engine anti-icing and oil cooling augmentation, of course, but air must be routed through the bleed air manifold shown in Figure 46 for the other services. Air can be fed into this manifold from an external source (by attaching a gas turbine compressor at the connector as shown in Figure 45) or from the compressor of an operating engine by opening a motor-operated bleed air shutoff valve just aft of the firewall. This manifold carries air at temperatures and pressures which are

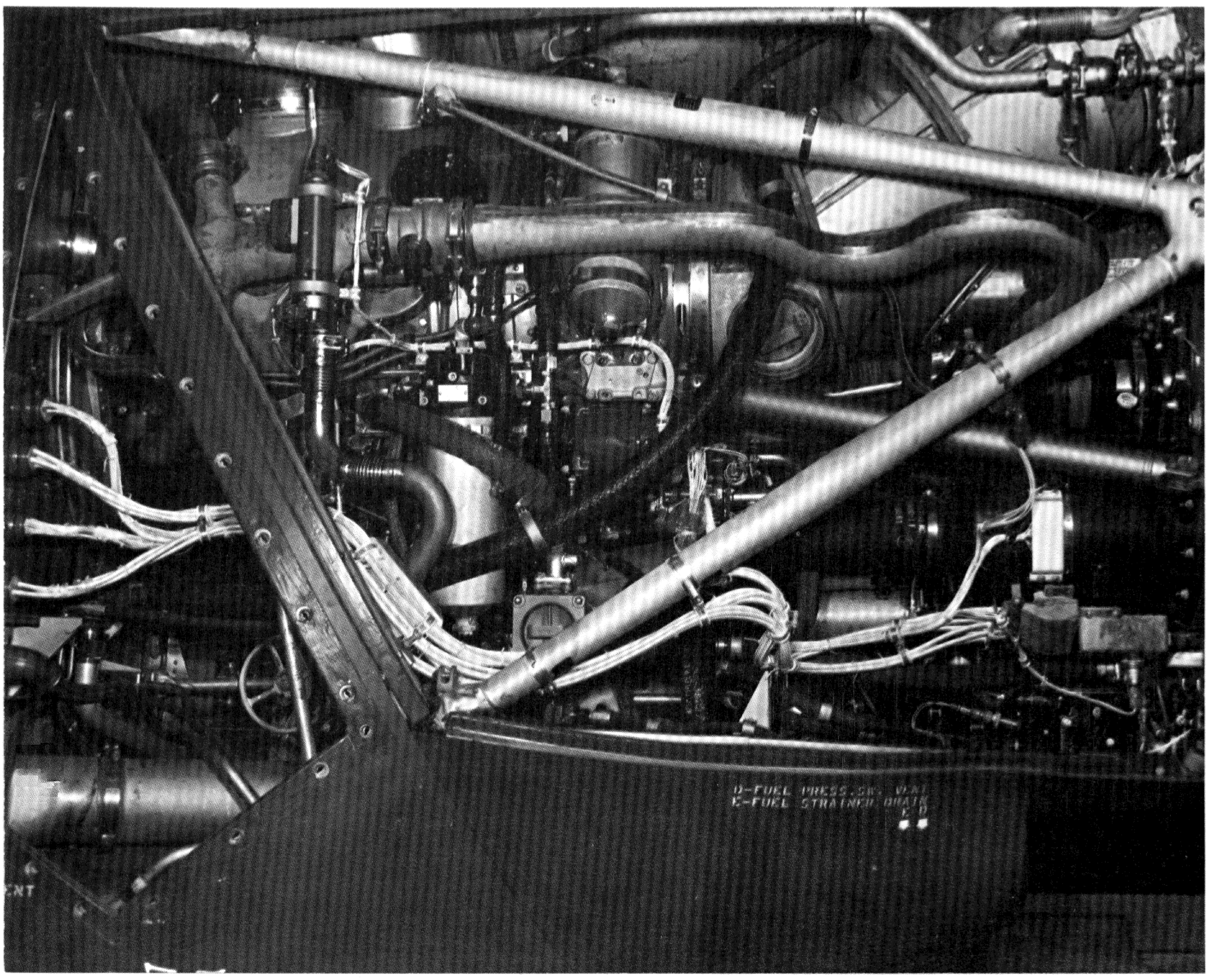


Figure 44
Top and Right-side
Views of
Engine Installation

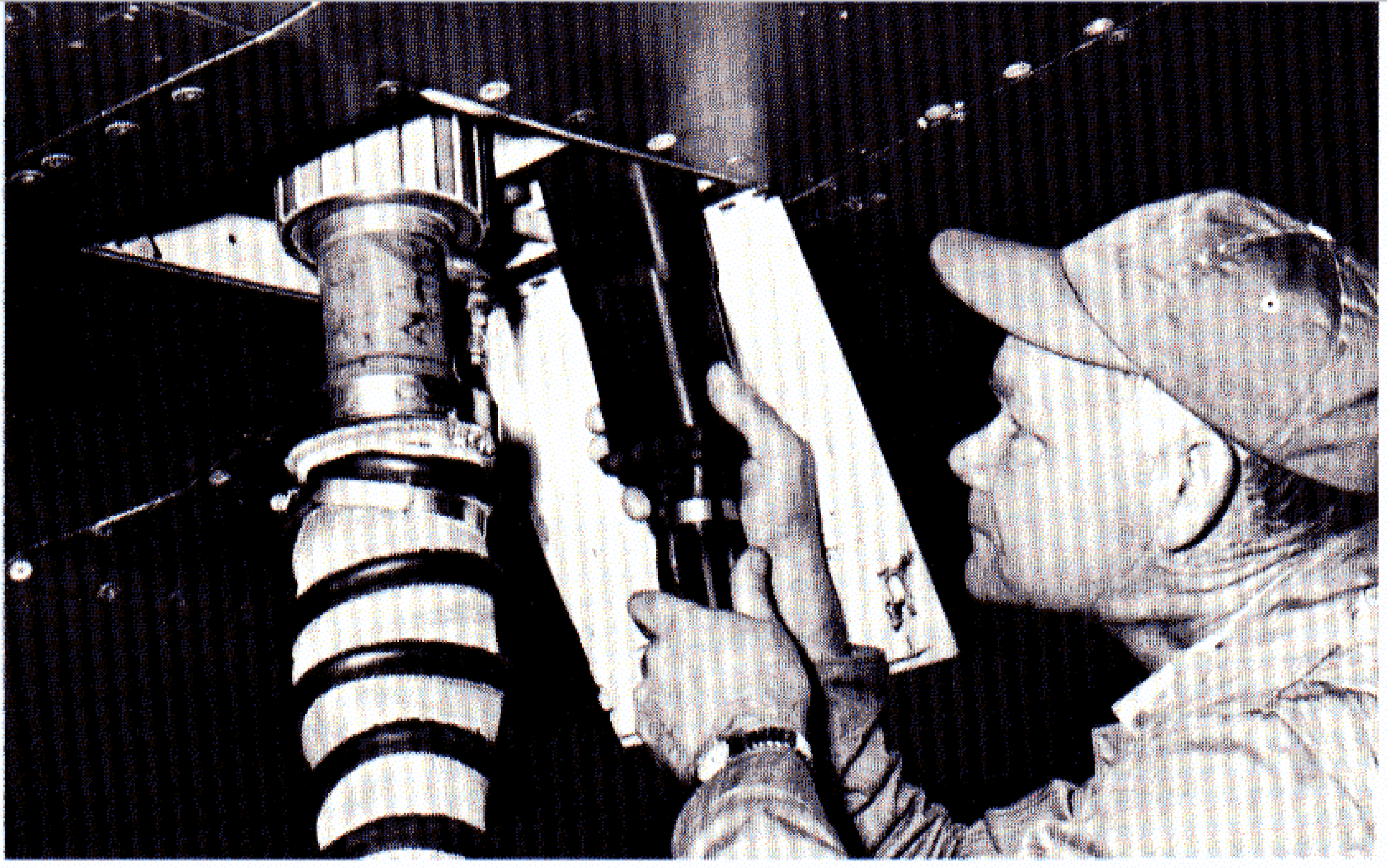


Figure 45 Starting Air and Electrical External Power Connections

potentially hazardous, and suitable safeguards are provided in both the structural and operating design. For instance, we provided a built-in pneumatic-electrical leak rate testing system which utilizes pressure switches and a time delay relay to measure the pressure-decay rate in the manifold during an 8-second test period. If the manifold valves and joints are acceptably air tight, an "ACCEPT" light in the flight station is illuminated. There are also area-overheat lights which will be energized by strategically located temperature-actuated switches if a leak in the duct should cause an appreciable temperature rise in any of the seven principal plenum chambers through which the duct is routed. Air can be routed from wing to wing, but normally the manifold is sectionalized by closing valves on either side of the fuselage (known as fuselage bleed air shutoff valves), unless a cross-ship flow is needed for a specific purpose.

ENGINE STARTING procedure is generally to start the initial engine from an external gas turbine compressor, which is then disconnected and the remaining engines are started by opening firewall shutoff valves and fuselage bleed air shutoff valves as necessary to channel bleed air from the operating engine to the starter control valves of the other engines.

The starters are small air turbines mounted on each engine's reduction gear box. The Start circuit, which opens the starter control valve, grounds through a speed sensitive switch* in the starter. The starter control valve has a pressure regulating feature which maintains a constant starter torque until the engine has accelerated to about 60% speed, at which point the speed sensing switch opens, cutting off starting air, and the starter turbine coasts down due to a non-reversible type drive which allows the engine to overrun the starter.

An engine operating at normal speed can easily supply enough air for engine starting, but note that the engine being started "lights off" when or before

**Engine driven speed sensing switches also operate during the starting cycle; opening the fuel cutoff valve at 16%; energizing two ignitors at 16%, de-energizing them at 65%.*

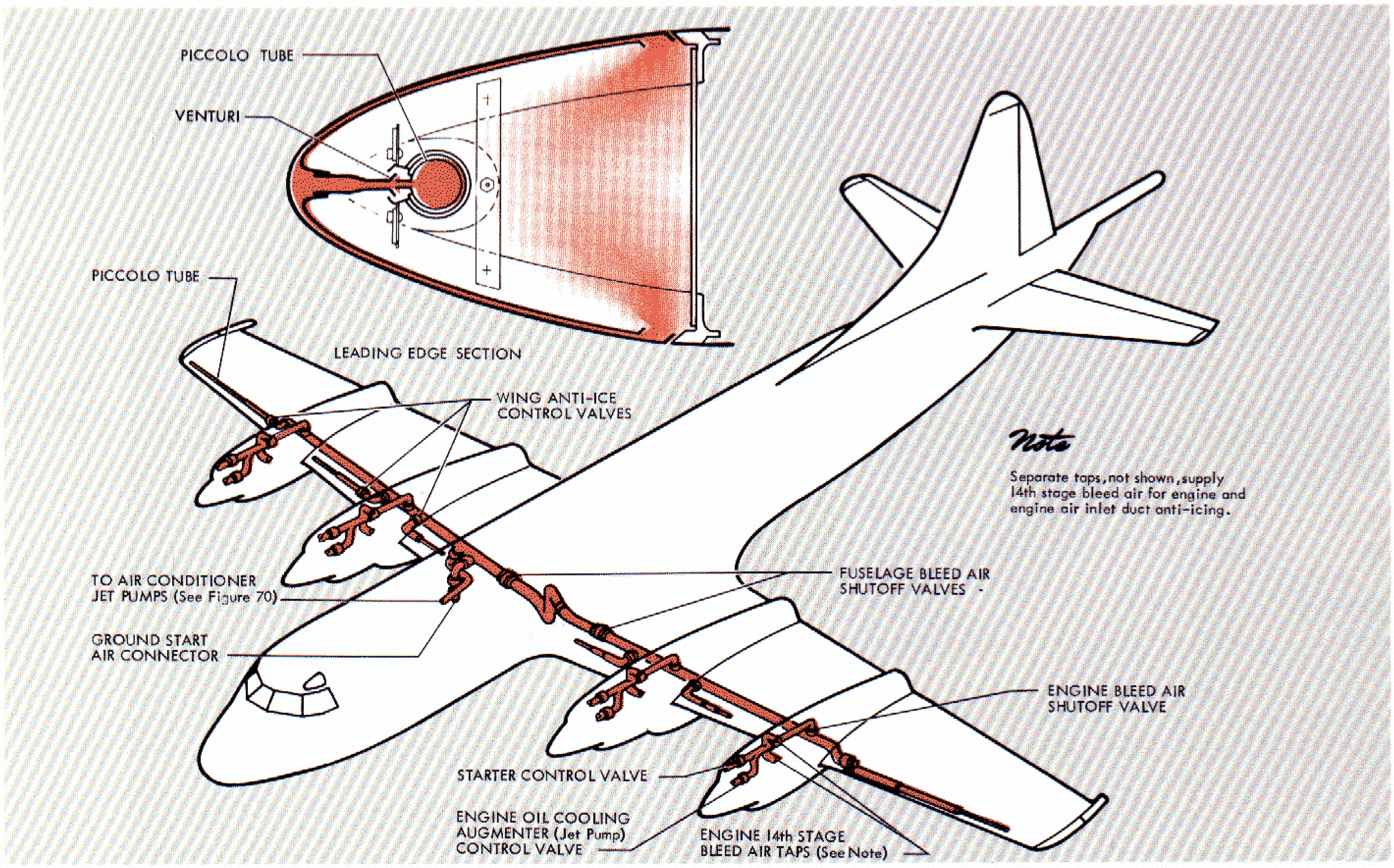


Figure 46 Bleed-air Manifold and Wing Leading-edge Section Detail

it reaches 24% speed, and the starter continues to work to pull the engine through the critical acceleration range to 60% speed. It is essential, therefore, that any gas turbine compressor used for starting the first engine be able to maintain at least 25 psi in the bleed air manifold during the start cycle.

THE WING ANTI-ICING SYSTEM also uses air taken from the bleed air manifold. Three tapered ejector tubes, known as piccolo tubes because of their lengthwise row of jet nozzles, disperse the air into the 3 anti-icing zones of each wing (tip-to-outboard nacelle; nacelle-to-nacelle; and inboard nacelle-to-fuselage). Figure 46 shows a typical leading edge, cross-sectioned through one of the piccolo tube jet nozzles. Note that the jets discharge through a venturi, and hot bleed air mixed with recirculated plenum air is channeled between the double walls of the leading edge skin. Spent air is ducted from the 6 leading edge anti-icing zones to vents in the aft end of the engine nacelles.

The heat expended by wing anti-icing is a considerable drain on engine power when the six anti-icing valves are initially opened by their electrical control, but the valves have an automatic secondary control consisting of a pneumatic thermostat, and flow through the valves is modulated when a satisfactory anti-icing temperature is established. There is no automatic timer for on-off cycling of the wing anti-icing zones, but they can be cycled manually if it is desired to use the system for de-icing rather than anti-icing.

The six valves are controlled in left and right pairs through three switches on the Ice Protection Control panel (see Figure 43). This panel also has an overheat warning light and a 6-zone temperature monitoring selector which enables the flight crew to locate an overheating leading edge skin and then deactivate anti-icing at paired zones, that is, corresponding zones in each wing are deactivated simultaneously so that asymmetrical anti-icing will not create flight control problems.

An Ice Detecting System warns the pilot when icing conditions exist. When ice begins to form on a detector probe mounted in the air stream on the lower right side of the forward fuselage, air passages in the probe are blocked, causing a diaphragm operated switch to close. This illuminates a warning light in the flight station and energizes a heater which melts the ice covering the detector probe air passages, permitting the switch to open. Icing severity can be judged from the rapidity of cycling as indicated by the warning light.

EMPENNAGE ICE CONTROL

The empennage leading edges have integral stainless steel heating grids which utilize ac power for ice control. The grids are sandwiched between layers of impregnated fibre glass covered by a thin outer aluminum skin as shown in Figure 47. The leading edges are formed by bonding together these lamina with heat and pressure after which they are installed on conventional rib-and-stringer supporting members.

Some sections of the leading edges are anti-iced, that is, they are heated continuously when the system is in use, others are de-iced. In all there are 11 anti-iced strips interspersed strategically between 20 de-iced zones. The 20 de-iced grids are each energized for 8 seconds, de-energized for 168 seconds by a timer and power relays. Each zone circuit has its own circuit

