AIRCRAFT –HVAC 1930's

Boeing B314 Clipper

COMFORT IN HIGH ALTITUDE FLYING

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DURING the past 10 years the improvement that has been made in the airplane as a whole is almost phenomenal. The heating and ventilating system of passenger planes has always presented a major engineering problem, and the problem has not yet been completely solved. However, all air travelers will agree that the safety and comfort provided for the present day airline passenger has been greatly improved, and the contrast between the heating and ventilation of the modern Stratoliner of today and the aircraft of 10 years ago shows that some notable advances have been made.

Ten years ago heating and ventilating was considered of more or less secondary importance. The supply of cold air was taken in through small *horns* located at each seat, these horns extending through the fuselage to the outside. They were designed so they could be turned to take in the desired amount of air or turned up or back to stop the flow of air. Naturally, considerable noise, vibration, and quite often fumes from the engines were brought into the cabin, but at that time it was considered by most people as just part of air travel. No spent air or ventilation valve was provided to help control the amount of foul or used air escaping from the cabins. Leaks around doors and windows, which were usually plentiful, were depended upon to solve this problem.

The conventional heating system in airplanes of 10 years ago usually consisted of a metal shroud covering the exhaust tail pipe as shown in Fig. 1. This tail pipe was ordinarily on the under side of the plane and quite often extended almost the full length of the cabin in order to obtain sufficient heat. The air entered the duct thus formed at the forward end between the exhaust pipe and the shroud and after passing along the hot exhaust pipe, was admitted to the cabin through adjustable sliding valves in the aisle between the seats, or through tubular ducts along each wall near the floor as indicated in Fig. 1.

Admittedly poor circulation, and quite often inadequate heat, were obtained with this arrangement, yet it was many years before it was changed. The admittance to the cabin of exhaust gases and carbon monoxide from breaking exhaust pipes and loose connections was always feared, and now it is sometimes wondered how the airlines operated as long as they did without more

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serious trouble from the hazard of asphyxiation and fire in the cabin heating systems of that period.

In 1933, when the Douglas DC-1 was built for TWA, the first cabin steam heating system, to the author's knowledge, was installed for airline use. The system was of the low-pressure type, operating under only a few pounds pressure. The water entered the boiler at the bottom by gravity feed and went out the top as steam to the steam radiator, which was located in the fuselage below the cabin floor. The boiler was located in the exhaust manifold in one engine nacelle which is the streamlined compartment housing the engine on the wing. Cold air picked up at the nose of the plane was directed by an electrically operated automatic temperature control either through the steam radiator or around it, depending upon the cabin heat demand. Fig. 2 shows the heating and ventilating system of the DC-2, which is identical with that of the DC-1. After this first DC-1 steam heating system,

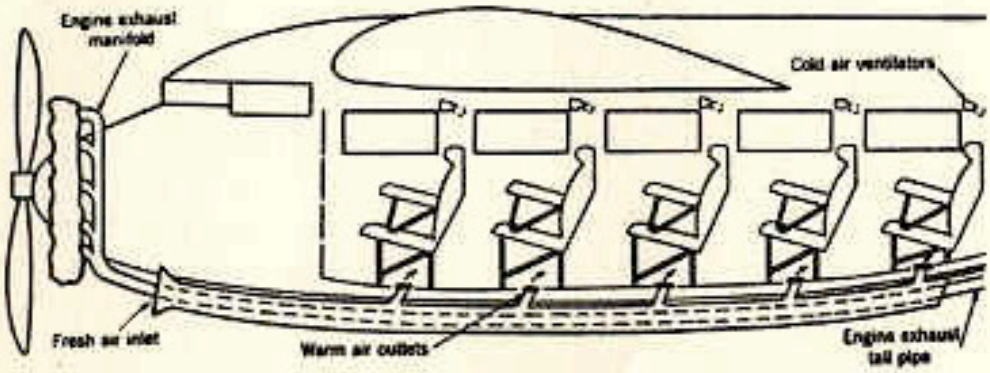


Fig. 1. Typical Heating System of 10 Years Ago

fast strides were made to the present-day heating and ventilating system now installed in the Stratoliner, designed and built by Boeing.

