PRODUCING THE DC-8 JETLINER

by

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The decision to commit the resources of the Douglas Aircraft Company to the DC-8 Jetliner was announced June 7, 1955, by Donald W. Douglas, Sr., founder and board chairman of the company.

When the DC-8 made its maiden flight May 30, 1958, it culminated 12 years of study of every phase of the jet transport problem. There was no prototype airplane. The first one took to the air while assembly operations were under way on number 14. (Fig. 1)

The DC-8 assembly facility, an integral part of the Long Beach division, was planned so that space would not impose any limits on the most efficient production methods.

This $20,000,000 facility, first to be built for the exclusive manufacture of commercial jet transports, embraces a total of more than 26 acres--or 1,143,043 square feet.

It consists of two massive buildings, one for structures assembly and the other for final assembly, plus three smaller service buildings, a paint building large enough to cover the entire DC-8 and an adjoining wing-tank sealing booth. (Fig. 2)

They are located on a 55 acre site directly east of the main Douglas plant and adjoining the Long Beach Municipal Airport.

Production lines determined the size and dimension of the buildings. The wide bays, for example, permit assembly of the swept-wing as a single unit with only one splice on the center line of the airplane.

Largest of the two buildings is structures assembly---1144 feet long and 480 feet wide. It contains three equal bays of 160 foot span.

The final assembly building is also 1144 feet long but has two bays, one 160 feet wide and the other 200 feet.

Structures assembly is 57 feet tall at its highest point and the final assembly building is 67 feet. Both ends of the buildings can be opened by means of power-operated hangar type doors.

In the production of the airplane, limited use has been made of integrally-stiffened sheet, chemical milling or plastic parts. Basically the proven methods of construction used in the DC-6/7 series of aircraft have been carried over.

Long fatigue life and fail-safe assurance were the major structural quality goals in the design of the DC-8.

There are three commercial versions of the airplane including the domestic, intercontinental, and extended range models. The last two feature increased wing skin gauges and additional strengthening in other areas to accommodate higher gross weights. All versions have identical dimensions and utilize the same basic tooling.

Major research and development attention was devoted to the wing root design both aerodynamically and structurally. Conventional bending loads on straight wings are transposed into bending and torsional loads on swept wings at the root section. This factor, in combination with the gust loading environment at the altitudes and speeds flown by the airplane, brings fatigue life to its critical values in the wing root. In order to eliminate joints and splices which contribute to fatigue problems, wing spar caps and plating are continuous across the wing root break station.

DC-8 inboard wing skins are stretch-formed across the sweepback and dihedral break. Prior to forming on a four way stretch press, they are stored at a temperature of minus thirty degrees Fahrenheit to prevent age-hardening.

These ten by fifty foot taper-rolled Alclad sheets are among the largest ever produced. When they are ready for forming, a lifting device with suction cups moves the skin into position on the press. The entire operation from refrigerator to stretch press is completed within two hours to minimize normal acceleration of metal hardening.

The wing skins, like the spars and other members, are tapered to provide minimum weight in areas of reduced loads, and maximum strength in areas of heavy and combined loading. The wing skin is thickest at the root and across the fuselage where there are high bending and torsional loads.

The complex contour of the airfoil surface is shaped on the dies of the huge Sheridan four-way stretch press, the only one of its kind in existence. (Fig. 3) It was designed and built to Douglas specifications at a cost of three quarters of a million dollars to perform this single operation on each of the eight inner wing skins of the DC-8. It went into production in a record 120 days after the start of design studies.

On the press, the sheet is gripped by four jaws while two hydraulically powered hold-down clamps fix the skin against spanwise movement. Each jaw pulls with a force of three hundred tons to stretch the airfoil contour in the area of the dihedral break.

After the contour is checked, the skin is trimmed and placed in an aging oven equipped with two 1,650,000 BTU gas burners. It is anodized before it is transferred to the wing tank assembly area.

The wing is fabricated entirely of 7075 aluminum alloy containing 1.6% copper, 2.5% magnesium, 5.6% zinc and 0.3% chromium. All sheets, of course, are Alclad on both sides.