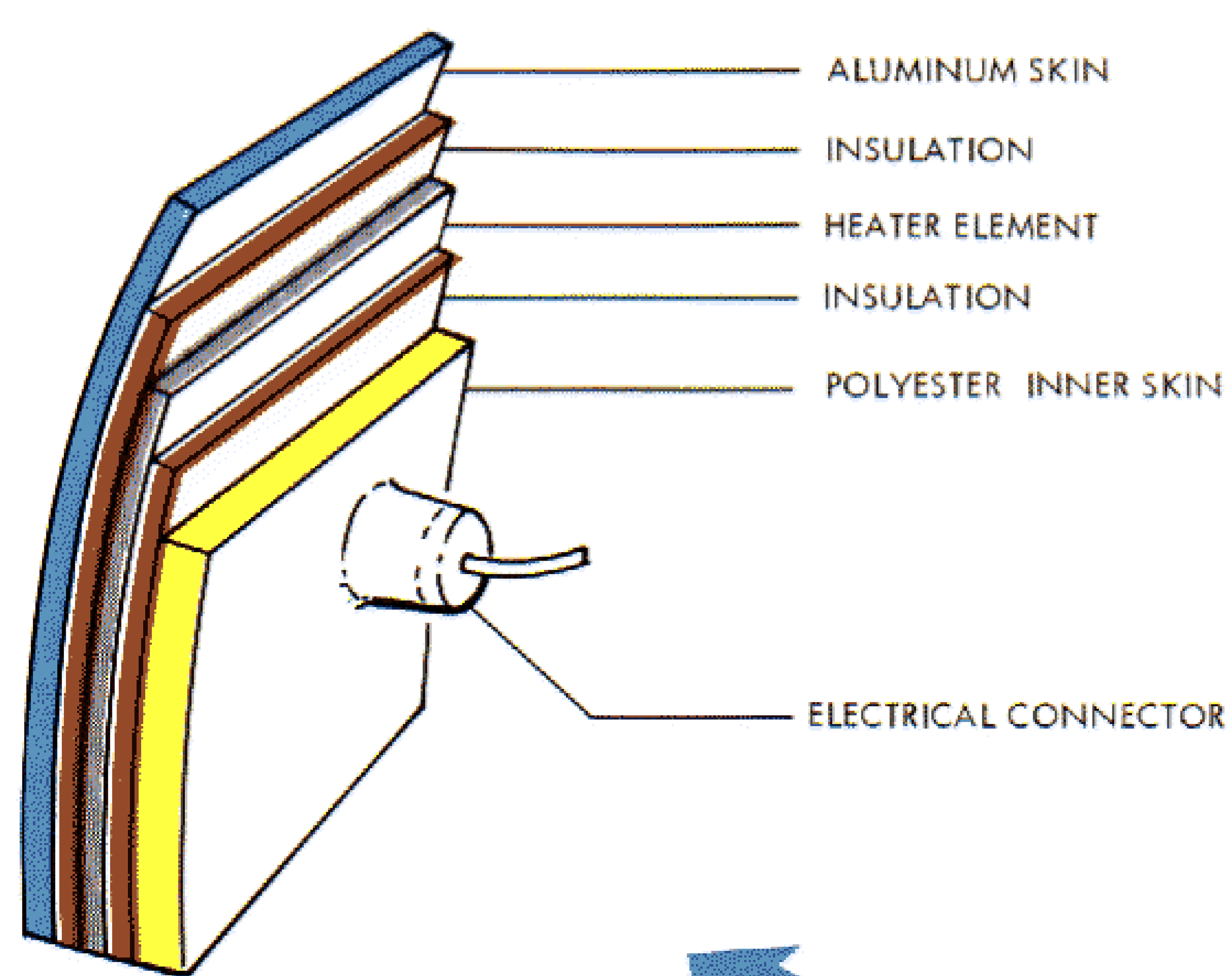
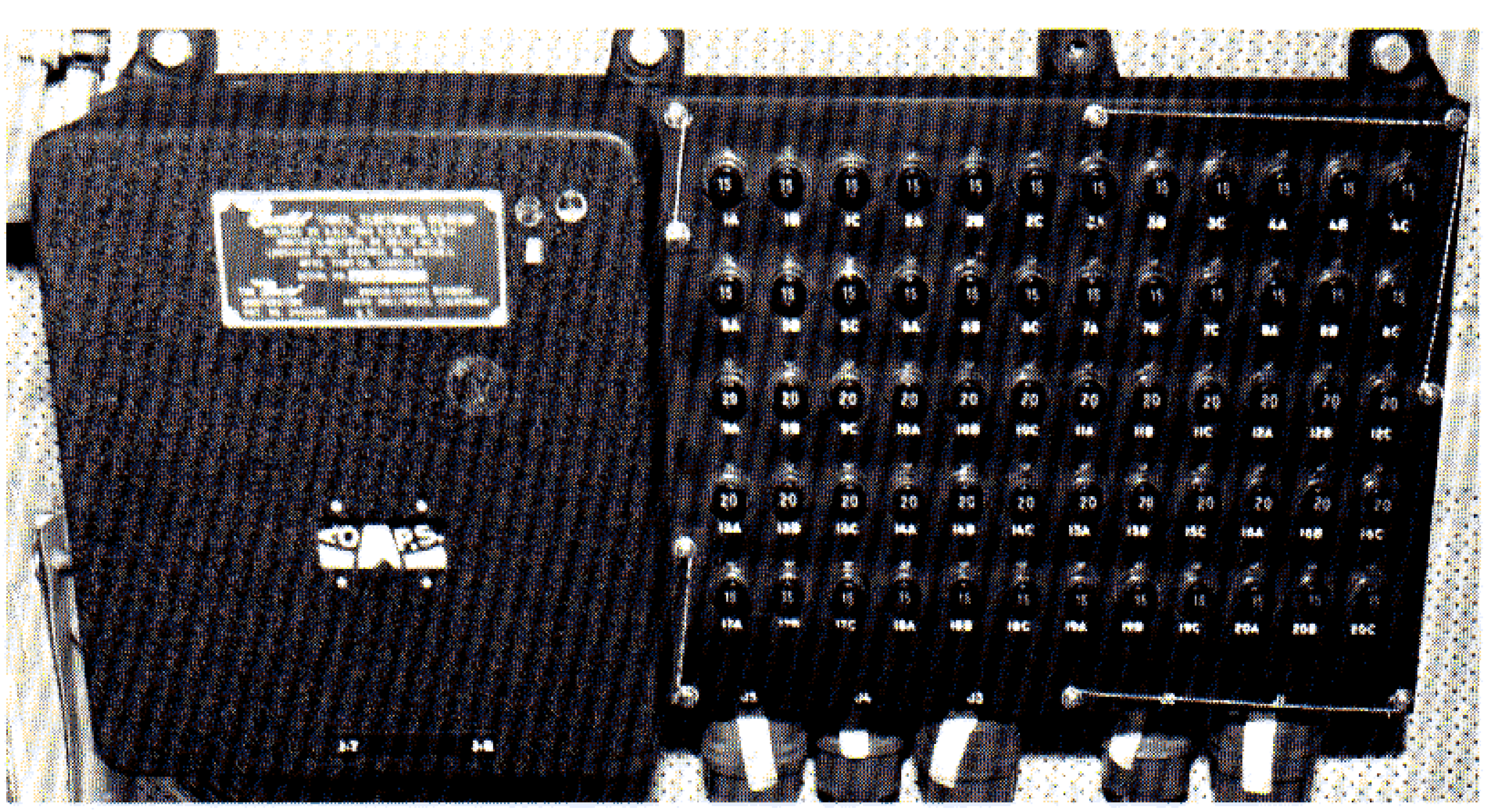
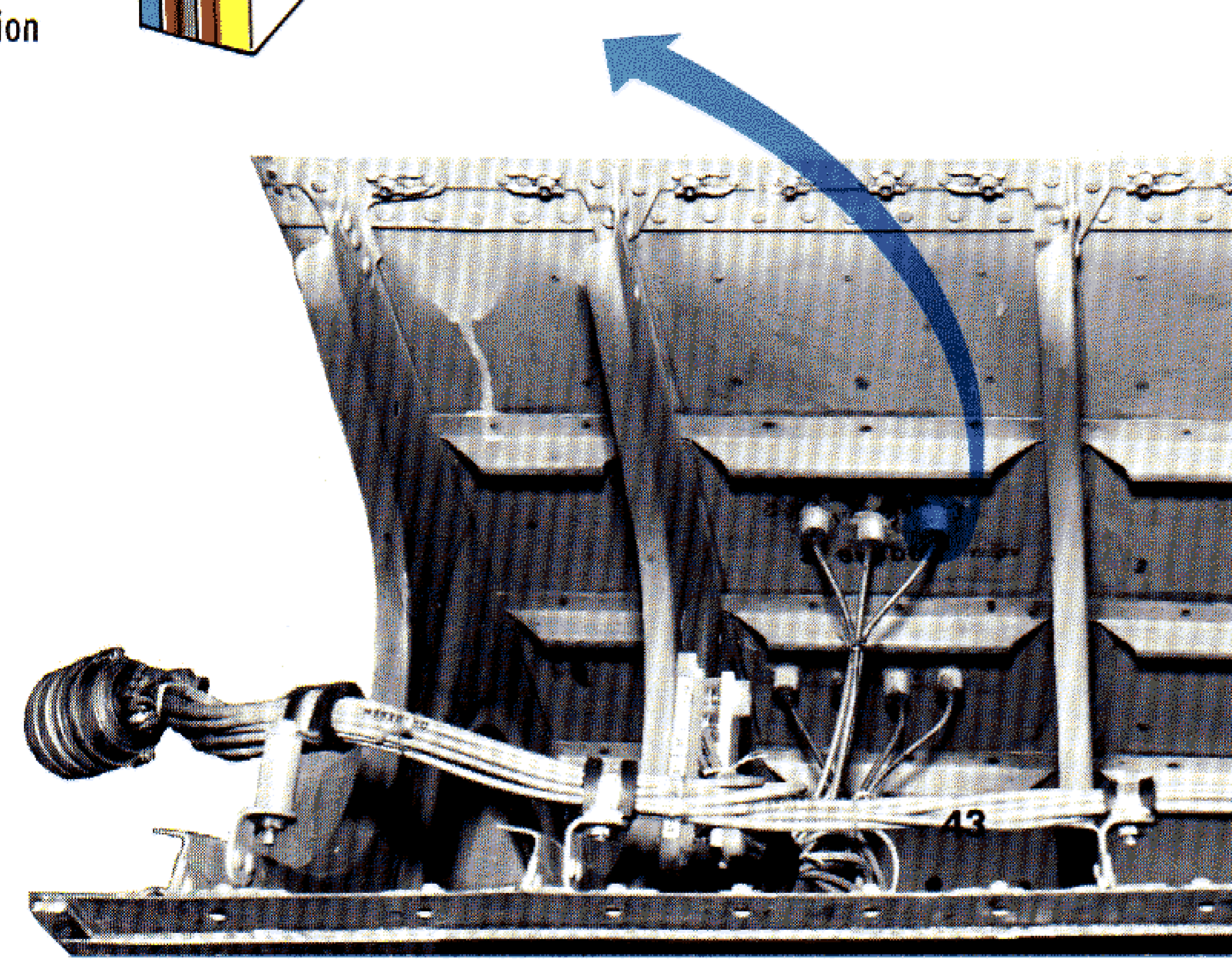


Figure 47 Empennage Leading-edge Ice Control Details and Timer Installation





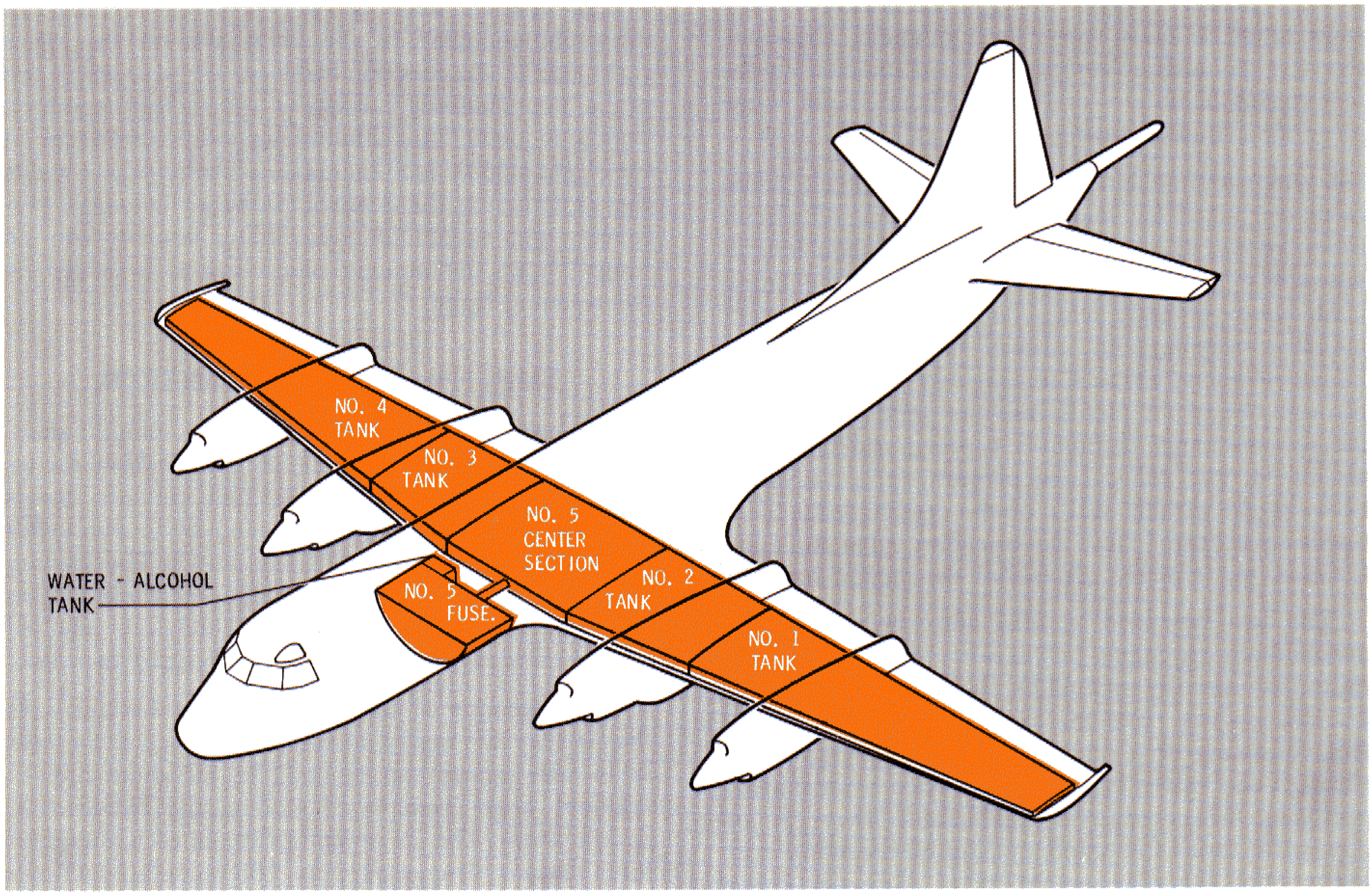


Figure 48 Fuel Tank Arrangement

breaker so a single fault will deactivate only a small part of the total system.

To allow ground checkout without overheating, the timer can be run at 4 times its normal speed, and control circuits are routed through overheat sensors to prevent a destructive overheat of the grids if they are operated too long in still air.

The total power requirement is considerable — 20 kilovoltamperes — and the system is given priority when a single generator is supplying all buses. In such a case, a tie-in with the load monitoring circuit will automatically deactivate certain non-essential aircraft loads when the Empennage Ice switch is turned "ON". This switch also has a "TEST" position. The "TEST" circuit initiates a fast operating cycle during which a load meter adjacent to the switch (see Figure 43) will detect any heating grid fault in respect to power consumption. A load meter check may be made either on the ground or in flight.

During normal system operation a fault sensing circuit continuously monitors many component control circuits. A fault of almost any kind will illuminate a warning light on the annunciator panel and one on the Ice Protection panel.

FUEL SYSTEM — WATER-ALCOHOL SYSTEM

In respect to plan, maintenance, and operation, the Orion fuel system is about as simple as may be devised for a long range, four engine aircraft. The straight wing holds the bulk of the JP-4 or JP-5 fuel in four integral engine-feed tanks of nearly equal size which are adjacent to the engine they normally serve and are designated, rather aptly, as Tanks No. 1, 2, 3, and 4. These tanks will hold about 71% of the maximum fuel load. Extra fuel for extra range is carried in No. 5 Tank, a tank made up of two compartments designated No. 5- Center (an integral tank in the wing center section) and No. 5- Fuselage (a bladder cell which is interconnected to, and just forward of, the center section tank). If more than a 71%-fuel load is needed, additional fuel is loaded into the two No. 5 compartments, utilizing insofar as possible the lower stratum of No. 5 Fuselage compartment (from which fuel will not gravity-flow through the inter-connect to No. 5 — Center Section compartment); then filling the remainder of No. 5 Fuselage and No. 5 Center compartments as necessary for the longer-range flights. Fuel is taken from

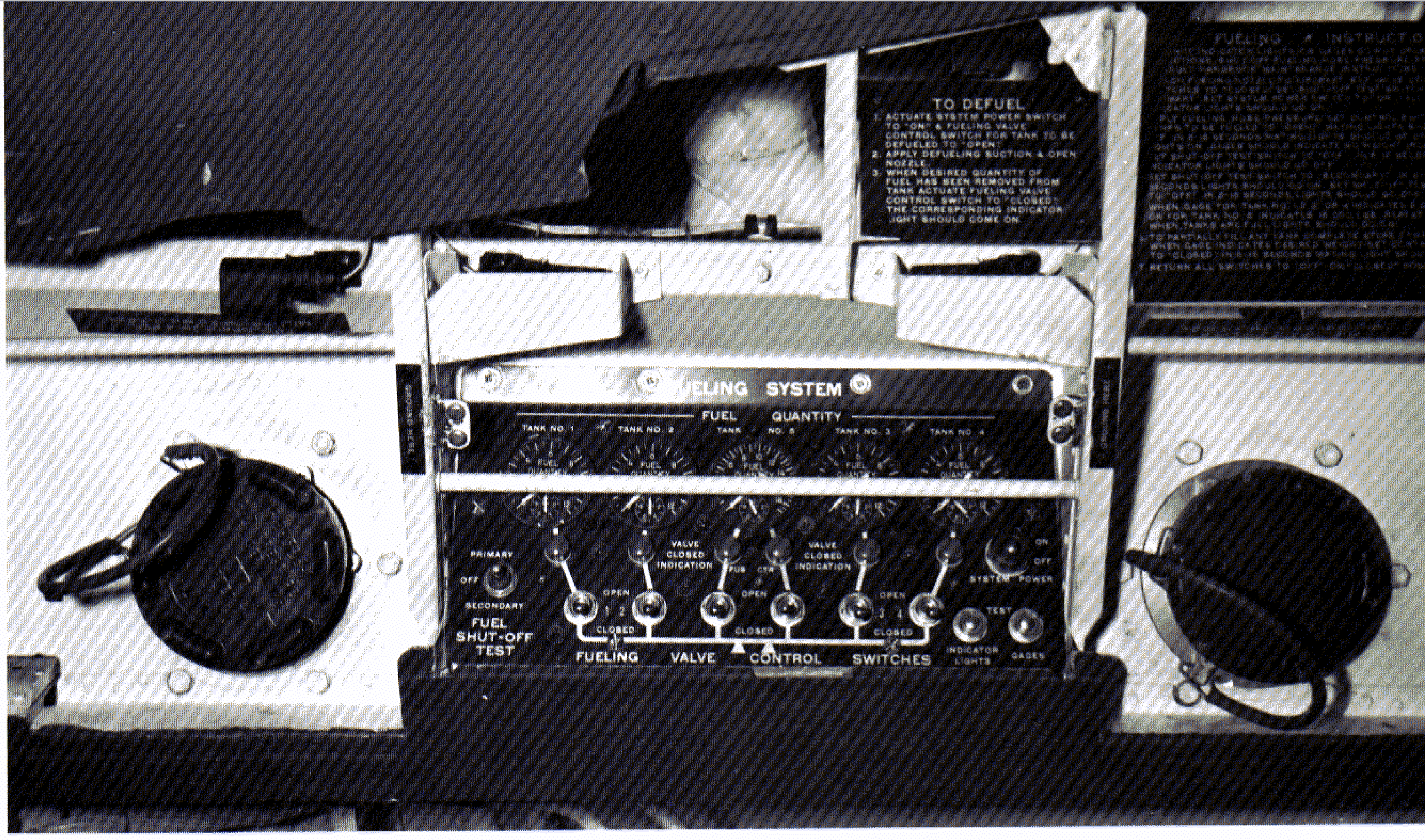


Figure 49 Pressure Fueling Facility

these two compartments in the reverse order by a transfer system which keeps the engine feed tanks replenished during the early part of the flight until the No. 5 tank is empty. A schematic of the tank layout and fuel flow for fueling, transfer, and engine feed is given in Figure 51.

The Orion will generally be fueled through the facility, shown in Figure 49, which is located inboard of No. 3 Engine in the lower wing-to-fuselage fillet. This facility comprises: adapters for two pressure-fueling hose connectors, a quantity gauge for each tank, switches that enable the fueling operator to open or close the fueling valves to each tank (or to either compartment of No. 5 Tank), lights that monitor the opening and closing of the individual fueling valves, and test switches that enable the operator to ascertain that the lights and quantity gauges are operable and that the automatic shutoff function of the fueling valves is operable.

Incidentally, we might well emphasize the importance of the automatic fill-and-shutoff feature of the fueling valves. Maximum reliability is provided by dual, float-operated pilot valves in each tank, either of which can independently cause the tank's fueling valve to close and terminate fueling to that tank when the tank is full. Both pilot valves can be checked for proper operation *before* the tanks are fueled, and both *should* be checked whether the tanks are to be completely filled or only partly filled, for most pressure fueling pumps can generate enough pressure to burst the structure of a battleship, let alone aircraft structure. Fuel can be loaded at a frightening clip — about 2 tons per minute, if two fueling pumps maintain 45 psi at the fueling adapters.

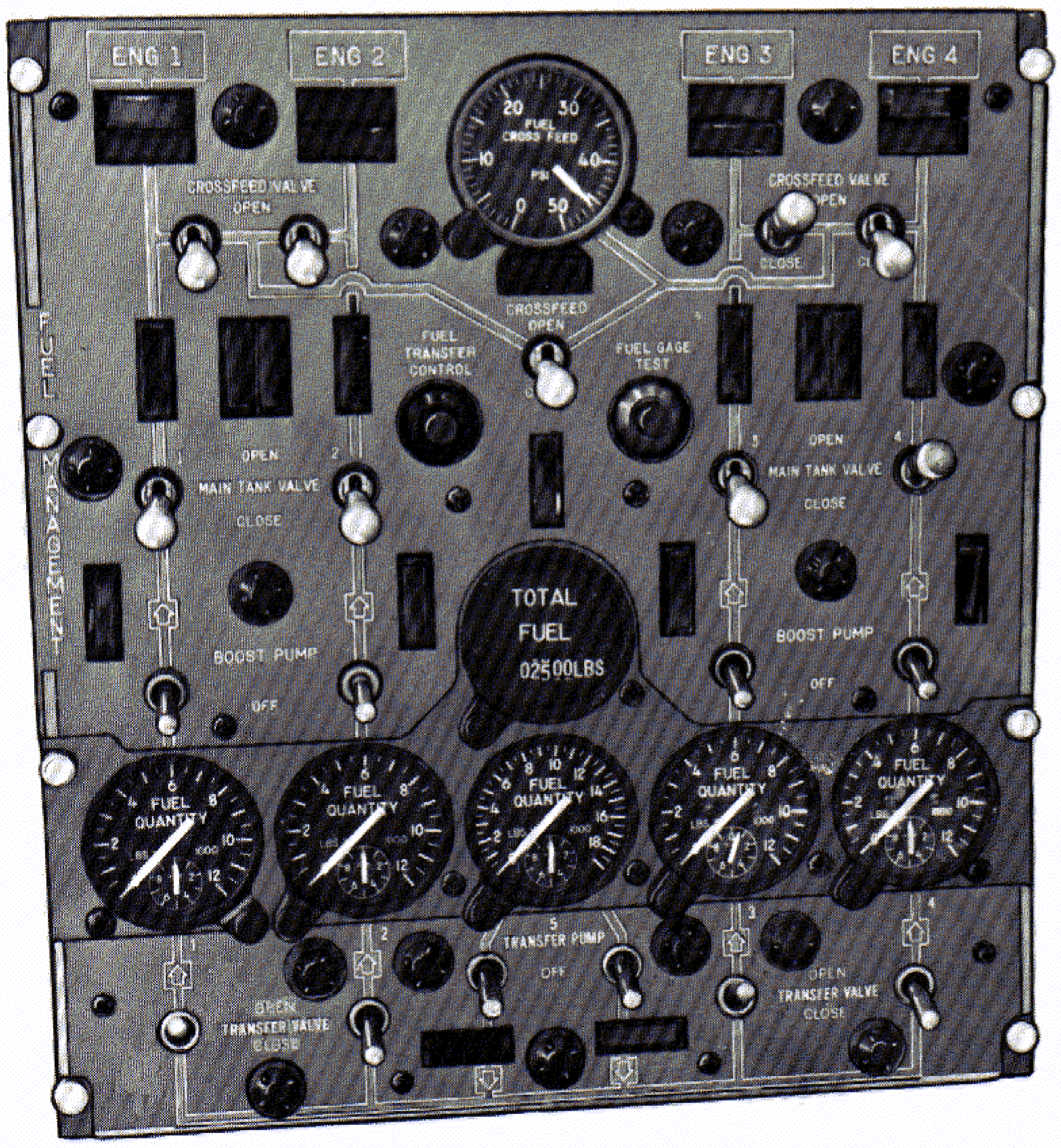


Figure 50
Fuel Management Control Panel

Defueling is simply a matter of reversing the tank truck fueling pumps, for the fueling manifold will allow reverse flow and the fueling valves respond equally well to a negative gauge pressure or a positive gauge pressure in the fueling manifold.

