NWA

NORTHWEST ORIENT AIRLINES 720B JET AIRLINER BY BOEING

FOREWORD

Northwest Orient Airlines this year will note the 35th anniversary of its inauguration of air service.

Through these years, Northwest has flown many types of aircraft, from the slow biplanes of the first years to today's jets.

Integration in its operations of a fleet of Boeing 720B's will enable Northwest, by the end of 1961, to offer 84 per cent of its flight service in turbine-powered airliners—the 720B's added to the pure jet and prop-jet aircraft Northwest is operating today.

Delivery of the 720B's will supplement Northwest's fleet of aircraft and enable the airline in this, its 35th anniversary year, to offer the best, fastest and most efficient service in its long history.

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HISTORY OF NORTHWEST ORIENT AIRLINES

The history of Northwest Orient Airlines is one of pioneering—over rugged mountains and vast oceans—and of the development of an international carrier from a small, regional airmail route.

The second-oldest air carrier in the United States with a continuous identification, Northwest began operation October 1, 1926, as an airmail carrier between Minneapolis/St. Paul and Chicago.

The Company was incorporated August 1, 1926, as Northwest Airways, a Michigan corporation. It was backed financially by businessmen of Detroit and Minneapolis/St. Paul. Control later shifted to the Twin Cities group.

Northwest inaugurated passenger service in July, 1927. Service continued for three months before it was suspended for the winter. In 1927, the Company carried 106 passengers.

In 1928, Northwest Airways began the route expansion that saw it develop in 20 years into Northwest Orient Airlines, one of the world's largest domestic and international airlines that now carries more than two million passengers yearly.

From 1928 through 1933 NWA expanded westward, city by city, through the Dakotas, Montana and Washington State.

Northwest Orient Airlines now serves a 20,000-mile route system stretching from New York/Newark and Baltimore/Washington, D.C., across the northern tier of states to Portland and Seattle/Tacoma. It also serves a domestic route between the Upper Midwest and the southeastern cities of Atlanta, Ga., and Tampa, St. Petersburg, Clearwater, Fort Lauderdale and Miami, Florida.

Northwest's "overseas" and international routes serve Honolulu, Hawaii and Anchorage, Alaska, and the cities of Winnipeg and Edmonton, Canada. It operates over the North Pacific "Great Circle" route from Seattle/Tacoma to Tokyo, Japan; Seoul, Korea; Taipeh, Taiwan; Naha, Okinawa and Manila. It also operates a Polar Imperial route from New York to Anchorage to the Orient.

Since its inception, Northwest has grown from within, expanding its route system in an orderly and logical manner, without taking part in an airline merger.

Northwest's route expansion through the northern areas—Canada, Alaska and the Aleutian Islands—came after World War II although Croil Hunter, long-time pioneering president of NWA and now its Board Chairman, visualized a "Northwest Passage" to the Orient in the early 1930's.

(The "Great Circle" route across the Pacific flown by Northwest is considerably shorter than the mid-Pacific route because it is far north of the earth's equatorial bulge. From New York City to Hong Kong, for instance, is 9,245 miles via the Great Circle, 11,154 miles via the mid-Pacific.)

Because of Northwest's experience flying northern transcontinental routes, the United States government called on Northwest at the onset of World War II to set up and operate a military cargo route to Canada, Alaska and the Aleutians.

With military C-46's and C-47's Northwest's pilots flew more than 21 million miles with a performance factor better than that of many airlines operating domestically at the time.

Four Northwest pilots were awarded Air Medals by the President of the United States for their contributions to the war effort and to aviation while flying this Northern Region operation.

Northwest's experience in this area during the war was taken into account by the Civil Aeronautics Board when NWA's Orient routes were granted and the vision of a "Northwest Passage" to the Orient became reality.