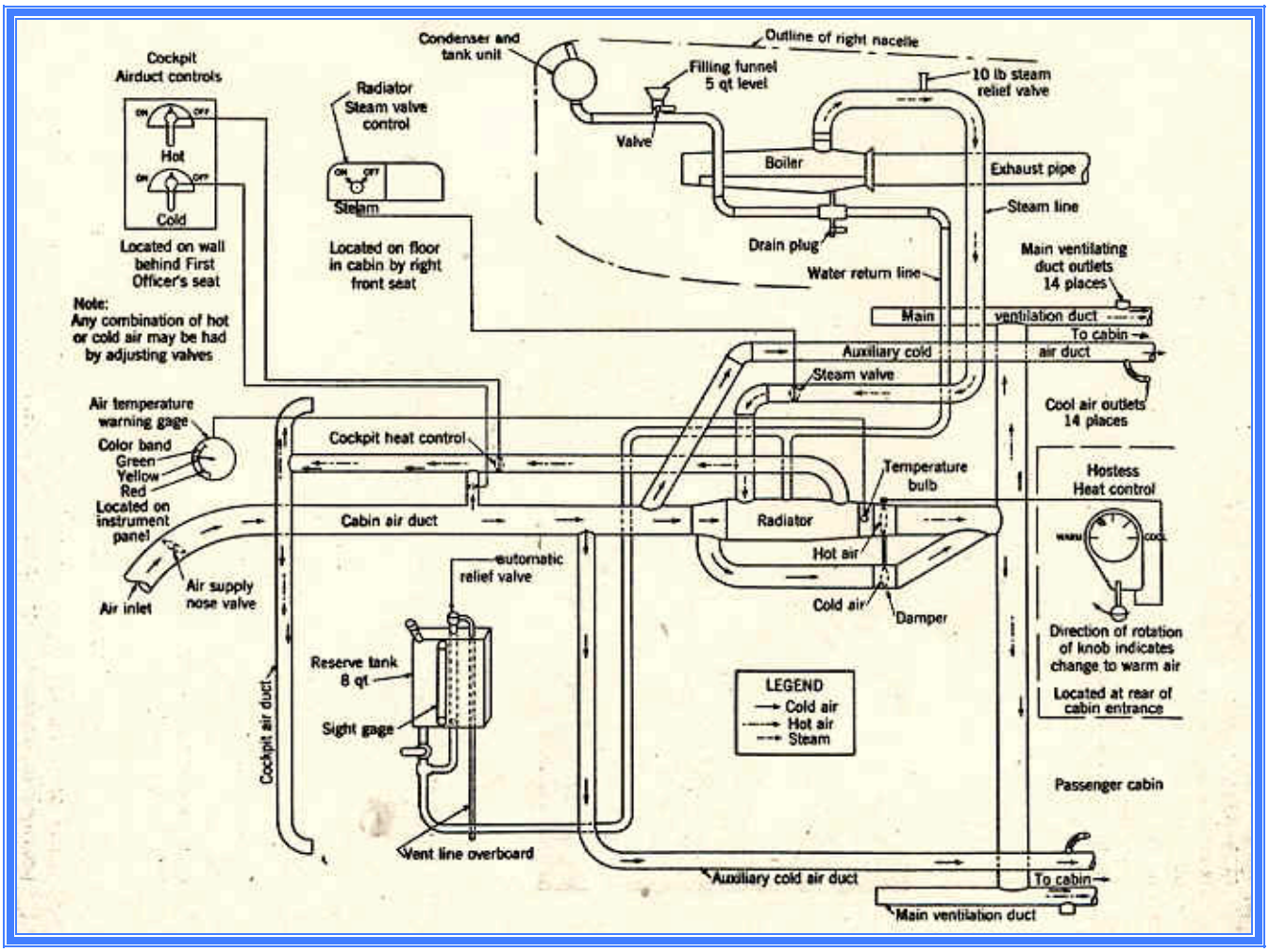
The heating and ventilating system of the Stratoliner consists actually of five separate, though intimately related, systems, as follows: (1) Fresh Air System, (2) Spent Air System, (3) Warm Air System, (4) Steam System, and (5) Ground Air Conditioning System.

Fresh air is supplied to the cabin by means of an air scoop on the upper side of the fuselage through which air is forced by the forward speed of the airplane into a distribution duct which extends the full length of the passenger cabin and which is located on the ceiling as indicated in Fig. 3. This is divided longitudinally into two sections; the lower of which contains grilles through which air is distributed directly into the cabin while the upper section is a supply duct for the individual outlets which are located at each seat and upper berth. The individual outlets are also provided in the ladies' and men's dressing rooms and other sections of the plane forward of the passenger cabin.