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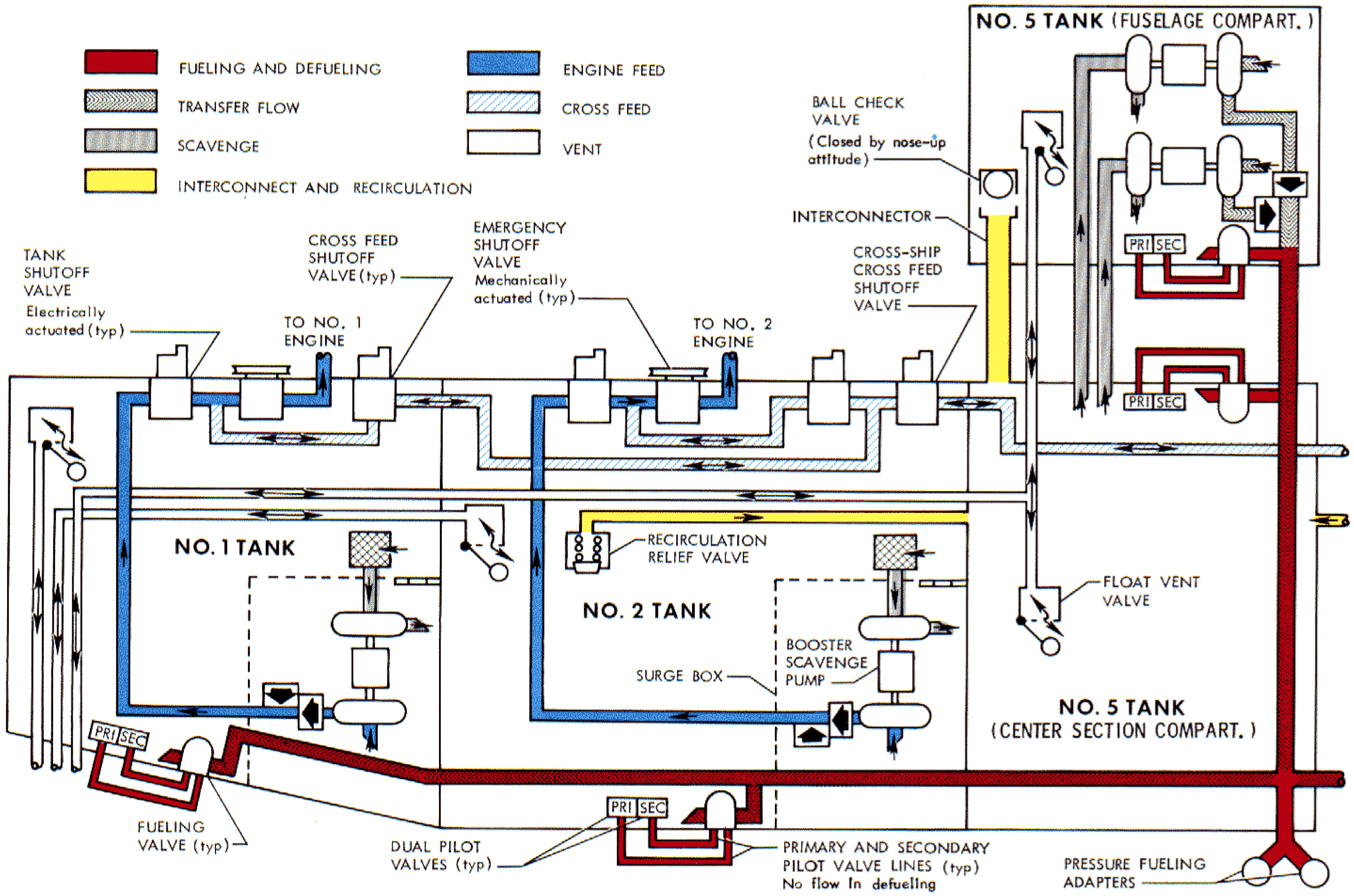


Figure 51 Fuel Tank Plumbing and Flow Schematic

The five fuel tanks contain six interchangeable ac motor pumps, each pump having a scavenging pump element (which draws fuel from one area to another area within a tank) and a booster pump element (which pumps fuel out of the tank).

Two of these pumps are located in the No. 5-Fuselage compartment, and are used as Transfer Pumps, scavenging fuel from the No. 5 Center Section compartment, boosting fuel into the fueling manifold for transfer into the engine-feed tanks through the Nos. 1, 2, 3, and 4 fueling valves. These four fueling valves are, of course, controllable from the flight station and are designated as Transfer Valves on the Fuel Management Panel (see Figure 50).

One booster scavenge pump mounted in a surge box in each engine feed tank, scavenges enough fuel to prime the boost pumps regardless of airplane attitude, and the boost pumps, in turn, maintain pressure in the engine feed lines.

As can be seen in the engine feed and cross-feed schematic (Figure 51), any tank can feed its own engine and, through the cross-feed system, any other engine or combination of engines, but the system does not permit fuel to be transferred from tank-to-tank between the engine-feed tanks, nor can it be transferred from an engine-feed tank into the No. 5 Tank.

Enroute from tank to engine combustion chamber the fuel passes through: 1] a tank shutoff valve (electrically actuated), 2] an emergency engine fuel shutoff valve (mechanically actuated), 3] a fuel heater (a heat exchanger with integral strainer and water trap, which utilizes engine oil to warm the fuel to an optimum temperature), 4] a centrifugal type boost pump (engine driven; capable of scavenging fuel from the engine feed tank should the tank mounted boost pump fail), 5] low pressure filters, 6] two engine driven high pressure pumps (either of which can supply sufficient flow and pressure to support engine combustion), 7] a high pressure filter, 8] the various engine fuel controls which meter the correct amount of fuel to be fed to the engine through, 9] an electrically operated flow meter transmitter which reports the mass fuel flow, and, 10] the six injection nozzles.

The tank vents are located at the wing tips; Nos. 1, 2, and 5 Tanks vent at the left wing tip, Nos. 3 and 4 Tanks at the right wing tip. Ordinarily these vents will only discharge vapor, but one of our

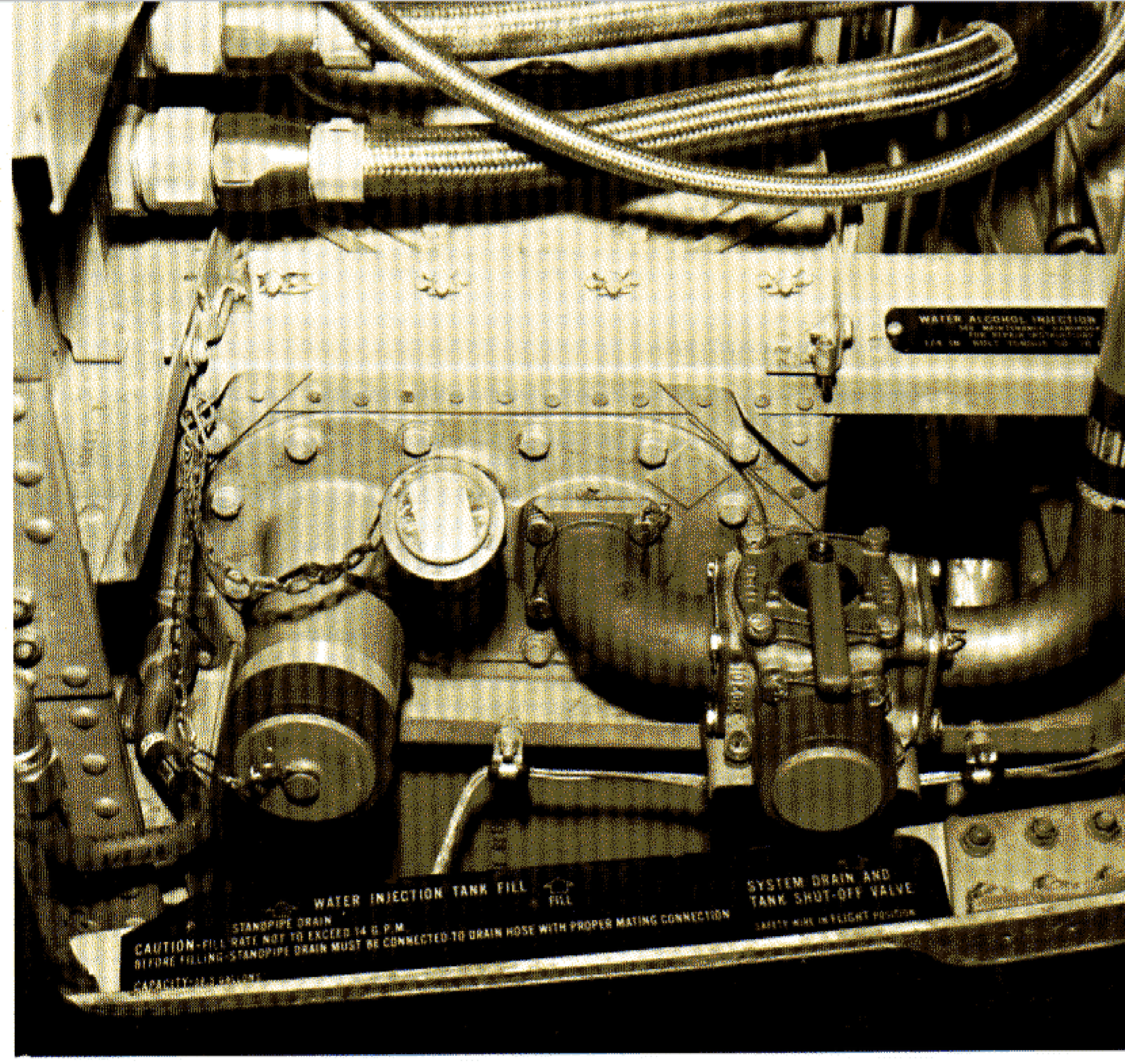


Figure 52 Water-Alcohol Tank and Service Facility

principal design considerations was to provide engine-feed tank vents able to discharge a certain amount of fuel without building up excessive tank pressure if the automatic fill-and-shutoff feature of the fueling valves should fail. Of course we cannot provide vents large enough to carry off the entire output of two pressure-fueling trucks, but tests indicate that there should be no in-flight over pressurization problem, for if both automatic shutoff systems of any engine-feed tank should fail while fuel is being transferred from No. 5 Tank, the vent system will carry off the overflow without incurring structural damage. If such a multiple failure should occur, some of the reserve fuel from No. 5 Tank would be jettisoned harmlessly from the wing tip vents, although it will be noted that if an inboard engine feed tank were involved, most of the overflow would pass through a recirculation tube back to the No. 5- Center compartment and little fuel would be lost.

The engine-feed tanks can be fueled through conventional filler wells if it is necessary to do so, and these wells are also used for "dip-sticking". There is no access to the top of No. 5 Tank, but a sight gauge slip-tube mounted in the bottom of the No. 5- Center compartment can be used to determine the combined tank fuel quantity. A remote quantity indicator for each tank is located on the fueling facility panel and on the flight station Fuel Management panel. The Fuel Management panel also has a Totalizer. These operate from conventional multiple capacitor-probes, which are top-mounted in the engine feed tanks, bottom-mounted in the No. 5 compartments.

In regard to fuel system maintenance, our chief design aims were to eliminate the need for defueling, opening, and entering tanks to perform routine maintenance tasks, to minimize the hazard of external fuel leaks, and to use interchangeable components wherever possible. In accord with this philosophy the engine-feed and cross-feed valves and pumps, the fueling valves, and many other tank mounted components are interchangeable units "plugged in" to permanently mounted shroud-valve housings from which they can be removed without defueling, opening and entering. Also, most of the fuel system plumbing is routed inside the tanks, and there are very few external plumbing connections.

The Water-Alcohol Injection System was provided to augment the already-considerable thrust of the four Allison power plants for shorter take-offs on normal days, and to offset the adverse effects of elevated inlet air temperature during take-off on hot days. On a normal day, water-alcohol injection increases engine power about 11%.

The small storage tank (38.5 gallons) is sandwiched between the two No. 5 Fuel Tank compartments (see Figure 52) where it is readily accessible from the ground through a hatch in the belly just forward of the wing center section. The tank is pressure-filled through quick disconnect fittings with a 2 to 1 (by volume) water-alcohol mixture. The entire supply will only suffice for a little more than a minute of augmented power, and the tank must be replenished after each augmented take-off.

The system's two ac motor-pumps, which are mounted adjacent to the supply tank, are plumbed in parallel and operate from a common switch. Either can supply the system if one should fail.

The pumps begin to operate when their arming switch is turned "ON", but water alcohol is not injected unless the engines are operating and their power levers are advanced beyond the 75° coordinator position, at which point micro-switches open a solenoid operated poppet in each nacelle mounted water-alcohol regulator. These regulators, which also contain filters, damp out manifold pressure fluctuations and maintain a smooth injection flow through 8 radially spaced nozzles at each engine compressor air inlet.

ELECTRICAL SYSTEM

The P-3 electrical requirements are markedly increased over those of the P-2, and it would be understandable if this statement were viewed with some trepidation on the part of the uninitiated. Many future P-3 flight and ground crews will be familiar with the somewhat complicated electrical systems that have evolved on older aircraft designs — particularly where these aircraft have, over a period of years, reached the limit of their growth potential. These future crews are due for a pleasant surprise in this latest addition to the Navy's ASW fleet of aircraft.

Although it has been completely redesigned, the P-3 electric system has two things in common with that of its commercial forebear: first, a basic, service-proved alternating-current generation system of which the P-3 has three to the Electra's four; and second, a design philosophy that, whenever practicable, electric power will be used as the prime system power source. In practical terms this means that, besides supplying what could be termed the usual electric and electronic services, the P-3's electric system also powers all the hydraulic functions on the airplane including the flight control boosters, and the empennage ice control system.

It might be expected that such an extensive use of large amounts of electrical power would necessitate the use of many generators with a correspondingly complex paralleling system, but such is not the case. In fact the basic power system is so simple as to be almost unbelievable: two large capacity generators, each supplying a separate group of loads; a third generator on standby; automatic switching in the event of failure; no paralleling of generators; and no constant-speed drives (see Figure 54).

The use of high-voltage, alternating-current made this system possible and where, in the past, the primary electric power source was usually dc, and ac was only employed where necessary, the opposite is true on the P-3. All power, except that obtained from a battery, is generated as 120/208-volt, 400-cycle, alternating current. Systems and components requiring low voltage ac are supplied by step-down transformers, and dc power is supplied by transformer-rectifiers. A limited number of ground and essential flight loads can be supplied by a small battery, which also powers an inverter to supply alternating current for emergency engine starting.

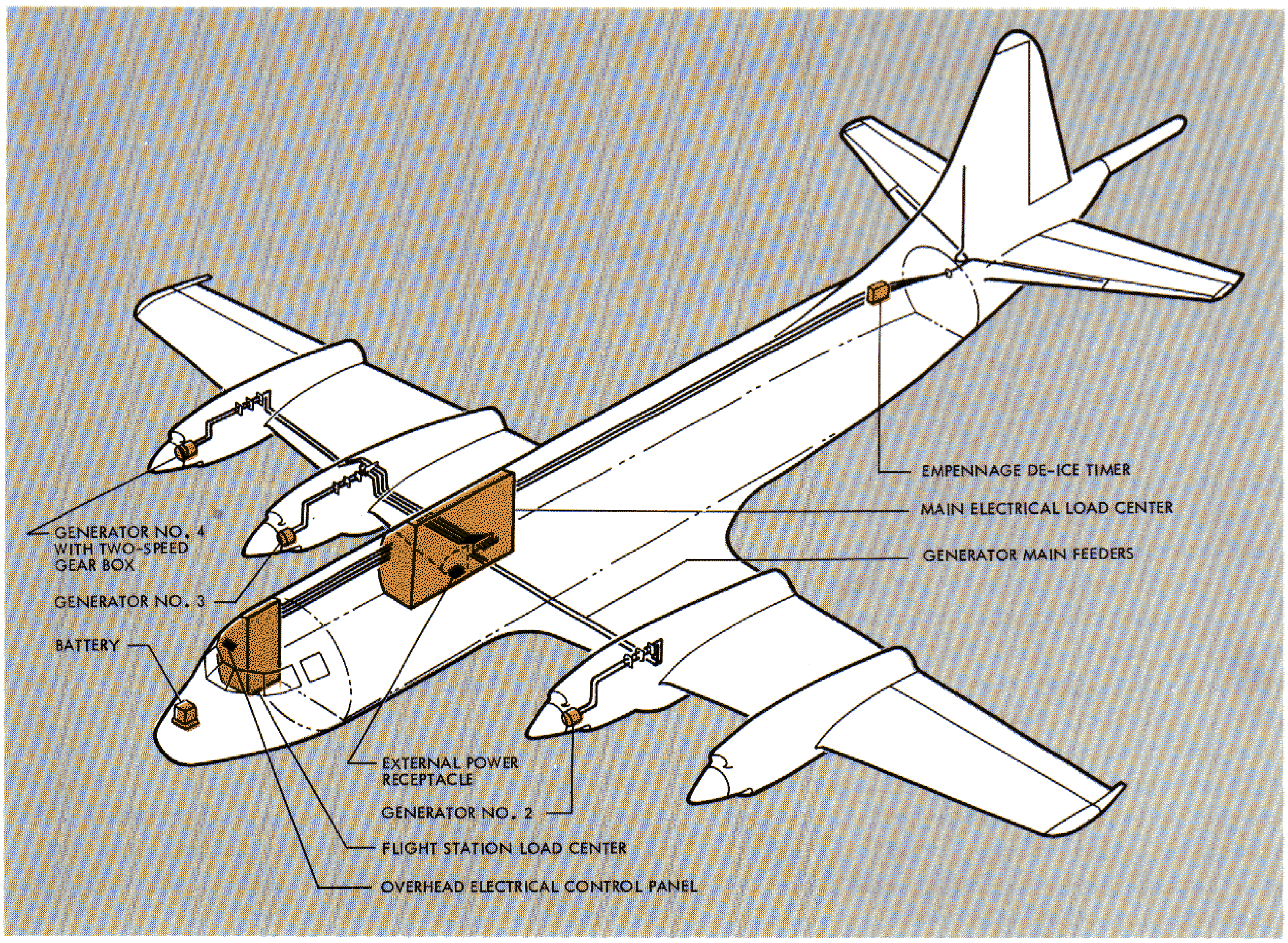


Figure 53 Electrical Layout — Generators, Feeders, Service Centers, and Other Components

