# LAVIGUEUR HEATING SYSTEM FOR AIRCRAFT EQUIPPED WITH RECIPROCATING ENGINES

## DOUGLAS DC-3 Aircraft L.H.S. installation

### DESCRIPTION

The primary heating system units are installed on the R.H. side, between stations 156.5 and 177.5.

Stainless steel sheets have been installed along with fiberglass on the R.H. interior side of the fuselage between stas. 156.5 and 177.5, and on the bulkhead at sta. 177.5. The bulkhead has been re-inforced with .025 T.-24 St that section chanel to increase its rigidity to properly support the heater and accessories. Flooring in the heater area has been changed from plywood to stainless steel.

For flight operation, ventilation air is supplied by a ram air scoop situated between no. 5 to 6 longerons in the heater compartment. Ventilation air is available at the rate of 1294 C.F.M. to be heated by the heater and distributed through the system.

Combustion air is supplied by a ram air scoop situated between No. 4 and 5 longerons. Combustion air is directed from the scoop to a squirrel type blower (operated only on the ground) and thence to the combustion air inlet at the heater through a 3 ins. I.D. stainless steel tube. Exhaust from heater is carried overboard on the R.H. side of the fuselage between Nos. 12 and 13 longerons with a 3½ ins. I.D. stainless steel pipe through a stainless steel doubler and asbestos gasket attached to the fuselage skin well over the fuel tanks level to minimize fire hasard.

Fresh air for mixing warm air in cabin is available from the combustion inlet scoop and is directed to the hot air distribution duct underneath the flooring. The fresh air stream is controllable by the operation of a butterfly valve situated on the forward bulkhead of station 177.5.

Individual hot air outlets are incorporated to heat the cockpit, supply the windshield defrosters, heat the passenger cabin and lavatory compartment, and provide a hot air stream to the engines for additional de-icing while in flight and for engine pre-heating while on the ground.

(continued)

Ground operation of the heating system is made possible with the use of electrical power supplied by the auxiliary power unit mounted in the tail section and operating a ventilation blower at the rate of 740 C.F.M., a combustion blower, ignitor unit, fuel control assembly and fuel supply assembly.

1. The Janitrol heater unti is installed in an up right position in the heater compartment.

   a) The heating unit is 23 ins. in length over all and is securely mounted in position by mean of support and clamp bands at the top and bottom.

   b) The heater assembly is made of inconel welded gas tight. Combustion takes place inside a cylindrical combustion chamber. The combustion chamber itself is approximately 20 ins. in length and is surrounded by a full length doublewalled radiator. The inner wall of the radiator return passages is corrugated to further strengthen the unit and increase heat transfer efficiency.

   c) Fitted over the inlet end of the combustion chamber is a removeable spray-type head. This head contains a spray nozzle stamped 5.0 (meaning 5 gallons per hour) which breaks down the liquid fuel into a fine mist or spray for rapid mixture with the combustion air to form a combustible mixture.

   d) Also installed in the spray-type head is a one piece spark plug for igniting the fuel air mixture. A 3/16" - 1/32" gap is factory set and adjustment should not be attempted except during overhaul of the heater. The installation is designed such that spark plugs may be replaced between overhaul without gap readjustment. Care should be taken to avoid bending the spark plug electrode out of its concentric position.

   e) Surrounding the combustion chamber, attached radiator assembly and spray head, is a stainless steel jacket clamped into position.

   f) A 3/8" dia. heater drain line is connected to the bottom of the heater combustion chamber by means of ¼" pipe plug boss and is attached to the heater jacket by means of a stainless steel clip and a 3/8" flared tube bulkhead fitting.

2. The ignition unit is a compact high voltage vibrator ignition system consisting of a coil, vibrator resistor, condenser, radio noise filter, a single pole double throw switch and shielded lead assembly. When the heater is in operation the ignition is continuous, thus insuring positive combution. The heater is cycled by the cycling fuel solenoid valve which turns the fuel to the heater on and off.

   a) The unit is mounted on the aft wall of the heater compartment, operates from the airplane or auxiliary power unit 24 Volt power supply, and delivers up to 20,000 volts to the spark plug, thus assuring positive firing at all operational altitudes.

X b) The vibrator has an alternate set of contacts which can be used in the event of failure of the first set. The vibrator should be operated with the switch in the "in" position until failure of the first set of contacts. By pulling the switch to "out" position the auxiliary contacts can be used.

   c) In the event that the ignition system is checked by holding the cigarette end of the ignition lead near ground to produce a spark care should be taken to insure that the are gap does not exceed ¼". The fuel solenoid cannon plug at the fuel control assembly should be disconnected during this test.

The fuel control assembly located on the rear heater compartment wall consists of a fuel filter, airloaded fuel pressure regulator, a fuel cycling solenoid valve and a fuel pressure switch contained in an explosion proof air tight two-piece metal contained vented to atmosphere.

   a) The fuel filter removed any impurities that might get into the system.

   b) The air-loaded fuel pressure regulator is designed to vary the rate of fuel flow into the heater in response to changes in combustion air differential pressure. Control is accomplished by the action of a large diaphram in the top housing. Combustion air inlet pressure is applied to the top diaphram and heater exhaust pressure is applied to the bottom of the diaphram. The ~~net~~ loading is the combustion air pressure differential. Movement of the large diaphram is transmitted to the small disphram in the regulator which in turn regulates the fuel flow.

c) Thus the air loaded fuel regulator serves three separate functions.

1) It acts as a pressure reducer. Taking fuel from the airplane's system or the electrical fuel pump at 17 P.S.I. and reducing it to a lower pressure suitable for heater operation.

2) It serves as a fuel pressure stabilizer. A constant outlet pressure is maintained to the heater at any given loading, regardless of fluctuations in fuel pressure on the inlet side of the regulator.