After the air enters the scoop, it passes through a centrifugal water separator device which is an integral part of the duct just inside the fuselage skin, and which is intended to prevent water from being forced into the distribution duct in the cabin. There are two valves located in the outlet duct behind the water separator, the foremost one being used for closing the air inlet during the time the cabin is supercharged or during extremely cold weather, when

Douglas DC-1

Douglas DC-2



Heating & Ventilating System of DC-2 Airliner

Boeing 307 Stratoliner

the outside cold air is not necessary. It is operated from the cockpit by means of a lever on the floor behind the seat occupied by the First Officer. The rearmost valve controls the flow of air through the lower section of the ceiling duct only and can be operated only from the control on the front bulkhead in the passenger's cabin. Thus the Flight Engineer, who controls the cabin supercharging system, determines the source of all air entering the cabin but cannot control the distribution of it; and conversely, the hostess in the cabin determines the distribution of the air but cannot control the source.

The individual ventilator nozzles located in the wall next to each seat and within each berth, have both a directional and a volume flow adjustment which is formed by a ball-and-socket made of sound-deadening plastic material. Each nozzle may be adjusted to release a high velocity air jet in order to obtain

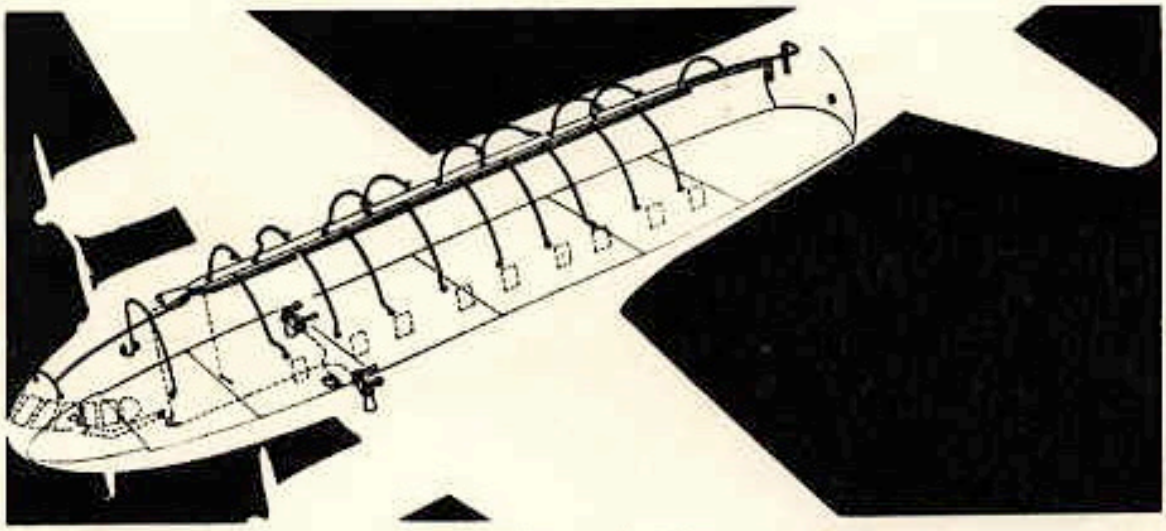


Fig. 3. Fresh Air System

maximum air recirculation effect. A rubberized fabric hose connects the individual ventilators to the main supply duct and is concealed behind the cabin lining.

The spent air is exhausted into the lower fuselage section below the cabin floor through vents in the floor, which are located under the seats and so arranged as to give even distribution throughout the cabin. The air is discharged from the airplane through either an auxiliary outlet valve, or the supercharger control units or both. The auxiliary outlet valve is located in the lower covering of the airplane just aft of the front spar bulkhead in the accessory compartment and is manually operated by the same lever which is used to operate the fresh air inlet valve.

Cabin Supercharging and the Warm Air Supply

The pressure, air supply, control, and temperature conditioning system is provided in duplicate, there being one system on each side of the airplane. (Fig. 4) either system being capable of maintaining satisfactory cabin temperature and pressure should the other system fail.

All doors and hatches open inward and, therefore, are sealed against rubber gaskets under the influence of cabin pressure. The skin or fuselage covering continuity is not broken at the intersection with the center section of the wing and forms a cell which is circular in section, cigar-shaped in form. There are 17 passenger compartment windows measuring 12 in. high x 16 in. wide, and the panes of which are a single-ply section of 5/16 in. Plexiglas. Plexiglas was chosen for its high strength-weight ratio. The cabin is designed to withstand 6 lb per square inch internal pressure, although the maximum internal working pressure intended for transport operation at present optimum altitudes is but 2.5 lb per square inch.