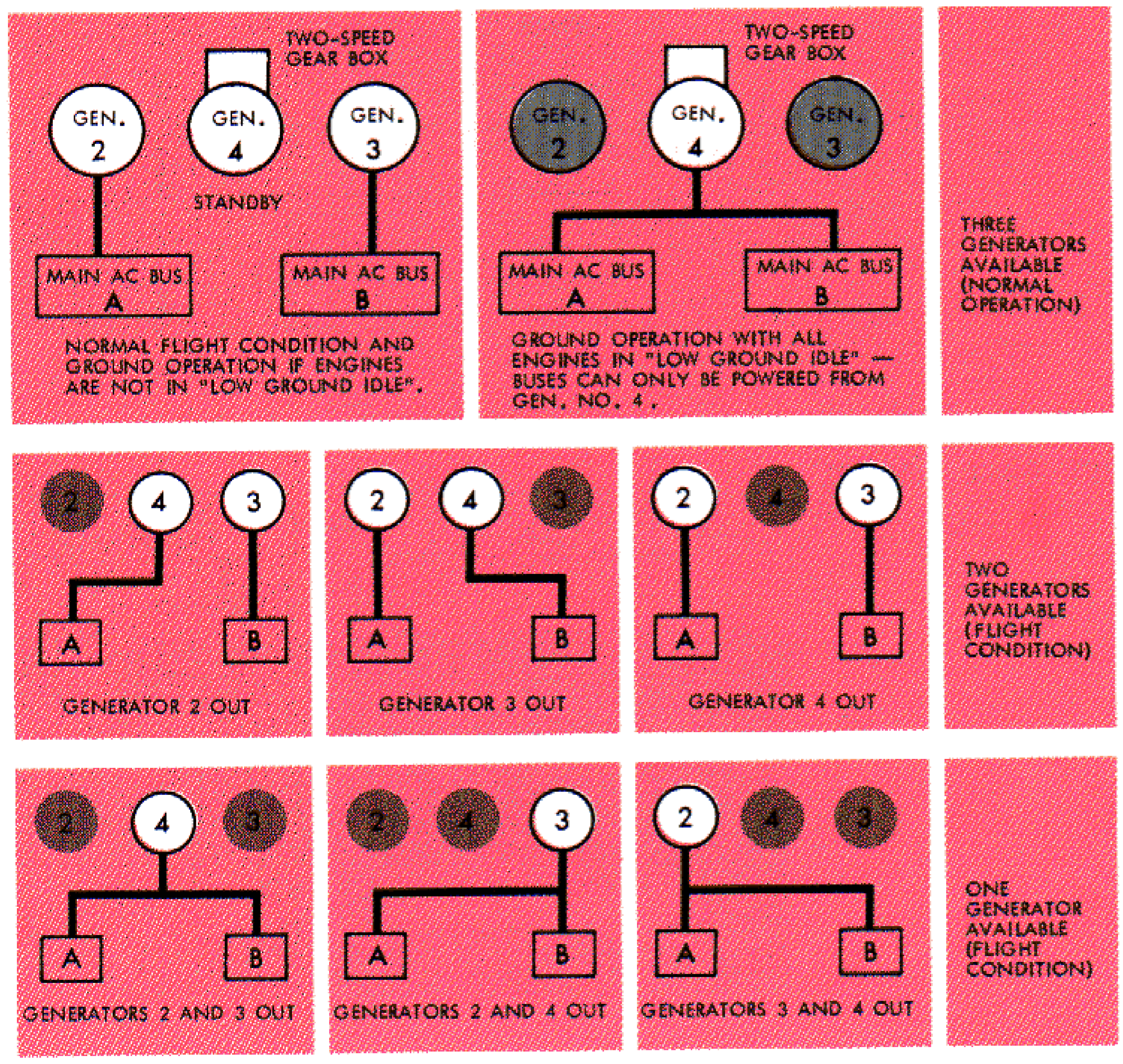


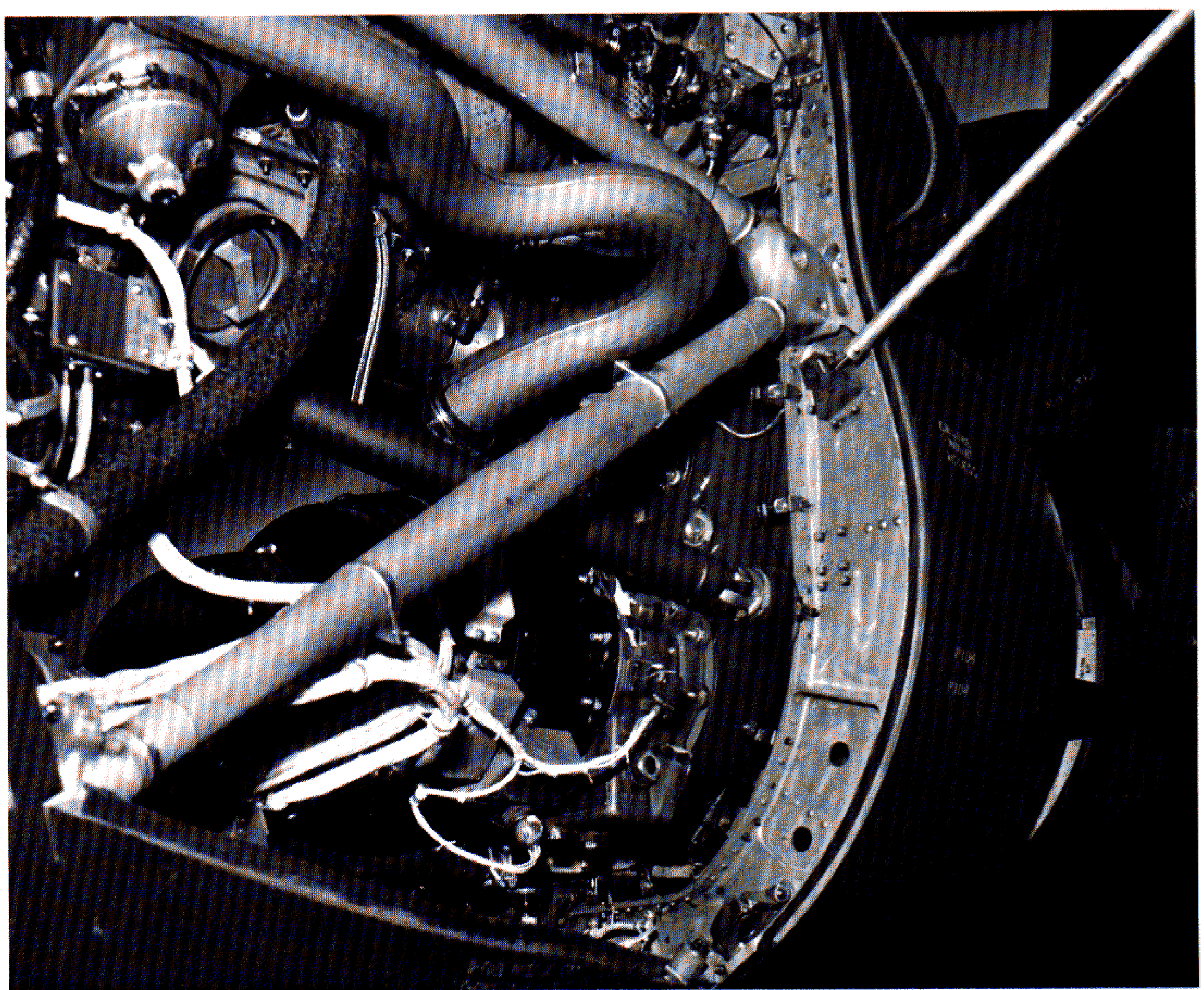
Figure 54 Generator/Bus Support Diagram

There are numerous advantages derived from this comprehensive ac electric system. From a designer's aspect, weight saving is high on the list. From the maintenance viewpoint, perhaps the electrically-powered hydraulic system is the most significant improvement over previous aircraft designs; all hydraulic functions can be checked on the ground by merely plugging-in external electrical power. Thus the presence of a hydraulic gig is no longer required on the flight line, and the attendant contamination hazard involved with breaking into a closed hydraulic system with such equipment is effectively avoided. To air crews, the advantages of an automatic transfer system are obvious, and the knowledge that full hydraulic power is available with the loss of any two engines serves to emphasize that the P-3 electric power system offers a significant advance, not just on past electric systems, but on all previous functional system designs whether they are electrically, hydraulically, or pneumatically powered.

Delving a little deeper into the layout of the P-3 A's basic electrical power system, which is shown in simplified form in Figure 56: A 60-kva generator is mounted on the reduction gear box of engine Nos. 2, 3, and 4, and the three generators are numbered accordingly. Generator Nos. 2 and 3 are driven directly by their respective engines, but the No. 4 generator is driven through a two-speed gear box (see Figure 55), thus providing a source of 400-cycle power when the engines are operated at reduced speed (Low Ground Idle) on the ground for noise abatement purposes.

In normal operation, generator Nos. 2 and 3 operate independently and each feeds one of the two separate groups of loads or distribution buses, which are called the MAIN AC BUS A and the MAIN AC BUS B. The No. 4 generator normally serves as a "standby" (except for low engine-speed ground

Figure 55 Engine No. 4 Generator Installation



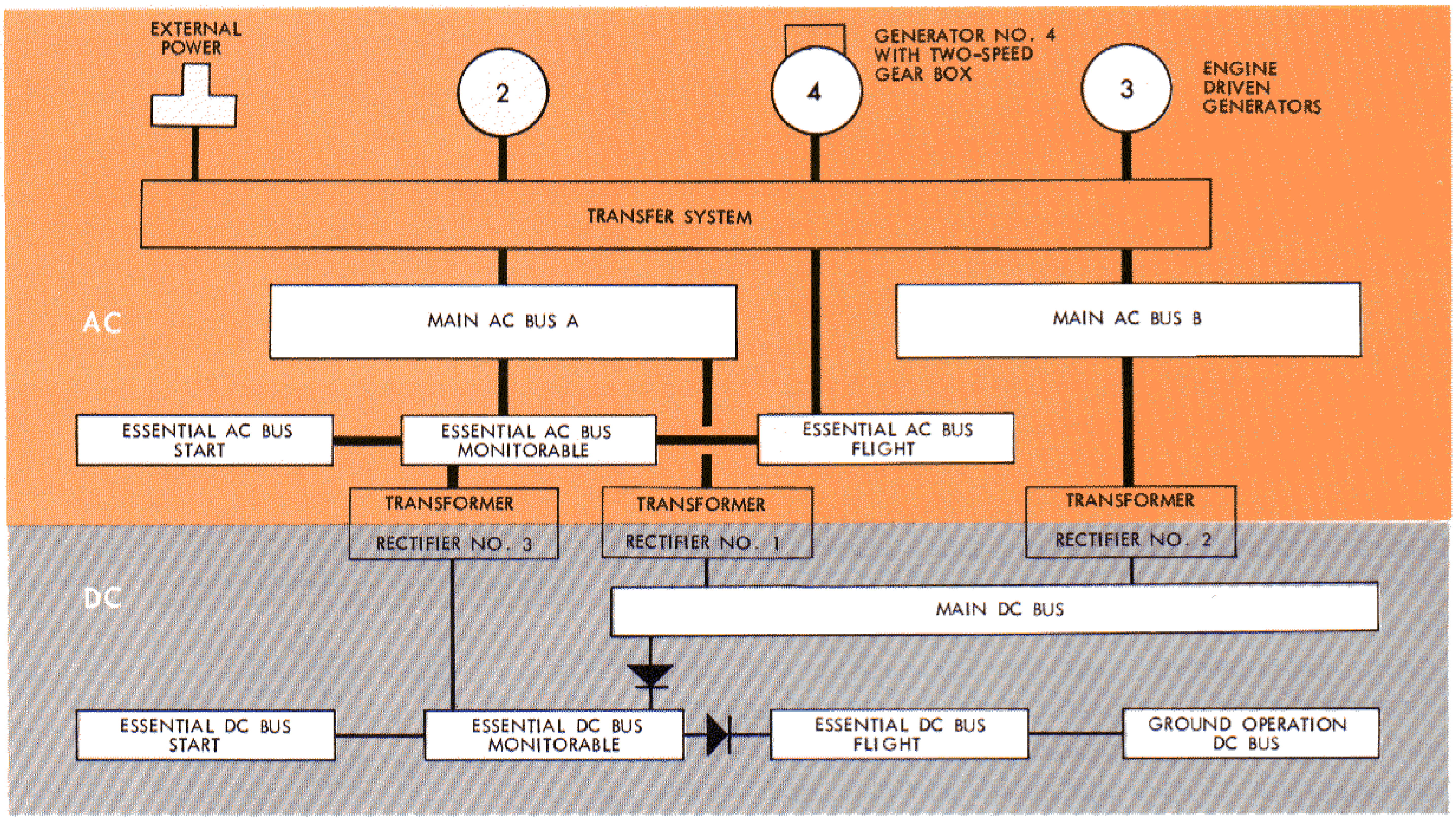


Figure 56 Electrical System Block Diagram

operations) and is connected to supply power in place of either of the two generators should a failure occur. If any combination of two generators should fail, both buses will be supplied by the remaining generator. This generator switching operation is entirely automatic and the action taken is indicated to the flight crew by means of annunciator lights in the flight station.

Any one of the three generators can supply all airplane loads except for a situation when the airplane encounters icing conditions. In this event — and this assumes of course that two out of three generators have failed—a remaining generator would supply the essential loads as well as those loads required for de-icing.

To a large extent the system owes its basic simplicity to the decision to utilize the constant-speed characteristics of the Allison prop-jet engines and drive each generator directly through suitable gearing. For all operational regimes the engines maintain each generator output frequency well within the airplane's equipment limitations of 380 to 420 cycles. This decision precluded of course any possibility of paralleling the generators — a design concept which has questionable advantages — and the final result is a simple automatic switching circuit rather than a complex circuit with constant-speed drives, and paralleling controls.

The General Electric generators were developed especially for the Electra and the use of static excitation permits the control components to be located well away from the power source, as opposed to the older method of incorporating rotating exciters within the generators. The static exciters are installed in the main load center and basically consist of transformer rectifiers for converting part of the generator ac output to direct current. A magnetic amplifier type voltage regulator controls the magnetic field strength of these static exciter transformers, and therefore controls the direct current output to the generator fields.

Each generation system is provided with over-voltage, under-voltage, differential-current feeder, and under/over frequency protection systems, the components of which are nearly all contained in control units located in the main load center. The necessary control power for these protective systems is obtained from a small permanent magnet generator integral within each main generator. Thus the control, operation, and protection of each generation system is largely independent of any other source of power.

Particularly interesting is the provision of a mechanical failure warning light for each generator. Should the rotor contact the stator due to bearing or other mechanical failure a circuit is completed to ground which illuminates the pertinent warning light in the flight station. For generator No. 4, a "DISENGAGE" light is connected to high temperature and low pressure sensors in the two speed gear box oil system, and the gear box also incorporates a solenoid-operated disconnect mechanism.

The flight station electrical control panel which contains most of the indicator lights and control switches, reflects the efforts of the designers to keep controls simple and free of components unnecessary for efficient system operation (see Figure 57). This policy was in fact one of two design criteria that were established at an early Navy/Lockheed conference. The other design policy, was that system operation would be essentially automatic, and this aim has also contributed to the establishment of a flight station unclutterred with numerous switches and indicators — the absence of meters on the electric power control panel for example is particularly apparent.

One feature of this electric power system was discussed earlier in this article but is well worth mentioning again since it represents a significant advance over past designs: the main electrical load center is provided with walk-in space behind the racks of equipment giving the maximum accessibility for maintenance and test purposes.

Everything considered, the P-3's electrical power system must be considered a major change in aircraft design philosophy and although one would normally expect such a new design to have "teething troubles", there is the additional advantage that the main system components have been subjected to extensive service on the Electra, and design weaknesses, which inevitably develop when a totally new concept is implemented, have already been corrected.

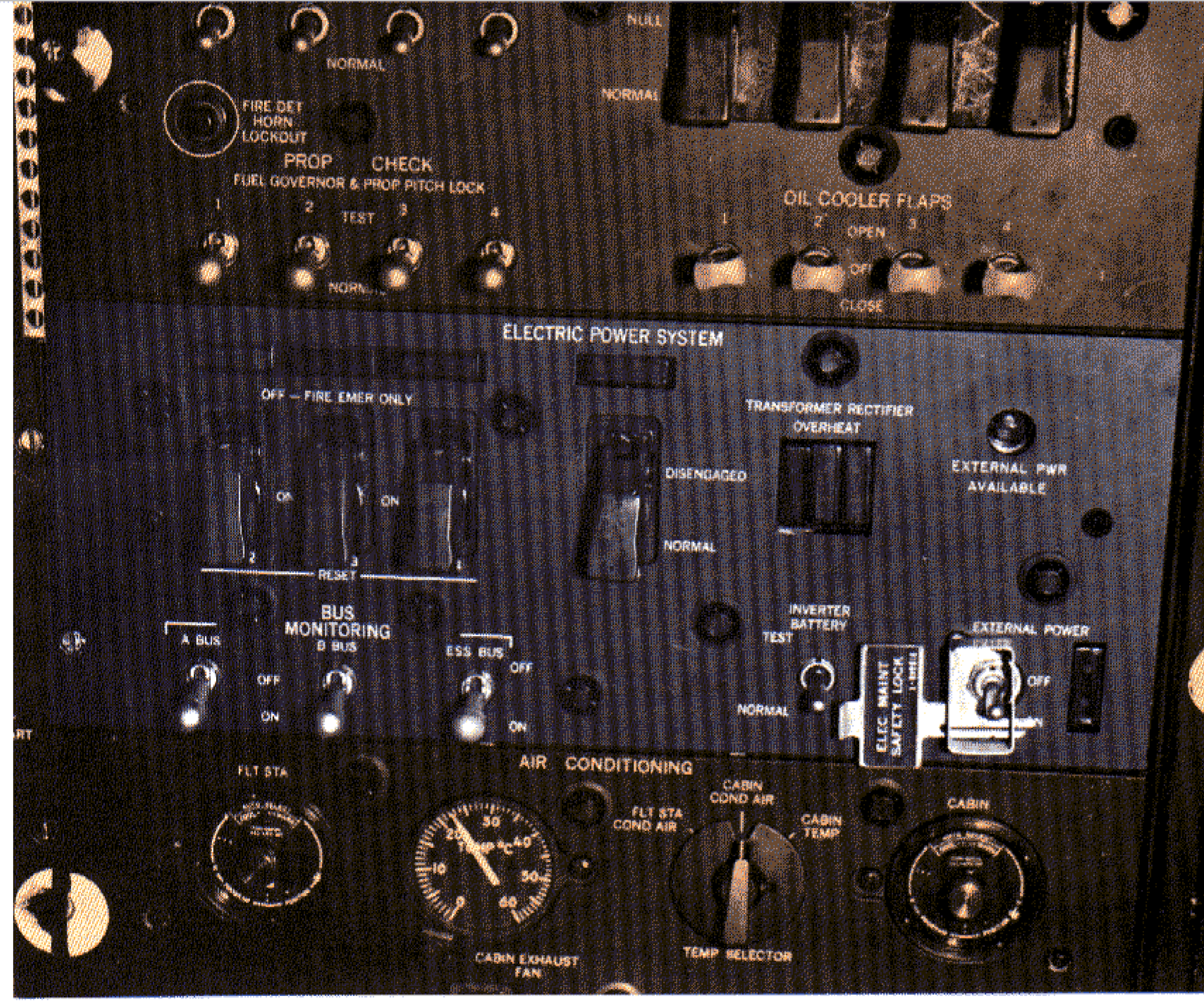


Figure 57 Electrical Control Panel

HYDRAULIC POWER SYSTEM

The hydraulic power system is, perhaps, the chief beneficiary of the Orion's ample and dependable electric generating and distribution system. By using motor-pumps to convert electrical power into hydraulic power, the hydraulic system designers were able to provide a system wherein none of the vital hydraulic functions are dependent on the operation of any specific engine. Any or all hydraulic pumps can be powered from any engine driven generator or from an external electric power source and, as shown in the Figure 58 block diagram, the hydraulic system is configured so that any of the three ac motor-pumps alone can power the actuators most essential to flight. If any two motor pumps are operable, all hydraulic services are available. Indeed, except for brief periods when peak-demands are to be expected a considerable part of the hydraulic power potential is on stand-by to supply the peak demand which is *not* expected.

The three Vickers motor-pumps are, of course, completely interchangeable. Two of the pumps (Nos.