3) It varies the rate of fuel flow in the heater in response to changes in combustion air pressure differential.

d) Fuel pressure switch functions.

1) When the fuel pressure for the heater operation cannot be supplied by the R.H. engine driven fuel pump, the fuel pressure switch de-energizes the fuel shut-off solenoid valve in the fuel supply box assembly and energizes the electric fuel pump also installed in fuel supply box assembly, to supply the heater through the fuel control assembly.

2) When the fuel pressure is supplied by the R.H. engine driven fuel pump, the fuel pressure switch de-energizes the electrical fuel pump and energizes the fuel shut-off solenoid valve to conduct fuel to the fuel control assembly.

3) When the heater is operated on the ground the fuel pressure is automatically obtained from the electric fuel pump in the fuel supply box assembly. When in flight the R.H. engine fuel pump pressure is used and if the R.H. engine has to be shut down and feathered the electric fuel pump is immediately started as soon as the engine fuel pressure registered in the fuel pressure switch drops below 14 P.S.I.

4) The two ram air switches mounted on the aft bulkhead of the heater compartment, have pressure lines connected, below the ventilation ram air and blower air duct mainly to cut off electrical supply to the fuel solenoid valve in the case of lack of air flow in the heater.

a) No. 1 ram air switch has the following functions; when the heater is switched "ON" during flight at speeds in excess of 100 MPH, the ignition is turned on, the ram air pressure conducted to the No. 1 ram air switch energizes the actuator which closes the vent blower duct and opens the ram air duct, subsequently the fuel solenoid valve opens due to air pressure now applied in No. 2 ram air switch and fuel flows in the heater supplied from fuel pressure obtained from the R.H. engine driven pump, in response to the combustion air pressure differential governed by the fuel control assembly.

b) When the flying speed decreases below 98M.P.H. (or when on the ground), the No. 1 ram air switch de-energizes the fuel solenoid valve and energizes the actuator which closes the ram air duct and opens the blower air duct.

When the butterfly control arm reaches the microswitch mounted on the side of the duct, a 15 amp. relay is energized, setting in motion the combustion blower. Five seconds after the combustion blower is in operation the ventilation blower starts, after its 35 amp. relay is energized. (The ventilation blower relay coil being connected in series after the combustion blower relay coil). As the ventilation blower operates air pressure is conducted to No. 2 ram air switch which in turn re-energizes the fuel solenoid, valve and operates the heater. The operation is reversed when the heater is operated on the ground. When the heater is shut-off in flight or on the ground, the butterfly valves are automatically returned to blower operation and off.

The heater operation control box is installed on the left hand side of the cockpit and contains, on the R.H. side of the box, one heater "ON" "OFF" switch, an amber warning light at the upper most position to indicate that the heater is working in flight position in the center is a red warning to indicate that the heater is over-heating (over 350°F), and below is a green warning light indication that the heater is working in "ground position. The L.H. side of the box contains one, three positions switch for Auxiliary Power Unit operation and an amber "Running" warning light.

In the case where is no electrical power supplied by the aircraft engine driven generators (when aircraft resting on the ground) or in the case of aircraft electrical power failure and/or to prevent complete drainageof the aircraft batteries, the Auxiliary Power Unit is put in operate the heater system and/or other electrical accessories

5. The two heater cycling thermo switches mounted in the hot air distribution duct, one for the cabin heating and the other one for engine preheating, control the heater output by alternately energizing and de-energizing the cycling fuel solenoid, thus controlling the fuel flow to the heater the switches are set at 200°F, and are adjustable between 100°F. and 300°F.

6. The heater overheat limit switch is also mounted in the hot air duct at 12 inches below the bottom of the heater, it acts as a safety switch and controls the heater electrical circuit such that in the event the heater output exceeds the pre-set switch operating temperature of 350°F., the heater electrical circuit is de-energized and the heater overheat red warning light is energized on the control box in the cockpit.

7. The leak proof vented fuel supply box mounted on the rear bulkhead of the heater compartment contains a flame proof electric fuel pump and pressure relief valve, a fuel filter, a fuel shut-off solenoid valve and an emergency manual fuel shut-off valve mounted in the box with the lever protruding outside of the box so that it may be turned "ON" or "OFF" without opening the box cover. Description of functions given in paragraph 3-d) with fuel pressure switch functions.

8. The 2 lbs. C)2 fire extinguisher (trigger type) is mounted on the front bulkhead of the heater compartment and is connected at both; the heater combustion air inlet and the hot air distribution duct underneath the floor level.

9. The electrical junction box is mounted in the heater compartment on the rear bulkhead and contains the complete electrical circuit including the necessary relays to operate the heater system.

10. Three circuit breaker type toggle switches mounter in the aircraft main electrical distribution panel, guard against heater electrical supply overload.

OPERATION

The general sequence of operation is as follows:

ON THE GROUND

When the "ON" - "OFF" switch is placed on the "ON" position, the ignitor unit is turned "ON", the fuel shut-off solenoid is energized, the combustion air and ventilation air blowers operate, the electrical fuel pump takes fuel from the R.H. Front fuel tank and delivers it to the fuel control assembly which meters the proper amount of fuel to air pressure ratio and conducts it to the heater for combustion.

Air for the combustion enters the combustion chamber air right angle to its length and on a tangent to its inner surface, causing air to have a spinning action. The atomized fuel intermixed with this spinning thus produces a whirling flame.

Heat is therefore liberated through out the full length of thecombustion chamber. The resultant flame is stable and sustains combustion under the most adverse conditions because it is whirled around itself many times; the re-ignition being continuous and the combustion process being self-piloting. The high velocity whirling flame scrubs inithe inside surface of the combustion chamber and minimises the accumulation of carbon, lead salts, or any combustion products on heating surfaces.