The cabin floor level is located below the center line of the fuselage at its largest section. The cargo compartments and the accessory compartment

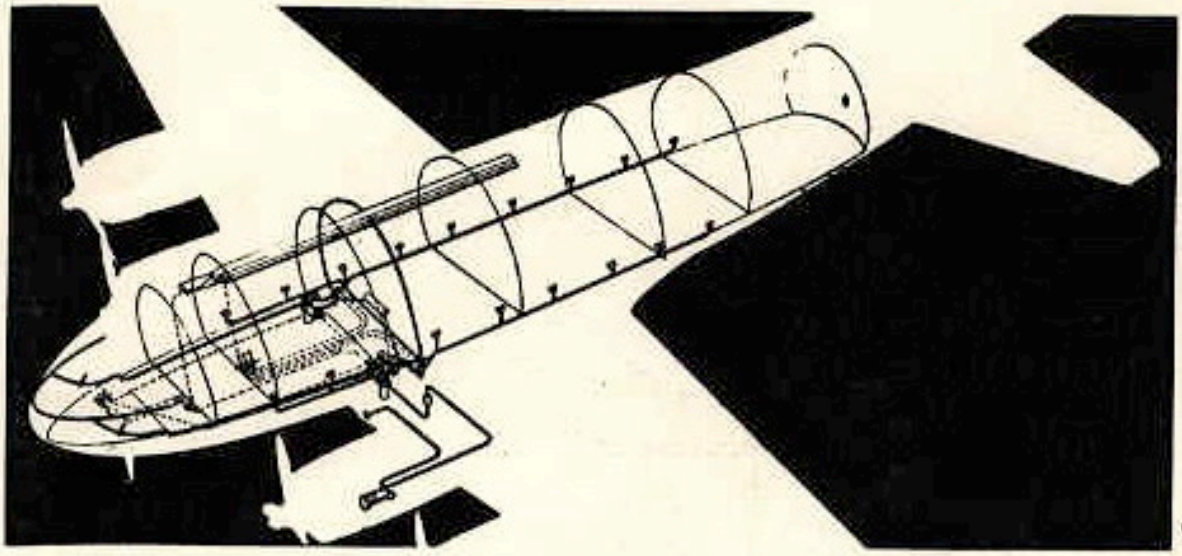


FIG. 4. HOT AIR AND SUPERCHARGING SYSTEMS

between them under the floor are maintained under full cabin pressure and are part of the circulatory system. The fuselage is pressurized only to the rear end of the cabin and at that point, there is a removable circular hatch in one side of the hemispherical bulkhead to enable inspection of the interior of the tail of the airplane. An emergency air valve set to relieve at a pressure of 2.65 lb per square inch is also located in the bulkhead as a safeguard against building up excessive internal pressure. This valve has a capacity equaling the total overloaded discharge of both cabin superchargers at sea level and during maximum supercharger speed, without causing the cabin pressure to exceed 3.6 lb per square inch.

This airplane carries a Flight Engineer as part of the flight crew, one of his duties being to handle the cabin supercharging. His station is behind the co-pilot and he has an instrument board in the side wall of the flight compartment on the right hand side of the cockpit as shown in Fig. 5. The pressure-cabin instruments are mounted on this panel in a group by themselves, separated from the surrounding instruments. In this group and at the lower left is a supercharger discharge pressure gage and a two-way selector valve for connecting the gage to the right or to the left supercharger in order that the

pressure rise may be known. On the right is a suction gage with a three-way selector valve connected to it. When the latter valve is in the central position, the suction gage indicates cabin pressure referred to outside pressure. When the valve is in the left or right position, the suction gage indicates depression in the throat of the flow-measuring venturi of the right or of the left pressure. air supply system. A selector valve is located in the uppermost portion of the panel for the purpose of manually selecting operation on either the right or left outlet valves, or both as desired. Below this space, a vertical speed indicator, referred to cabin pressure instead of to atmospheric pressure, indicates the rate of cabin pressure change in terms of feet per minute. Next to this gage