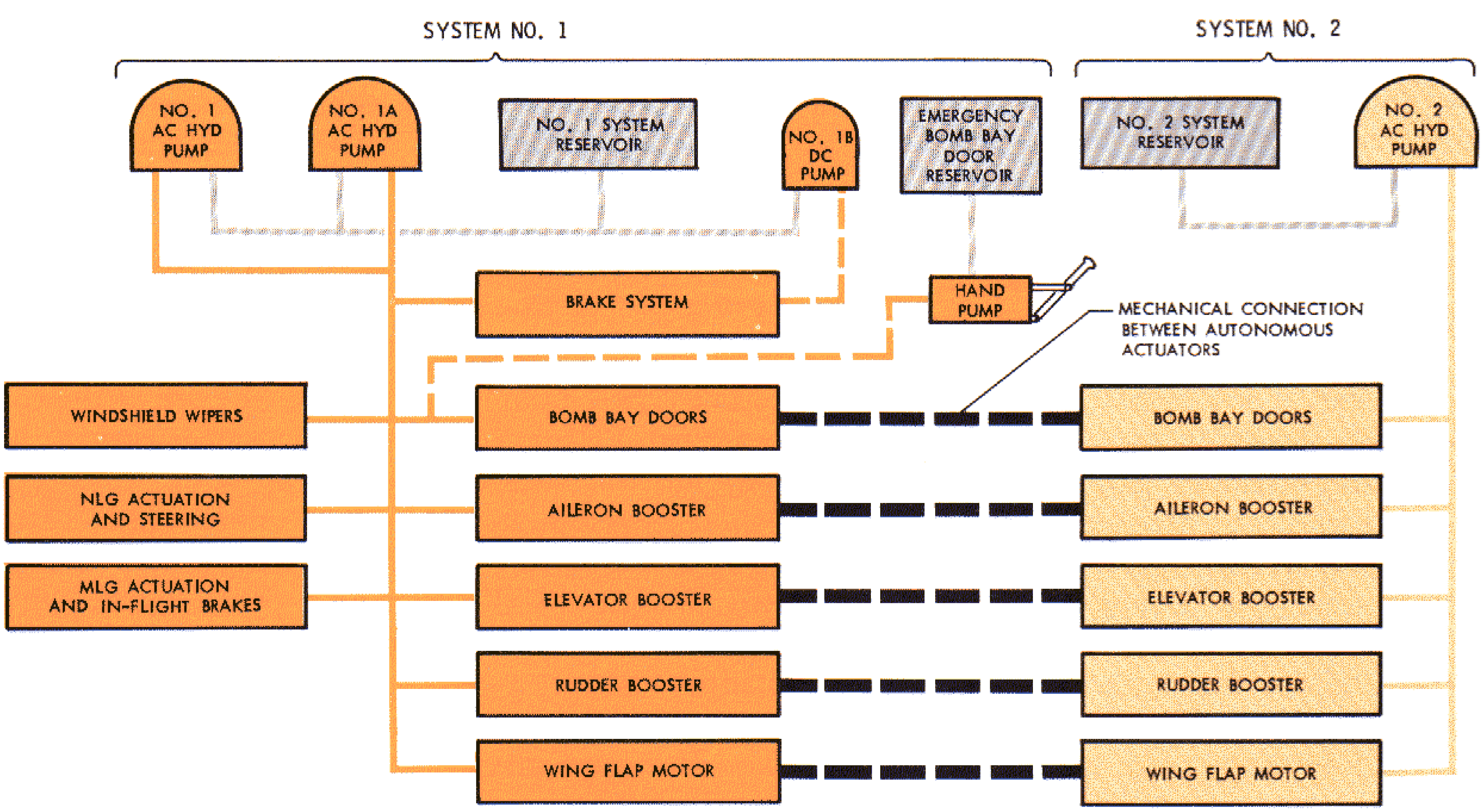


Figure 58 Hydraulic Systems Block Diagram

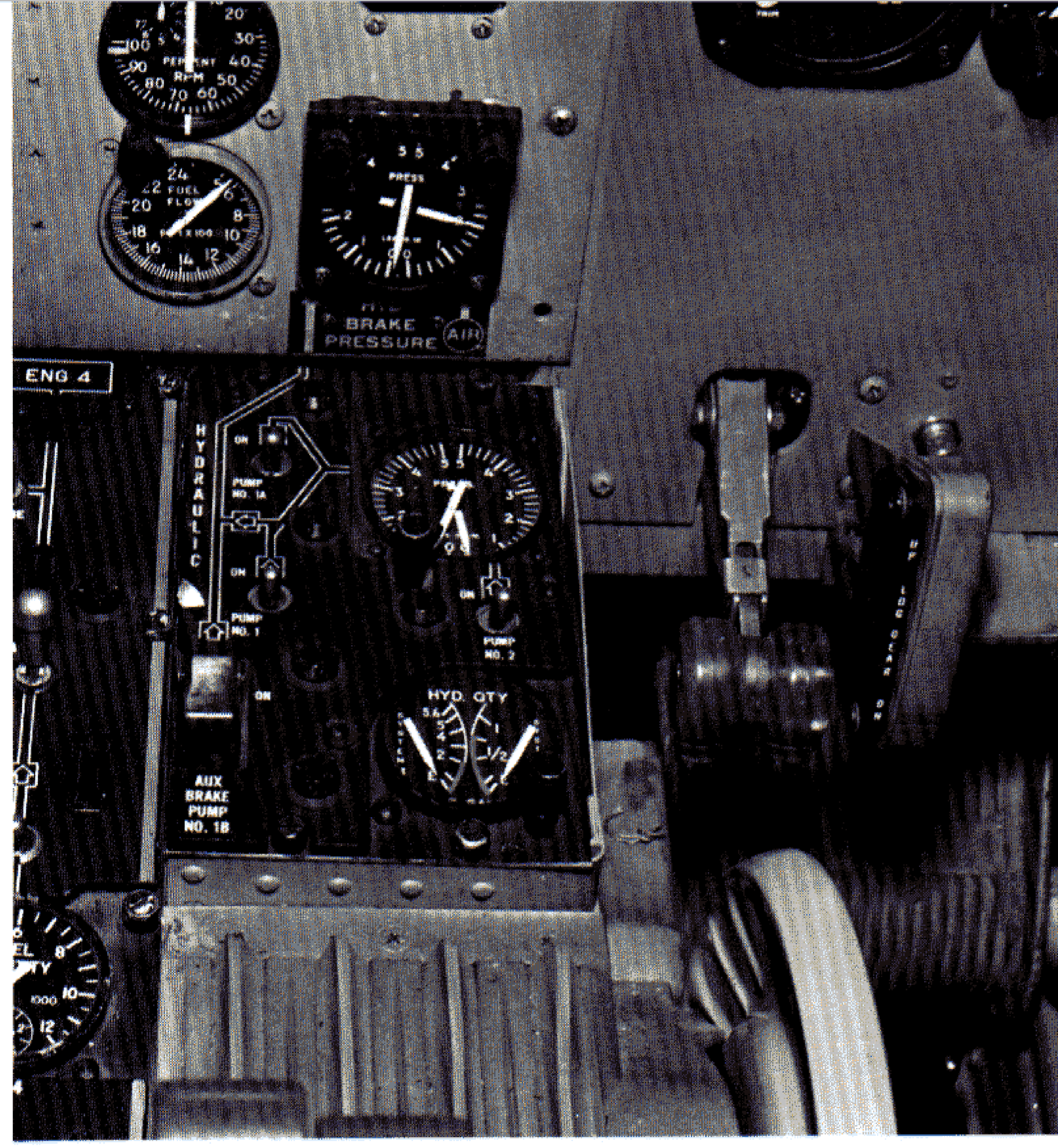


Figure 59 Hydraulic System Control Panel

1 and 1A) work in parallel to power every hydraulic function on the airplane through the major hydraulic power system (No. 1). The No. 2 pump powers an abbreviated system (No. 2), pressurizing separate actuators for the bomb-bay doors, flaps, and flight controls, all of which are mechanically interconnected with the No. 1 system actuators. Thus there is no need for a cross-over system, and since the two systems have separate reservoirs (a 5- and a 1-gallon reservoir for the No. 1 and the No. 2 systems respectively) there is little chance that a single component failure will drain both systems or that a contaminated system will contaminate the other one.

Aside from a wing mounted heat-exchanger tube for each system, all of the components of both power systems are mounted in the Hydraulic Service Center (see Figure 60), a compartment below the deck just aft of the wing center section which is within the cabin pressure area and may be entered from the ground or from the main cabin.

A manifold housing (known as a Service Center Assembly) is provided for each power system. These have drilled passages, check valves, high pressure filters, and miscellaneous taps for directing, limiting, and monitoring the suction, pressure, and coolant flows to and from the motor pumps. These assemblies also have quick-disconnect couplings for hydraulic gig connection, but we feel that hydraulic gigs should *not* be used on the Orion unless there is good and sufficient reason that the airplane motor pumps cannot be used to perform ground checks. Hydraulic gigs are notorious for introducing contaminants into airplane hydraulic systems, and for spreading contamination from one airplane to another.

The reservoirs are not purposely pressurized, but neither are they openly vented. The air spaces of the two reservoirs are interconnected by their vent lines through a small pressure-vacuum relief valve which ensures that reservoir pressure will not be less than 1 psi below nor more than 12 psi above cabin air pressure.

MIL-H-5606 (red) hydraulic oil is used in the Orion hydraulic system for cooling the motor-pumps as well as for the 3000-psi high pressure systems. Each motor-pump has a low pressure centrifugal pumping element that draws oil from the reservoirs and boosts its pressure about 20 psig to supply the high pressure pump inlet and to maintain a continuous coolant flow of about 2 gpm. This coolant flow, which is routed through the cooling jacket of the pump motor and through the case of the high pressure pump, carries the heat from the No. 1 System motor-pumps through a loop of finned tubing on the floor of the No. 2 fuel tank, from which the flow returns to the reservoir of origin. No. 3 fuel tank contains a similar heat exchanger for the No. 2 System pump. The fuel in the inboard tanks may be regarded as a "heat sink" and, although the minimum operational fuel load will provide a sink of sufficient capacity, and it is almost always proper and preferable to use the hydraulic system motor-pump to perform ground checks while the airplane is parked, it is obvious that the related pump should *not* be used if one or both inboard fuel tanks are empty.

Thermal switches in the pump motors open their circuits if an overheat occurs. A manual reset of the switches has been provided but we feel that this feature should be used with discretion, for misuse can cause more trouble than it cures. Obviously, if a reset is made indiscriminately, without finding and rectifying the fault which caused the overheat, it is very like putting a penny under a blown-out fuse. Preferably, overheating motor pumps will be removed to a shop having proper trouble shooting and repair facilities, unless the fault is *known* to lie elsewhere.

The power pumps (see Figure 61) are of the conventional Vickers variable displacement design, but they are not compensated in the same manner as engine driven pumps are, that is, to produce full rated flow at full rated system pressure. At full rated system pressure (3000 psi), each pump can supply a 6-gpm flow, but the compensation design allows the pumps to supply a larger flow at a lesser pressure — maximum flow being 8 gpm at 2200 psi. This "Constant Horsepower" compensating arrangement allows

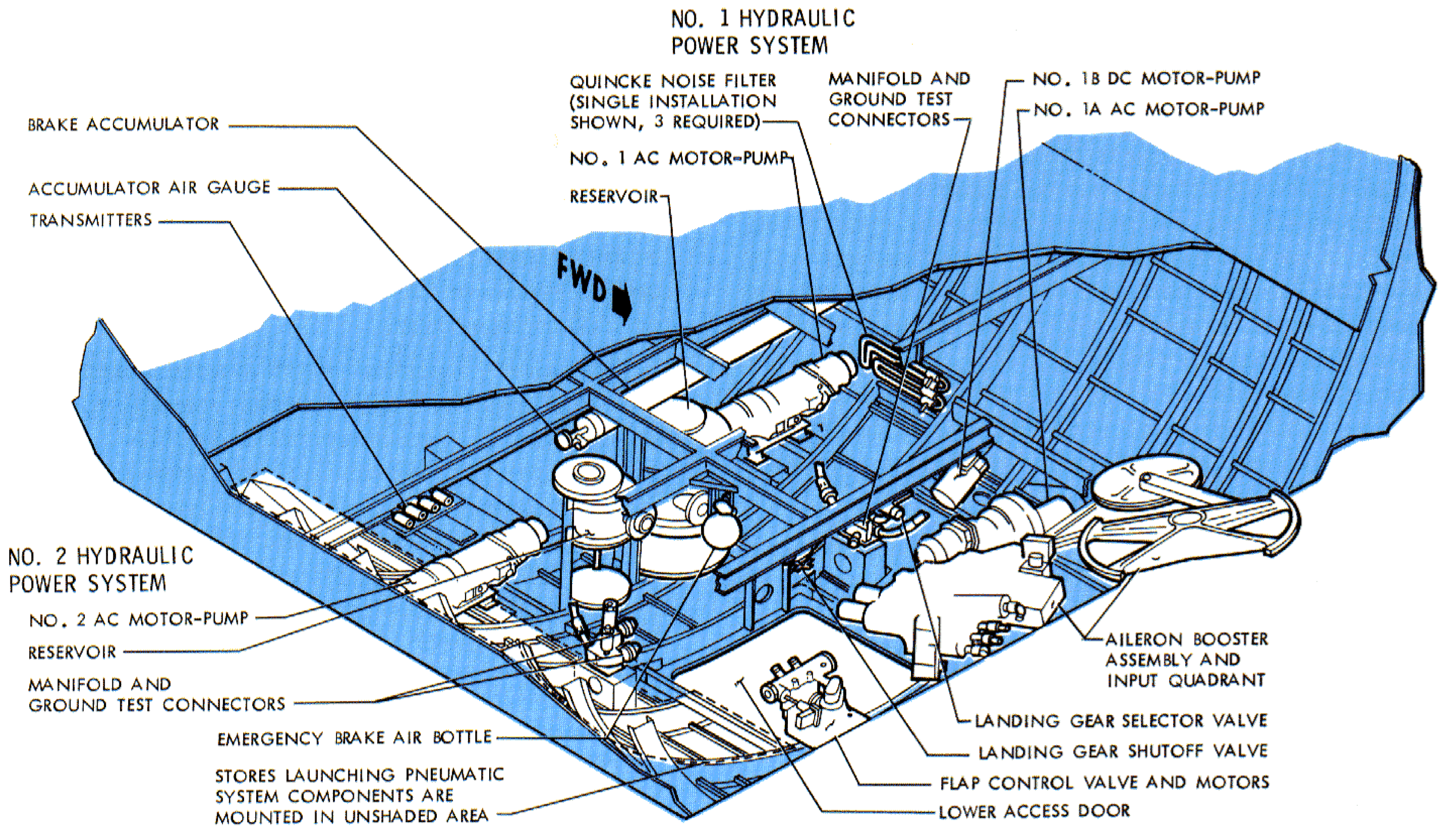


Figure 60 Hydraulic Service Center

faster actuator operation than would otherwise be possible during periods of peak hydraulic power system demand, and since the extra flow is delivered at a considerably lower pressure it does not overdraw the horsepower limitations of the pump motors.

The Orion pumping system does not require expensive hard-to-maintain noise dampers, for the constant speed motor-pump produces a pulsation frequency which is so nearly constant that the simple "Quincke tube installation" (Mr. Quincke was a British physicist) provided for each pump keeps the noise level acceptably low. This simple 4-tube network—vaguely resembling a trombone — ingests the high pressure flow from the pump, and carries it through opposing U-shaped tubes whose size and shape induces pulse frequencies that are "180° out of phase" with one another. Thus at the confluence of the opposing tubes a peak pressure wave encounters a low pressure wave, quite effectively cancelling the noise propagation before it reaches the various branch lines of the hydraulic power system.

One characteristic of the Orion's hydraulic system requires frequent and careful attention. The design incorporates numerous reusable 10-micron filter elements which are purposely made strong enough to support full pressure in the event they become clogged, and no bypass is provided for these filters. The intent of this arrangement is to ensure that contaminants and abrasives do not migrate from their point of origin to damage other, and perhaps all, of the components in a system. This design philosophy ensures that proper preventive maintenance is done to keep the system clean and the filters serviceable rather than building in a tolerance for slip-shod maintenance which will, in the end, result in major overhauls, repairs, and replacements.

Several of the functions which are normally done hydraulically can, if necessary, be done by alternate means. Two functions, bomb bay doors and wheel brakes, have alternate hydraulic systems. A hand pump and a small reservoir under the floor near the radio operator's station can be used to pressurize the No. 1 System bomb bay door actuators. A small dc motor operated pump (known as the 1B Pump; manually controlled by the Aux Brake Pump switch) located in the hydraulic service center can be used to charge the normal brake accumulator from the No. 1 System reservoir.

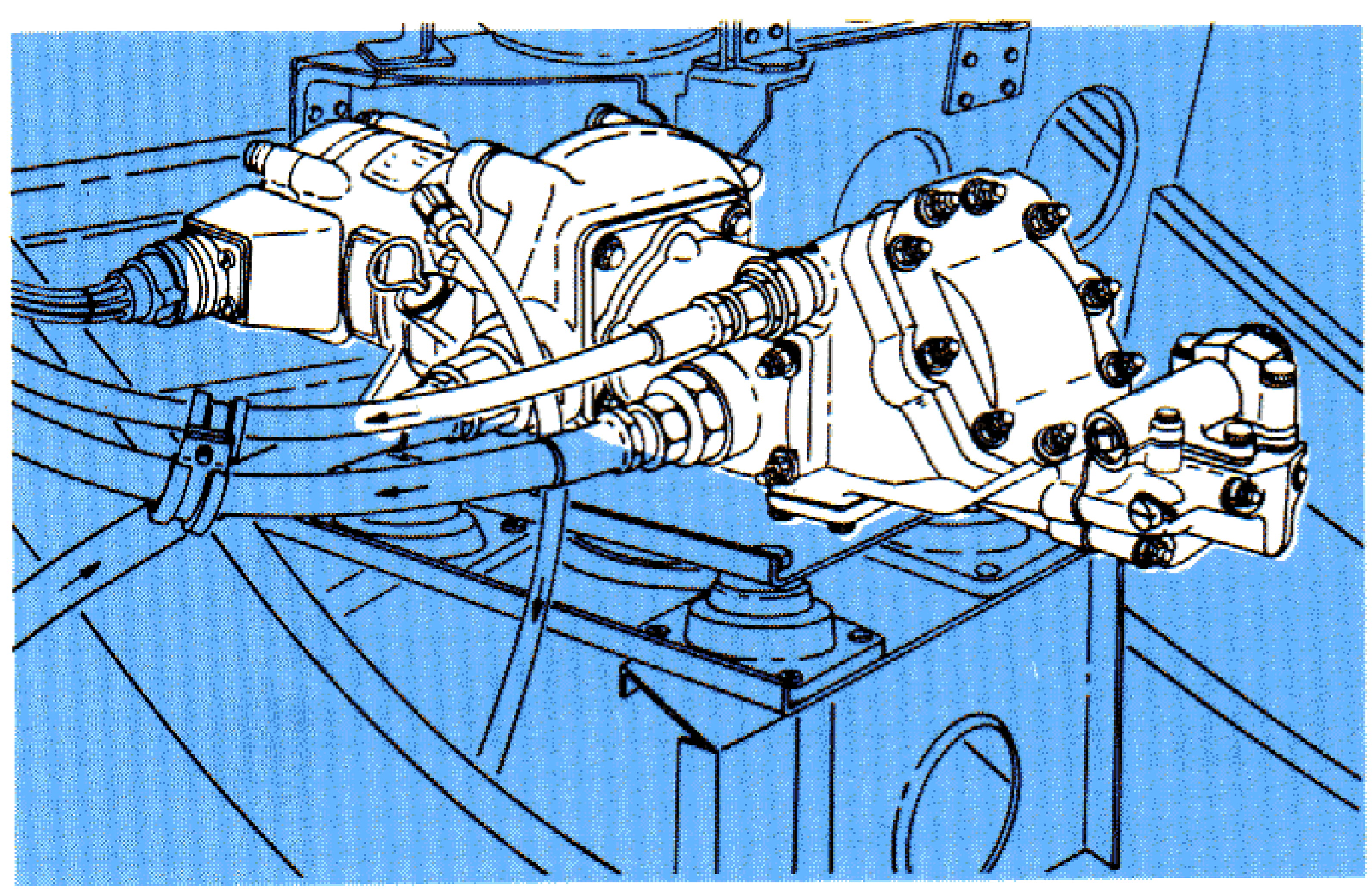


Figure 61 Vickers Motor-pump

Generally speaking, the Orion's hydraulically-boosted control system is the same as a basic cable-actuated control system with the addition of hydraulic cylinders helping the pilot to move the control surfaces in each control axis. A hydraulic control valve governs the direction and amount of travel of the boosters and the valve is also connected to the system control mechanism (see Figure 62). It will be noted that this same booster control valve is utilized by the autopilot, enabling the autopilot signals to be converted into control surface movement as efficiently as possible.

Since the need for boosters is often questioned, we might point out that as aircraft become larger and performances increase, the pilot force required to move the controls also increases — often beyond the pilot's ability — and he requires assistance. The application of hydraulic boosters is not necessarily the only way of giving this assistance, but past experience has proven that it is quite often the easiest and most practical method, and is sometimes the only solution.

Lockheed has a long background of development experience on hydraulically-powered controls, which began with an aileron application on the P-38 Lightning during World War II, and they have subsequently been used on most of Lockheed's post-war aircraft. One notable exception, the P-2 Neptune, was originally designed at a time when mechanically-operated controls assisted by servo-tabs was considered to be the best solution for an aircraft of this size and performance. Since then, hydraulically-assisted control systems have been developed to a high state of reliability. Each aircraft application — Constellation, F-104, C-130, and Electra to name a few — has introduced more refinements, and the P-3 flight controls represent the latest example of a steady program of improvement.

The Orion's 3 primary flight control systems each have dual type hydraulic booster assemblies, which are supplied by two independent hydraulic systems (see Figure 58). Normally both boosters in each assembly operate in tandem, although the airplane can be flown satisfactorily with any one of the dual boosters in each control system inoperative, and no action involving the flight controls is required from the pilot in the event of such a failure.

Should a complete hydraulic or double booster failure occur, each control system can be quickly changed to a secondary manual type of control in which the pilot's effort is applied directly to the control surfaces. In this "boost-off" configuration the pilot's mechanical advantage is increased by a "gear shift" mechanism, which reduces the total movement of each control surface to minimum but adequate proportions.

Although the P-3's flight controls can be manually operated, the necessity for such operation is unlikely in view of the power systems design with their built-in tolerance for failures. This aspect has been described in the previous section discussing the

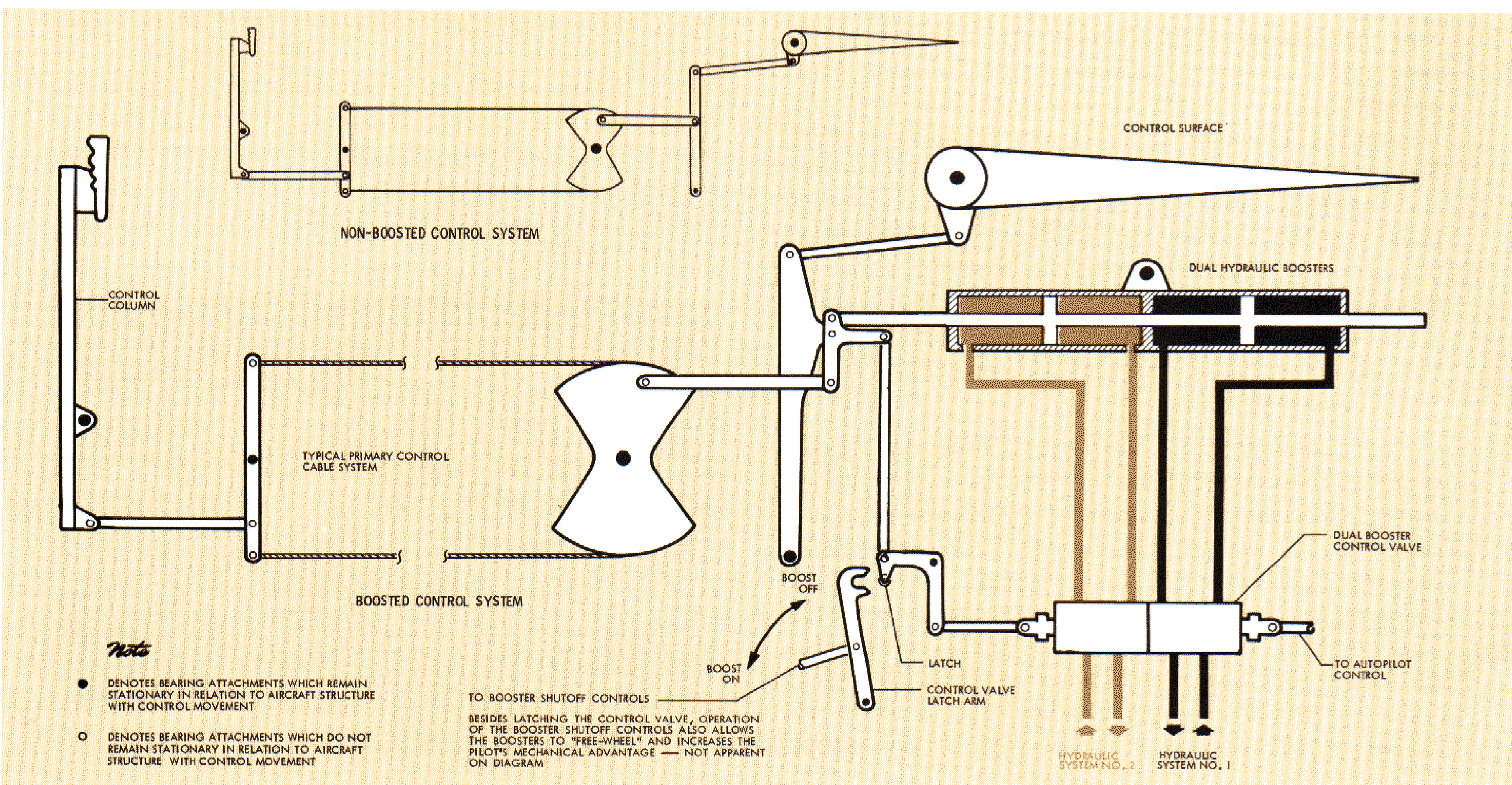


Figure 62 Surface Control Booster — Basic Operating Principle

hydraulic power system, but will bear repeating here. Briefly, all electrically-driven hydraulic pumps to both systems are operable when any engine-driven generator or external power source is available. Thus the boosted controls are unaffected by the loss of any two engines or generators during flight, and still unaffected by the loss of three engines so long as engine No. 1 is included, which of course does not have a generator. Another advantage of this configuration is that "boost on" operation of the flight controls can be ground tested by merely plugging in electric ground power.