Northwest made other notable contributions to the war effort. It set up and operated a bomber modification plant in St. Paul, Minnesota, and another at Vandalia, Ohio. Thousands of B-25 and B-26 bombers were flown directly from manufacturing plants to these modification centers and outfitted for "cold weather" operation in northern areas of the world. Bombers modified at Northwest's bases were among the first to bomb the Kiel and Ploesti oil fields, and they pulverized enemy defenses in Normandy on D-day. Northwest also cooperated with the Air Force in several vital projects, among them research into plane icing, communications static and high altitude flying.

Because of Northwest's experience flying the short Great Circle route across the Pacific, the Air Force in 1950 called on Northwest to be a prime contractor in the operation of the now famous Korean Airlift which began shortly after the Korean war broke out in June of that year.

Flying DC-4 aircraft, Northwest completed 1,380 Korean Airlift round-trip trans-Pacific crossings—a total of more than 13 million miles—before its part in the airlift was completed. During this period Northwest flew 40,000 soldiers and 12 million pounds of high-priority military cargo—from bomber engines to medical supplies—across the Pacific Ocean.

This was done with no disruption to Northwest's regular commercial schedule of trans-Pacific flights.

Northwest crews, based in Tokyo, also operated "UN-99," a United Nations DC-3, which carried a UN observer team to Allied positions in South Korea during the fighting.

Northwest started operations in 1926 with two rented planes, an OX-5 Curtiss Oriole and an OX-5 Thomas Morse, both open cockpit jobs. Its first "fleet" consisted of three 85 mile-an-hour Stinson "Detroiters." They carried three passengers and were so named because they were designed by Eddie Stinson and built in the Motor City. They were the first closed-cabin planes used by any commercial airline.

"Detroiters" were followed by the all-metal Hamilton high-wing monoplane, the Ford Tri-Motor (advertised as the plane with "windows that open and close and complete lavatory facilities"); the Waco J-6; Travelaire 6000; Lockheed Orion; Lockheed 10A (Electra); Lockheed 14H (Zephyr); a Sikorsky Amphibian (used between airports in the Twin Cities and the Duluth, Minnesota, boat harbor); the Douglas DC-3; Douglas DC-4; Martin 202; Boeing B-377 Stratocruiser; Douglas DC-6B; Lockheed 1049G Super Constellation; Douglas DC-7C; Lockheed L-188 prop-jet, Douglas DC-8C and the latest, the Boeing 720B turbo-fan medium jet airliner.

In 1954, Donald W. Nyrop was named president of Northwest Orient Airlines. Mr. Nyrop replaced Gen. Harold R. Harris who held that position briefly. Croil Hunter, NWA president for 15 years previous to the advent of Gen. Harris, still serves as Board Chairman.

Mr. Nyrop is a native of Elgin, Nebraska and was graduated from Doane College, Crete, Nebraska in 1934. He taught high school at Humboldt, Nebraska during the school year 1934-1935.

In 1935 he went to Washington, D.C. to study law at George Washington University. He received his LL.B. degree from that school in 1939. While attending Law school he worked as an auditor in the government's General Accounting office.

In October, 1939, he became an attorney in the General Counsel's office of the Civil Aeronautics Authority. On January 1, 1942, he was named special assistant to the chairman of the Civil Aeronautics Board.

He served with the Army Air Force from August, 1942 until January, 1946, being stationed in Washington as executive officer for operations of the Air Transport Command. He left the service with the rank of Lieutenant Colonel.

