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A R.C. Technical Report

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G-Alun Engineering Appraisal

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MARINE AIRCRAFT EXPERIMENTAL ESTABLISHMENT, FELIXSTOWE, SUFFOLK.

SAUNDERS-ROE PRINCESS FLYING BOAT G-ALUN

ENGINEERING APPRAISAL

S U M M A R Y

The total flying time of the aircraft was 96 hours 50 minutes, and therefore only a limited engineering appraisal is possible. Assessments are however given of most of the main installations provided, as well as of ease of launching, beaching and maintenance. Full reports on each of the main installations have been prepared by Saunders-Roe.

The various aircraft systems and services are briefly described and assessed where possible, and items requiring further development and investigation are discussed. The general conclusions are that the launching and beaching facilities are satisfactory and that few difficulties are likely to be encountered with any of the installations.

A number of detailed recommendations are made.

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1. INTRODUCTION

A total flying time of 96 hours 50 minutes was completed by the aircraft in 47 flights; a detailed engineering appraisal is *not therefore* possible. *However*, considerable experience on launching and beaching, as well as servicing and maintenance, was accumulated whilst, in addition, an appreciable amount of data on the functioning of the various installations was obtained. It was considered desirable, therefore, to place on record provisional conclusions and recommendations, even though these might have to be revised in the light of increased flight experience on the flying boat, or as the result of new equipment, revised operational requirements, etc.

Separate reports have been written by the Company concerning each of the main installations, and describing the methods developed for handling the aircraft on the slipway and in the water.

This report summarises the important points of the individual engineering reports, and with References 1, 2 and 3 provides as complete an appreciation as possible in view of the limited flying time.

Leading particulars of the airframe and power plant are given in Reference 1 and weight details in Reference 3. A general arrangement of the aircraft is given in Figure 1.

2. AIRFRAME

2.1 Condition

During final erection and assembly as well as during the period of flight trials, in all nearly three years, the aircraft was constantly exposed to a salt laden atmosphere. A complete inspection of the airframe and hull was made after flying had been concluded (Reference 5). This showed that the aircraft was in an extremely satisfactory condition with the exception of the following minor points.

- (a) The edges of some stringer attachment brackets, which had been fitted in situ, showed signs of corrosion at the unanodised cut edge. The worst area was in the hull bilges around Frame 24.
- (b) Cadmium treated Chobert rivets and steel bolts and nuts generally showed some signs of corrosion, but this was easily cleaned off.
- (c) The elevator tab control rods and the ball races on the aileron and flap controls had corroded.

2.2 Flight trials

Although instrumentation was provided to measure structural loads and stresses during take-off, flight and landing conditions, it was not possible to make more than a very brief investigation into these problems. The measurements obtained from strain gauges on the main spar frames however showed reasonable agreement with theoretical estimates.

On five occasions during take-off or landing at high all-up weight and in a moderately choppy sea there was slight hull pounding. Attempts were made to measure the pounding frequency and to relate this to acceleration records from various points in the hull and wings. Although recorders were operated during a number of take-off's the attempts all proved abortive, due either to there being no pounding or to the records being too confused for analysis.

Some records of the damping characteristics of the mainplane and tailplane, following rapid application of control, were made over the whole airspeed range. The results (analysed by the RAE. Vibration Dept. and the Company's Stress Office) showed positive damping, in good agreement with estimates.

During flight in turbulent air conditions, such as occur in or below low cumulus clouds, the aircraft tended, from time to time, to develop lateral shudder for short periods. This appeared to be the result of airframe flexure and was apparent as a low frequency, large amplitude, damped lateral oscillation, noticeable throughout the hull, but being less pronounced amidships, greater at the bow and largest at the stern. The phenomenon, which was normally encountered only during short periods of a flight, i.e. when entering the base of low cloud, was regarded mainly as a source of passenger discomfort and not as a probable structural stressing problem. Proposals were made regarding equipment for measuring the oscillations, but time did not permit this to be installed, so that no quantitative investigation was possible.

3. FLIGHT DECK AND INSTRUMENTS

The normal operating crew would consist of two Pilots, two Flight Engineers, a Navigator, and a Radio Operator. The layout of the deck is shown in Figure 2. During the trials an additional seat was provided for a supernumerary crew member, generally a Flight Engineer.

The early stages of flight trials on any aircraft are not representative of the operational role for which it was designed. An assessment of the facilities and layout of equipment provided for the crew may therefore be misleading if attempted too early. For this reason comments on and criticism of the flight deck have in the main been treated as provisional only.

3.1 Pitot static system

A diagram of the pitot static system is given in Figure 3. The two pressure heads were mounted on a mast at the top of the hull at Frame 7, i.e. approximately eighteen feet from the bow and thirty four feet from the wing leading edge. It will be seen that No.1 head supplied the instruments for the first pilot and navigator, No.2 head being used for the second pilot and all other services. A number of additional connections were added to the No.2 supply lines for flight test instrumentation purposes. Full details of the installation are given in Section 5, Chapter 2 of Reference 4.

The installation was satisfactory and gave no troubles during the test period. The measured position error correction is given in Reference 4.

3.2 Oxygen system

An emergency oxygen installation was provided on the flight deck, supply points being available for both the pilots, the flight engineer and the radio operator. This installation was only intended for use in the event of any failures of the pressurisation system.

For the purpose of flight trials, this installation was increased to provide points for all crew members. In addition, a separate system was provided on the passenger deck for the convenience of additional crew members.

During the test period, no troubles were encountered with either of the systems. They were used on a number of occasions when hull pressurisation was not available, and proved satisfactory.

3.3. Pilot's assessment

(a) General

It was easy to enter either pilot's seat, and these were extremely comfortable, with an adequate range of adjustments.

The field of vision was excellent under all conditions of taxiing or flight. Lateral view was sufficient to enable both floats to be seen by bending slightly forward. The clear vision panels were satisfactory to operate, but when they were opened the noise level increased unpleasantly and made intercommunication difficult. The draught with the panel open was also unpleasant.

The windscreen wipers functioned efficiently, but tended to creep from their parked position.

It was not possible to assess the suitability of the cockpit lighting, as no night flying tests were made.

(b) Controls

The flying controls, rudder and column were satisfactory. The radio and intercommunication buttons on the column were too bulky and difficult to operate. The trimmer controls were easy to operate.

Engine throttles were easy to manipulate with one hand even when asymmetric power was required. The operation of selecting reverse pitch on the two outer engines, by withdrawing a mechanical lock and then lifting the throttle lever and moving it rearwards, was unacceptable in practice. The process needs simplification. The controls for operating the floats and the flaps were satisfactory.

(c) Instruments

In general, the instrument layout was good, but when the pilot moved his seat to the raised position for take-off or landing, the top of the Air Speed Indicator was obscured by the coaming of the strip lighting. The radio altimeter was positioned too low on the panel for easy reference when making instrument let downs. The flying control position indicators were satisfactory as a pre-flight reference, but no experience of the emergency warning light system was obtained.

3.4. Flight Engineer's station

(a) General

The compartment air temperature generally became much too high for comfort, but at floor level it was unpleasantly cold. This uneven temperature distribution might have been overcome had the air conditioning plant been fitted. On the other hand it is possible that insufficient insulation was provided between the pressure hull and the marine compartment around the level of the upper decking.

The general level of lighting was good but the screens around the strip lamps were too small to shield them completely,

The noise level was not uncomfortable but radio motor generator sets in the vicinity were rather distracting.

/ (b) Instruments

(b) Instruments

The ten burner pressure indicators proved to be unnecessary and it was suggested that they be deleted

The dial markings on the fuel contents gauges were not easily deciphered. The graduations need to be more easily defined.

The compressor and turbine r.p.m. indicators did not register less than 2,000 r.p.m.; this was a handicap when starting up a motor. Accuracy of indication is not necessary at these low r.p.m.'s but an indication that the motor has started might prevent over priming.

It was considered that the engine oil system instruments should be brought more nearly to eye level and that a warning lamp should be also added to indicate a failure of oil pressure.

(c) Engine controls

The electric throttle control system functioned well. Only minor difficulties occurred and these were easily rectified during servicing. The automatic Jet pipe temperature limiting switch was considered a good safety device. The r.p.m. governing system was not completed, but such a service could prove most helpful on a multi-engined aircraft. Synchronisation of compressor r.p.m. for ten engines was a tedious job, particularly under test flying conditions. It may eventually prove desirable to consider the re-positioning of the flight engineer's throttle levers. With the existing arrangement it was difficult to view a set of engine instruments and at the same time reach far over to the right hand side to make throttle adjustments; frequently the wrong lever was selected by mistake.

Propeller synchronisation was controlled manually during the first thirty-six flights, with a rather limited degree of success. After automatic synchronisation had been fitted for the coupled engines there was a marked decrease in vibration and the flight engineer's operating difficulties were greatly reduced.

3.5. Navigator's station

This station was not used for its intended purpose during the trials, since it was not normally necessary to carry a navigator. No comments on the suitability of the station were therefore recorded, other than the general points made by the flight engineer regarding compartment temperature, noise levels, etc.

3.6. Radio Operator's station

As mentioned in Paragraph 11, the radio equipment installed was not necessarily that which would be required in an operational aircraft. However, the layout of the equipment and facilities provided proved satisfactory, and no adverse criticisms were made.

4. ELECTRICAL GENERATING SYSTEM

The main electrical power installation was a 120 volt D.C. system with an earth return, supplied by four 39 kW engine driven generators. A 28 volt system, with two 5 kW engine driven generators, was also provided. In addition there were a number of motor driven convertor units which provided the various AC requirements for the aircraft. Full details of the installation are given in Section 5, Chapter 2 of Reference 4.

The two main DC systems gave no trouble during the trials. Their loading was seldom in excess of 30% of the design full load, since the prototype aircraft was by no means fully equipped.

Considerable difficulties were experienced with one type of converter unit (B.T.H. Model D2A1), three of which were fitted. They provided current at 115 volts, 3 phase, 400 cycles, for the submerged fuel pumps and flying control centralising motors. The starter and voltage regulator unit on these sets was generally the cause of failures (resistances were burnt out and carbon pile regulators proved unreliable). It was finally possible to set the regulators of the sets supplying the fuel pumps to give reasonable serviceability. In the case of those for the centralising motors, which ran continually under no load conditions, it was never possible to maintain them in a serviceable state for more than a few hours at a time.

5. POWER PLANT

Ten Proteus 2 (Series 600 and 610) free running propeller turbine engines were installed in six nacelles. A single engine was used in each outboard nacelle driving a four bladed reversible pitch propeller. Each centre and inboard nacelle housed a coupled unit of two engines driving eight-bladed contra-rotating propellers. A single engine installation is shown in Figure 4A and a coupled unit in Figure 4B. A full description of the installations is given in Section 4, Chapter 1 of Reference 4.

The engines used were either prototype or sub-standard units, therefore the main endeavour during the trials was to maintain them in a serviceable condition, rather than to attempt any quantitative testing. Initially, compressor stalling in flight was a frequent source of trouble. This was found to be due to salt deposits on the compressor blades, and was overcome by regular after-flight compressor and turbine washing with a mixture of fresh water and kerosene.

Cases occurred of fractured oil pipe lines, which caused engine bearing failures. The Bristol Aeroplane Company modified the rigid pipe lines by inserting sections of flexible tubing; after this, no further pipe line failures were encountered.

Spurious engine fire warnings occurred on three occasions in flight and also during maintenance periods. These resulted from failures of flame switches, apparently due to corrosion by the salt laden atmosphere, which also seriously attacked the screened electrical leads in the nacelles, decreasing the overall insulation resistance to a point below the acceptable minimum.

As discussed in Reference 1, the propeller thrust with engines at minimum r.p.m. for electrical generation was too high, minimum taxiing speed being approximately eight knots even with the single engines in reverse pitch. A superfine pitch setting for the contra propellers was therefore introduced (-5° setting), in addition to the flight fine pitch setting of +23°. This allowed more reasonable taxiing speeds but did not overcome the manoeuvring difficulty, e.g. picking up moorings (see Reference 1).