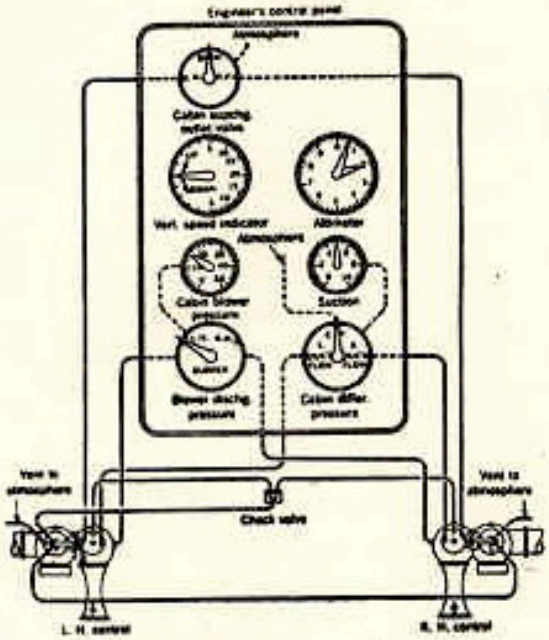


FIG. 5. INSTRUMENT AND SUPERCHARGER CONTROL UNIT CONNECTION DIAGRAM

is an apparent altitude green warning light to inform the engineer of the absolute pressure in the cabin. The green light can be pre-set by a knob below it to shine at consecutive apparent pressure altitudes of 8000, 15,000 and 18,000 ft.

The air to be compressed is drawn from an inlet in the leading edge of the wing adjacent to the wing fillet. From there it passes through a water separator, through the supercharger (Fig. 6) which is driven by the engine, through the steam radiator in the leading edge of the wing, through the intercooler to reduce the temperature of the air, through the inflow control regulator, on through the cabin, out of the cabin through the floor into the compartments under the floor and then through the outflow valve which is incorporated in the unit containing the inflow valve.

If the cabin temperature is too cold, feedwater pumps supply water to the boilers and these in turn supply steam to the radiators, thus raising the temperature of the incoming air passing through the radiator. If the cabin temperature is too high, the feedwater pumps do not operate, consequently

the air passes through the cold radiator and the intercooler. On warm days during supercharged operation, the supercharger discharge temperature is such that it is necessary to operate with the intercooler valves open for maximum cooling.

The inflow of pressure air is fixed by the automatic controls at an impact value corresponding to the impact produced by 250 cfm per blower at sea level. Except for changes due to cabin leakage, the flow value is unaffected by changes of other conditions, such as blower speed. The absolute pressure in the cabin is maintained substantially constant between 8000 ft and 15,000 ft pressure altitude. At altitudes higher than 15,000 ft, the differential pressure of the cabin referred to the atmosphere is automatically held at approximately

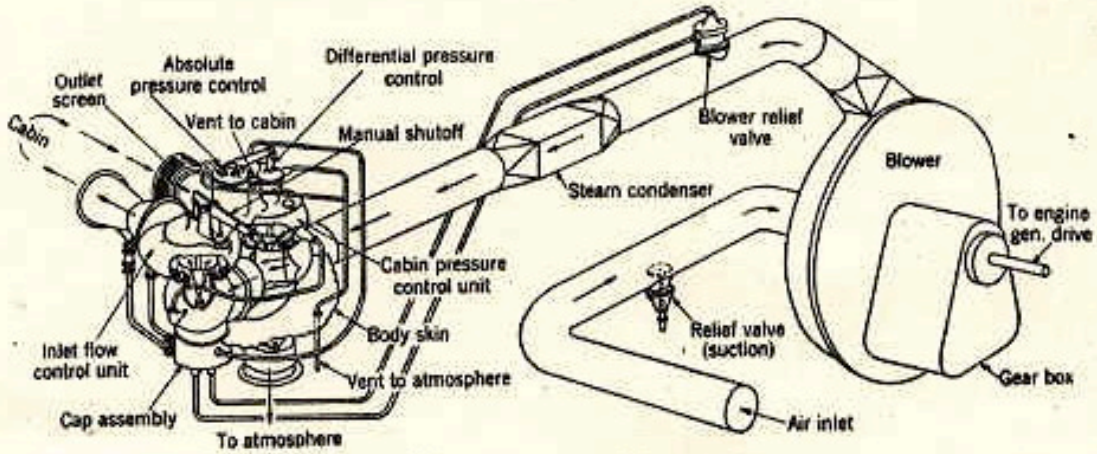


FIG. 6. CABIN SUPERCHARGING CONTROL INSTRUMENT

2½ lb per square inch, resulting in an apparent cabin altitude of 11,000 ft at an actual altitude of 19,000 ft (see chart Fig. 7).