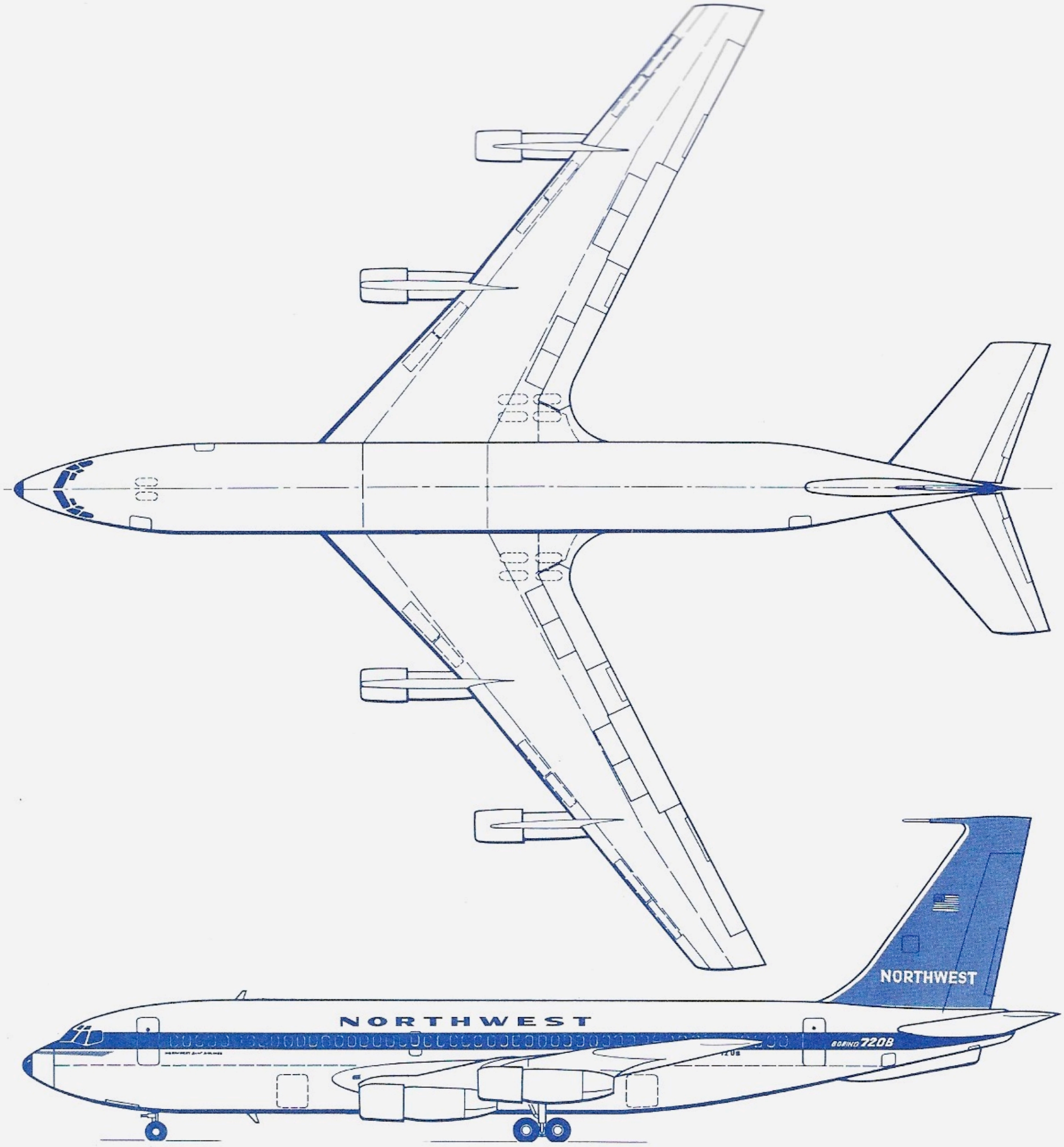
In 1946 Mr. Nyrop joined the Air Transport Association of America. He represented the carriers of this organization as a member of the official United States delegations at the International Civil Aviation Organization operations conferences in 1946 and 1947.

In July, 1948, Mr. Nyrop returned to government service as deputy administrator of the Civil Aeronautics Administration. By Presidential appointment, he served as Administrator of the Civil Aeronautics Administration in 1950 and 1951.

He became chairman of the Civil Aeronautics Board in April, 1951, and remained in this position until October, 1952. In January, 1953, he joined the law firm of Klagsbrunn, Hanes and Irwin as a partner. It was from this private law practice that he came to Northwest Orient Airlines.