Minimizing friction in the cable systems to the boosters was a primary design objective. Long straight cable runs have been established and these allow extensive use of Lockclad cable, which consists of normal flexible cable, pre-stretched, with aluminum tubing swaged around it while the cable is still in tension. Use of Lockclad cable reduces cable deflections under varying loads and is used in preference to flexible cable, which is used primarily around pulleys.

The ailerons and rudder use single closed-cable systems, and slack absorbers are employed to take up slack in the unloaded cable of these systems when they are subjected to high tension loads during control operation. The elevator employs a double closed-cable system, and cable tension variation is somewhat more critical than with the aileron and rudder control axes. Consequently, instead of slack absorbers, tension regulators are employed at the elevator booster input quadrant. These maintain the desired cable tension in each elevator cable system while still performing the same function as slack absorbers.

Plain hinged control surfaces are used in all three control systems. Metal skin and ribs are built upon one or two spar beams with hinge brackets attached to the forward beam. The elevators and ailerons are balanced to varying degrees by static balance weights also attached to the control surface front spar.

The rudder and elevator boosters are located in the aft fuselage and drive their respective surfaces through push-pull rods which are attached to large torque tubes on the surfaces. Wherever possible, nonmagnetic materials are used in this area because of the proximity of the submarine detection equipment.

The aileron booster is most conveniently located in the hydraulic service center in the fuselage. It drives the ailerons through bellcranks and push-pull rods along the aft face of each wing rear beam. These rods are exposed to view whenever the wing flaps are extended.

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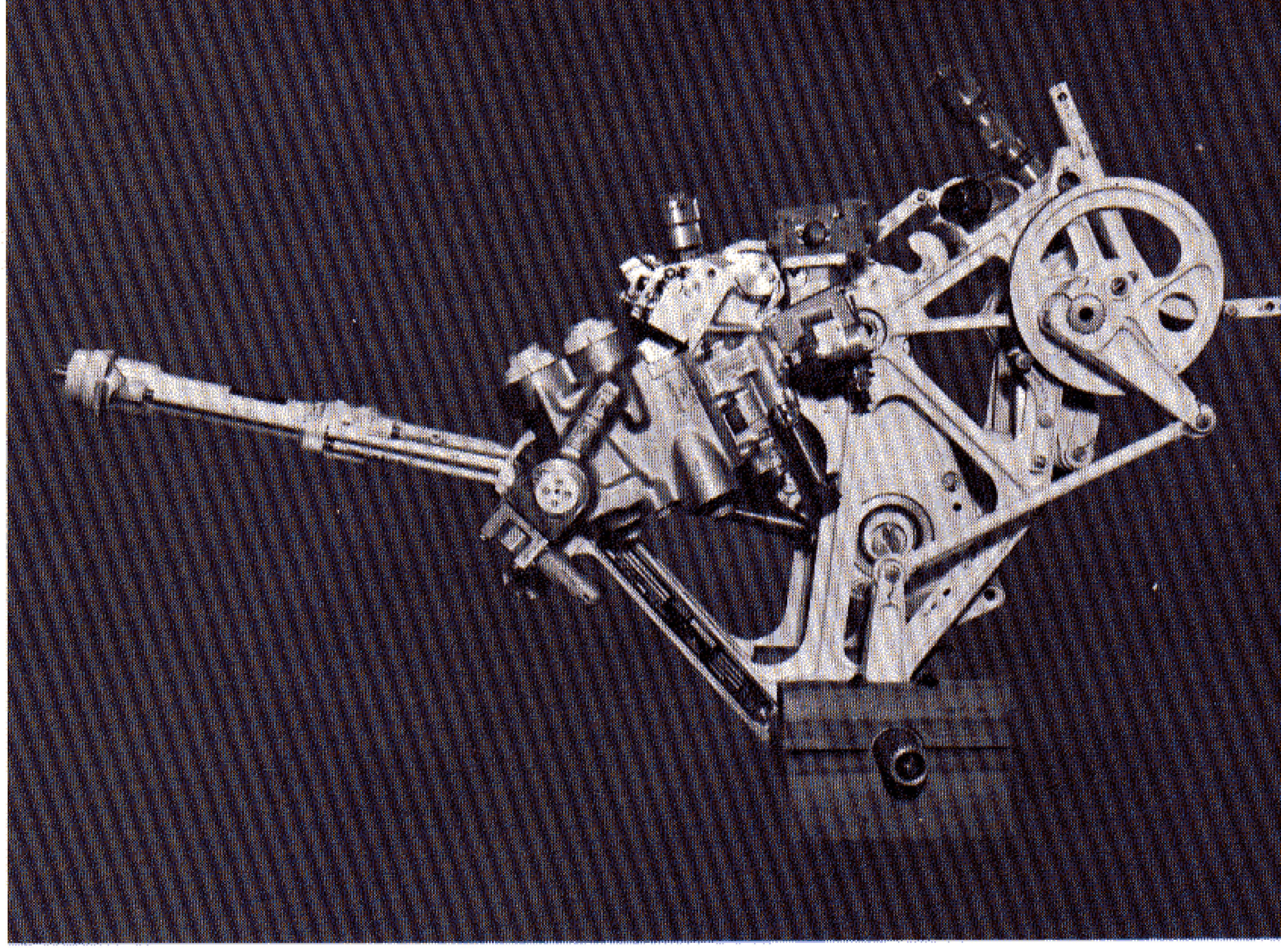


Figure 63 Typical Booster Package — Aileron shown

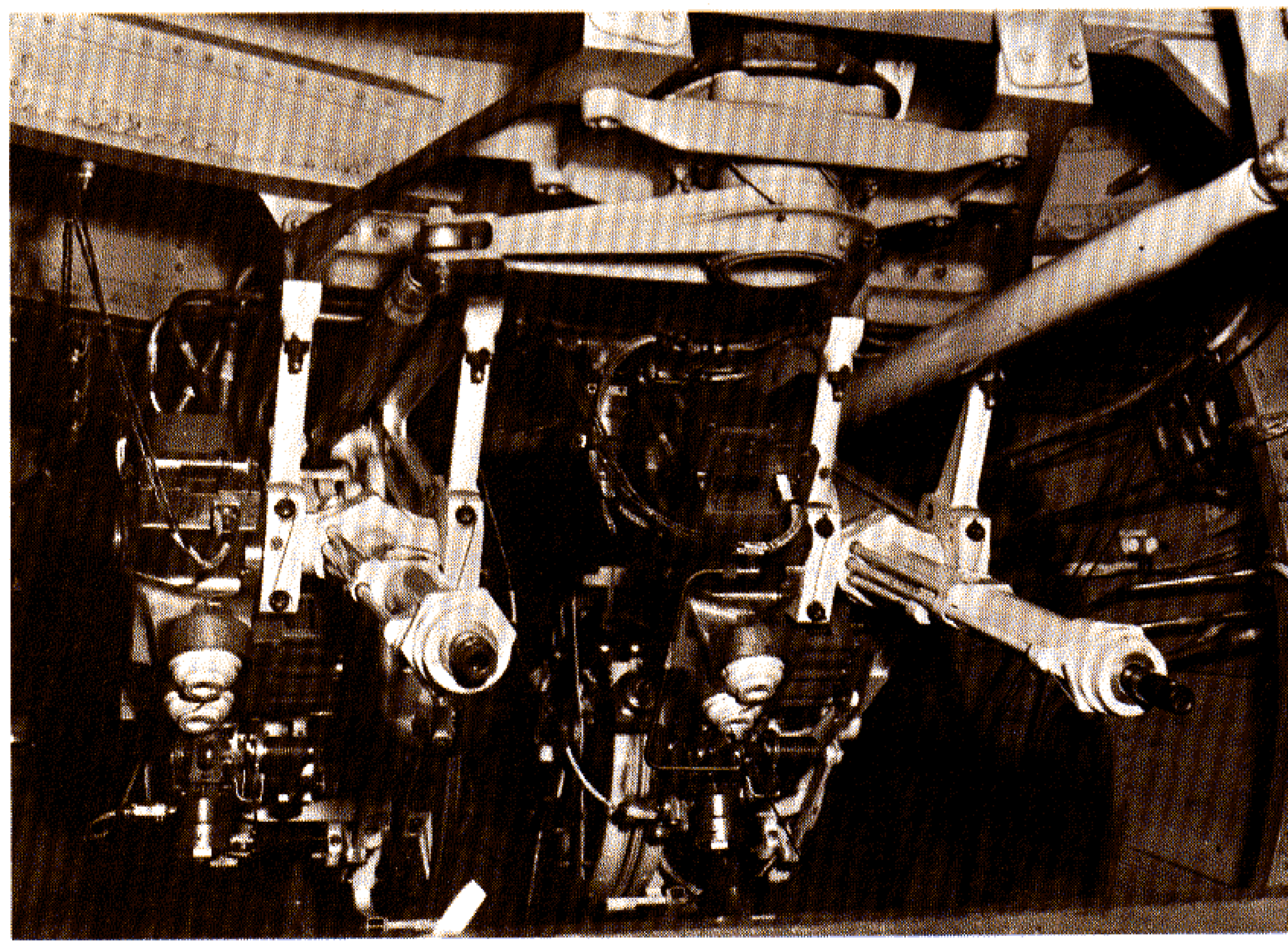
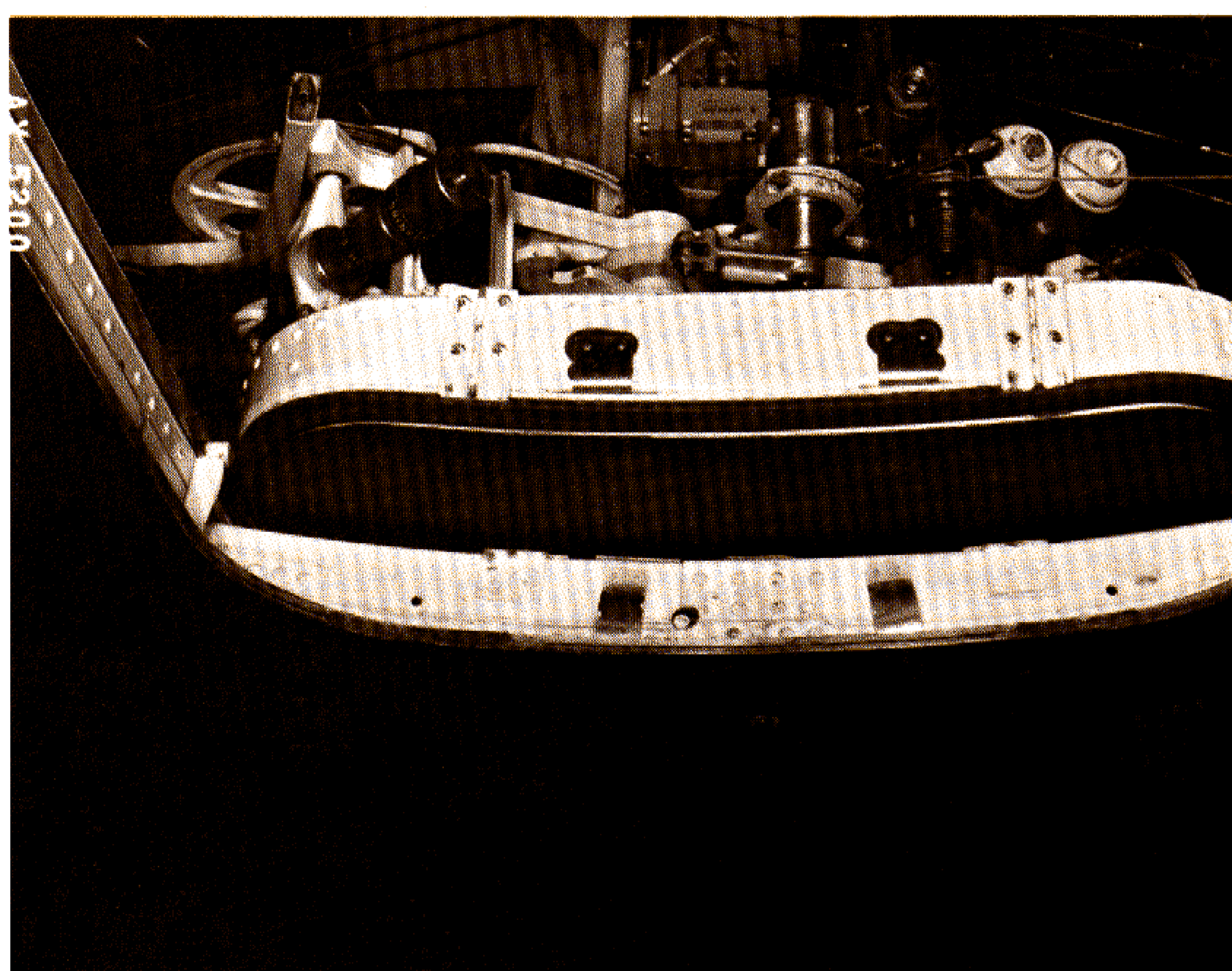


Figure 64 Rudder and Elevator Booster Installation — View looking forward

Figure 65 Aileron Booster Installation — View looking forward through hydraulic service center access door.



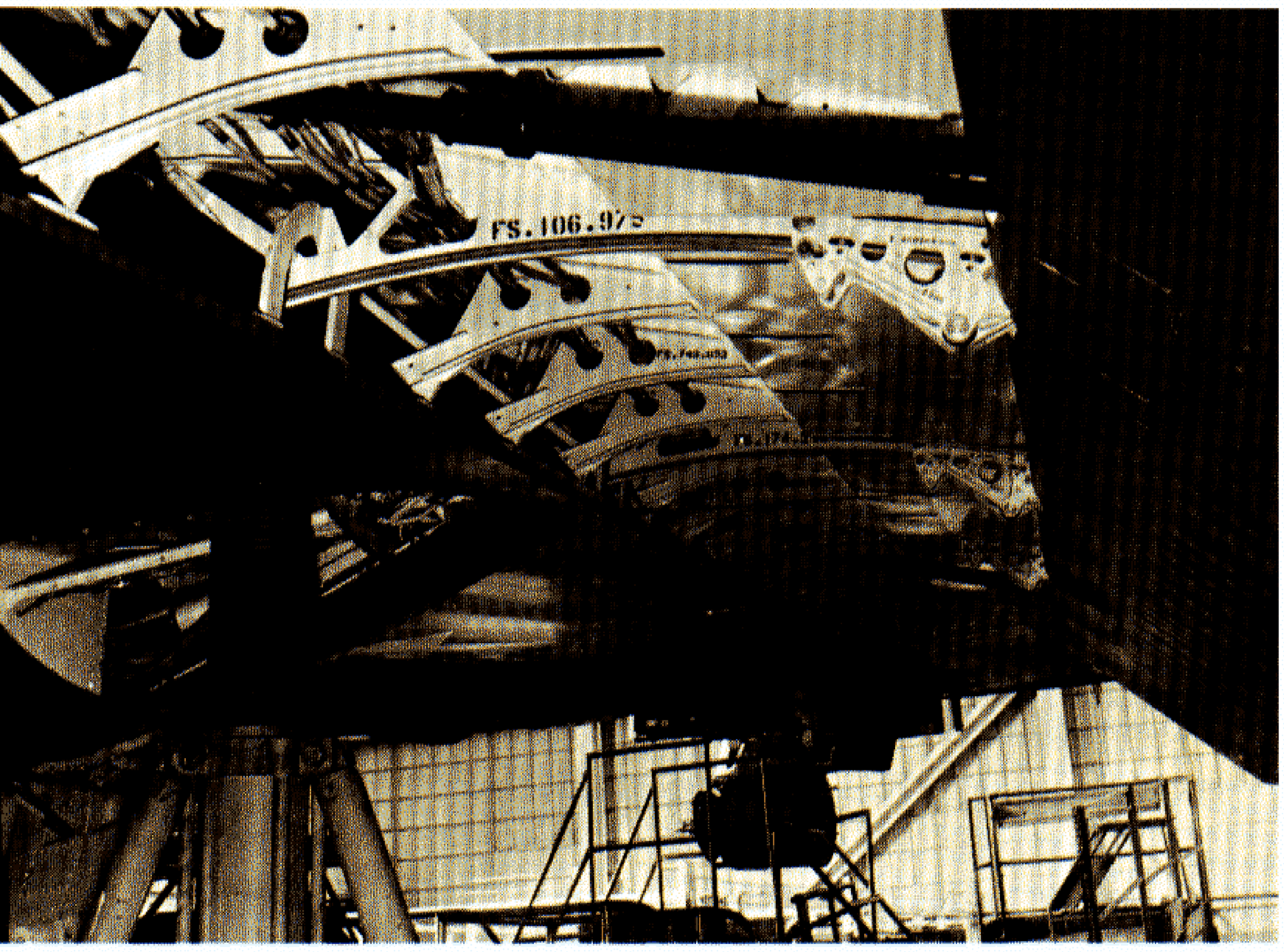


Figure 66 Right Flap and Flap Well
Showing Screw Jacks and Flap Tracks

Conventional trim tabs, which have no servo action, are provided on all control surfaces, and they are mechanically operated through cable systems to actuators mounted on the primary control surfaces.

An additional tab of unique design is installed inboard of each elevator trim tab to tailor the elevator control forces (pilot stick forces) to the desired magnitude. These two tabs, called force link tabs, are linked to, and are monitored by, the elevator trim tab controls so as to provide optimum control forces throughout the flight spectrum of the airplane.

Dampening devices are added to both the rudder and elevator surfaces. They resist rapid aerodynamic reversals and also provide resistance to flutter if by some remote chance a control failure should cause a free surface. Incidentally if such a failure should happen, control of the free surface or surfaces can still be maintained by use of the trim tabs.

It is undoubtedly true that one's first impression of a boosted flight control system is that it is complicated. However, with further acquaintance one begins to appreciate their advantages. In particular their use makes the rest of the control system much simpler than if some other method of pilot control assistance were adopted. Further, each booster assembly is built as a package so that it can be removed from the airplane as a complete unit and replaced by another package. No installation adjustments are required on the replacement package and the removed one can be overhauled, aligned, and tested, ready for installation in another airplane.

FLAP SYSTEM Like the P-2 Neptune, the P-3 has Fowler-type flaps. There are, of course, many system detail differences and one significant addition on the P-3 is a flap asymmetry detection system. The carriage mounted aluminum flap panels, one on each wing, are interchangeable and are hydraulically powered. They are controlled by the wing flap lever located in the flight station on the right side of the control pedestal. Flap movement during the first 80 percent of flap extension is mostly aft in order to increase lift, and downward during the last 20 percent extension in order to increase drag.

Flap position is selected by depressing a release button on the side of the flap handle, and moving the control lever to the desired flap setting. When the button is released, the flap lever will remain locked in that position. Adjacent to the flap lever is located a nameplate that denotes the lever setting for FLAPS UP, MANEUVER, TAKEOFF-APPROACH, and FLAPS DOWN.

Flap control lever movement is transmitted through a cable system to the hydraulic service center, operating a follow-up mechanism. This follow-up mechanism positions a hydraulic control valve to port hydraulic fluid from the two separate 3000 psi systems to two hydraulic motors that drive the flaps. After the flaps have been driven to the selected position, the follow-up mechanism positions the control valve to turn off the hydraulic pressure to the flap drive motors. The flap position is reflected by the flap position indicator located on the copilot's instrument panel. Because each flap motor is driven by fluid from a separate hydraulic system, malfunction of one hydraulic system would not render the flaps inoperable, although a reduction in airspeed may be necessary during flap extension.