The pressure air flows into the spherical casting of the cabin supercharger control and then rises past an inlet flow control valve and flows horizontally into a measuring venturi to be distributed to the cabin. This inlet valve, incidentally, acts as an outflow check valve if the air flow ceases. It may also act as an inflow relief valve if the cabin pressure should tend to fall below the atmospheric pressure on the outside of the cabin.

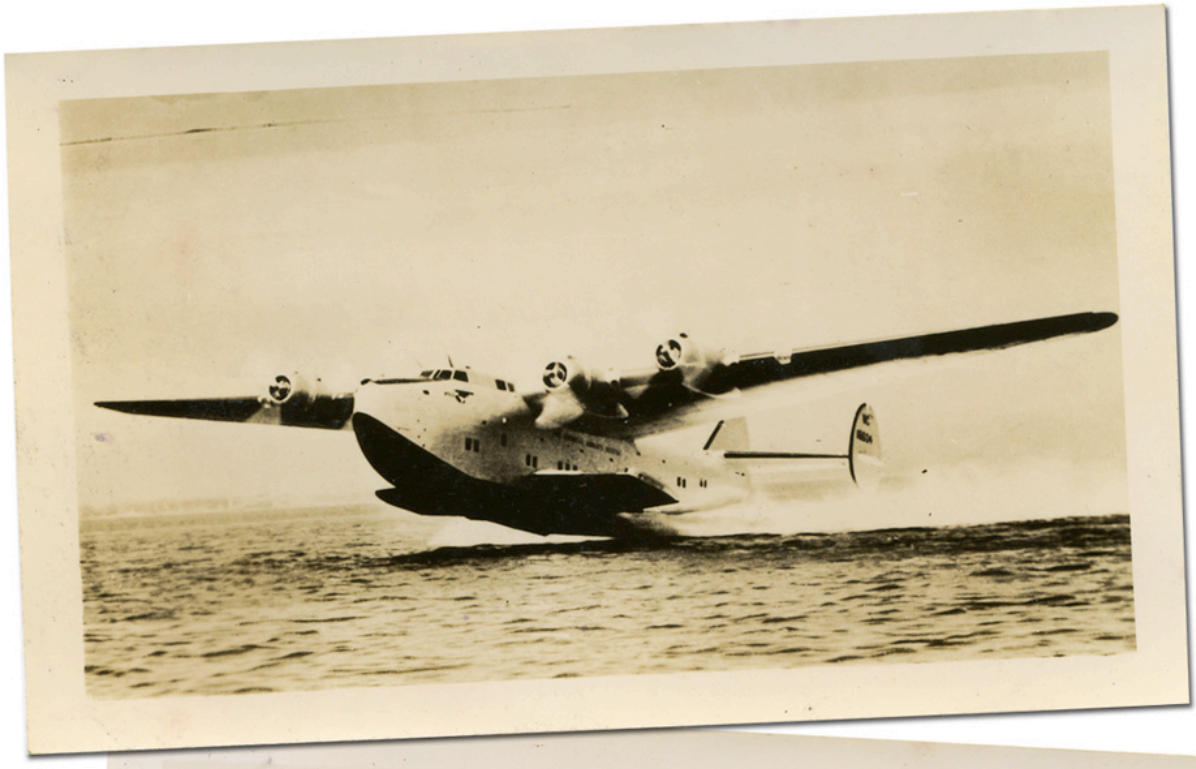
Air to be exhausted from the pressurized area passes through a screen and then escapes to the atmosphere past an outlet valve which is also a part of the supercharger control unit. The seat of the outlet valve is extended downward through the inlet duct, forming a diffuser; in this manner the seat and diffuser of the outlet valve are heated by the incoming air from the superchargers to prevent formation of ice which might form under the cooling influence of the expanding outflowing air. The outlet valve also acts as an inflow relief if the cabin pressure tends to fall below the atmospheric pressure on the outside of the cabin.