On five occasions, after flights at high all-up weight and in moderately rough seas, certain propeller blades were found to be slightly bent, presumably through rather heavy spray entering the propeller disc. In four cases the bending was in a forward direction and in one case rearwards. No effects were noticeable in the aircraft during any of these flights. Investigation showed that the blade section was, in fact, weaker than that used on flying boats in the past. A sample propeller with strengthened blades was supplied by De Havillands, and this was used for the final thirty take-offs. No blades were bent, but since all the latter tests were made in calm sea conditions, and there was no damage to any of the other propellers, there was no indication as to the merits of the new propeller.

Stress and vibration measurements were made by De Havillands, in one single engine propeller and one coupled unit contra rotating propeller. Reference 6 shows that the general level of stresses recorded was not high and full clearance was given for all-up weight up to 275,000 lb. (the weight at which tests were made). Shank and tip stresses were considered satisfactory for weights up to 330,000 lb. but some mid-blade strengthening was proposed for unlimited operation at this weight.

The total engine flying time was 968 hours and total running time 1,581 hours, during a programme of 48 flights which included 86 take-offs.

6. OIL SYSTEMS

Each coupled power unit had its own oil system and also a separate transmission oil system. A single unit installation had one common system for both engine and transmission. The layout of the oil systems for two coupled and one single engine is shown schematically in Figure 5 and a full description may be found in Section 4, Chapter 3 of Reference 4.

The four coupled engine transmission systems and the combined single engine systems were satisfactory. The oil systems for the coupled units were not satisfactory. Even under temperate summer conditions it was not possible to warm the oil up to a desirable operating temperature, or to maintain it at a figure above the minimum limit in flight. This over-cooking was mainly due to the low oil circulating rate through the engine, and was aggravated to some extent by air leaks around the cooler shutters. Temporary sealing was fitted to the shutters, and part of the cooler matrix blanked off; this enabled flying to continue, but was only a temporary arrangement.

7. FUEL SYSTEM

Fuel was carried in four integral tanks in the inner wing structure. The inner tanks supplied the two inboard power units, whilst the two outboard supplied the remainder. Tank capacities were as follows:-

Port and Starboard Inboard	3,480	gallon ³	each
" " " Outboard	3,770	"	"
" " Total Capacity	14,500	gallons.	

There were three fully immersed electrical pumps in each tank, two of which supplied fuel to the power unit; the third acted as a transfer pump. A diagram of the system is shown in Figure 6, and a full description is contained in Section 4, Chapter 2 of Reference 4.

It was not possible to devote time to specific tests on the installation, but it gave satisfactory service throughout the whole trials period. Measurements were made of fuel delivery pressures to the engine fuel pump. These showed that, under the worst conditions, with engines at take-off power, the submerged pumps in the fuel tanks were more than capable of maintaining a satisfactory rate of delivery. Tank venting proved satisfactory both in flight and during re-fuelling or de-fuelling. Although not systematically investigated, the fuel transfer arrangement appeared to provide an adequate supply for a coupled and single engine at take-off power.

The fuel flowmeters gave no trouble and were satisfactory, but the fuel contents gauges developed some electrical faults in the relay boxes, which were not fully overcome. There was also an unexplained difference in the calibration of the contents gauges and dip sticks. The dip sticks were apparently correct, but the gauges showed a consistent error which required correction.

8. FLYING CONTROLS

A diagrammatic arrangement of the powered flying controls is shown in Figure 7. From this it will be seen that control column and rudder bar movements were taken by cables, via a transmitter unit, to a pair of electrical/hydraulic power units for each of the three flying controls. The power units in turn operated the control surfaces by means of torque shafts and screw jacks. By splitting the surfaces into sections it was so arranged that one power unit of each pair operated half of the particular control surface. This ensured that a power unit failure would leave half of any control system operative. A means of centralising the surfaces, in the event of such a failure, was also provided by fitting separate actuators in the surface operating lever, aft of the main screw jack. A full description of the installation is given in Section 3, Chapter 4 of Reference 4.

The installation gave trouble free operation throughout the trials, with two exceptions, both associated with the emergency control surface centralising gear,

Firstly, the actuators of the centralising jacks were unsatisfactory, since on certain occasions in flight they tended to creep, i.e. the jack lead screw and motor slowly rotated under vibration, causing the jack to extend or retract. This resulted in the particular control surface section being moved out of alignment. Simple preventive measures were tried, but with only a very moderate degree of success. Some form of positive mechanical braking appears to be required.

Secondly, the motor generator sets which provided A.C. current for the centralising actuator motors were not satisfactory. These sets, Type B.T.H. D2A1, were running under stand-by conditions (no load) during all flights, current only being required from them in the event of a flying control power unit failure. The functioning of these generator sets is discussed in Paragraph 4.

Flight experience generally proved that the controls were pleasant to operate, column and rudder bar forces being satisfactory. In order to make the pilot's task less exacting under instrument flying conditions, however (i.e. to increase the amount of control column or rudder bar movement for a given control surface deflection), recommendations have been made regarding changes to the gear ratio between pilots' controls and control surfaces, also requiring a decrease in the rate of trim application.

8.1. Automatic pilot

The auto-pilot was only used on a very few occasions, but after preliminary 'setting up' by Smiths Instruments, the indications were that it was capable of giving satisfactory control in normal flight conditions, including turns on to new headings.

9. FLAP SYSTEM

Slotted type flaps in six sections were fitted, which extended over the inner sections of the wing. The flaps on each side of the aircraft were divided into three separate units, inner, intermediate and outer.

As can be seen from Figure 8, two electric motors driving through a differential gear box operated screw jacks, two on each unit. In the event of one motor failing, an automatic electrical brake came into operation, allowing the other motor to drive the system at half speed; flap movement at half speed was satisfactory.

/Incremental

Incremental control was provided for the pilot by an eight position switch, the fourth position (marked 'take-off') giving 15° extension. Flap position was shown on a 0-100% indicator, full flap being 45°.

A full description of the construction and operation of the system is given in Section 3, Chapter 17 of Reference 4. Short-rated motors were installed and these imposed a limitation on the number of operations permissible in a fired period of not more than two-and-a-half complete retraction and extension cycles without a subsequent cooling period of at least forty-five minutes; under these conditions flap operation was satisfactory. This limitation, whilst probably being quite acceptable for normal operation, was exceeded during test flying (measured take-offs and landings) with the result that two motors were burnt out. The installation of up-rated motors should be considered to give a higher operating frequency for specific testing or training programmes.

10. FLOAT SYSTEM

The floats retracted upwards and outwards to form the wing tips. Retraction and lowering was effected by separate hydraulic systems on each wing extremity. Each float could also be lowered by an emergency air system,

The hydraulic system consisted of an electrical power pack, driving motors which actuated control valves supplying high pressure oil to the hydraulic jack; oil was also fed to the float release locks.

The emergency air system could be used to lower the floats in the event of a hydraulic failure and when operated allowed air from a storage bottle to release the uplock and actuate the jack ram. The systems are shown schematically in Figure 9. A full description is given in Section 3, Chapter 5 of Reference 4.

Initially, trouble was experienced with the uplock micro-switches. The type fitted did not allow for sufficient over-swing of the float during retraction, and consequently were crushed. Modified switches and brackets were fitted, which proved completely satisfactory. During early flights, occasional rapid float retractions occurred, taking approximately half the normal time of from 10-12 seconds, and resulting in fractured hydraulic reservoir seals. This was overcome by fitting an additional variable flow and pressure relief valve in the return line from the jack to the rotary control valve.

After the above two modifications, the installation was free of trouble for the remainder of the trials. The emergency pneumatic extending system was operated on several occasions in flight, with satisfactory results.

11. RADIO, RADAR AND INTERCOMMUNICATION SYSTEMS

The full radio and radar requirements for the operational aircraft had not been finally determined before the trials and certain other systems were installed for flight trials use only. The equipment actually installed was as follows:-

- (a) Intercommunication and bow speaker system Ultra Type UA.17.
- (b) H.F. communication equipment S.T.R.18.
- (c) V.H.F. equipment S.T.R.12C, T.R.1934.
- (d) Communications receiver A.D. 94.

- (e) Automatic direction finding equipment A. D. 7092A.
- (f) Radio altimeter S. T. R. 30.
- (g) Search radar (cloud and collision warning equipment), type ARI. X245.
- (h) Rebecca Mk. IV. ARI. 5610.
- (i) Decca Navigator and Flight Log.

Items (c), (d), (f) and (h) were satisfactory and only required general maintenance.

The bow speaker installation was fitted to enable the pilot and bow-man to converse while on the water, without the latter having the encumbrance of microphone and headphones. The system picked up all bow compartment and local noises, which, even without the engines running, swamped all inter-communication reception. The remainder of the inter-communication system was satisfactory.

The S. T. R. 18, H. F. equipment and the search radar installation were only used on one or two occasions and no assessment was therefore possible.

The A. D. 7092A, A. D. F. equipment initially gave poor results, apparently due to the screening effect of the large hull and mainplane. This was overcome by using as a sense aerial the Decca Navigator anti-static aerial, in conjunction with a dual sense amplifier unit. Very satisfactory results were obtained with this latter arrangement.

The Decca Navigator, apart from some servicing troubles, was satisfactory. The Flight Log gave a number of troubles, most of which were finally cleared towards the end of the trials.

12. DE-ICING SYSTEMS

Provision was made for de-icing the tailplane end fin leading edge, the outer wing leading edge, the inner wing, the engine intakes, the pilot's windscreen and the propellers. Descriptions of all these systems are given in Section 3, Chapter 9 of Reference 4.

The engines used were not cleared for flight in icing conditions, and turbine bleed points for air intake de-icing were not provided. It was not possible therefore to operate any of the systems in actual icing conditions and, due to the priority of other tests, very little time could be devoted to de-icing system trials.

12.1 Tailplane and fin leading edge

The system provided is shown schematically in Figure 10. TWO 400,000 B. T. U./hr. combustion heaters (Lucas Type C/TD/400K. Mk. 2) were installed at the base of the fin leading edge. A ram air supply was ducted through these to a distributor box, from which further ducts led away to the three leading edges. The controls for the units were mounted at the second engineer's station.

Safeguards against overheating and fire were provided by an over-heat cut-out, operated by a temperature sensitive element. A ram pressure switch opened if the air speed fell below 110 knots. In the event of combustion ceasing, flooding of the heater was prevented by a combustion pressure switch, which was opened by the resultant loss of pressure. Fire warning lamps were mounted on the engineer's panel, and were operated by a flame cord surrounding each heater.

The system was not used during the limited flight trials, but preliminary air mass flow measurements in the main supply duct to the heaters were attempted. These, unfortunately, proved unreliable during analysis and changes were made in the instrumentation. Only one or two measurements were made after this, and these were mainly to check the method of measurement.

Following early flights, sea and rain water tended to collect at certain points in the ducts. This was caused by the water drainage pipes becoming blocked by corrosion, since fine spray entered the main intake during taxiing and take-off. After larger drainage points and improved piping had been fitted, no further troubles were experienced.

12.2. Outer wing leading edge

The system provided for the outer wing (see Figure 11) made use of the engine tail pipe cooling air supply. This air, after being heated by circulating around the tail pipe, could, by selection, be ducted to a de-icing distribution duct which ran the whole length of the outer wing leading edge. When operating the system the Flight Engineer was able to select a hot air supply from one or two tail pipes depending upon the requirements. A leading edge skin temperature indicator was provided at the control station.

On several occasions during flight the system was operated, and satisfactory duct air temperatures were obtained. Records were also made of the skin temperature rise, and those gave a good indication of satisfactory functioning. Instrumentation was provided to measure the hot air mass flow in the distribution duct, and the skin temperature distribution. It was not possible however to make those detailed tests.

No difficulties occurred with the system at any stage of the trials.

12.3. Inner wing leading edge

The engine intake lips and all the local surface were built with a hot air internal jacket for de-icing purposes. The air was obtained by tapping into the engine turbine casing around the third stage. Each engine supplied the Jacket surrounding its own intake. Air intakes supplying the air conditioning system, located in the centre section leading edge, were de-iced by air from the engine tail pipe in a similar manner to the outer wing leading edge.

As already mentioned the engines were only development units, and as such were restricted to flight in non-icing conditions, therefore turbine bleed points for the engine intake de-icing were not provided. Under these circumstances, although the full de-icing system had been provided in the airframe, it was not possible to make any tests or comments upon it.