In the domestic version, lower wing plating is roll-tapered from 0.230 in. at the root to 0.064 in. at the tip.

The wing box beam retains Douglas' traditional three-spar arrangement and comprises a complete, integral fuel tank. Spars have conventional sheet webs with riveted vertical stiffeners and 7079ST forged spar caps at the inboard ends that are completely machined. Outboard spar caps are machined from 7075 extrusions.

Wing ribs are of formed 7075S sheet with tab segments along their periphery. These tabs are tied into the skins by clips milled from 7075S forgings. Each wing box beam section is divided into four individual tanks separated by solid bulkheads. When the two wing sections are joined with top and bottom splices, a ninth tank is created by the wing junction. The wing halves thereby create a complete integral wing with a minimum of joints and splices. This design resulted in considerable weight savings over previous configurations and greatly improved fatigue resistance.

During wing tank assembly operation, specified areas are hand filleted with Products Research PR-1422 Thiokol sealing compound. (Fig. 4) This brown paste cures in about four hours at room temperature. This operation is accomplished in wing tank assembly jigs which are 80 feet long with three working levels. They can accomodate four sets of wings simultaneously, each of which can be drilled and riveted from front to rear spar without removal. For efficiency, working crews are alternated, with drilling operations underway on one set while riveting is done on the other. An extensive venting system assures safety and comfort for the workers. (Fig. 5)

After the wing sections are assembled, they are lifted out by one of the traveling cranes of an extensive network which can transport an assembly any place in the building. After placement in the trailing edge-to-tank assembly jig, the pylons, trailing edges and flap hinge fittings are attached.

The sections next are lifted vertically and moved into a horizontal position for the joining of the right and left hand wing sections at the center line of the airplane. During the mating of the wing halves, the final tank sealing and testing is accomplished.

At this time the wing weighs 27,610 pounds. From one closing bulkhead to the other the length is 136 feet without wing tips. Range in chord of the wing is from 340 inches to 74 inches. (Fig. 6)

It is then placed on a dolly to carry it out of the structures building for movement to a separate building where 0.001 inch of protective top coating is applied to the interior of the tanks by a fill and drain method. The entire wing is installed on a massive tilting platform and the tanks are filled. Two hydraulic cylinders, each with a diameter of 14 inches and a seven foot stroke, tilt the wing 10 degrees up and down to insure complete coating of the interior. After the mixture of synthetic rubber compound and solvent is pumped out, hot air is circulated through the interior to cure the coating. The wing had been checked for leaks previously by using the standard "soap-bubble" technique.

Another measure to extend the fatigue life of the DC-8 wing is demonstrated in the automatic drilling and riveting of skin and stringers in one operation on General Drivmatic machines to assure uniformity and even distribution of stresses. (Fig. 7) With this type of construction, the entire DC-8 wing tank assembly becomes a single structure of unique integrity and strength. The National Aeronautical and Space Administration's riveting method is used. (formerly NACA)

The DC-8 incorporates the well-known principles of Douglas fail-safe design. In the tubular pressure cabin, titanium rip stop doublers (Fig. 8) reinforce the external skin at strategic frames and surround every door and window. Among the fail-safe features--window frames are solid, tapered, and blow-out proof and fabricated from a single piece of aluminum stock.

Where testing has indicated unusual stresses, holes are coined to increase fatigue life by reducing stress concentrations.

High tension type fasteners are used throughout the DC-8 fuselage. Huckbolts, for example, fasten the window frames to the fuselage assembly.

In attaching fuselage skins to frames, stringers and doublers, the NASA riveting method again is used. This work is accomplished by using Douglas-designed Manco Crispin riveting machines. (Fig. 9) These semi-automatic machines make a uniform fastening while a clamping action holds the members together under a pressure of 1750 pounds per square inch. On the external surface, rivets are upset into countersunk cavities and shaved smooth. Sealing qualities and fatigue life are greatly improved by this method and there are no irregularities on the exterior of the cabin to cause drag.