Important dates in Northwest's route expansion:

- June 1, 1945: Northwest became the nation's fourth transcontinental airline when service was extended eastward from the Twin Cities to Newark and New York City via Milwaukee and Detroit.
- Aug. 1, 1946: Northwest was certificated to fly to the Far East via the short "Great Circle" route.
- Sept. 1, 1946: Northwest began operating into Anchorage, Alaska, via the "outside" route up the Canadian and Alaska coasts from Seattle/Tacoma.
- Jan. 2, 1947: Service to Anchorage began via the "inside" route from the Twin Cities across northwestern Canada, with Edmonton, Alberta, a fuel stop.
- July 15, 1947: Scheduled service began to the Orient. Stops included Anchorage, Tokyo, Seoul, Shanghai, Okinawa and Manila.
- March 15, 1948: Service was extended to Washington, D.C., from Detroit via Cleveland and Pittsburgh.
- Dec. 2, 1948: Northwest began service to Honolulu, Hawaii, from Seattle/Tacoma and Portland. Northwest was the first airline certificated to link Hawaii with the Pacific Northwest.
- April 30, 1950: Edmonton, Alberta, became a passenger stop on the "inside' route to Alaska and the Orient.
- June 30, 1950: Northwest extended its service to the Chinese Nationalist island of Formosa (Taiwan).
- Oct. 30, 1955: Northwest began direct service between Chicago and New York.
- Dec. 6, 1958: Service inaugurated to Tampa/St. Petersburg/Clearwater and Miami, Florida from the Upper Midwest.
- Sept. 27, 1959: Service inaugurated to Atlanta, Georgia.
- Jan. 1, 1960: Service inaugurated to Fort Lauderdale, Florida.
- Dec. 15, 1960: Service inaugurated to Baltimore, Maryland.



DETAIL OF THE NORTHWEST ORIENT AIRLINES BOEING 720B

Manufacturer	The Boeing Company, Seattle, Washington
Model	720-051B
Seating Capacity	Maximum 139 economy; Normal 107 (38 First Class forward, 69 Tourist aft)
Cargo Capacity	1390 cubic feet
Operating Speeds	Takeoff—170 miles per hour; Maximum Cruise—625 miles per hour; Landing—150 miles per hour
Cruising Altitude	25,000 to 42,000 feet
Range	Over 3200 miles and still allowing for normal operational reserves
Engines	Four Pratt and Whitney JT3D-1 with thrust reversers
Static Takeoff Thrust	17,000 pounds per engine
Maximum Gross Weight	235,000 pounds
Fuel Capacity	14,700 gallons
Payload	32,000 pounds
Length	130 feet 6 inches
Wing Span	130 feet 10 inches
Tail Height	41 feet 6 inches
Fuselage Width	12 feet 4 inches
Cabin Pressure	7000 feet at 40,000 feet airplane altitude; sea level cabin at 22,500 feet airplane altitude

BEHIND THE NEWEST JET AIRLINER

FLASHBACK

The newest jet airliner in the sky is the Boeing 720B. It is the fastest airliner now in operation. Yet it can operate from runways as short as those used by the propeller airliners it replaces.

New as it is, this latest Boeing has a long and impressive background—a background that imparts to it safety and reliability not easily or quickly achieved. Its background begins with the first successful turbojet engine.

POTENTIAL UNLIMITED

The turbojet engine operates according to Newton's Third Law of Motion: For every action there is an equal and opposite reaction. A toy balloon, blown up and then released, is a rudimentary jet engine that illustrates the operation of a powerplant under this law. Just as the air rushing from the balloon produces thrust to speed the balloon in the opposite direction, so the gases exhausted from the jet engine cause the reaction which pushes the airplane ahead. The simplicity of the toy balloon is not quite equalled by the modern aviation turbojet, but the modern turbojet is nevertheless vastly more simple than the large modern piston engine: it requires no propeller, no reciprocating pistons, no complex engine control or ignition systems.