12.4. Propeller de-icing

The normal De Havilland propeller de-icing system was fitted. This consisted of electrical heater elements in the leading edge of each blade, which were energised by an intermittent 120 volt supply. A cyclic timing switch fed electric current supply to the propellers in turn for periods of twenty four or one hundred seconds (as selected) at intervals of ninety-six or four hundred seconds. The order of current switching to the propellers was as follows:

- (a) Engines 3 and 4 rear discs.
- (b) Engines 2 and 5 rear discs.
- (c) Engines 1 and 6.
- (d) Engines 3 and 4 front discs.
- (e) Engines 2 and 5 front discs.

The operating controls were situated. at the second engineer's station

The installation was completed in the aircraft but no tests were attempted. No servicing difficulties occurred and very little maintenance was necessary.

12.5. Windscreen de-icing

12.5.1. Fluid de-icing

Provision was made for de-icing four of the pilots' windscreen panels by means of a spray of de-icing fluid to each panel. Figure 12 shows a layout of the system, and little additional description is necessary. The fluid (DTD. 389) was contained in a four gallon tank, while an electrically driven pump delivered it, via selector valves at the pilots' station, to a series of spray jets at the base of each panel. The rate of flow was set by the pilot, using a rheostat which controlled the pump motor speed.

The system was operated several times in flight, not normally to de-ice the windscreen but to study the distribution of fluid over the panels, since the final arrangement of the spray jets was subject to flight test results. Two changes were made in the jet layout and each gave improved distribution, but the full tests were not completed.

12.5.2. Sandwich and laminated screens

A dry air system of the sandwich type was incorporated on Panels Nos. 1, 2 and 4 in the pilots' windscreen. The drying medium, silica gel crystals, was stored in two "Triplex" containers mounted on the mid-sill below each pilot's sill light. Provision was also made for de-misting the windscreen by hot air, derived from the cabin pressurisation system, blown down and across the panels.

On high altitude flights, both pressurised and unpressurised internal frosting occurred on all laminated screens, including the clear vision windows. The field of vision remaining through the sandwich windows was inadequate for safe navigation.

The dry-air sandwich windows remained free from internal frosting on all flights, but on those at 30,000 ft. (pressurised) spot and streak condensation occurred inside the sandwiches.

13. PRESSURISATION AND AIR CONDITIONING

A full description of the installation may be found in Section 3, Chapter 8 of Reference 4. However, the two engine-driven B.A.C. air conditioning units were never completed, and part of the aircraft installation was not finalised. To allow a first appreciation of the aircraft under pressurised conditions in flight, a pair of B.A.C. units to sub-installation standard one were installed late in the trials period. This installation consisted of a blower unit complete with hot air temperature control, but did not include the refrigeration or humidity control sections of the full plant.

Only three flights were made with this hull pressurising system operating, and these were mainly devoted to performance measurements at 30,000 ft., the highest altitude attained. A maximum differential pressure of 4.25 p. s. i. was used as ground testing had not been completed for the full differential of 8 p. s. i. No quantitative tests were made on the installation, since the system was not representative of the final one; also the flight crew were familiarising themselves with the control of the system. Apart from some troubles with the discharge valve control gear, which were not fully explained, the functioning of the system appeared quite promising.

14. BILGING SYSTEMS

Bilging arrangements were provided for the hull and wing tip floats. An electrically driven pump was connected to a main gallery in the hull, and any one of the fifteen watertight compartments could be selected to the pump, by specially provided selector valves. A diagram of the hull system is given in Figure 13. A twin filter unit at the pump allowed a change over to clear a blocked filter without having to stop the pump.

The floats were divided into five watertight compartments, each of which could be drained either by a drain plug, or by fitting a hand pump to each of the five bilging connections in turn.

A full description of the bilging installations is given in Section 3, Chapter 15 of Reference 4.

The float systems were satisfactory and presented no difficulties, other than on occasions which demanded working on the floats in a choppy sea.

The hull installation was satisfactory providing it was regularly serviced. Otherwise it suffered from corrosion at several points, due to salt water. This is discussed in subsequent paragraphs dealing with the servicing and maintenance aspects.

15. BOW MOORING COMPARTMENT

The bow compartment, forward of the pressurised section of the hull, housed the various facilities for marine handling, picking up and slipping moorings, releasing the anchor, etc. Access was from the lower deck via a pressure-tight hatch. A bow door was provided, which proved rather too small to allow the bow-man to work efficiently, and immediately below this the mooring attachment was fitted. The main items of marine equipment were:-

- (a) a hand-operated (ratchet lever) winch, complete with warping drum and bellard,
- (b) an emergency anchor (Danforth type, weighing 100 lb.), complete with handling tackle,
- (c) two drogues complete with lines and fittings,
- (d) a boathook and line (Grabbit type).

Only two small modifications were made in the compartment during the flight trials. Firstly the fairlead radius was slightly changed to prevent chafing of the warping line. Secondly, the hand-operated winch was replaced by an electrically powered model.

16. LAUNCHING, BEACHING AND TOWING

16.1. Launching

The method described in Reference 4 proved satisfactory, twenty-five launchings being made. The technique described was straightforward and readily practised. Launchings were made with up to a 15 knot cross wind, but only in very moderate sea conditions.

The removal of the beaching chassis presented no difficulties, and the marine crew quickly became experienced in the recommended procedure.

A list of the main items of ground handling/servicing equipment is given in Table I.

16.2. Beaching

The facilities provided at the Company's slipway at Coves, described in Section 2, Chapter 1 of Reference 4, enabled the aircraft to be beached without difficulty, under wind and sea conditions similar to those for launching.

The beaching chassis was easily handled and fitted in calm water, but the operation naturally became more hazardous when adverse sea conditions were encountered.

16.3. Towing (water)

An R.A.F. 65 ft. pinnace (see Table I) was used to tow the aircraft. Initially, handling in restricted waters or coming up to moorings proved a very difficult operation in other than no wind, slack water conditions. A more successful method was devised, which consisted of making fast a stand-by launch and the servicing launch, one to either side of the aircraft aft of the main step. The coxswain of the towing launch then instructed the assisting craft to run their motors ahead or astern as required. This method of towing proved satisfactory in moderate sea and wind conditions, but should be considered only as a temporary expedient. The whole question of docking and marine handling facilities for large flying boats requires investigation.

16.4. Picking up and slipping moorings

The difficulties of low speed taxiing and manoeuvring are discussed in Reference 1 together with the associated problem of engine control in reverse pitch or near zero thrust conditions. This lack of manoeuvrability on the water, with only the two outboard engines having reverse pitch propellers, was a serious handicap when attempting to pick up moorings. In most cases it was more convenient to use a launch to pass a line to the aircraft and then to tow to moorings. Two drogues were provided to assist at low water speeds, but in practice they either proved ineffective, or were carried away. Tank tests on a re-designed drogue were made with a view to preventing the porpoising which occurred with the type being used. The new design appeared satisfactory, but full scale tests were not made.

Slipping moorings, both bow and stern, presented no difficulties. Both quick release attachments functioned satisfactorily; the conditions at release are discussed in Reference 1.

17. SERVICING AND MAINTENANCE

17.1. General

A full description of the servicing arrangements for the aircraft is given in Reference 4, which lists the main items of ground servicing equipment

/used

used are listed in Table I. For the initial flight trials, 'period' checks were laid down as follows:-

- (a) Pre-flight check.
 - (b) After-flight check.
- | | | | | |
|---------|-------|-----|--------|--------|
| Check 1 | valid | for | 36 | hours. |
| Check 2 | after | 5 | flying | hours. |
| Check 3 | " | 25 | " | " |
| Check 4 | " | 50 | " | " |
| Check 5 | " | 100 | " | " |
| Check 6 | " | 250 | " | " |
| Check 7 | " | 500 | " | " |

Detailed inspection schedules were prepared for each of these periodic checks, while as the trials proceeded checks were modified as appropriate. When flying ended at approximately 100 hours, the check periods were as follows:-

- (a) Pre-flight.
 - (b) After-flight.
- | | | | | | | | |
|---------|-------|-----|--------|--------|----|---|-------|
| Check 1 | after | 10 | flying | hours | or | 7 | days. |
| Check 1 | after | 25 | flying | hours. | | | |
| Check 2 | " | 50 | " | " | | | |
| Check 3 | " | 100 | " | " | | | |

This maintenance system proved quite successful; naturally it was necessary from time to time to modify the checking schedules, but in general the system was comprehensive and easily practised. It was originally intended that the period check schedule should be incorporated into Section 2 of the overall Servicing Manual (Reference 4). This has not yet been done, however, since with less than 100 hours flying experience to substantiate the schedules they are considered as preliminary issues only.

The aircraft was designed on the assumption that all servicing, minor and major, must be possible while riding at moorings, in sheltered water. It was considered that for engine changing, etc., the aircraft would normally be beached, but in the event of beaching facilities not being available, it would be necessary to provide handling equipment to cover all types of work at moorings. During the flight trials all general inspection and maintenance work was completed whilst afloat, but as beaching and launching was a comparatively straightforward operation, all major work such as propeller or engine changing was done on the slipway.

Details of the equipment manufactured for engine changing, air conditioning blower removal, etc., are given in Section 2 of Reference 4. No comments on the suitability of these are possible, since, as already stated, many were not used during the trials.

17.2. Installations

Maintenance of most of the main installations presented no particular problems and therefore no discussion on them is included in this report. In some cases, however, minor difficulties were encountered, such as inaccessibility or frequent failures of a component. These points are recorded in the following paragraphs:-

(a) Electrical generating system

(i) Circuit breakers

On all these items the 28 volt control connections were inaccessible when the component was being removed or replaced.

/ (ii) Converter

(ii) Converter units (B.T.H. D2A1)

The control boxes for these units have presented **servicing** problems. Clearance **between** components **in** the control boxes **and** between the **side** plates **and** **cover** was **insufficient**, and the **setting** up of the regulator was very difficult.

(b) Power plant

For various reasons it was necessary to remove the **propeller** and engines on a number of **occasions**. Removal **and** replacement of **an** engine was not difficult, **and** only required a small number of **man** hours, but dressing the replacement unit, with the equipment from the one being removed (i.e. cowling sections, **C.S.U's**, pipe lines, etc.) was quite a lengthy **procedure**, taking in fact more time **than** engine removal.

Propeller constant speeding **characteristics** were not very satisfactory, **and** changes of Constant Speed Units and **actuators** were frequently necessary. **Setting** up the **C.S.U's** involved a considerable amount of **ground engine** running.

As mentioned in Section 5, the **flame switches** for the **fire-warning** system were not satisfactory, false alarms resulting from failures of flame switches, apparently due to corrosion by the salt-laden atmosphere, **which** also seriously attacked the screening of the electrical leads in the nacelles, decreasing the overall Insulation resistance to a **point below** the acceptable **minimum**. **Again**, although the **indicator** valves fitted to the methyl bromide bottles in the fire **extinguishing** system enabled a discharged bottle to be readily identified, access to the bottles was very difficult.

(0) Engine oil system

Several cases of **leaking** oil **tanks** occurred; the reason for this appears to have been the **lack** of **anodic** treatment on the **inside** of the tanks, **this** allowing corrosion to **take** place. **Initially** a considerable number of coolers had to be replaced due to leaks, but after modifications to the matrix no **further** troubles occurred. Access to the lower coolers on both **inboard** engines was difficult.

(a) Fuel system

Mal-functioning of the **relay** units in the fuel content **indicating** system frequently **caused** pointer **oscillation** at the indicator, **and** consequently constant servicing of these **units** was necessary.

Fuel **tank** vent pipes tended to corrode and improved. protective treatment appears **necessary**. Certain fuel pipe line connections were inaccessible. **These** were, **however**, not ones **which** **required** attention during normal **servicing**, but should **replacement** of some pipe line sections become necessary, it might be a **difficult** operation

(e) Powered flying controls

For setting up the **cables** and general **installation**, a different datum was **used** from that at which the **centralising** of surface **elements** was checked. It would be preferable if both these operations were based on a **common datum**.

The mounting bracket of the transmitter unit for the rudder showed signs of flexing when high **rudder** loads were **applied**.

/It

It was difficult to replenish the reduction gear boxes of the power units with the correct amount of oil. The 'oil level plug' was unsatisfactory for use with the aircraft riding at mooring.

The pressurised universal joints in the after bulkhead gave some trouble due to loss of lubricating grease when being flown under pressurised conditions.

Access to the oil refuelling cap on the outer elevator operating jacks was difficult. The jack had to be in the closed position for filling, i.e. elevator fully up. In this condition the filler cap was hidden by various structural members.