Cross over passages near the inlet end carry the gases into an outer radiator that is as long as the combustion chamber. Here the gazes are collected into a tube and exhausted overboard. Throughout this course the flame conveys a very high percentage of its heat to the radiator and heat transfer surfaces.

Ventilating air from the ramair scoop enters the inlet or forward end of the heater passing between the combustion chamber and the radiator section. Heat is transferred through the corrugated metal combustion chamber and radiator walls and carried out into the heat distribution system.

When the heater ventilating air reaches a temperature of 200°F, the cycling thermo-switch shuts off the heater fuel supply at the fuel control assembly by operating the cycling fuel solenoid. A cabin thermostat is also connected in series with the cycling fuel solenoid and the cycling thermo-switch there by regulating cabin temperature at will.

When the heater cools off to a temperature/approximately 10°F., lower than the cycling thermo-switch setting the switch closes, the cycding fuel solenoid opens thus allowing the heater to produce another heat cycle. The cycling time depends on the outside air temperature and the cabin thermostat controlling the inside temperature, thus the heater output temperature remains pratically constant over the range of operating conditions.

A Shakespeare manual control mounted near the aisle on the forward bulkhead of the heater compartment controls the distribution of the hot air blast either to the cabin or the engines. The hot air blast can be directed to both engines in the case where the engines are too cold to be started without pre-heating.

When operating the heater system on the ground to either heat the cabin and cockpit or the engines, it is highly recommended to start the Auxiliary Power Unit to avoid drainage of the aircraft batteries.

The maximum efficiency in heating the engines can be obtained by observing the following procedure: Install the nylon engine nose covers on the engines by snapping together the pressure snaps on the covers and the engine ring cowling, close the cowl flaps, close the two defroster valves, the cockpit heat selector "OFF" (up), the cabin/engine heat selector control "UP" for engine heat ("DOWN" for cabin heat). Aircraft master switch "ON", start the A.P.U. and place the only heater switch in "ON" position, open both throttles wide and select both regular carburator heat controls in full hot position. Theengines temperature rise can be observed on both carburator air temperature gages and cylinder head temperature indicators.

When the throttles are opened wide, and the carburator heat controls are in fully hot position, the two carburator heat control valves shut-off the fresh air inlet at the carburetor air scoops at the same time opening the lower front end of the carburator scoop adapters underneath the engine cowlings.

Hot air from the heater is conveyed in ducts running in the wing center section to the wheel wells and up through the nacelles, in faired eleptical conduits and through the rear of the carburator air scoop streamliners and adapters, directed by a deflector, thus directed inside the carburators' throats, it keeps on going down to blower case section thereby heating the intermediate rear engine sections, rear crankcase sections, up in the intake pipes to the cylinder heads (better engine heat can be obtained by slowly turning the propellers by hand). The excess hot air is directed upward through the opening in the front of the carburator adaptors thereby heating the exterior of the engines as the interior. The cowl flaps small openings permitting circulation of hot air.

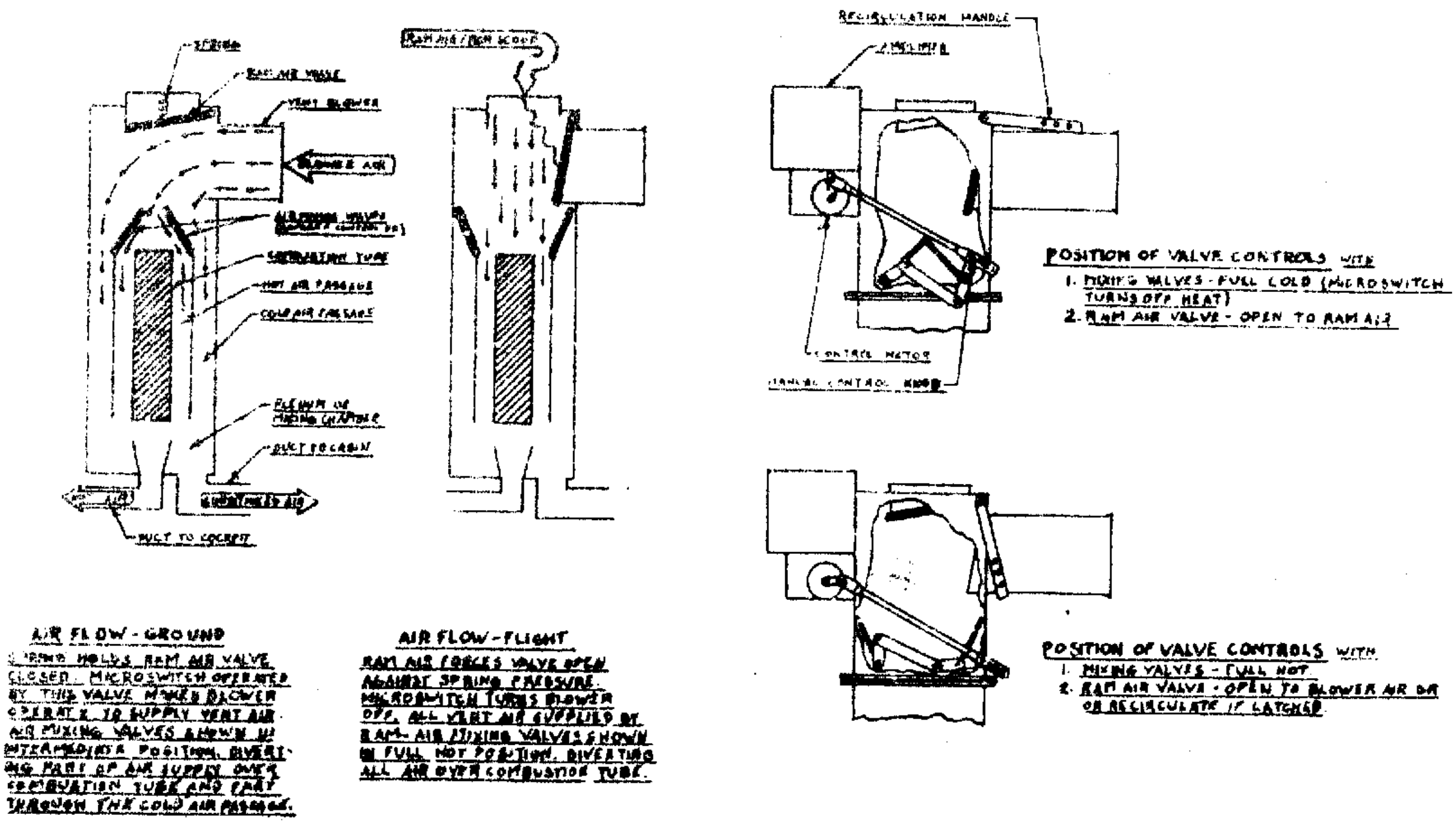
Two separate heater hot air outlets are provided to permit heating of the cockpit and the windshields on both sides. One hot air outlet is installed underneath each pilot and co-pilot seat, connected to two other outlets running to the nose of the aircraft and directing an hot air flow rearward to the vicinity of the pilot and co-pilot rudder pedals. The cockpit hot air output can be varied by moving a Shakespeare manual control "down" for full hot and up for "off" or at intermediate positions, the control is situated on the forward side of bulkhead No. 86 near the aisle and behind the co-pilot. Individual shut-off valves are provided for the windshield defroster conduits and are situated on the left hand and right sides of bulkhead No. 86 behind pilot and co-pilot.