At the time turbojet engine development began, piston engines had almost reached their practical maximum in size and complexity and speed of operation. They were limited in maximum power potential. Because they employed propellers, they were limited in speed, for as the propellers rotated their tips came up against the "sound barrier" and at that speed lost efficiency.

There were no such limits on the turbojet. It could grow into a much more powerful engine than any of its weight ever designed. Its speed was practically unlimited. The turbojet thus opened up new horizons in air transportation.

Working with this growth potential engineers developed the turbofan engine—the power plant utilized on the 720B airplanes. The turbofan is basically the same as the turbojet but is more efficient, providing more power and speed with less fuel consumption.

LARGE JET AIRPLANES BY BOEING

The Boeing Company began design studies of large jet airplanes shortly after the first jet airplane flew in World War II. In these studies, the great potential of turbojet power plants was linked with large military airplanes.

At the close of World War II, Boeing engineers went to Germany and there studied captured German data on wings that were raked—or "swept"—backward. The German data was correlated with information gained in concurrent studies by the United States National Advisory Committee for Aeronautics. The swept wing, it was shown, could cut through the air better than a straight wing of the same thickness. Thus it could approach closer to the speed of sound.

At Boeing it was also found that flexible swept wings of a certain "aeroelastic" design would have a cushioning effect when the airplane flew through air bumps caused by gusts of air. Flying through these, the wing would flex slightly. This meant a smoother ride.

Boeing engineers also determined after much study and many tests that the best way to place jet engines on large multi-jet airplanes is in pods suspended on struts below and forward of the wing.

Flexible swept wings and pod-mounted engines were features incorporated in the Boeing B-47 Stratojet medium bomber, which first flew in December, 1947. Proved and refined in this airplane, they also became a part of the giant, eight-jet B-52 heavy bomber, along with new jet plane developments such as wing spoilers and manual flight controls. All these features were proved in flight operations by large Boeing jet airplanes long before the first Boeing commercial jet transport first took to the air.

Boeing jet airliners include in their family tree jet transports built of nothing more substantial than paper. These "paper airplanes" were some 150 important design studies of turboprop and turbojet transports carried out between 1946 and 1952. The studies took full advantage of what The Boeing Company had learned in building and flying large military jet aircraft. Among them were small, medium and large jet transports. Each design was carefully evaluated mathematically to determine if it would satisfy airline requirements for a safe, practical and economical airliner. In 1950 one design almost met requirements. But not quite. The Boeing Company, as a pioneering firm in a pioneering industry, had to be sure before going ahead.

$16 MILLION TO WIN

In 1952, an engine of great power with less appetite for fuel than earlier turbojets was finally developed by the respected firm of Pratt & Whitney Aircraft. Boeing preliminary design engineers applied the engine characteristics to a Boeing jet transport design and came up with the first airplane that could meet the demanding requirements which Boeing itself had established—a jet transport safer, more economical and easier to maintain than contemporary propeller-driven transports, with jet speed and comfort in addition.

Facts on the design were presented to the Boeing directors in the spring of 1952. In spite of the fact that there were no orders for the jet transport, the directors decided to set aside $16 million to build a prototype. The prototype would serve as a test vehicle and as a demonstrator for military and commercial developments of the basic design. The action of the directors was termed "the $16 million gamble" in some circles.

Virtually a hand-built airplane, the prototype was completed in two years. On July 15, 1954, with A. M. "Tex" Johnston, Boeing flight test chief, at the controls, it made its initial flight from Renton Municipal Airport, adjacent to the Boeing Transport Division plant where it was constructed. From the first it was a successful airplane.

FLYING PROOF

Much has been written about the value of controlled aero-dynamic experiments in wind-tunnels. Boeing, with company-owned subsonic, transonic, supersonic and hypersonic tunnels, makes more use of wind tunnels than any other aircraft company. But Boeing engineers recognize that the final proof of an airplane is in the flying.

As a demonstrator for military and commercial jet transport developments, the prototype soon proved its worth. A month after its initial flight, the U. S. Air Force placed orders for a military development, the KC-135 multi-purpose jet tanker-transport.