(f) Bilging systems

The hull bilging system operated satisfactorily, but this was only achieved by extensive servicing and maintenance, and the maintenance time on the system was excessive. The items which required attention were as follows:

(i) Bilge pump

The troubles encountered on the main bilge pump were the result of corrosion in the units due to the dissimilar metals in the pump, which was aggravated by the effects of salt water. Fresh water was pumped through the unit, but this did not overcome the electrolytic action of the dissimilar metals.

(ii) Bilging selector valves

The rubber sealing rings in the disc valves had to be changed on several occasions. These rings were generally damaged whilst sliding past the main gallery unions. The rings expanded into the gallery as the valve was being opened or closed, and were cut away by the continual action of the valve. This process was aggravated by the effects of salt water on the seats, which perished the rubber. A leak in one valve could render the system unserviceable.

(iii) Rubber piping connections

The hose piping used for connections at various points in the system was affected by sea water and replacement was necessary on several occasions.

18. RECOMMENDATIONS

18.1. Airframe

The lateral shudder which occurred from time to time when flying in turbulent air was disconcerting to passengers. Although these low frequency vibrations were only encountered very occasionally, it is considered that an attempt should be made to reduce them or make them less apparent.

18.2. Power plant

Since the engines used were development units, no comments are made concerning their functioning. The minimum r.p.m. for taxiing (dictated by the electrical generators) gave too much thrust and needs modification; engine/propeller control for taxiing also needs improvement, particularly in the case of the engines with reverse pitch propellers.

A stiffer section propeller blade is necessary to meet the stressing requirements and to prevent damage by spray, for operation at weights in excess of 275,000 lb.

After flight, engine washing has proved essential; washing facilities should be built into the engine.

The standard "Graviner" flame switches are affected by moisture, and the associated electrical equipment has suffered from corrosion. An improved type of flame switch and screening cables are required.

An unproved method of adjusting the Constant Speed Unit actuators is necessary. The present actuators must be partially stripped before adjustment can be made.

18.3. Oil system

The oil system needs modification to prevent over-cooling of the coupled units.

18.4. Flying controls

Creep in the centralising jacks must be prevented, and a more satisfactory A.C. convertor unit should be provided for supplying electrical current to these jacks.

Improvements should be made to the gear ratios between the pilot's flying controls and the control surfaces to make instrument flying easier, now that flying experience has been obtained on the system.

18.5. Bilging system

Improvements should be made to prevent the corrosion which occurred of several components, and hence reduce the amount of maintenance necessary on the installation.

18.6. Towing, mooring, etc.

Towing the aircraft, or manoeuvring it while coming up to moorings, was difficult even in relatively calm weather. In adverse sea and wind conditions, great skill was required in handling the launches. It is suggested that any future test programme should include an investigation into improved methods of marine handling for large flying boats,

19. ACKNOWLEDGEMENTS

Acknowledgements are made to Messrs Saunders-Roe, Ltd., for preparing this report and in particular to their Flight Test Department who compiled it.

LIST OF REFERENCES

<u>No.</u>	Title
1	Saunders-Roe Princess Flying Boat G-ALUN. Air and water handling tests. C.P. 257. January-1 955.
2	Saunders-Roe Princess Flying Boat G-ALUN. Air and Water Performance Tests. C.P. 279. February, 1955.
3	Saunders-Roe Princess Flying Boat G-ALUN. Weight and Centre of Gravity Determination. M.A.E.E. Report No. F/188. S.R. Report No. FT/15/O/24, Part 4.
4	Princess Flying Boat Servicing Manual.
5	Princess Flying Boat G-AL-UN. Inspection Report on Condition of Aircraft Structure prior to Laying Up. S.R. 45/INSP/501.
6	Tests on 4 + 4/6/6+7 $\frac{1}{2}$ and 4/6/4. Propellers at 16'6" dia. on the Princess Flying Boat Powered by Bristol Proteus Engines. De H. VR838.

, /TABLE I

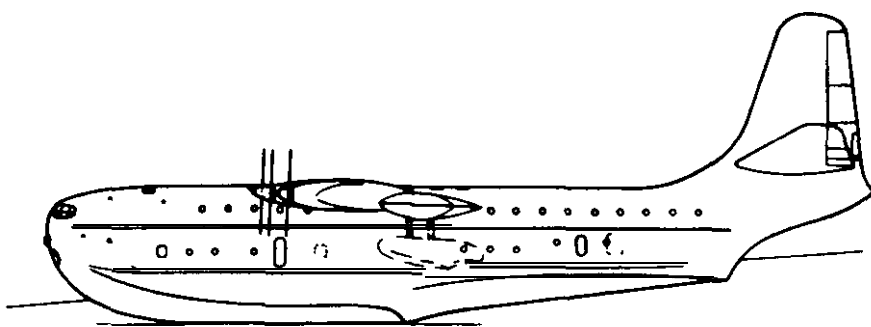
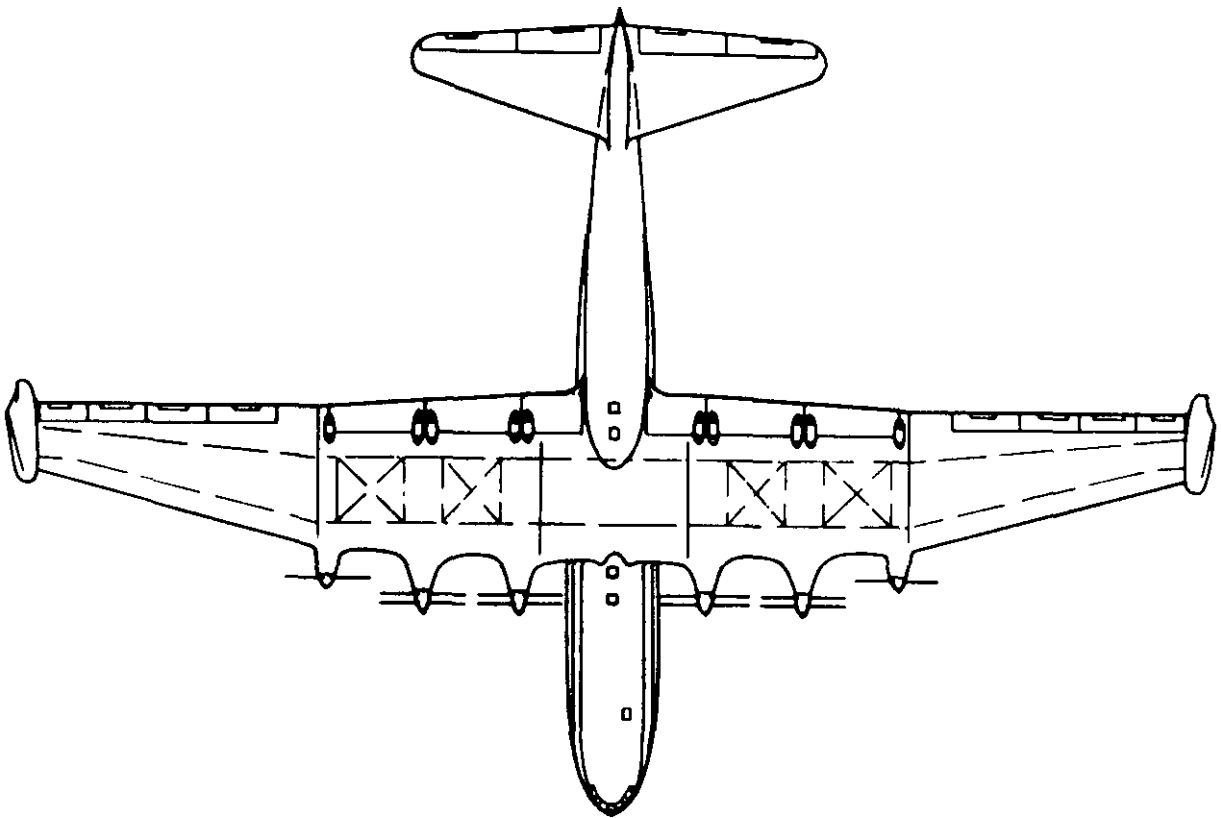
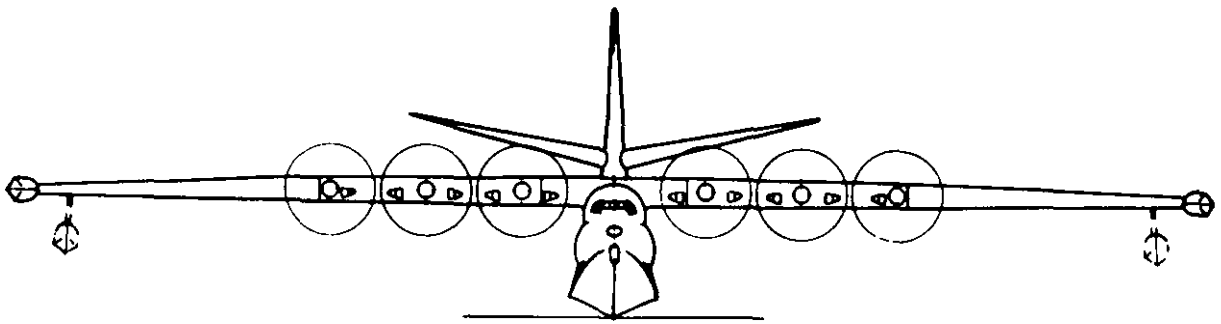
TABLE I

GROUND SERVICING EQUIPMENT

MAIN ITEMS USED DURING FLIGHT TRIALS

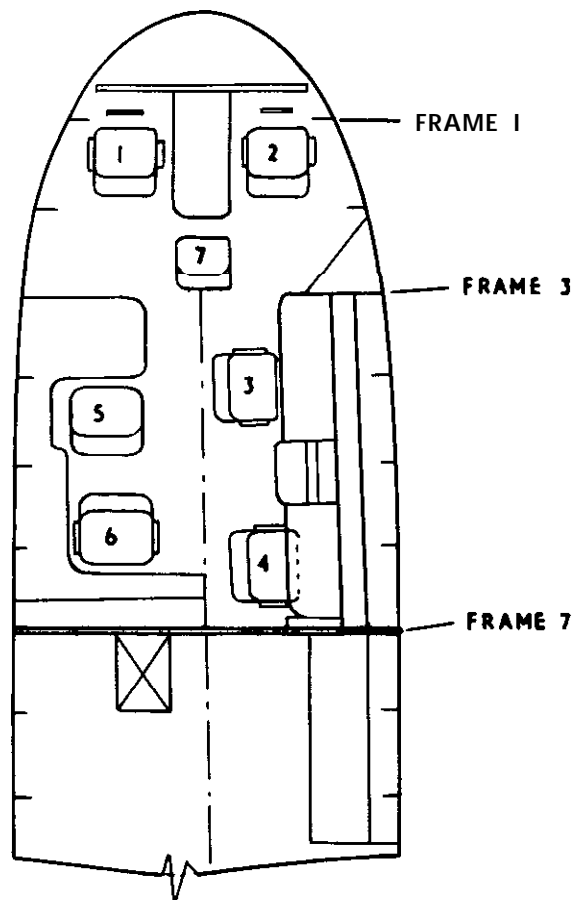
Item	Purpose	Brief Description
R. A. F. 60 ft. Pinnacle	Towing aircraft. and fire fighting.	Powered by three 'Perkins' diesel engines (Type S.6.M) 100 H.P. each. Standard R.A.P. fire fighting equipment was installed.
Refuelling Launch	-	R. A. F. Mk. II 50 ft. launch. Powered by two 'Perkins' diesel engines (Type S. 6.M) 100 H.P. each.
40 ft.. B.O.A. C. Aircraft Tender	Servicing aircraft at moorings.	Modified to take a 'Murex' generating plant, with Rolls Royce 90 H.P. engine, Type B.80. Mk. 22A driving a generator unit, Type GPU. This consisted of two generators, supplying 120 volts, 220 amps and 28 volt 100 amp. Powered by two 'Perkins' diesel engines (Type S.6.M) 100 H.P. each
Launch.	Servicing, towing beaching chassis, crew transport, etc.	Ex naval launch 35 ft. long, powered by two 'Meadows' 80 H.P. engines.
Scow	Servicing, carrying beaching chassis side bracings, etc.	Manufactured by Saunders-Roe, 30 ft. long, powered by one 'Ailsa Craig' 15 H.P. diesel engine, Type R. F. I.
Pontoon	Servicing aircraft at moorings.	Six pontoons of Saunders-Roe manufacture, connected together to form a servicing platform 24 ft. x 12 ft.
Ground Generator (Mobile)	Servicing aircraft on slipway.	Manufactured by Saunders-Roe. Two 'Perkins' 100 H.P. diesels (Type S. 6.M), each engine driving two B.T.H. generators, Type LG4228/1, with 120 volt 37KW output, and Type LG2411/3 with 28 volt 6KW output.
Winch	Beaching and launching.	Powered by a 'Crompton Parkinson' 415 volt, 3 phase, 50 cycles, 35 H.P. motor with two speed reduction gearing, 70 ton towing cable.
Cranes (Mobile)	Fitting and removing engines, propellers, etc.	Manufactured by Saunders-Roe. Maximum hook height of 36 ft. 2 in. two speed hand winching. Max. load 4 tons stationary, 3 tons with crane mobile.