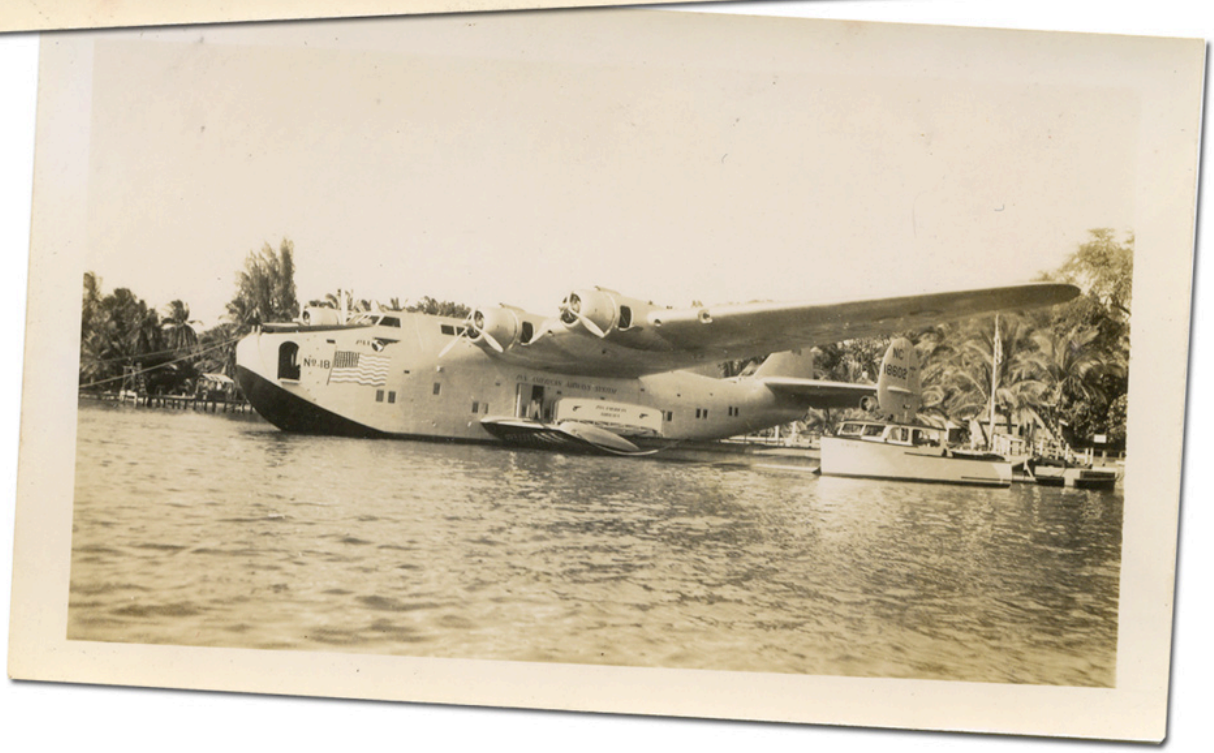
The history of development has been strikingly repetitive. First hot air, then steam and water with automatic controls. Mr. Tomlinson's valuable paper will be better appreciated by those who realize the limitations imposed on aircraft installations. Space and weight are the most important limitations, and before the construction of a new airplane is undertaken a mock-up is built. Practically every item entering construction and equipment is duplicated in this imitation model, the cost being comparable to the cost of a finished plane. The principal function of a plane is to carry a load. In passenger service a pay load amounts to approximately 10 per cent of the total weight. In fighting craft the disposable load is the important factor. One pound of weight saved in construction is considered worth $100.00.

Fortunately, freedom from dust and the satisfactory humidity conditions encountered simplify the engineers' problem. Control instruments subject to influence of vibrations may not be used, and manually operated instruments over-ride automatic controls. This paper describes the hot air system using engine exhaust shroud. The author refers to the later type of steam heating installed on the DC-1, the hot-water type installed on the DC-2, an indirect hot air-hot water system and finally the hot air-steam system used on the Boeing Stratoliners, requiring supercharging of cabins for high altitude flying. The hot air system is in use on the B314, Boeing, 74 passenger Clipper where two of the 4, 1500 hp engine exhausts are equipped with stoves. Air is changed every 3 min. Either engine can supply all of the heat required—estimated to be 400,000 Btu per hour. The Clipper weighs 42 tons—the average weight of a railway car loaded with coal. High altitude flying is desirable on account of weather conditions, but requires provision of comfort for the passengers and structural problems resulting. At 20,000 ft the atmospheric pressure is approximately 7 lb per square inch, temperature —12 F, but a much lower temperature may be experienced.

Extract from Discussion

Dining area of Boeing B314 Clipper Seaplane





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