But the prototype was no show-room demonstrator. It was a working test airplane. Flight tests of the control and performance of the prototype were carried out. The systems of the airplane were proved in flight and improved and refined where necessary. The structure of the airplane was tried out for strength. The handling qualities were tested not only by Boeing flight test personnel but also by visiting airline pilots who went away enthusiastically proclaiming that the Jet Age would not only be a great improvement for the passengers but for the flight crews as well.

Today the prototype is still working as a test airplane. It has been tested more thoroughly than any other transport-type airplane before it. It has provided flying proof that the airline passenger can travel secure in the finest airliners ever put into service.

SKY-HIGH RECORDS

By the time the first Boeing jet airliner was delivered to an airline in 1958, the prototype had flown 1000 hours and in the process had set up some interesting new flight records.

Most notable flight, was a coast-to-coast dash March 11, 1957. On that occasion, with members of the nation's press aboard, the prototype streaked from Seattle, Washington, to Washington, D.C., in 3 hours and 48 minutes. Average speed for the 2350 miles was 612 miles per hour.

Earlier the prototype had flown to new heights and new speeds for transport airplanes. Within a few weeks of its initial flight in mid-1954, the prototype had climbed to an altitude of more than 42,000 feet.

The prototype also flew repeatedly to Mach .96—96/100ths of the speed of sound—gathering invaluable high-speed stability and control data.

It was flown by more than 150 visiting airline and military pilots, without the least difficulty. It carried aloft more than 1500 airline and government officials from all parts of the world. In flying 1000 hours it covered a distance equivalent to 20 times around the earth.

More important, it provided data which was useful not only to the designers of the jet airliners which were developed from it but also to the planners preparing for operation of the airliners.

Flight test data, accumulated during six years by a battery of special instruments, was gathered on 105 miles of oscillograph paper and 50 miles of movie and data-recording film.

Today the grand old pioneer of American jet transports is still flying, helping develop and prove refinements that will be found in Boeing jet airliners of tomorrow.

DESIGN PHILOSOPHY

A SET OF PRINCIPLES

Every airplane has behind it a set of principles which are an expression of a philosophy regarding design and performance. In the revolutionary Boeing jetliners, the philosophy of the design, far from being revolutionary, is reasonable and practical. In spite of the speeds of more than 600 miles per hour planned for the airplane, its design was based on principles that are mandatory in any form of public transportation: Safety, Dependability and Economy.

These are interrelated, but safety was the primary consideration. In Boeing airliners, the airplane as a whole and each of the parts making it up was designed with safety in mind. Off-the-shelf items, already fully proved in airplane use, were incorporated whenever possible. All parts which were to undergo flight loads were designed with a substantial factor of safety. The "dual path" concept of structural design was followed so that if one member were ever to fail the stresses it carried would be safely imposed on a neighboring structural member. All parts of the Boeing jet airliners were designed so that even if the chances of failure were remote, any failure would never interfere with the safe operation of surrounding parts or the airplane as a whole. This is "fail-safe" design. To provide a margin of safety not found in other means of transportation, each system is backed up by reserves. The electrical system, as an example, can operate essential electric equipment even when three of the four generators are inoperative.

For economy of operation, the airplane was designed to have a high work capacity—to carry a large number of passengers at very high speed. Since the work capacity of the airplane depends on its being in the air as much as possible, "turn-around" time was cut to a minimum by design simplicity, which results in simple maintenance and quick servicing, and by the dependability of the airplane as a whole.

With the Boeing 707 prototype, the dependability, economy and safety of Boeing jet airliners was proved long before the first passenger stepped into the spacious cabin. The development incorporated in these newest Boeings—the leading edge flaps that add lift at low speeds and the wings with increased sweep for higher cruising speeds—were proved in flight on the prototype.