FIG 1



SCALE Inch = 33feet

PRINCESS GENERAL ARRANGEMENT



- 1 CAPTAIN
- 2 FIRST OFFICER
- 3 FIRST ENGINEER
- 4 SECOND ENGINEER
- 5 NAVIGATOR
- 6 RADIO OPERATOR
- 7 SUPERNUMARY CREW MEMBER

DIAGRAM OF FLIGHT DECK

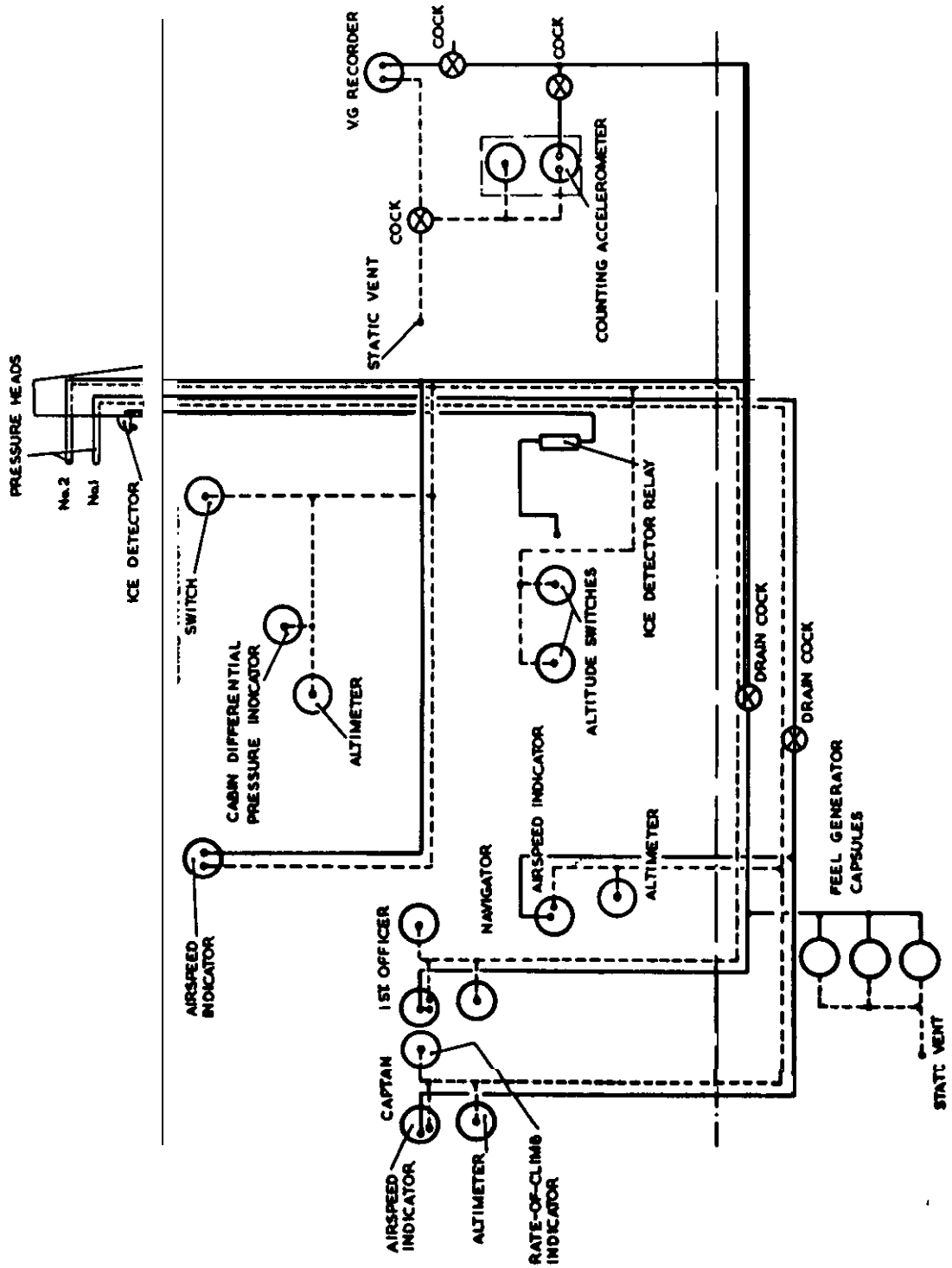


DIAGRAM OF PITOT STATIC SYSTEM

SINGLE POWER UNIT COWLING ARRANGEMENT

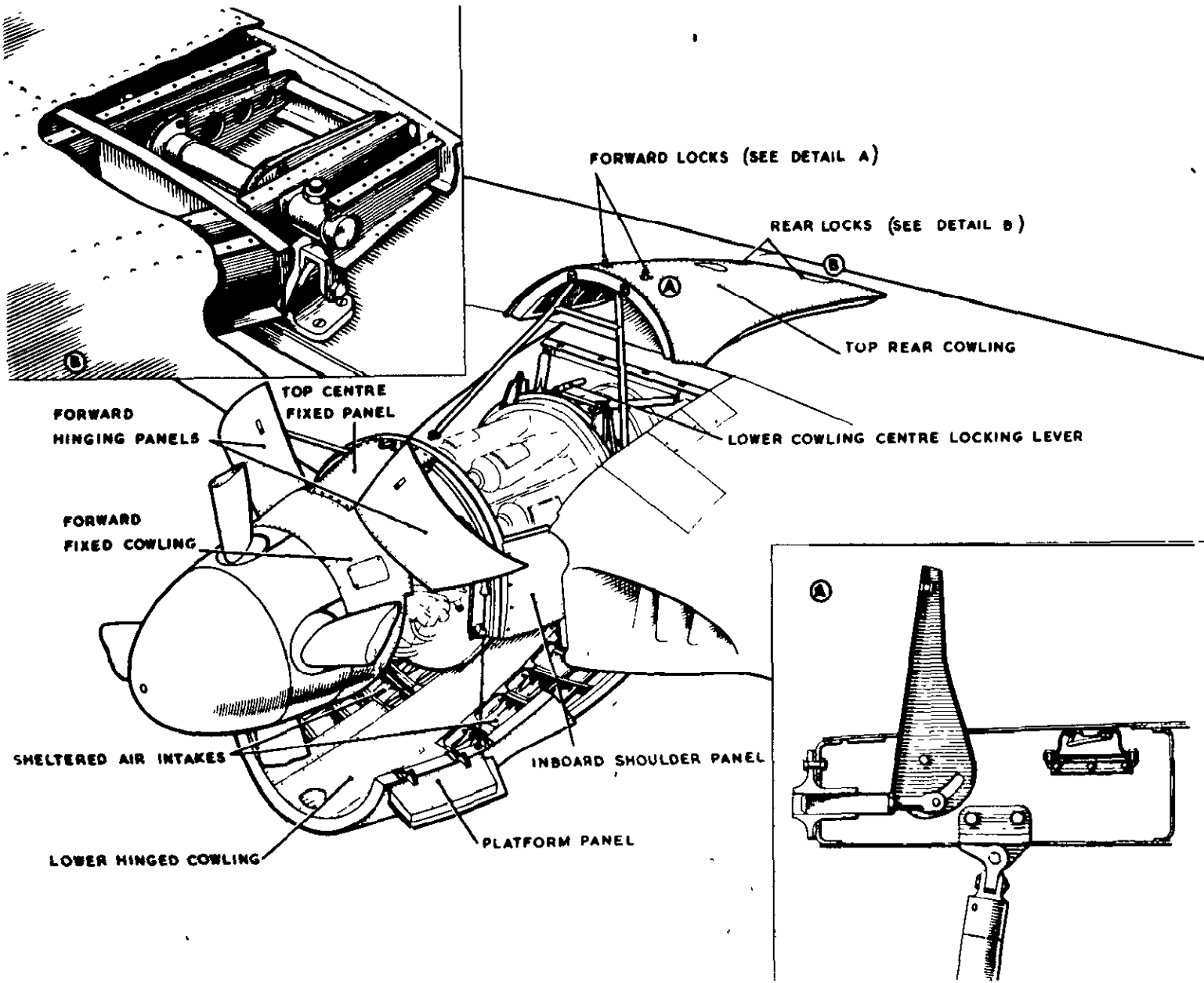
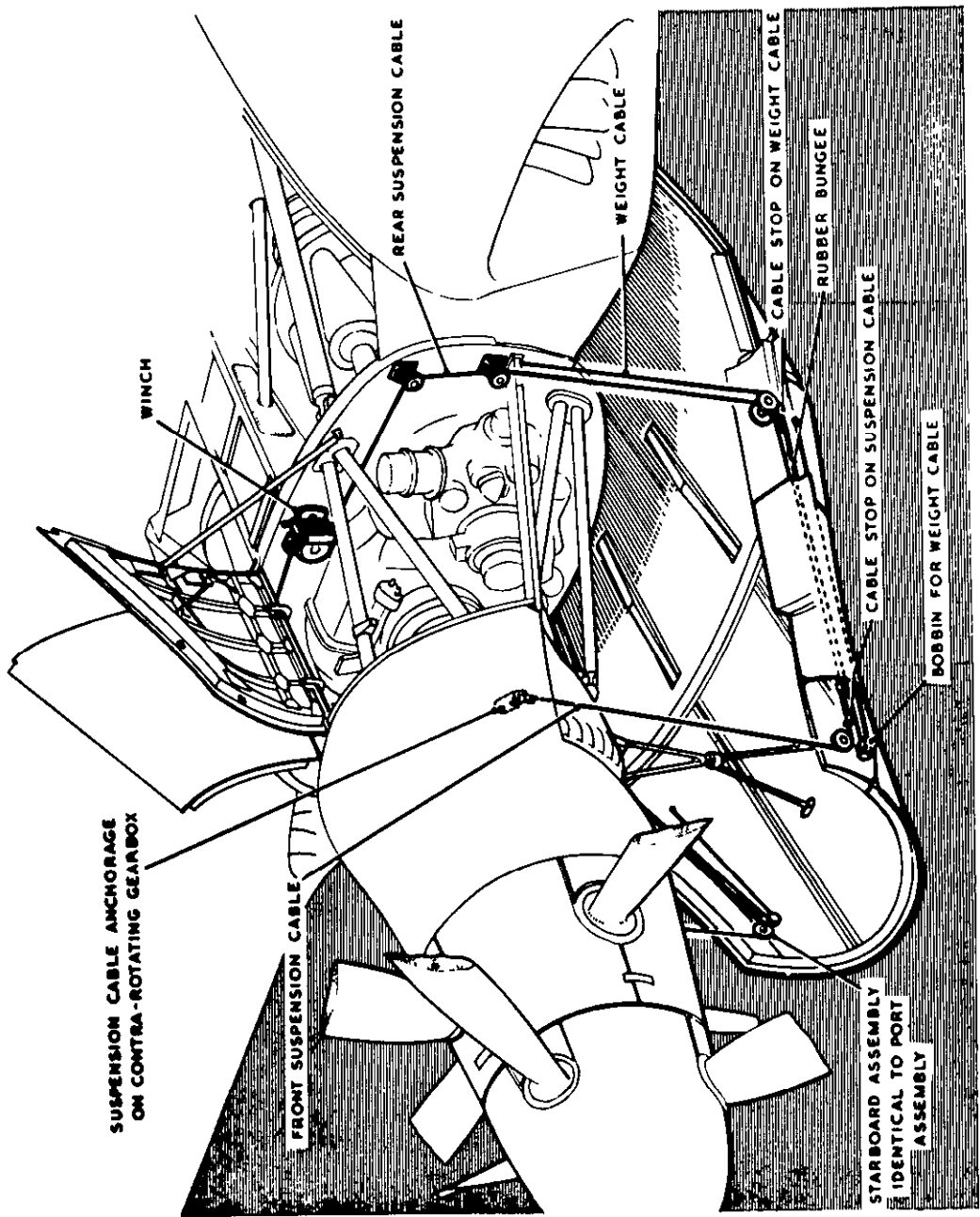