In flight, jet engine noise is barely audible forward of the engine tailpipes but to the rear of the passenger compartment extensive weight penalties in non-structural sound proofing would have been required if Douglas engineers had not tried a new design concept. Structural engineers asked themselves this question, "Since mass of material is being sought, why not use metal for sound alleviation in the aft section?"

Following extensive tests this simple concept proved to be an ideal solution. In all DC-8's the rear portion of the fuselage is lined with extra thickness plating and closely spaced longitudinal stiffeners of a flattened hat-section. (Fig. 10) This proved desirable because of the longer fatigue life obtained for the aft fuselage with no increase in weight penalty.

The aft fuselage is covered with 7075ST skin, and the forward area, which is supported by conventionally spaced stiffeners, is covered with 2014ST skin. The stress level in the aft section is only about one-half that of the forward area. Skin gauges in the forward portion are typically 0.060 in. and those in the aft section typically 0.080 in. A minimum skin thickness of 0.050 is used in the pressure cabin section.

The lower fuselage, which is built in two sections, contains 16 panels. The sections are constructed in an upside down position and secured in turning rings to place them physically in their proper positions. They are transferred next to dollies before movement to the fuselage joining line.

Special fixtures were attached to the lower sections during assembly. They are used subsequently through the lower half pick-up, turn-over position, fuselage joining line, fuselage installation line, and ultimately the wing-to-fuselage joining position. Once attached to the lower sections, they need not be removed and are used to index, carry, handle, and support the structures through all of the fuselage major positions plus the critical wing and fuselage joining position. This concept is a valuable time saver in production because it eliminates non-productive time, changing tooling handling fixtures, and also reduces the hazard of handling these large sections to a minimum.

The upper fuselage, containing 18 panels, has stretch-formed, rolled or extruded "Z" transverse frames which are flush riveted to the skins.

After completion as a continuous section, it is hoisted into position directly above the two lower sections in the mating jig and the fuselage is riveted together. (Fig. 11)

The nose section is manufactured in three major sections: lower nose, upper nose, and cockpit enclosure. Material is 0.050 inches 2014ST throughout, with the exception of a 0.100 inch panel above the cockpit.

When fuselage line movement reaches the nose sub-assembly area, nose and fuselage are joined together.(Fig. 12) The entire fuselage length at this point measures 125 feet. It is 162.5 inches deep and 147.0 inches wide with an upper cabin radius of 73.5 inches. Radius at the lower cargo compartment is 68.68 inches. It weighs approximately 19,000 pounds, including the nose equipment items. This does not include doors, windows or floor panels.

When this phase is completed, the fuselage moves sidewise to another track and through several fuselage installation positions. It then proceeds rearward through a paint booth where it receives appropriate customer paint and markings.

Long Beach division's tooling section designed and built two fuselage dollies for transferring the large assembly from the structures building to prevent strains on the fuselage. It is moved by tug and tow bar with steel casters riding over a V track welded to steel plate.

After the fuselage has been moved to final assembly, it is lifted on slings to await mating with the swept wing. The relative ease with which this is accomplished, in only a few minutes, is one of the supreme tests of the production process and of the design and tooling engineering behind it. (Fig. 13)

There are 13 positions in final assembly, twelve within the assembly building and one outside where each fuselage completes a pressure check before going down the final bay. Each cabin is proof-tested to 12.33 psi. At normal operating pressure of 8.77 psi the cabin leakage rate must not exceed 150 cu. ft. per minute.

Following this operation, the airframe moves back into final assembly for additional installations and to receive its tail assembly. This is an integral unit containing laminated plastic isolation band panels for HF, VHF and VOR flush antennae. (Fig. 14)

Irregularities on control surfaces affect aerodynamic characteristics of individual airplanes. They affect the stall characteristics, for example, and so they should be kept to a minimum. At the Long Beach division such irregularities have been reduced by maintaining full contour control on the control surface assembly jigs.

An interesting production technique is employed in the trailing edges of the wing and control surfaces. As one example, a billet of unexpanded aluminum honeycomb is milled into a flap vane templet and expanded to full scale in all dimensions. It is inserted in the formed vane skin and bonded to provide a lightweight structure of extreme rigidity and fully-controlled contour.