The flap motors drive torque tubes that extend the telescoping ballscrew type actuators, two of which are attached to the rear beam of each wing. Since the torque tube system is torsionally continuous from the outboard end of one flap to the outboard end of the other, the flaps are driven symmetrically.

The wing flap asymmetry system is installed in order to safeguard against a failure of the type which would result in unequal extension or retraction of the flaps. When a flap panel, or one end of a flap panel, lags a significant amount, the asymmetrical condition is detected, a shut-off valve turns off hydraulic flow to both flap motors, and disc brakes located at the extremities of the torque tube system are applied to prevent further rotation of the torque tubes. The flight crew is informed of an asymmetry trip (actuation of the asymmetry system) by a light on the center instrument panel.

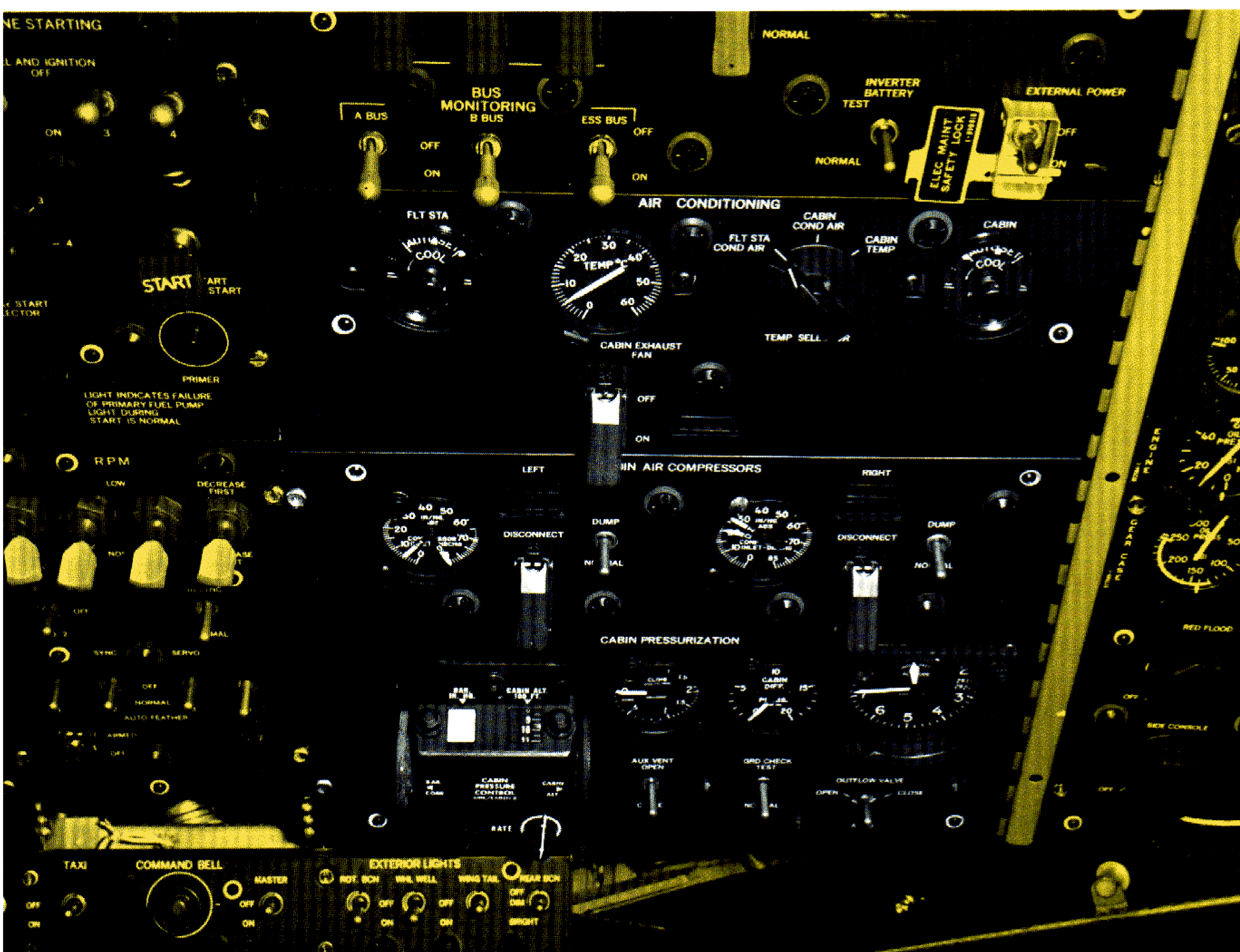
AIR CONDITIONING

Sub hunters working in the P-3's pressurized, air conditioned cabins will be enjoying a "fringe benefit" which was considered an unjustifiable luxury when earlier ASW airplanes were designed. This fringe benefit is partly a legacy from the craft's airliner antecedent, but it would have been provided, even if a completely new design had been necessary, because better performance and longer service-life may be expected from properly cooled electronic gear operated by crews unencumbered by heavy clothing and oxygen equipment.

The system that keeps the crew comfortable and the black boxes cool, features two independent engine driven compressors, two independent "bootstrap" air-cycle refrigeration units, and a cabin pressurization system. These three sub-systems have separate control panels (shown in Figure 67) grouped together on the flight station overhead. The panels are designated Air Compressor, Air Conditioning, and Cabin Pressurization, and we will discuss them in the above logical order — following the air from intake to exhaust.

ENGINE DRIVEN COMPRESSORS Pressure is supplied by two compressors, one of which is mounted on an accessory drive pad of each inboard engine. Our use of EDCs (short for Engine Driven Compressors) to pressurize the cabin of a turbine powered airplane warrants some explanation, for it is common practice, particularly on military aircraft, to use air bled from the engine compressor section for this purpose. The EDC was mandatory on the Electra because of existing Civil Air Regulations which forbade the ducting of engine bleed air into the cabin to eliminate the chance of the cabin air supply being contaminated with engine oil. In re-assessing the system for military use we were pleasantly surprised to find that it is actually *more* efficient in terms of fuel economy to tax each inboard engine 80 hp to drive one of these

Figure 67 Air Conditioning and Pressurization Control Panels



compact compressors than it is to bleed the necessary volume of air from the Allison engine compressor section.

The constant speed feature of the turbo prop engines obviates the need for a variable speed compressor drive. Delivery flow is regulated by tilting inlet vanes to account for the variation in air density with altitude. Each compressor has its own pressurized oil system which is used for lubrication and also as "muscle" to operate two completely automatic servo systems. These systems position the tilting vanes of the flow control and operate an anti-surge spill valve which protects the compressor from "stall" when back pressure becomes too high.

A lubrication system overheat or under-pressure in either EDC lights a warning in the flight station, and if it is deemed necessary the offending compressor drive can be disconnected by placing the appropriate guarded switch to "DISCONNECT." (The engine should be operating when this switch is used, for rotational speed is required to effect a clean disconnect).

A Dump switch is provided for each compressor. The Dump switch circuit induces the anti-surge valve to spill the entire compressor discharge overboard through a door in the side of the nacelle and simultaneously closes the supply duct leading to the cabin. This is also one of the many functions performed by pulling the appropriate engine's Emergency Shutdown lever. *Both* compressors are dumped simultaneously when the Aux Vent switch is turned to "OPEN", and both are dumped automatically when the airplane touches down.

AIR CONDITIONING Hot, compressed air from the EDCs is ducted through the wing leading edge and the fuselage to the air conditioning equipment which is mounted in the nose wheel well. There are two similar air conditioning installations, one on either side of the well. Figure 68 shows a schematic of one of these systems. The cooling capacity of each package is about 7 tons and each operates independently of the other. Newcomers to the airplane are apt to feel that someone is trying to confuse the Navy when they find the conditioning equipment for the port EDC

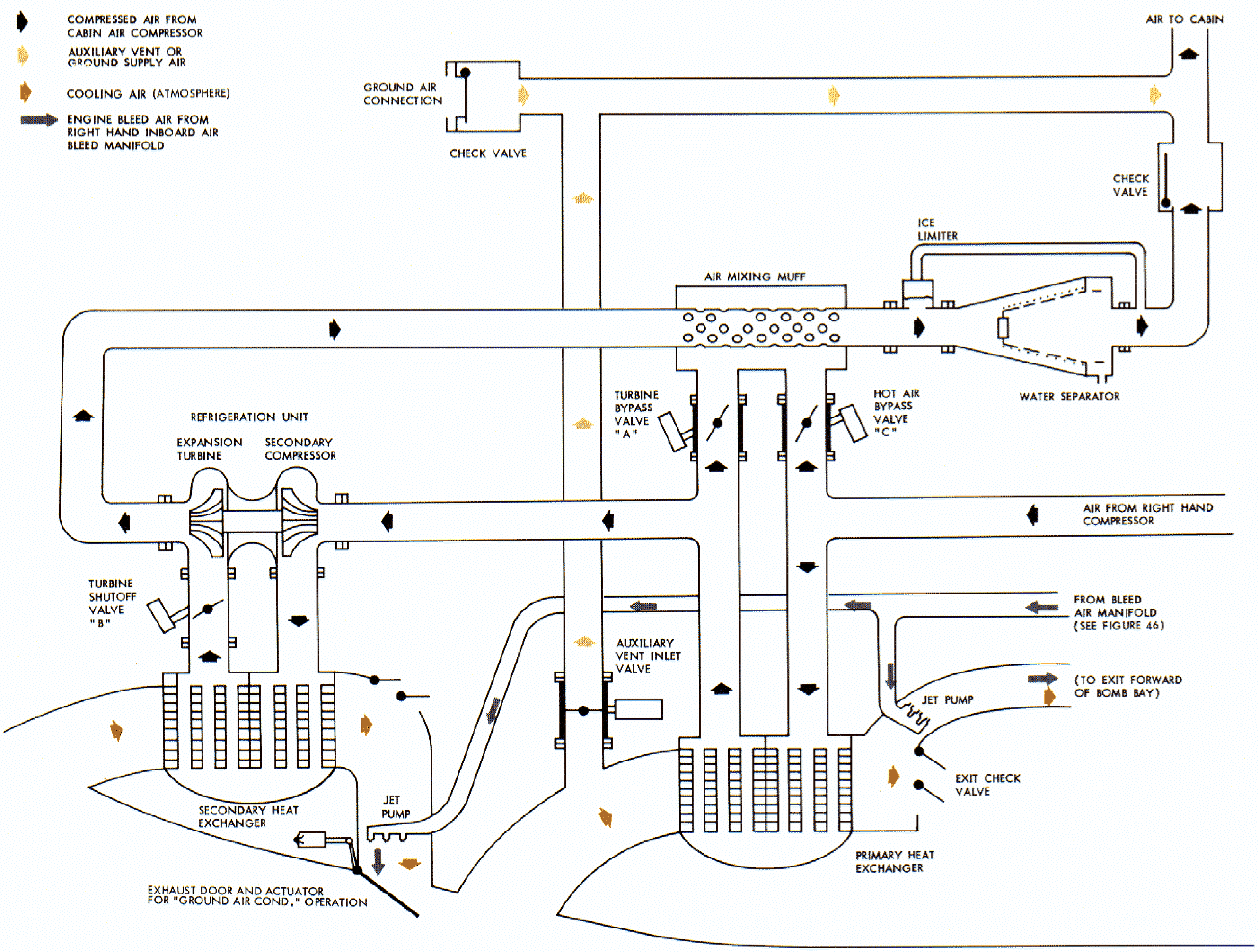


Figure 68 Air Conditioning Installation Schematic

air located on the starboard side of the nose wheel well and vice-versa. Steam fitters, however, will recognize that the cross-ship duct routing provides flexibility for duct expansion and contraction due to temperature and pressure changes.

Air can be made to bypass all the cooling equipment if the full heat of compression is needed to maintain cabin temperature, but some cooling will generally be required. The operator has two cooling control units shown in Figure 67 (one for control of flight station temperature, one for cabin) which can be operated in either of the two modes identified on the control panel as "PUSH-MANUAL", "PULL-AUTO".

Regardless of which mode is used, each unit controls the positioning of three motor operated valves (shown in Figure 68) to direct more or less compressed air through one of the twin air conditioning packages, and a dial below the knob will indicate the approximate percentage of the package's cooling capacity which is being used.

In "MANUAL" mode, the bypass valve positions are directly selected by the operator. The valves will move only when the control knob is turned.

In "AUTO SET", the control knob is set to a desired temperature and the system automatically positions the valves as necessary to maintain the selected temperature. The "AUTO" temperature setting is indicated on the dial above the control knob, and although the dial range between "COOL" and "WARM" is not calibrated in degrees, the operator can interpolate the approximate temperature selected by considering full cool to be about 65° F, full warm about 85° F.

To satisfy a *Flight Station* "COOL" demand, air from the port EDC is directed through the starboard primary heat exchanger, where it is cooled nearly to Outside Air Temperature by air from a ram air scoop, and, if it is still too warm, the cooled air will be fed into a secondary compressor and forced through the starboard secondary heat exchanger and then expanded through a turbine. The compressor and turbine are on a common shaft, constituting what is commonly called a "boot-strap" arrangement because the energy removed in the turbine is used to boost the air pressure and thereby increase the refrigeration potential of the air. The air at boosted pressure is re-cooled to a temperature slightly higher than OAT in the secondary heat exchanger, and as the air expands a great deal in passing through the turbine, it experiences a proportional heat loss.

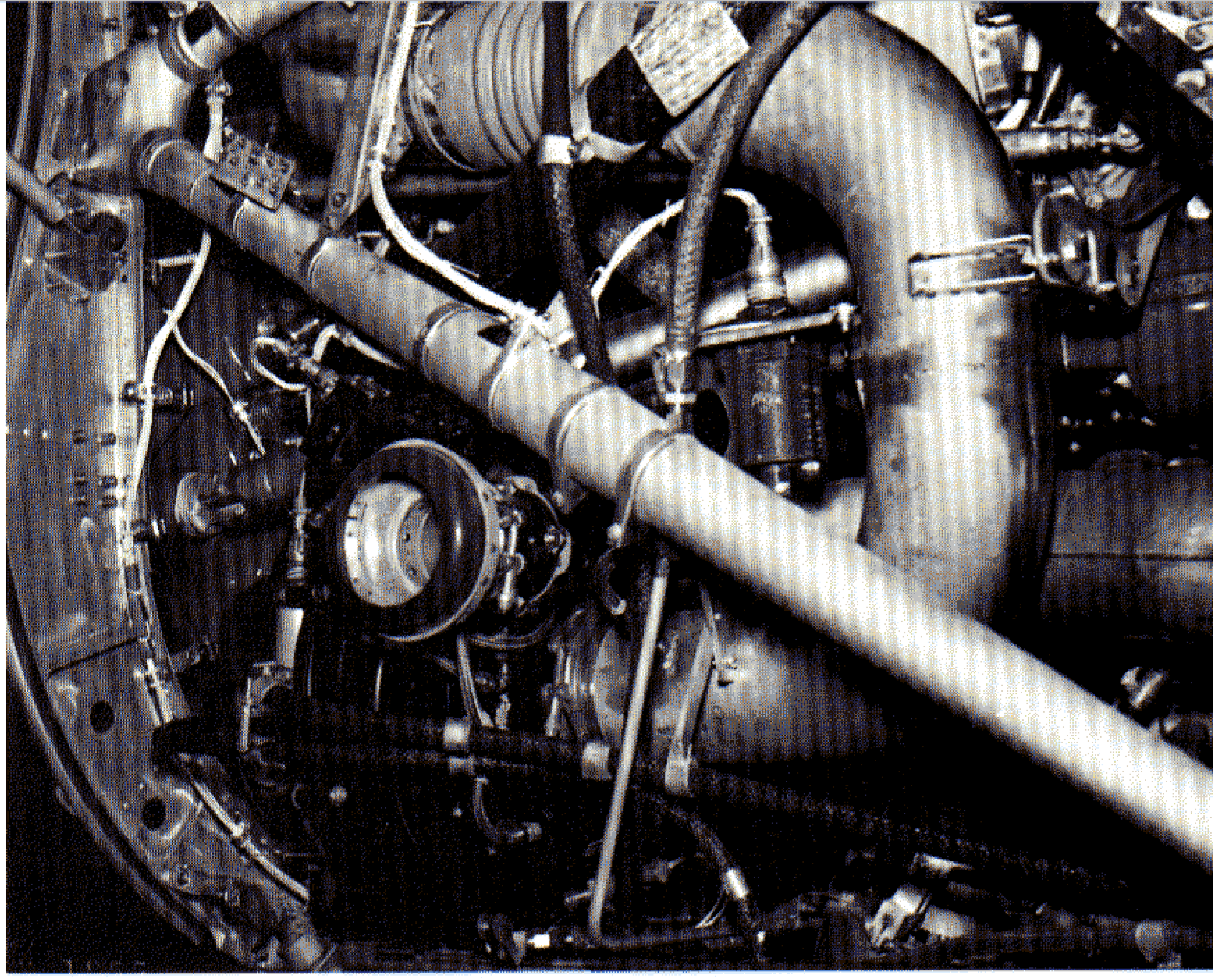


Figure 69 EDC Installation — Left Side of Inboard Engine

Since the cooling gear will often chill air below its dew point, it is necessary that all incoming air be passed through a water separator to strain out the clouds before they enter the cabin. If *ice* clouds are formed, the water separator would clog completely in a short time if it were not for the ice-limiting system shown in Figure 68 which, when operating in "AUTO" mode, senses the pressure drop across the water separator and mixes enough hot EDC air with the cooled air to keep the separator from freezing.

Only about 50% of the air which is conditioned by the starboard cooling gear is needed to control temperature in the comparatively small volume of the flight station. The remainder is diverted to the cabin supply air riser where it mixes with air from the port cooling gear.

The air conditioning gear on the port side of the nose wheel well is the same as that we have described except that its air supply comes from the starboard EDC, it is controlled by the cabin temperature control knob, and all of it goes to the cabin.

At flight speed, ram air will provide sufficient cooling flow through the 4 heat exchangers. If cooling is required when the airplane is parked or taxiing, the Ground Air Cond. switch can be used to sustain the necessary flow of ambient air through the heat exchangers.

A series of valves are opened or closed by this switch, the net result being that the EDCs are "undumped" to supply cabin air, and engine bleed air is channeled to ejectors (jet pumps) which suck cooling air through each heat exchanger.

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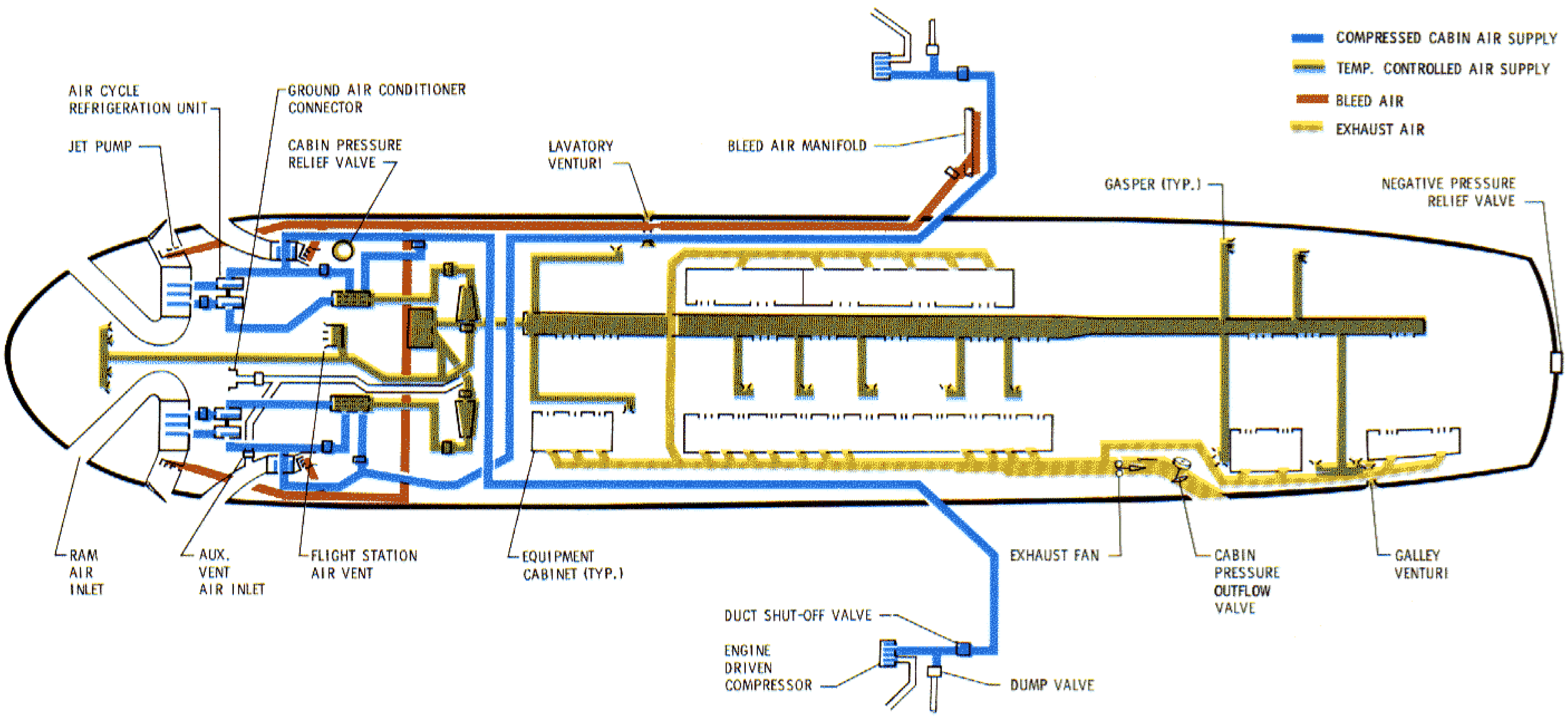

Figure 70 Air Conditioning — Supply, Exhaust, and Jet-pump Ducting

There is no air conditioning if the EDCs are not operating, but during unpressurized flight an Auxiliary Ventilation system may be used, which routes air from the port primary heat exchanger scoop directly into the ship's distribution system. Also, a connector is provided for use of a ground air conditioning rig.