## FLIGHT OPERATION

The heater operating in flight has the same qualities as when operating on the ground, except that the combustion air blower, ventilation air blower and electrical fuel pump are inoperative since ram air is used for combustion and ventilation and R.H. engine fuel pressure is used to maintain combustion and proper heat output. The electric fuel pump automatically comes in function if the R.H. engine fuel pressure drops below 14 P.S.I. thus assuring constant heater operation regardless of R.H. engine or fuel pump failure. Should the heater electrical fuel pump fail (which is less likely to happen) fuel pressure can still be obtained from the R.H. engine electric fuel booster pump.

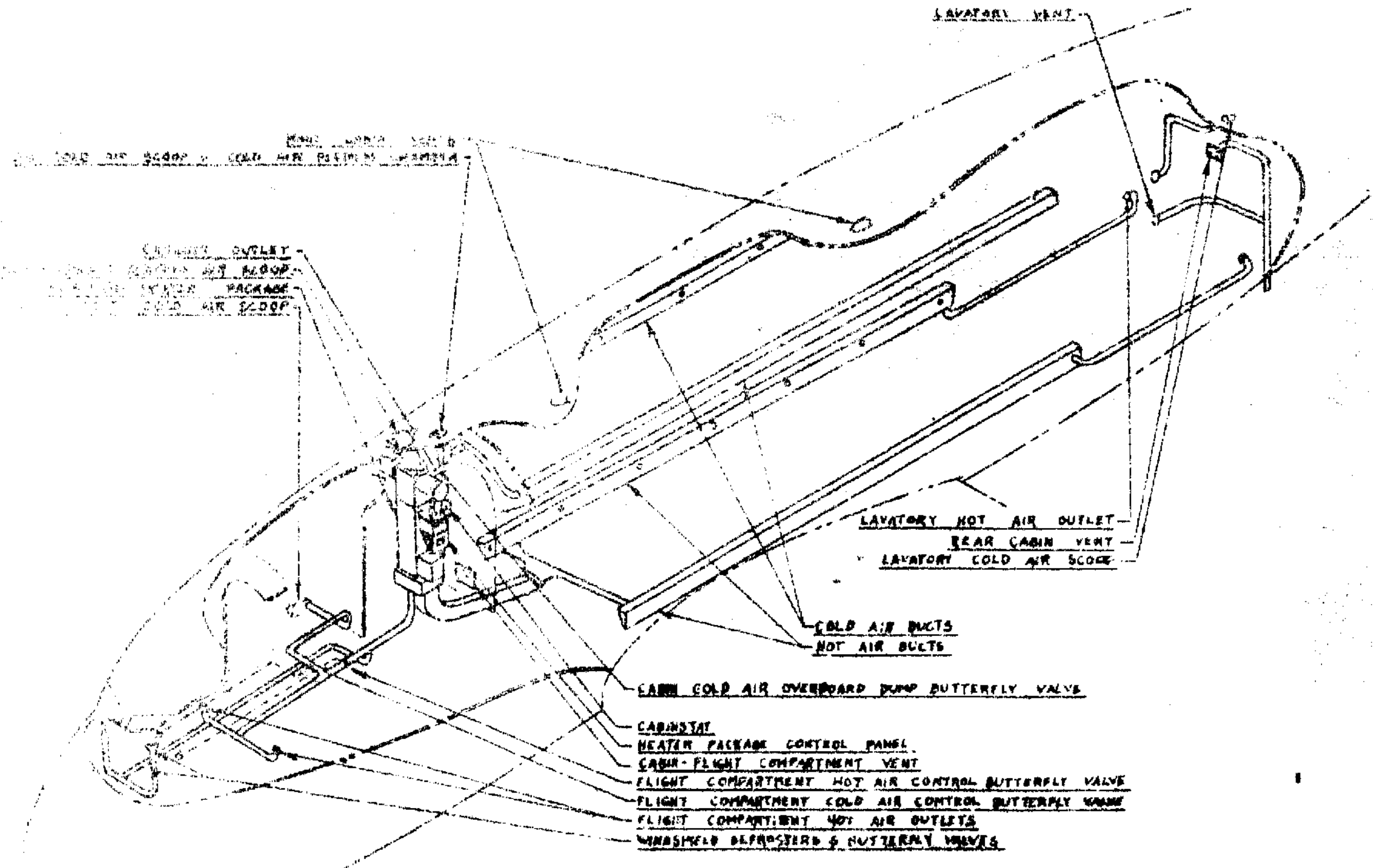
Should the red overheat warning light flash, immediate action should be taken by shutting-off the only one heater switch, closing the emergency manual fuel shut-off valve on the fuel supply box assy near fire extinguisher and depressing the carbon dioxide fire extinguisher trigger.