FIG. 4A

FIG. 4B



COUPLED POWER UNIT COWLING ARRANGEMENT

DIAGRAM OF OIL SYSTEM

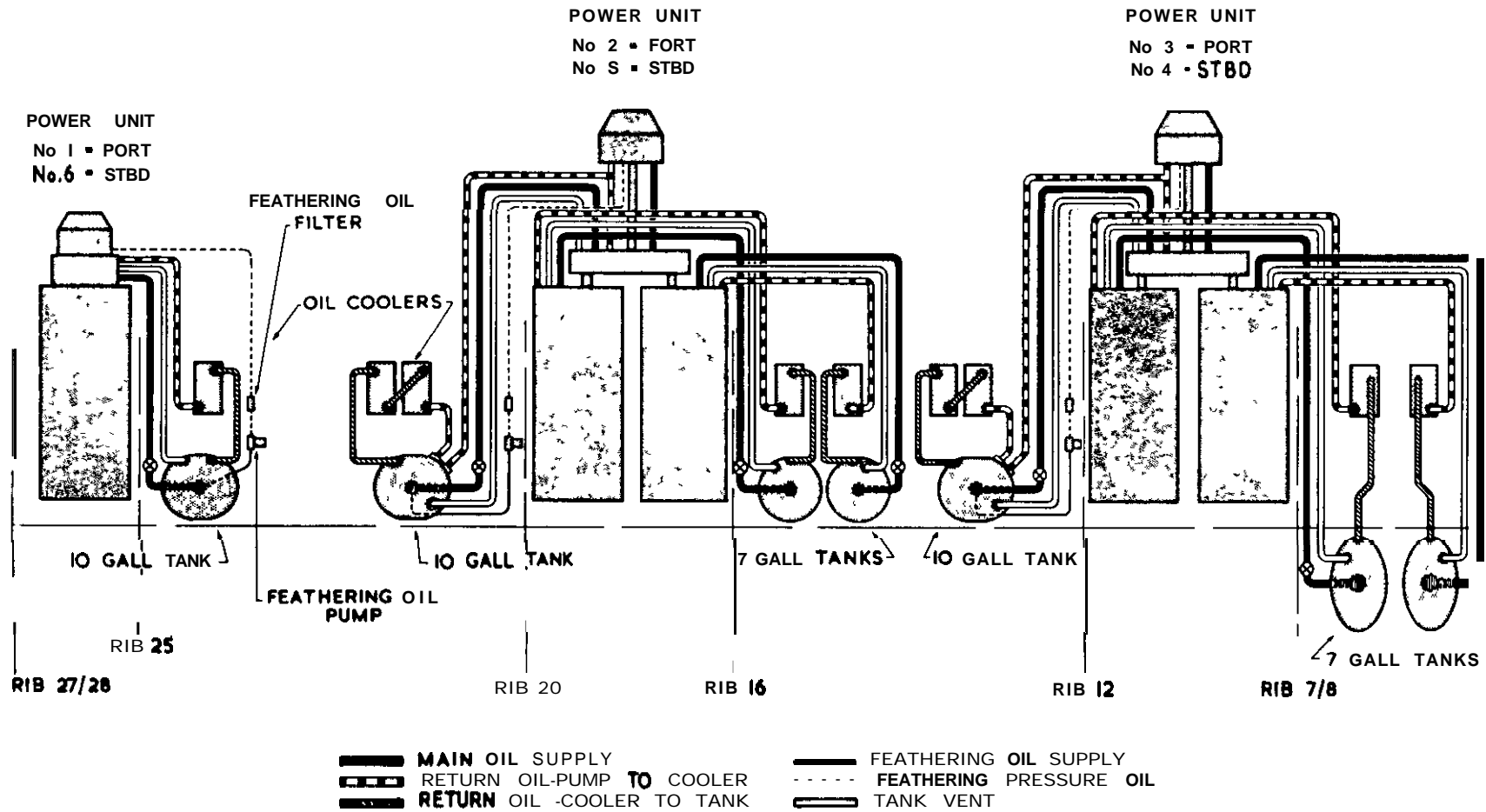
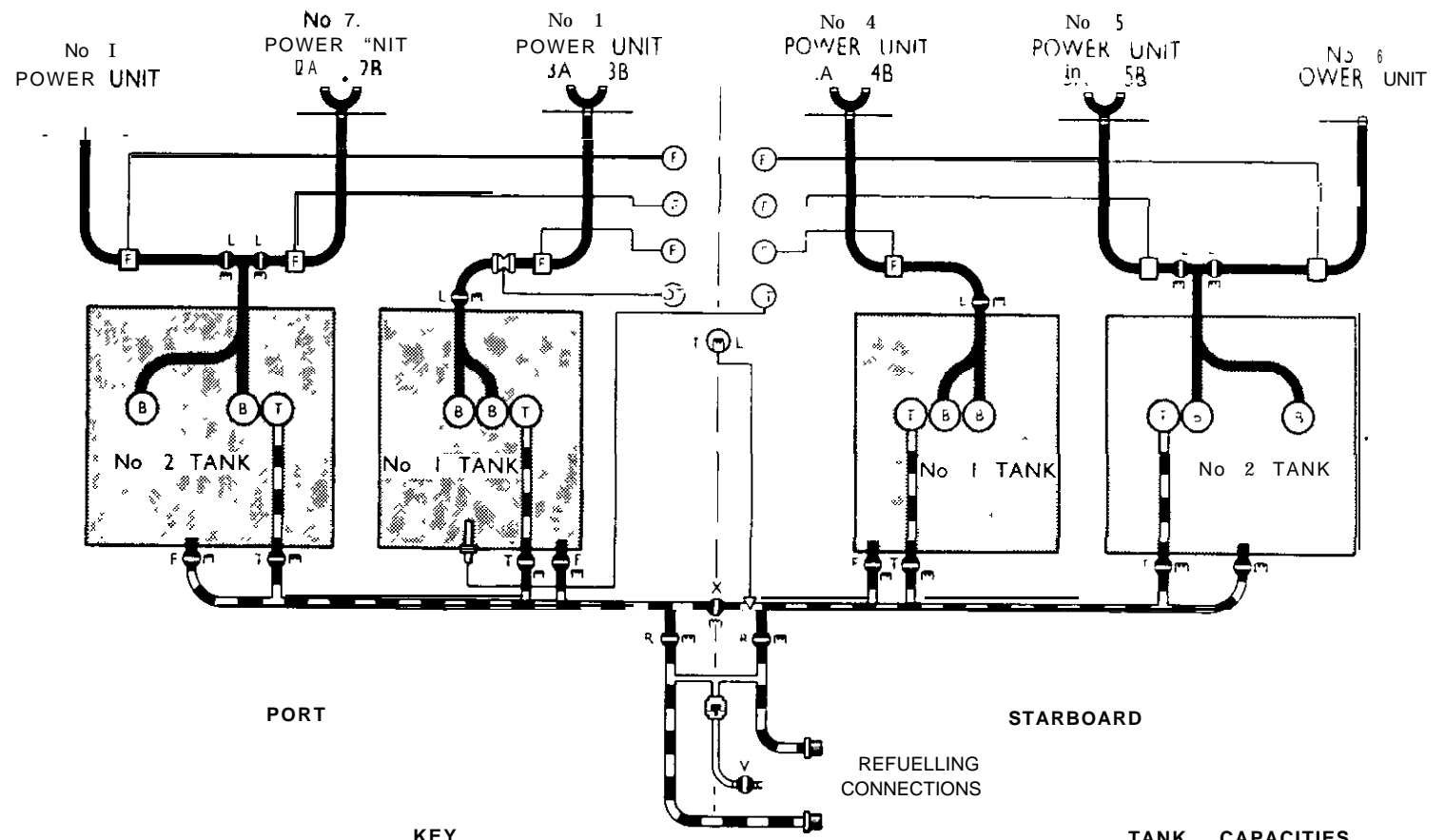


FIG. 5

FUEL SYSTEM DIAGRAM



- KEY**
- MAIN FEED
 - TRANSFER AND REFUELLING
 - REFUELLING VENT
 - BOOSTER PUMP
 - TRANSFER PUMP
 - FLOWMETER TRANSMITTER
 - FUEL FLOW INDICATOR
 - LP COCK
 - TANK FUELLING COCK
 - TRANSFER COCK
 - REFUELLING COCK
 - CROSS-CONNECTION COCK
 - REFUELLING VENT COCK
 - NON-RETURN VALVE
 - REFUELLING VENT LINE
 - @TRANSFER PUMPS TEST LAMP
 - DELIVERY FUEL TEMP GAUGE
No 3 POWER UNIT SUPPLY ONLY
 - TANK FUEL TEMP GAUGE
No 1 TANK PORT ONLY

TANK CAPACITIES

PORT AND STBD No 1, 3480 GALL EACH
(15820 LITRES)

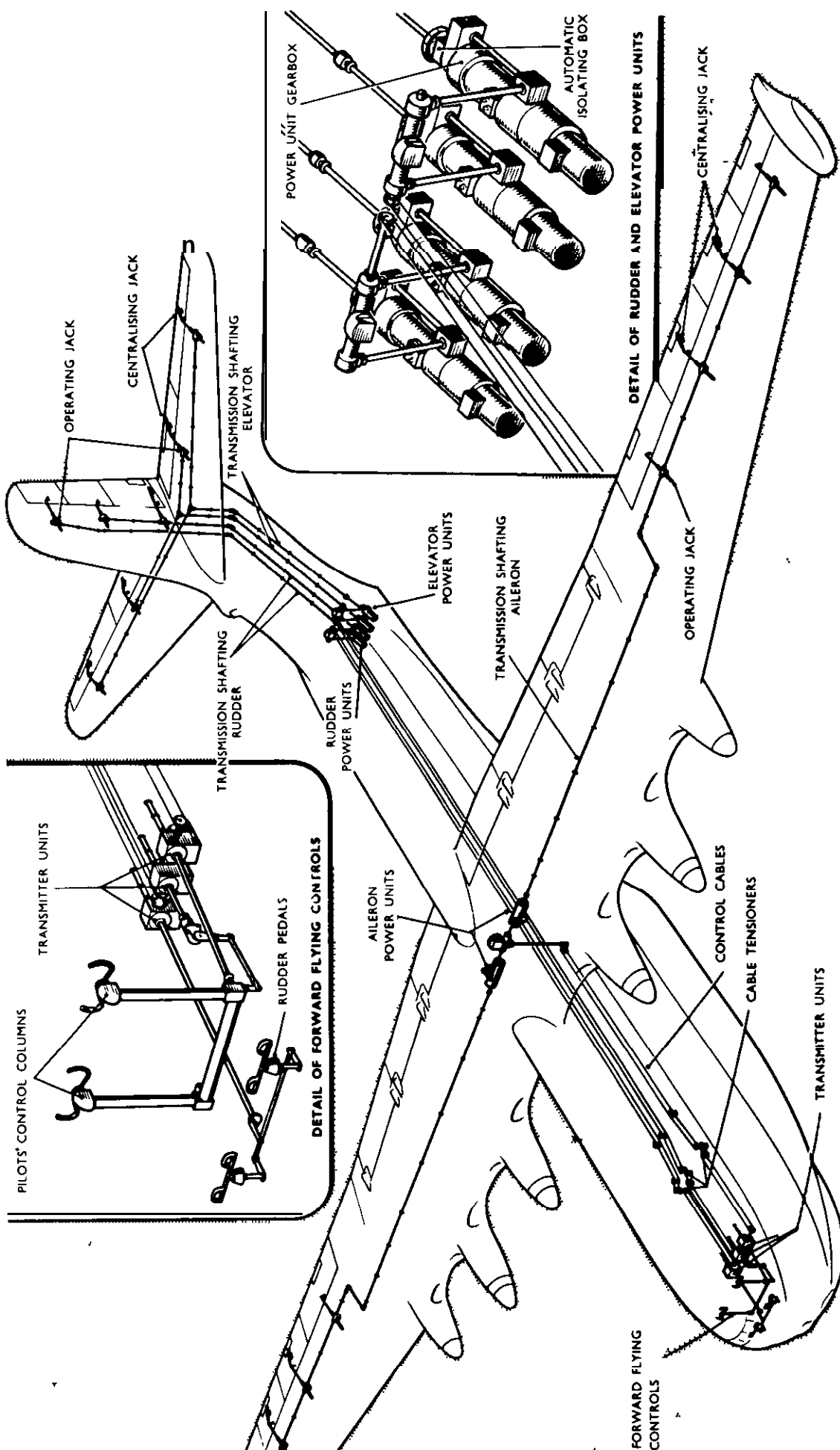
No 2 3,770 GALL EACH
(17138 LITRES)