Smooth surfaces and closely fitted joints are characteristic of all the structures in the DC-8 whether they are large or small. These result from higher manufacturing standards than have been required for any previously built commercial airplane.

Equal emphasis has been placed on the development and testing of the systems of the DC-8. The extremes of altitude and temperature in which the airplane operates put new demands on cabin pressure and air conditioning systems. These were tested for more than a year on a full scale pneumatic system's mock-up, and with cabin sections in environmental chambers.

Actually, test facilities can reproduce more severe conditions than the DC-8 encounters in flight. An elaborate control system jig allowed Douglas and airline pilots to test the DC-8 hydraulic and manual control forces for coordination in a wider variety of flight load conditions than would be possible in an actual flight test program of reasonable duration.

DC-8 elevators, which are manually controlled by cables, employ spring control tabs for aerodynamic boost. Hydraulic pressure controls the powered rudder, but mechanical control is automatically available in the event of hydraulic failure.

It is interesting to note that, during hydrostatic tests, simulating more than 120 thousand flight cycles of take-off, cruise and landing, a single DC-8 pressure-cabin withstood cycles of load exceeding 100 years of normal operation.

The Pratt & Whitney powerplants, last major units to be joined to the airplane, are delivered to Long Beach by Ryan Aeronautical Company. The DC-8's four turbojet engines are available in three basic types, the Pratt and Whitney JT3C and JT4A, and the Rolls-Royce Conway by-pass engines. The latter is built-up at the Douglas Santa Monica division.

Ryan fabricates the engine pylons and pods, making extensive use of titanium for its superior structural strength and heat resistant properties.

Both pylons and wing center sections are assembled against master gauges provided by the Douglas tooling department to assure fit and interchangeability.

The complex nose cowl and assemblies contain the Douglas-developed anti-icing ducts and the blow-away jet device for protection of the engine impeller blades against damage while taxiing or during ground run-up.

In order to provide the aerodynamically clean surface demands of the DC-8 design, the titanium skins are spot-welded to eliminate rivets and screws from the cowl and pod doors.

When the components and accessories are assembled, the completed engine pods and pylons are inspected and approved by Ryan, Douglas, and Federal Aviation Agency inspectors.

For three years, the Douglas company engaged in the development, design and testing of a combination noise suppressor and thrust brake for the DC-8. Nearly nine hundred variations were tested and the production version was selected on the basis of obtaining the best balance between sound reduction, thrust loss, and drag in an installation compatible with Douglas reliability and safety standards. Sound reduction is accomplished by the fluted pattern of the engine exhaust nozzles, in combination with the retractable ejector.

Thrust braking is done by rotating clamshell-type doors to a closed position with the ejector fully extended thereby deflecting the jet exhaust forward.

Each of the main landing gears consists of dual tandem wheels mounted on a bogie beam. Castered rear wheels give the DC-8 a turning radius of 91 feet.

Interiors vary with the individual airline requirements. The Douglas Palomar unitized seating provides passenger facilities which are built into the seat backs. This offers the ultimate in passenger convenience and interior flexibility.

Four Douglas-designed turbo compressors, located forward of the flight deck, automatically control temperatures and pressurization. A most desirable and unique feature of the interior is the radiant heating of all side panels.

After the airplane leaves final assembly, it is towed to the adjacent paint shop. After painting, it is ready for check-out of all systems on the ramp prior to flight. (Fig. 15)

The DC-8 represents a lengthy technological advance over present commercial airliners, therefore the extremes of speed, altitude and temperature in which it operates place unusual demands on quality control throughout the manufacturing process.

The DC-8 Jetliner was designed by the engineering staff of the Douglas Santa Monica division and they retain engineering responsibility for it.

Although engineering and production responsibility are separated by a distance of 31 miles, no coordination difficulties have been encountered by the thousands of men and women participating in the program. It is a clear indication of the calibre of outstanding teamwork which has been responsible for the production by Douglas of more than half the commercial aircraft flying in the world today.