An added safety factor is incorporated in the heating system due to the fact that when the only one heater switch is turned "off" the electric actuator operating the ram air duct and blower air duct butterfly valves, automatically shuts off the ram air duct, thus preventing fire propogation in the distribution ducts.




## SCHEMATIC DIAGRAM

T.C.A. #100 PACKAGE HEATER. SHOWING AIR VALVE POSITIONS




## HEATING & VENTILATING SYSTEM

DC-3/P

## ENGINE AND AERONAUTICAL INSTRUMENTS

1. The main instrument panel is made up in five sections, attached to a shock-mounted frame. Duplicate flight instruments are provided with the exceptions that a single directional gyro, a single magnetic compass and a single radio compass are provided. The flight instruments are arranged one set on each of the panel sections, immediately before the Captain and First Officer.

2. The Captain's section includes the directional gyro, the radio compass and an oxygen flowmeter. The First Officer's section includes the fuel quantity gauge, the turn and bank vacuum regulator, the vacuum gauges, the de-icer pressure gauge, the de-icer pressure selector valve, the anti-icing fluid quantity gauge and the inverter selector switch and inverter voltmeter. The magnetic compass is shock-mounted in the centre of the view of the windscreen.

3. On the centre section of the instrument panel, the engine instruments are mounted in the left top quarter, the temperature gauges in the right top quarter, and the fuel and oil pressure gauges and warning lights and the manifold pressure selector valve across the bottom. The fire warning lights for the left and right engines, the heater and the cargo space are also mounted across the top of the section, and the marker lights on the left hand edge. Of the two small outboard sections, that on the Captain's side mounts the vacuum warning lights and the static selector valve. That on the First Officer's side mounts the landing gear warning lights and the heater warning lights.

### Altimeters

4. The altimeter is merely an aneroid barometer, the capsule being sealed and actuated only by atmospheric pressure in the instrument case. Due to the possibility of the pressure in the cockpit being different from that of the air surrounding the aeroplane, the altimeter case is connected to the static line of the pitot-static system of the aeroplane. The dial of the altimeter is graduated in terms of altitude in feet, rather than barometric pressure in inches of mercury. Each instrument is equipped with a barometric scale (commonly called a "Kollsman" scale) and a control knob by means of which the mechanism may be adjusted for variations in atmospheric pressure. The instrument is calibrated, with the Kollsman scale set at standard sea level pressure 29.92 inches HG., on the basis of a standard air column.

5. Thus, an altitude of 1000 feet is indicated at a pressure of 28.86 inches Hg., 2000 feet at 27.82 inches Hg., etc., as laid down in Standard Atmosphere Tables. True altitudes will be indicated only when the Kollsman scale has been set to the correct atmospheric pressure as determined by a ground Kollsman instrument, and then only after the aeroplane has landed at the airport where the ground Kollsman pressure was determined. In the air above the airport, or above any other point, the instrument does not necessarily indicate true altitude.

6. Disregarding instrument calibration errors, there are two factors which must be applied to determine as closely as possible the true altitude at which the aeroplane is flying. First, the Kollsman scale must be set to the reported ground Kollsman's setting along the route which the aeroplane is flying. Second, the altitude then indicated must be corrected for the difference between the actual air temperature and the standard air temperature for the particular pressure level. This second correction may be obtained by use of the Cruise Control Chart in "Performance Information" of this manual or by means of a Flight Calculator.

7. "Pressure Altitude", which is the hypothetical altitude referred to in the altitude scale of all engine charts, may be determined in flight by setting the Kollsman scale to 29.92 and reading the altimeter.

8. "Density Altitude", which is the hypothetical altitude to which all aeroplane performance data is referred, may be determined in flight be reading the "Pressure Altitude" as above and the air temperature, and converting by means of the Density Altitude chart in "Performance Information" Of this manual.