EACH SIDE 7750 GALL
(32958 LITRES)

TOTAL CAPACITY 14,500 GALL
(65914 LITRES)

ALL TANK PUMPS INCORPORATE A
NON-RETURN VALVE AND SUCTION
BY-PASS

FIG. 6



DIAGRAMMATIC LAYOUT
OF POWERED FLYING CONTROLS

GENERAL ARRANGEMENT
OF FLAP CONTROL SYSTEM

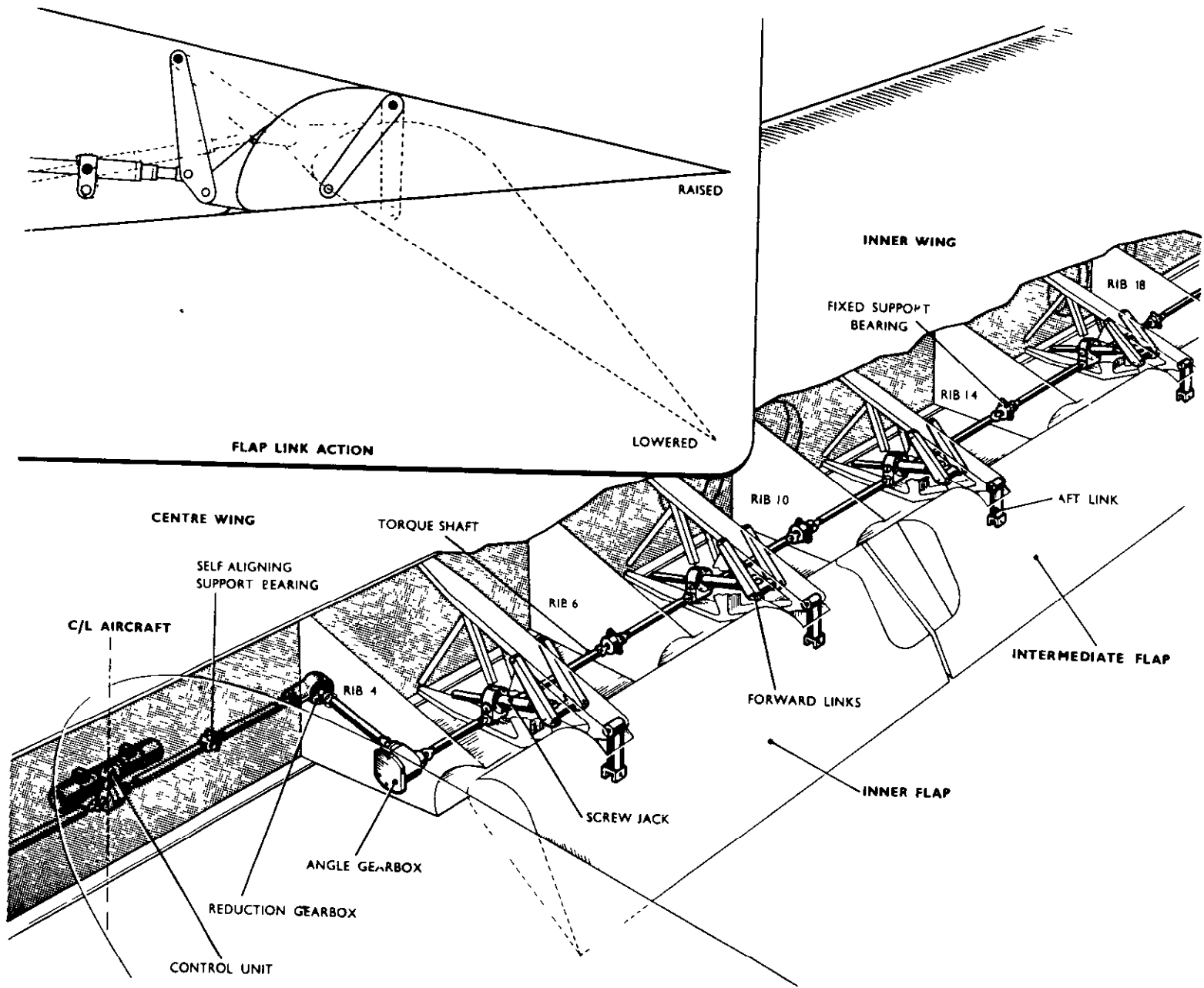
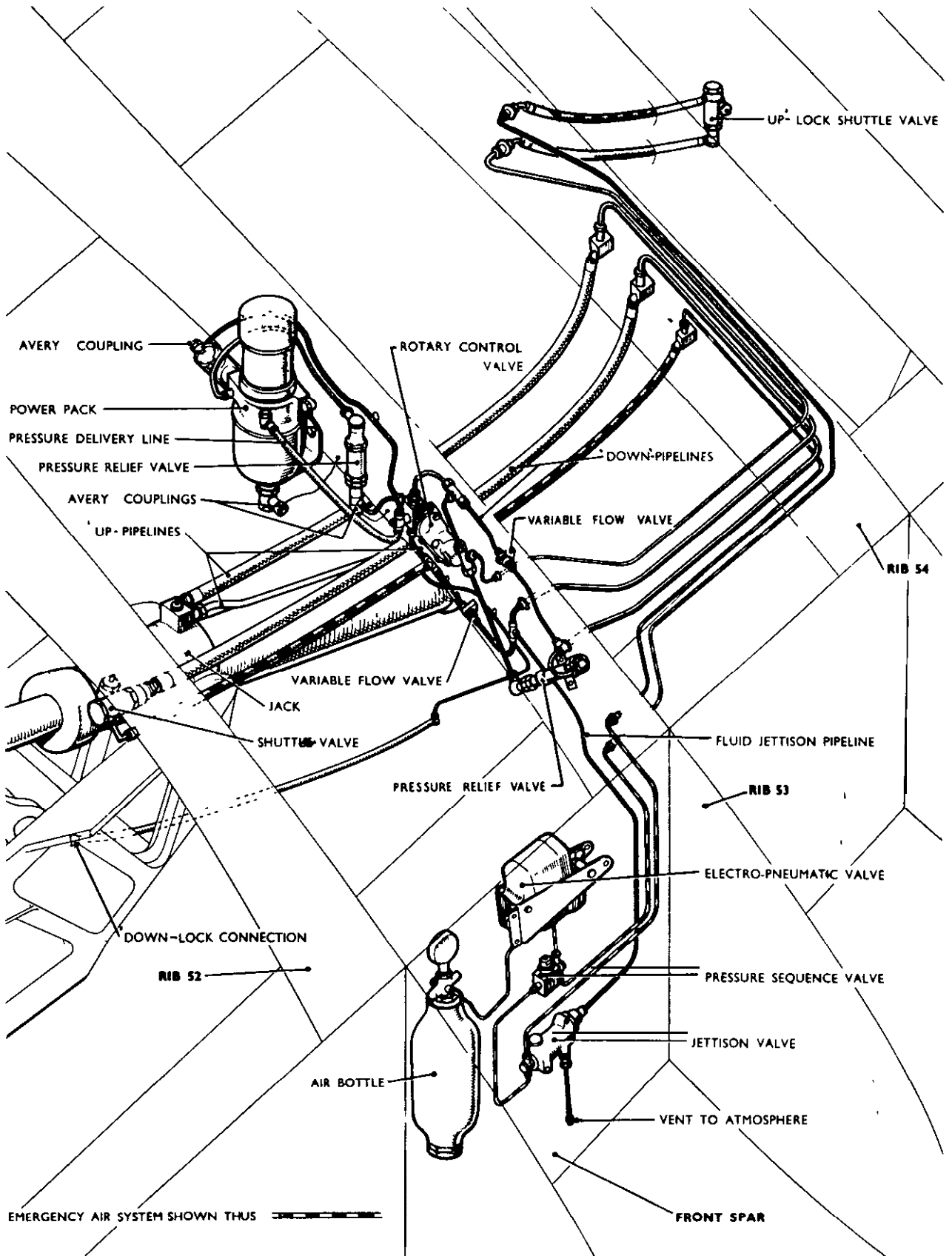
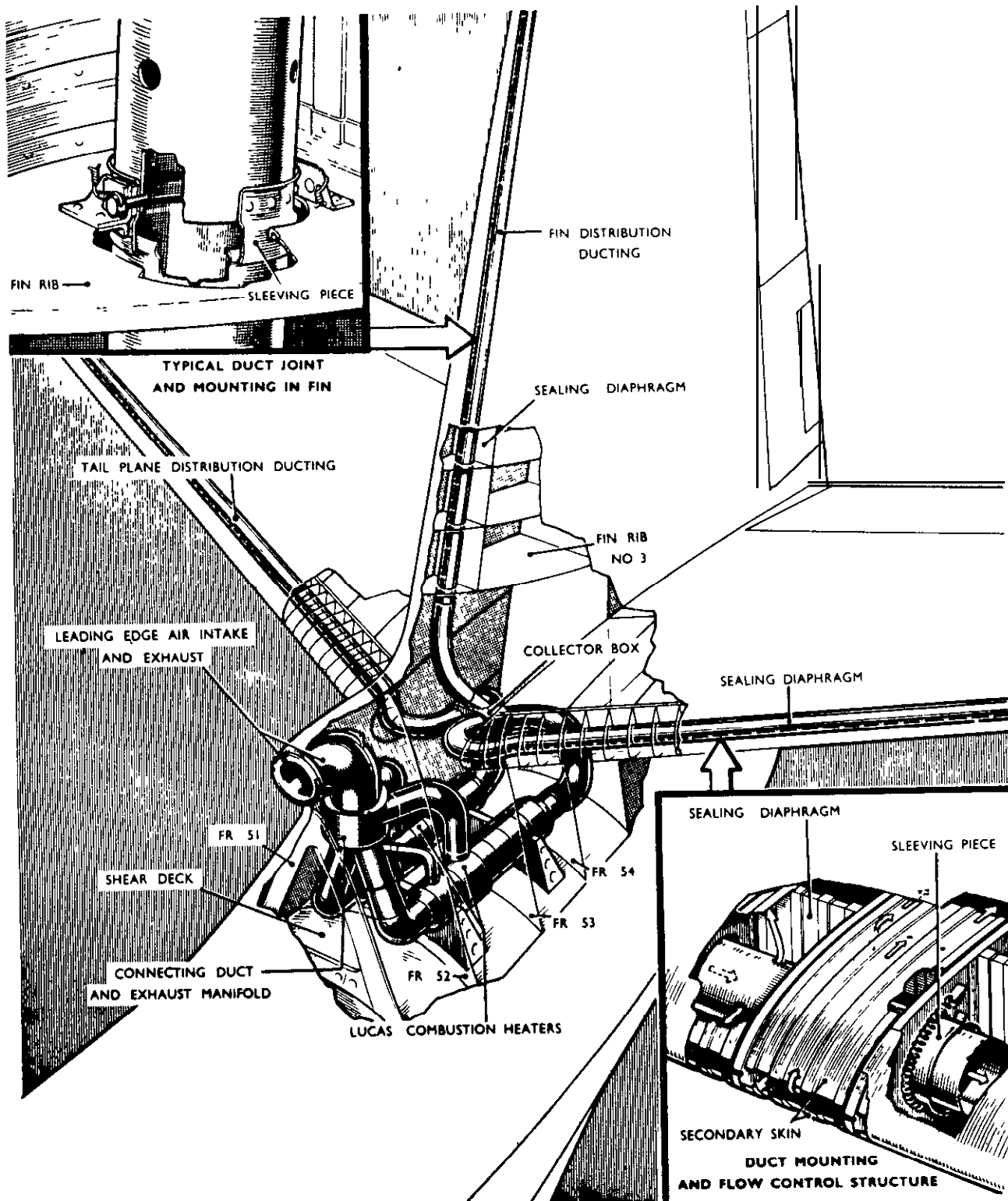