The fresh air supply is delivered to the cabin and flight station principally through outlets in overhead ducting, but each crew station also has an adjustable velocity outlet (gasper). Figure 70 shows the distribution and the exhaust ducting. Note that a constant flow is exhausted overboard from the lavatory and a controllable flow from the galley area.

To keep the crew from getting cold feet, the normally occupied cabin areas, including the galley, are floored with electrically heated panels which are automatically controlled to maintain a 70° F temperature.

Cabin air is admitted at the bottom of the racks in which the electrical and electronic gear is mounted, and this air rises through the gear to be drawn off at the top into a trunk line that ducts the air overboard through the cabin pressure controlling outflow valve. The amount of cooling in each equipment bay is determined by the size of the air exit hole into the trunk line. The system is designed to maintain temperatures below 130° F in each bay under the most adverse conditions. Whenever electrical power is on, an exhaust blower near the outflow valve operates constantly and maintains the necessary cooling flow for the electrical gear if the cabin is not pressurized.

CABIN PRESSURE CONTROL The cabin pressure regulating valve is located near the outflow vent in the lower aft fuselage skin. It is a pneumatically operated valve when used in the automatic mode of pressure controlling, and for manual over-ride it has an electrical actuator which can be controlled by toggling the Outflow Valve switch on the Cabin Pressurization panel. When the airplane touches down, the outflow valve is driven open electrically by landing gear scissors switch action regardless of the position of the Outflow Valve switch.

For normal flight operation the manual over-ride switch is left in "AUTO" and cabin absolute pressure is pneumatically controlled through the Cabin Pressure Controller shown in Figure 67. The operator can select a given cabin pressure-altitude and adjust the Rate knob on the controller to obtain a cabin rate of climb (or descent) from 200 to 2000 ft. per minute. The pneumatic controller has a self-limiting feature in respect to cabin differential pressure which stops pressure buildup at 5.4 psig. In terms of pressure-altitude, this means that sea level cabin pressure can be maintained up to 12,300 ft., and an 8000 ft. cabin pressure can be maintained at 25,000 feet.

If the self-limiting feature should fail, or if the operator should over-ride the pneumatic control by closing the outflow valve electrically so that cabin pressure reaches approximately 5.8 psig, a safety relief valve opens and exhausts air into the nose wheel well. This valve, which is located under the co-pilot's seat, is large enough to carry off the entire output of both EDCs, if necessary, without over-pressurizing the cabin.

ELECTRONICS

Although the electronic systems may justifiably be regarded as the major part of the modern ASW airplane, the complexity of all the equipments, and the classified nature of some, precludes our providing adequate coverage in this magazine. Brief summaries covering the various navigation and communication equipments follow, but little can be said about the submarine detectors and locating equipment. We may point out, however, that a classified issue of the U.S. Naval Aviation Electronics Digest, Vol. 21, No. 9; March 1962, contains specific descriptive information on these and other equipments.

Insofar as the arrangement of equipment goes, those familiar with ASW tactics will find that the P-3 designers, starting with a clean slate and working closely with Naval experts, were particularly successful in integrating men and equipment to eliminate confusion and waste-motion. Many of the equipments are interconnected with automatic or semi-automatic data transmission links to provide pertinent information to all who need it — such as the automatic repeating of sonobuoy range data at the Tactical Coordinator's position. These links reduce the load on the interphone, the chances for error, and the time required for data transmission.

The Tactical Coordinator's station is, in itself, a significant advance in design. The title is truly an apt one — the TC will be able to monitor the complete tactical situation in respect to stores, detection, and localization, coordinate the individual crew efforts, and, under the direction of the pilot, plan and execute the search and attack phases.

The P-3 crew stations can be seen in Figures 71 and 72, and are also depicted in Figure 15. Although there are 12 stations, the P-3 will normally carry a 10-man crew. The Plane Captain (Flight Engineer) is seated immediately aft of the Pilot (Patrol Plane Commander) and Copilot. Aft of the flight station, the Radio Operator serves also as the Port Forward Observer and, opposite him, there is a Starboard Forward Observer's position. In the center of the aircraft, a series of consoles on the port side accommodates the five tactical station operators. There are port and starboard observer's stations in the aft fuselage.

Three cabinets — one forward of the tactical station, one forward of the electrical service center on the starboard side, and one aft of the entry door — contain the majority of the electronic equipments.

NAVIGATION In addition to airways navigation, both long range and tactical navigation capabilities are required for the ASW mission; first, to guide the aircraft to a site perhaps 1000 miles away; second, in the tactical area, to furnish navigation information needed by the tactical systems to bring weapons to bear on a target. Some general information as to the three navigational modes will be helpful in gaining acquaintance with the P-3.

Mode 1 — Long Range Point-to-Point As the name implies, this mode of operation requires a navigational system capable of determining aircraft geographical position at any time. Following are very brief descriptions of the many long-range navigation choices:

Pure Inertial — The AN/ASN-42 Inertial Navigator is used. No inputs are required except initial alignment at a known starting point and continuous signals thereafter from a compass magnetic flux valve. Outputs are: magnetic and true heading, variation, ground speed, distance travelled, track, and latitude/longitude.

Doppler-Damped Inertial — This choice is the same as the pure inertial, except that the AN/APN-122 Doppler Navigator damps out the long-term oscillations inherent in an inertial system.

Doppler/Air Mass — The operation is functionally similar to the present day P-2 system, requiring inputs of heading, true airspeed, and Doppler ground speed. Outputs include wind, track, and readouts on the Latitude/Longitude Indicator (ID/888/U).

Air Mass — Operation is the same as in Doppler/Air Mass except that without Doppler the wind vector is inserted manually and ground speed is derived from wind and true air speed.

Grid Navigation — This can be effectively employed in the high latitudes (above 70 degrees) using the low-drift free directional gyro (FREE DG) of the AN/ASN-42 Inertial Navigator. The AN/ASN-37 AHRS also provides an adequate free gyro heading source which may be substituted for that of the Inertial Navigator. Operation is similar to Doppler/Air Mass or Air Mass type of navigation except for the Free DG.

Conventional navigational facilities are provided, including a periscopic sextant, a B5 driftmeter and the AN/APN-70 LORAN.

Mode 2 — Tactical This mode of operation requires that the Navigation System be capable of determining aircraft position in reference to a datum at any time during a tactical problem. Cartesian coordinates of position are generated, plotted, and stored in terms of distance traveled from datum. Means are provided to compensate for apparent movement of the datum; for example, the drift of a sonobuoy in ocean currents.

Three plotting and display devices are provided for tactical navigation. One of these we will not discuss here, but it was described in a classified edition of the U. S. Naval Aviation Electronics Digest, March, 1961 issue (not to be confused with the 1962 issue mentioned previously). This Navy publication is made available to those who have an established "need to know" to keep abreast of the latest developments in the ASW field, a discrimination we cannot make with this magazine. The other two plotting and display devices are briefly described as follows:

The PT-396/AS is an X-Y plotter which automatically provides a plot of aircraft ground track for the Navigator. Several scales are provided for selections appropriate to the particular tactics in use. Marks can be inserted to record positions along the track at which various events occur.

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The OA-1768/A/ASA-13 is an X-Y plotter which automatically provides a plot of aircraft ground track for the pilot. In addition to the track, the plotter can accept and plot remote positions inserted by the Tactical Coordinator.

Each pilot and the TC are provided with a BDHI (Bearing, Distance, and Heading Indicator). These are used for tactical operation to display true heading, target true bearing, aircraft true course, and distance to target, or other position selected by the TC for display.

The AN/ARA-25A UHF Direction Finder is a tactical homing device which utilizes an antenna system designed to provide bearings on UHF signals. In the P-3A it performs this function in conjunction with the pilot's UHF receiver.

Mode 3 — Airways The P-3A Navigational System includes the several equipments needed for operations on airways. These are the VHF Omni-Range (VOR), the Marker Beacon, Low Frequency ADF, and Tactical Air Navigation (TACAN). Two VOR receivers are provided and either may be selected by pilot or copilot.

COMMUNICATIONS The P-3A Communications System consists of four subsystems:

HF/MHF Subsystem — The dual HF set uses Collins 618T-2 Transmitter-Receivers and 714E-3 control units (AN/ARC-94). These operate in conjunction with a TT-264/AG Teletypewriter and CV-1053/ARC Teletype Converter, feeding into the long wire antennas. The AN/ARR-41 provides a third HF receiver for the aircraft.

VHF Subsystem — AN/ARC-84 (Bendix Type 21). The installation of one transmitter and two receivers allows the flexibility of either dual VOR, one complete VHF set plus one VOR, or one complete VHF set plus an additional VHF receiver monitor.

UHF Subsystem — The dual AN/ARC-52 UHF Radio Sets operate into upper and lower UHF blade antennas interchangeably.

ICS System — The above subsystems are tied together by the AN/AIC-22 intercommunication system as a fourth subsystem to make up the over-all aircraft communication system.

The AN/AIC-22 Intercommunication System, in addition to its normal function, enables crew members to listen to the various receiving units, and transmit over selected transmitters as required. The system also carries the audio outputs of the search and detection equipments to crew members and tape recorders.

The "ICS ALL" audio line permits any crew member to contact all other crew members simultaneously, provided they have not selected "DISCONNECT" at their control. Through use of a momentary toggle switch, the pilot and copilot can override even the "DISCONNECT" selection and reach all stations in the airplane. The TC can override only members of the tactical crew and the radio operator.

Loudspeakers are located logically throughout the airplane. The pilot and copilot master controls are wired to permit simultaneous operation of all speakers as a public address system, in which case the transmission will also be heard in all headsets.

The Audio Tape Recording System enables the crew to record ASW communication, navigation, search, and detection audio information for mission record, evaluation, crew training, and other needs. Except for two RO/28-UNH-6 Tape Transports, the system has been designed and fabricated by Lockheed specifically for the P-3A.

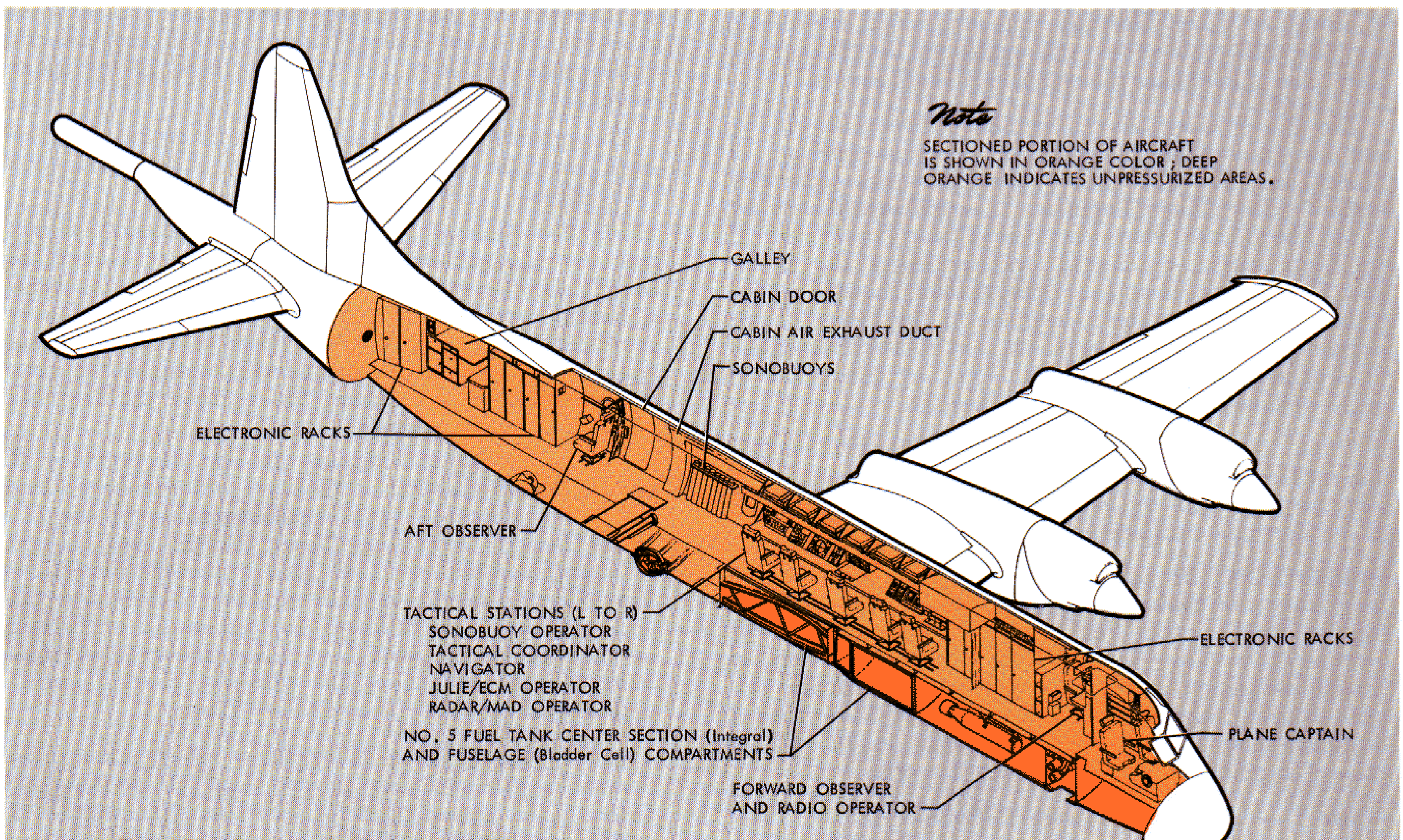

Figure 71 Fuselage Section — Left Side

THE SEARCH STORE SYSTEM controls the stores utilized in conjunction with the electronic detection equipment aboard the aircraft. Sonobuoys, both size A and size B can be dispensed singly, in pairs, or in sequence, with or without Intervalometer action. Except for one size A sonobuoy launching chute, the chutes can only be used when the cabin is unpressurized. The Under-water Sound Signals must also be released from an unpressurized cabin. The Marine Marker launcher can retro-launch a store at any time.

The Tactical Coordinator selects the search stores to be released. Release switches and status lights, which indicate that the stores are loaded and ready for release, are located at the Tactical Coordinator's station and in the Flight Station for Pilot or Copilot use. The Search Stores can be released in any combination. In fact, all launchers that are selected and ready, will be activated by any release switch, assuming that the Master Search Store power control has been closed by the Plane Commander. In addition, pickle switches are provided at every viewing window in the aircraft so that a man on watch can release a Marine Marker to mark a transient visual contact. The MAD operator also has a switch for this separate Marine Marker line.

The use of a "Data Display" system for the search stores is a new concept, and is being used on the P-3 for the first time. The Tactical Coordinator controls all inputs to this system from a control panel. Through it he indicates which chutes to load with which stores and the adjustments to be made to the stores, monitors that the orders are complied with, and transmits the information as to the loaded and ready configuration — via digital circuitry — to the appropriate stations in the aircraft.

THE KILL STORE SYSTEM. Selection and release of the kill stores is made in the Flight Station with one exception: The Tactical Coordinator has a release switch for use when the Plane Commander determines the tactical situation requires it. After the aircraft bomb bay and wing stations are loaded, the bomb bay loading panel switches are positioned to reflect the loaded configuration and locked in place. When the Pilot positions a rotary switch to select a kill-store appropriate to the tactical situation, status lights indicate the location and availability of the store after selection. Finally, the store is armed by a toggle switch and released by switches on either control wheel or at the TC station. The Tactical Coordinator monitors kill-store releases through status lights on his armament panel and these same status lights provide continuous store inventory.

GENERAL Other status lights on the Tactical Coordinator's panel indicate the position of all store ejection doors. The Flight Station Armament panel has controls and status lights for operation of the bomb bay doors.

Normally, a landing gear interlock prevents store release with the gear down, but an override switch is provided for routine system checkout on the ground. The Jettison circuit has a different type of interlock, which is dependent on a "weight-on-wheels" switch thus permitting jettison of all explosive stores as soon as the aircraft is airborne. Stores jettison is accomplished by the positioning of one well guarded toggle switch located in the Flight Station. When all doors are fully opened the stores will be released and the doors will automatically close. While this is progressing, all loaded photo flash cartridges will be expended. The entire jettison cycle takes but 20 seconds and leaves a clean aircraft ready for ditching if this be necessary. ▲▲

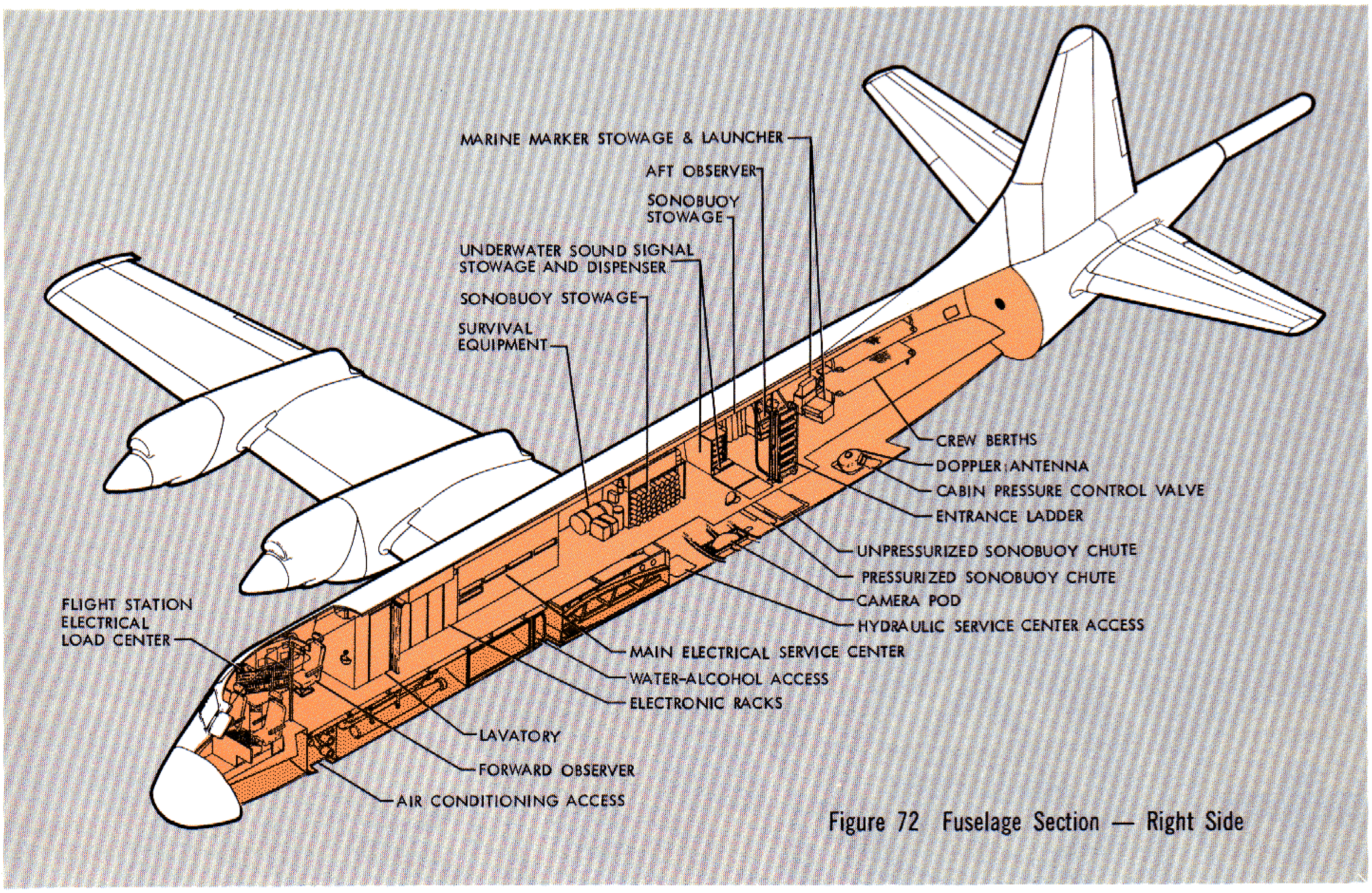

Figure 72 Fuselage Section — Right Side

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U.S. NAVAL AIR TEST CENTER PATUXENT RIVER, MARYLAND

WEAPONS SYSTEMS TEST

SERVICE TEST NATC

NAVAL AIR TEST CENTER FLIGHT TEST