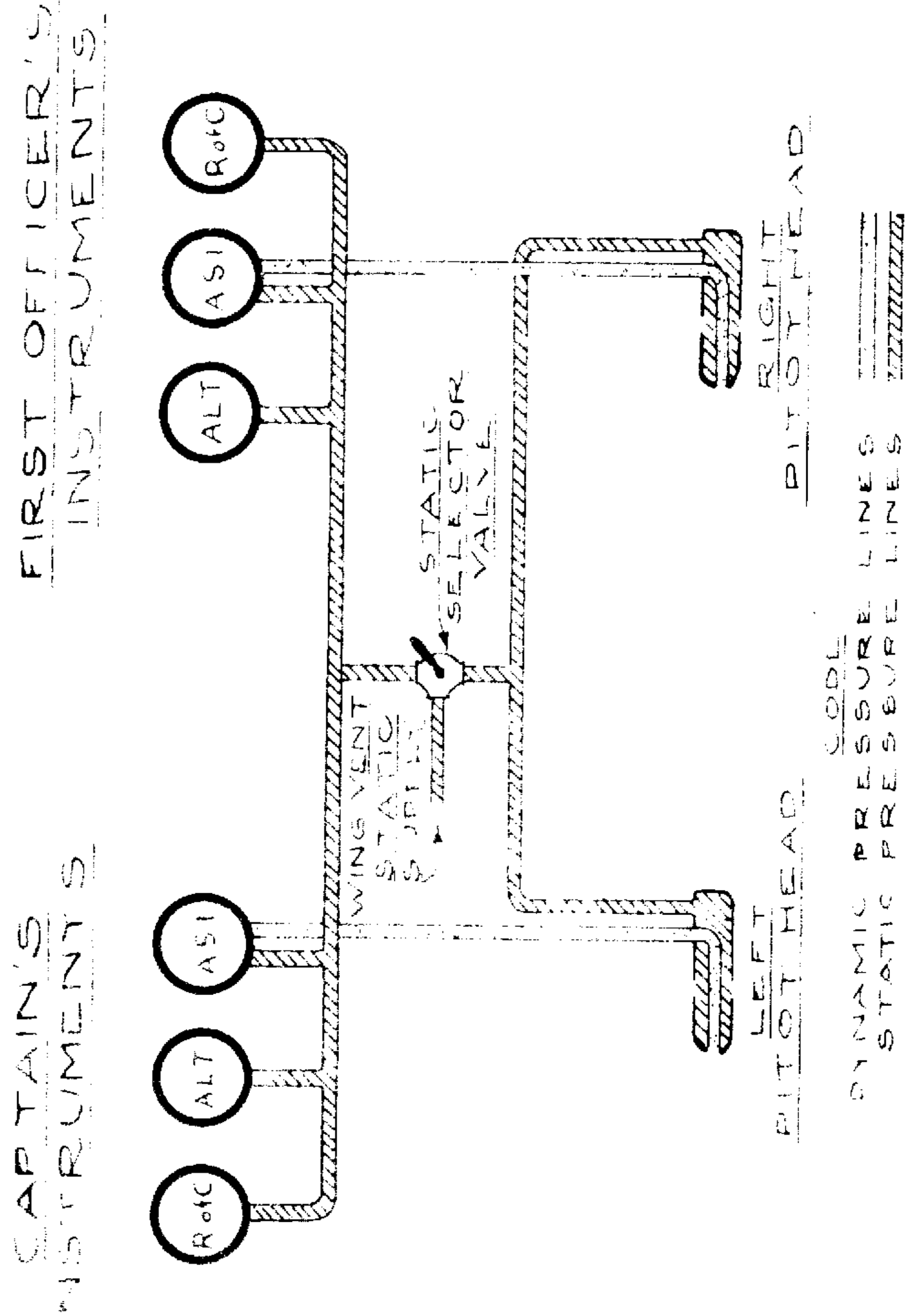
9. (Unassigned)

10. (Unassigned)

11. Duplicate altimeters are installed on the Captain's and First Officer's flight panels.

Airspeed Indicators

12. The airspeed indicator is similar to the altimeter in that it is a pressure instrument and contains an aneroid capsule by means of which the pressure is indicated on a dial. The pressure in this instance is derived from the air impinging on the open end of the dynamic line to the pitot head. The pressure is lead to the inside of the aneroid capsule which expands or contracts as the pressure increases or decreases. The dial is graduated in terms of miles per hour instead of conventional units of pressure. As in the case of the altimeter, and in order to eliminate errors due to changes in cockpit pressure, the case ofthe instrument is vented to the static line of the pitot-static systems.




PITOT STATIC SYSTEM
DC-3-S1C3G

13. Corrections must be made to the indicated airspeed for variations in air pressure and air temperaturein order to obtain the true airspeed of the aeroplane. This may be done by use of the Airspeed Correction chart in "Performance Information" of this manual, or the Flight Calculator.

14. Duplicate airspeed indicators are installed on the flight panels.

Rate of Climb Indicators

15. The rate of climb indicator is also a pressure instrument containing an aneroid capsule. The inside of the capsule is vented through a capillary bleed to the static line of the pitot-static system. As the aeroplane gains altitude the pressure on the outside of the capsule reduces immediately and that on the inside reduces slowly due to the capillary restriction. The differential in pressure causes the capsule to expand and indicate a rate of climb. During descent, the flow of air into the capsule is restricted and the action is reversed. There must be a differential in pressure caused by a change in altitude before the instrument will register. Thus, the indication of the instrument is not immediate. Likewise, the pressure must equalize to bring the indications back to zero. Thus climb or descent is indicated for a short time after the aeroplane has been leveled off.

16. Duplicate rate of climb instruments are installed on the flight panels.

Pitot-Static System

17. Of the foregoing instruments, the altimeters and rate of climb indicators are supplied with static pressure, and the airspeed indicators with static and dynamic pressure by means of the pitot-static system, which is shown in the schematic diagram on the following page.

18. Two separate pitot masts are installed on the underside of the forward portion of the fuselage each 9¾ inches on either side of the centre line. The left pitot head supplies dynamic pressure to the Captain's airspeed indicator and the right pitot head supplies dynamic pressure to that on the First Officer's side. The two static pressure lines from the pitot head are manidolded together. An alternate source of static pressure is provided for emergency by a line running to the left rear fuel tank bay. By means of the static selector valve, located on the lower left hand corner of the instrument panel, the static pressure for the altimeters, rate of climb and airspeed indicators may be supplied from either the pitot heads (all normal operations) or the alternate wing vent source (emergency). When it is necessary to use the vent static source, the airspeed indicators read faster than they do on the pitot tubes. The "Vent" correction graph overleaf shown the approximate conversion of the airspeed reading to give the correct indicated airspeed. Also, when on "Vent", the altimeters read higher than they would on the pitot tubes and the error increases as the aeroplane's speed increases.