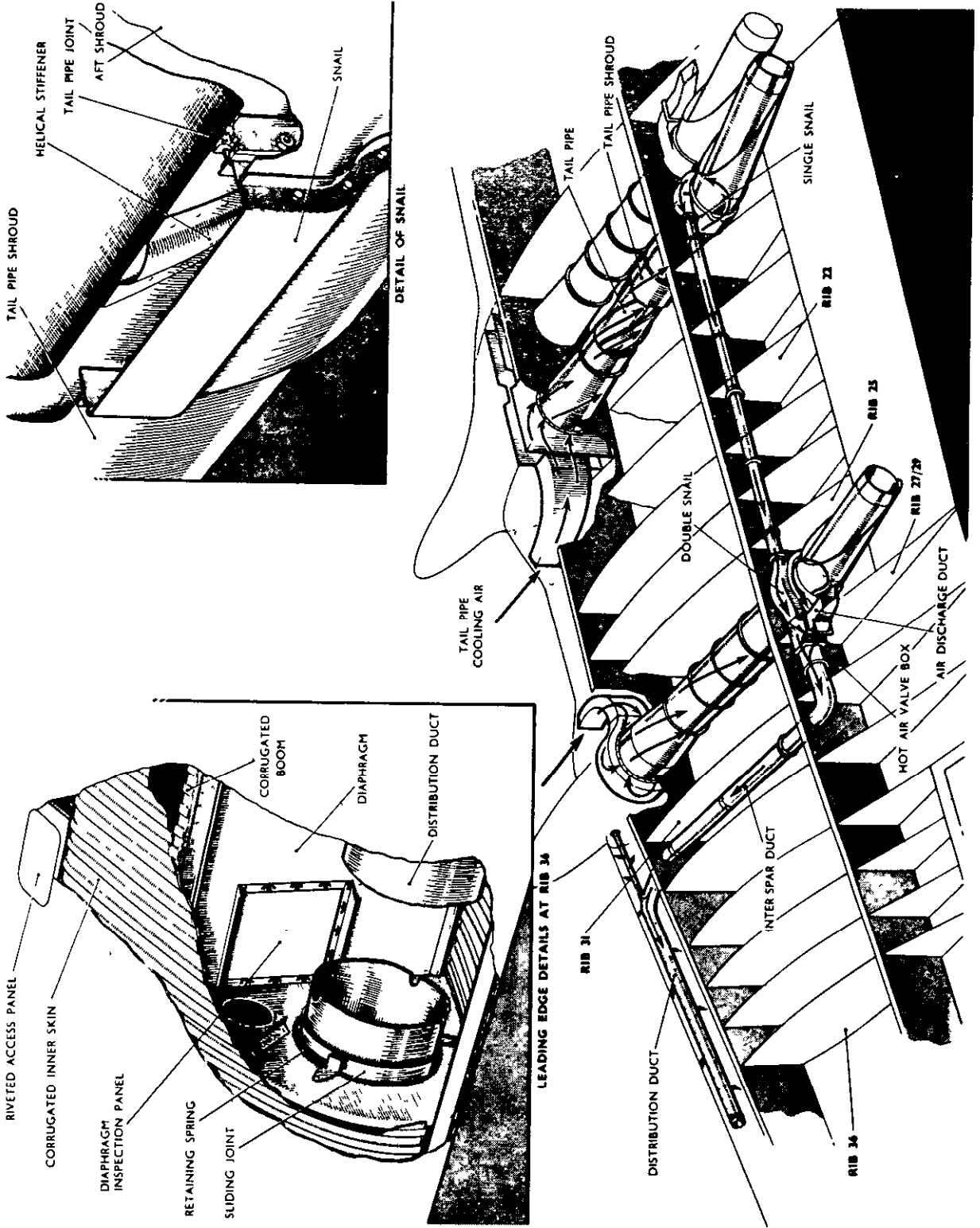
FIG. 8



FLOAT HYDRAULIC AND EMERGENCY AIR SYSTEMS-PORT SIDE

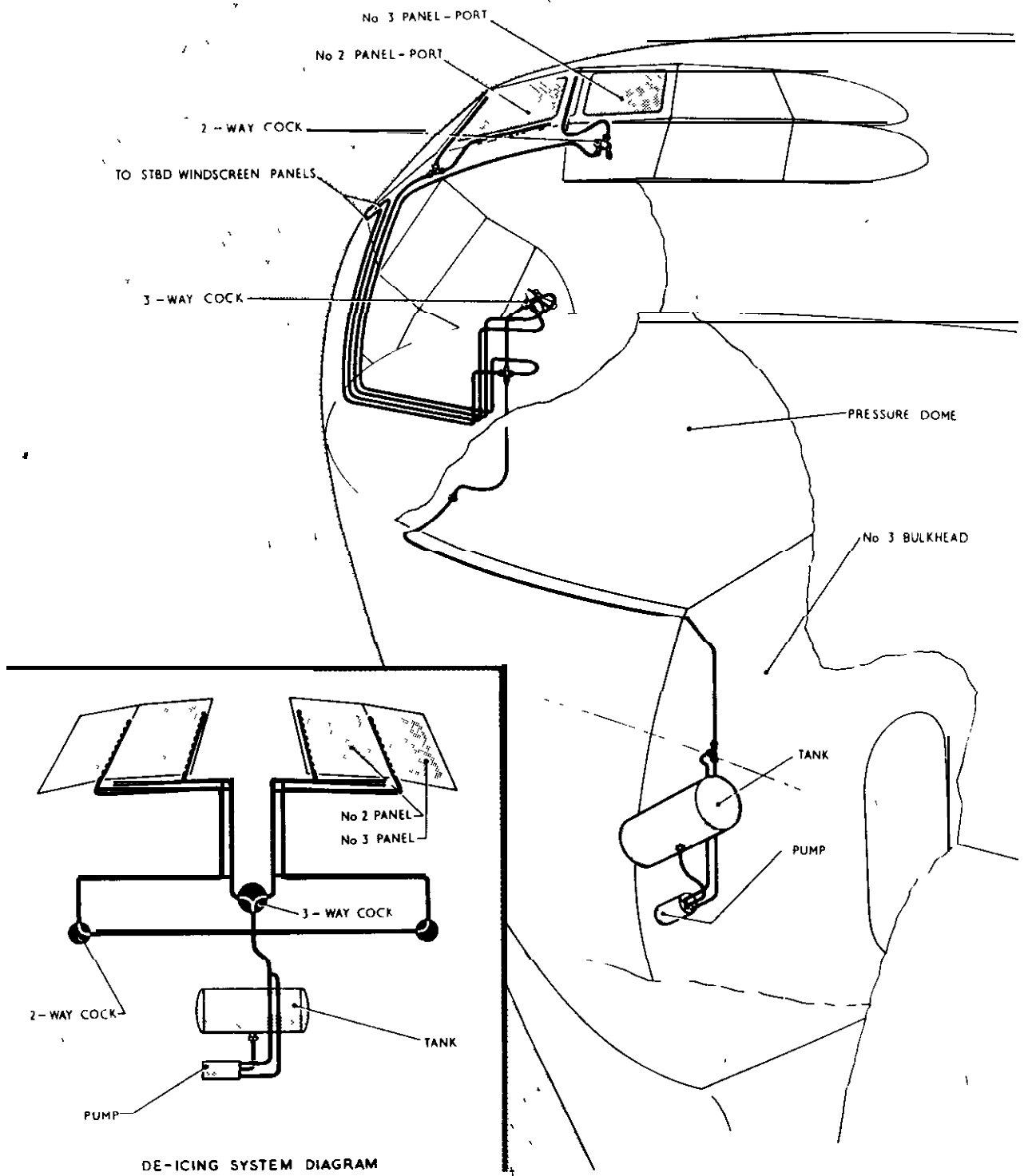


**TAILPLANE AND FIN
ARRANGEMENT OF DE-ICING DUCTING**



OUTER WING DE- ICING SYSTEM LAYOUT

FIG. 12



LAYOUT OF WINDSCREEN DE-ICING SYSTEM

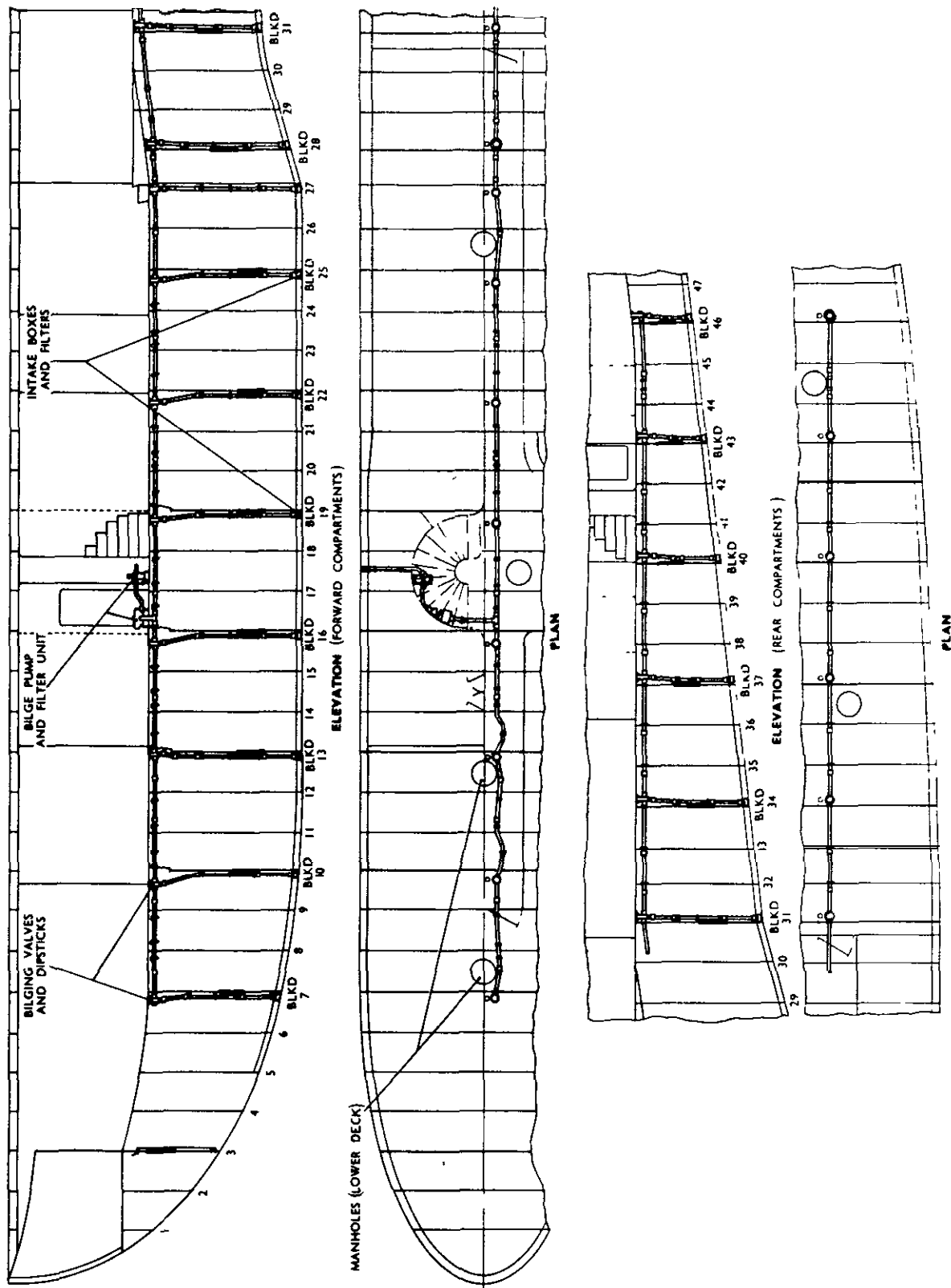


DIAGRAM OF BILGING SYSTEM

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