19. (Unassigned)

20. (Unassigned)

21. The following table gives the approximate corrections to be subtracted from the altimeter readings when on "Vent".

| Captain's A.S. Indication on Vent (M.P.H.) | Correction to Obtain Normal A.S. Reading | Altimeter Correction On Vent (Feet) |
|---|---|---|
| 80 | -4.5 | -29 |
| 90 | -5.0 | -43 |
| 100 | -6.0 | -56 |
| 110 | -6.8 | -70 |
| 120 | -7.7 | -84 |
| 130 | -8.5 | -98 |
| 140 | -9.3 | -112 |
| 150 | -10.1 | -126 |
| 160 | -10.9 | -139 |
| 170 | -11.7 | -153 |
| 180 | -12.5 | -167 |
| 190 | -13.2 | -180 |
| 200 | -14.0 | -194 |
| 210 | -15.0 | -208 |

22. The pitot masts are equipped with alcohol anti-icing tubes along the leading edge of each mast. The description and operation of the system are fully outlined under "Liquid Anti-Icing System", "Anti-Icing System" and "Pitot Mast Anti-Icing" in this section of this manual. The pitot heads each are equipped with an electric heater, for keeping the static and dynamic openings free of ice. The operation of the heaters is outlined in "Pitot Head Electric Heaters" section of this manual.

Gyro Instruments

23. There are five gyro instruments in the cockpit. These are the two gyro horizons, the two bank and turn indicators and the single directional gyro on the Captain's side. Of these, the gyro horizon and bank and turn indicator on the Captain's side are electrically driven by a special 3 phase, 26 volt, 400 cycle alternating current supply, the remaining three instruments depending upon a source of vacuum to drive the gyro rotors by means of air jets acting upon vanes on the rotor.

24. The gyro horizon is an instrument designed to afford the nearest thing to a natural horizon, an artificial horizon within the cockpit of the aeroplane. By means of a miniature aeroplane and a gyro actuated horizon bar it indicates whether the aeroplane is banking, or whether it is in a "nose up" or "nose down" attitude. By observing the gyro horizon the pilot can visualize the aeroplane in whatever lateral or longitudinal attitude he places it. The gyro horizon is a direct reading indicator of flight attitude for bank, level flight and pitch angle. However, mechanical stops are installed which limit the angles of bank and pitch. These limits are ample for all normal conditions of manoeuvring or rough air, but if they are exceeded, the rotor striked the stops and is thrown out of alignment. The lenght of time required for the rotor to assume its normal position, after being disturbed by striking the stop, is from three to six minutes.

25. The bank and turn indicator combines in one instrument, two functions essential to the accurate control of the aircraft, particularly when operating under conditions of reduced visibility. It provides, with reference to the straight flight path, indication by means of a needle of the direction of a turn and the rate of the turn in degrees per minute. This sensitive element of the turn indicator is a gyroscope operated electrically in the case of the Captain's instrument and by vacuum in the case of the First Officer's. This instrument does not depend on a given rotor position for proper functioning and the needle will indicate correctly in any position of the aeroplane. The bank indicator consists of a comparatively simple device, a metal ball sealed in a curved glass tube which is filled with a damping liquid. It provides a positive indication of the lateral attitude of the aircraft. The bank and turn indicator may be used to control the aeroplane accurately during manoeuvres, and has the advantage of normally being operative after the other gyro instruments have been put out of action by violent manoeuvre or rough air.

26. The directional gyro unit has no directional-seeking characteristics. Its gyro actuated compass card must be set with reference to the magnetic compass by means of the caging knob which lifts and rotates the card when in the engaged position (pushed in). Once so set and uncaged, the directional gyro has the advantage over the magnetic compass that it is not affected by rough air or normal accelerations, as is the magnetic compass card. The directional gyro gives a steady indication of heading, subject only to its inherent tendency to drift from the set heading. This drifting is slight and requires resetting only every ten to fifteen minutes. The single directional gyro, mounted in front of the Captain is driven by vacuum.

Vacuum System

27. There are three gyro instruments in the aeroplane requiring vacuum for their operation. These are the First Officer's gyro horizon and bank and turn indicator, and the single directional gyro mounted in front of the Captain. The suction is provided by identical engine driven vane type suction pumps, one mounted on each engine. The vacuum lines from the pumps are provided with regulators and check valves in each nacelle, regulating to 5" Hg., and the lines are then manifolded together. A regulator in the cockpit regulates vacuum to the directional gyro and gyro horizon at 4" Hg., and a further regulator at 2½" Hg., regulates vacuum to the turn and bank indicator. The vacuum system is entirely automatic and no vacuum selector valve is provided. If one engine becomes inoperative, the vacuum line from that engine is automatically closed and the operating engine supplies vacuum to the system.

28. Two vacuum gauges are mounted on the lower right hand side of the instrument panel. The one marked "D.G. and Horizon" should, in normal operation, read 4" Hg. The other gauge marked "Turn and Bank" should read 2½" Hg., during normal operation.

29. (Unassigned)

30. (Unassigned)

31. The two vacuum warning lights mounted on the extreme left hand side of the instrument panel are marked "Vacuum Warning" - L and R. If the vacuum supply from either engine driven pump drops below 3.5" Hg., the appropriate warning light will light up "red".

32. The exhaust side of the vacuum pumps supplies air under pressure, through oil separators and check valves, for the operation of the de-icer system and pressurizing the ignition harnesses.

33. Two manifold pressure gauges are installed in the centre section of the instrument panel. The instruments employ aneroud capsules and are graduated in inches of mercury. One gauge is connected direct to the intake manifold of each engine and thus indicates the absolute pressure of the mixture after it has been compressed by the supercharger.

34. The lines leading from the instruments to the engines are led through a manifold Pressure Vent Valve, (located on the lower right hand centre section of the instrument panel) by means of which either line may be vented to the atmosphere. In the "Off" position of the vent valve both gauges are connected to their respective engines. In the "Left Engine" position the left manifold pressure line and gauge are vented to the atmosphere and the right gauge remains connected to the right engine.

35. Similarly in the "Right Engine" position, the right line and gauge are vented and the left gauge remains connected to the left engine. It is important, when starting the engines, to turn the Manifold Pressure Vent Selector to "Left Engine" and "Right Engine" when starting the left and right engines respectively, in order to prevent damage to the gauges in the event of back-fire. After both engines are running smoothly, the selector is turned to the "off" position.

Tachometers

36. The two tachometer indicators, one for each engine, are mounted in the centre section of the instrument panel and are graduated in revolutions per minute. Two 3 phase alternating current tachometer generators are coupled, one to the tachometer drive shaft on the outboard side of each engine rear section. The generator generates a voltage which is directly proportional to engine speed and this voltage is transmitted to the indicator so that changes in engine speed are registered on the indicator face.

Temperature Indicators

37. There are seven temperature indicators on the centre section of the instrument panel allof which are individually operated by electrical transmission. The cylinder head temperature gauges are operated from gasket type thermo-couples located beneath the rear spark plugs of Nos. 1 and 2 cylinders of each engine. The outside air temperature gauge is operated from a temper-ature resistance bulb protruding on the underside of the fuselage.

(continued)

37. The carburator air temperature gauges are operated from temperature resistance bulbs installed on the aft side of the carburator scoop adapter of each engine. The oil temperature gauges are operated from temperature resistance bulbs installed at the lubricating oil inlet to each engine.

Fuel and Oil Pressure Indicators

38. There are four fuel and oil pressure gauges on the centre section of the instrument panel comprising a fuel pressure gauge connected by a direct line to the pressure chamber of each carburetor, and an oil pressure gauge connected by a direct line to the pressure side of each oil pump. All the instruments are of ~~the~~ Bourdon type, consisting of a flat coiled hollow tube which tends to straighten under internal pressure of the fluid and thus deflects the instrument needle which is connected to the centre of the coil. The gauges are graduated in pounds per square inch.

39. (Unassigned)

40. (Unassigned)

41. The de-icer pressure gauge is of similar construction and operation.

42. Fuel and oil pressure warning lights are mounted one below each corresponding pressure gauge.

Quantity Gauges

43. The contents of the four fuel tanks are simultaneously indicated on a single dial carrying four scale arcs. Each scale pointer is remotely operated ~~by~~ electrical transmission (two wire, with transmitter and indicator cases grounded) from a float actuated transmitter unit at the tank. The scales are calibrated in Imperial Gallons.

44. The anti-icing fluid quantity gauge is of similar construction.

Magnetic Compass

45. The aeroplane is equipped with a conventional type magnetic compass which is suspended by three rubber bungees in the vee of the windscreen. This instrument is very sensitive to erratic motions of the aeroplane caused by rough air and is of course, subject to deviation and turning errors. Correction for the deviation errors may be made by means of the deviation card on the instrument panel. The compass card and lubber line, being of the vertical type, are very easily read.

(continued)

Gyro Flux Gate Compass System

46. The Gyro Flux Gate Compass System is a remote indicating, gyro statilized, earth inductor compass system, consisting of a transmitter unit (located in the right outer wing panel), an amplifier unit (located in the radio rack), a master direction indicator (Captain's side of the instrument panel), a repeater indicator (First Officer's side) and the necessary electrical leads, switches and junction boxes. By locating the transmitter at a point where the magnetic disturbances created within the aeroplane are at a minimum, and by stabilizing the compass element beneath a gyro so that it is maintained in a horizontal position at all times, erratic compass behaviour during turns, climbs and dives is overcome, and all tendency of the compass to oscillate in rough air is prevented.

47. Two sources of power supply are delivered to the power junction box of the Gyro Flux Gate Compass, 26 volts direct current from the aircraft electrical system and 3 phase, 400 cycle, 110 volts alternating current from an inverter. The transmitter consists of a 3 phase power driven gyro, an erection mechanism which makes the gyro axis seek the vertical and maintain this position, and the Flux Gate or compass element rigidly attached to the gyro housing so that it is maintained in a horizontal position when the gyro axis is vertical. The Flux Gate constitutes a device for transmitting voltages which are set up in its windings in definite relation to the position of the windings in the earth's magnetic field. These voltages are transmitted through the amplifier to the master indicator and repeater, where by means of synchronous motors they influence the position of the pointers to indicate the same definite relation to the earth's magnetic field. The assembly is designed to allow the gyro 110° of freedom in bank and 70° in climb or dive. To prevent damage when not in use, and for quickly erecting the gyro when the limits just mentioned have been exceeded or the gyro has toppled for any other reason, a caging mechanism is provided. The mechanism is electrically operated by direct current from a caging switch in the cockpit, accessible to both the Captain and the First Officer.

Radio Compass

48. Two Radio Compass Indicators are mounted on the Captain's side of the instrument panel. The description and operation of the Radio Compass Receiver are given in detail in this section under "Radio System - Navigation Equipment".

Marker Lights

49. Three marker lights are installed on the left hand edge of the centre section of the instrument panel. These are marked from top to bottom "Inner", "Outer", and "Airway". The light jewels are provided with a dimming feature. The description and operation of the marker receiver is given in this section under "Radio System - Navigation Equipment".