JET THRUST FOR JET SPEED

BIG POWER, SMALL PACKAGE

Each of the Boeing 720B's Pratt & Whitney JT3D engines weighs only 4198 pounds, yet produces enough power to lift more than eight tons straight up. Power of a jet engine is expressed in pounds of thrust, and each pound of thrust equals one horsepower at 375 miles per hour. The 720B's engines are rated in the 17,000 pounds of thrust class. To equal the cruising power of the Boeing jet airliner, a piston airliner would require 43 engines.

The jet engine which provides this power is called a turbofan. It differs from its predecessor, the straight turbojet, in that a third stage, or fan, is added at the forward end of the engine replacing a portion of the first stage compressor. Some of the air taken in by the engine is exhausted immediately through an outlet duct just behind the fan to provide added thrust. The remainder flows through the compressor section as in the conventional jet engine. It is compressed and fed into eight burners where fuel is added and ignited. When the engines are producing takeoff power, each burner puts out enough heat to warm 300 average homes.

These hot gases rush on through the turbine section where the turbines take some of the energy out of the stream to drive the forward compressors and fan. The remainder is exhausted out the engine's tailpipe and it is this energy plus the fan exhaust energy in the form of thrust which powers the airliner. Cruising at 35,000 feet the engines produce a thrust equal to nearly 24,000 horsepower in addition to powering hydraulic, pneumatic and electrical accessories.

The larger inlet and the fan result in a greater quantity of air being taken into the turbofan than into the conventional turbojet engine. Additional air intake is provided at low speeds through eight circumferential doors at the front end of the cowling. During cruise these spring-loaded doors close to cover these inlets.

As a result of the fan arrangement a more efficient use of the air is made, providing an increase in thrust and speed with lower fuel consumption. The four engines are housed individually in Boeing-developed pods suspended below and forward of the wing.

REDUCING SOUND AND SPEED

An additional advantage of the turbofan engine is the definite reduction in sound levels below that of the straight turbojet engine. In fact, this reduction was found to be so favorable that the turbofan has been approved for operation without the need of sound suppressing devices. The reason for this lies in the nature of sound itself. The sound of a jet is caused by the engine's exhaust moving out the tailpipe at a very high speed and shearing through the ambient air. In the turbofan, this exhaust moves at a slower velocity with a proportionate reduction in sound.

To obtain the maximum braking effectiveness after landing the turbofan engine utilizes thrust reversers at both its forward and aft ends. Operated by the pilot, these simple, fail-safe devices direct nearly half of the engine's thrust forward to slow the airplane. At the fan, or forward end of the engine, a portion of the cowling is moved back and the fan air is directed forward. A second section of cowling is moved aft to expose fixed reverser vanes around the engine. Clamshell doors are closed over the tailpipe blocking the normal flow and directing the exhaust through the reverser vanes. When not in operation this trimly-tailored cowling encloses the engines keeping them aerodynamically "clean" and reducing to a minimum the effect of drag.

GOOD PERFORMER

Boeing jet airliners were designed to be good performers under all conditions of flight, from takeoff to landing. They can cruise at the speed of a .45 caliber pistol bullet, yet slow down to land at less than 130 miles per hour. They can climb at more than 3000 feet per minute—at more than 1000 feet per minute on only three of their four engines. If necessary, they can descend at 15,000 feet per minute. Even with a full load, the Boeing jet airliners can fly on any two of their four engines. At lighter weights, they can continue on only one engine. They cruise at altitudes from 25,000 to 42,000 feet, above virtually all weather disturbances. The takeoff run required depends on the weight of the airplane. Landing, using wheel brakes with no assistance from the reverse thrust, the jet airliners can be stopped in 1200 yards or less. In flight the Boeing jet airliners consume about 2000 gallons of fuel per hour. However, when this figure is broken down, fuel consumption is good even by passenger car standards—between 30 and 40 miles per gallon per passenger.

CABIN, COCKPIT AND CARGO HOLDS

STREAMLINED ROOM

The fuselage of the Boeing jet airliner in flight is like a rigid, streamlined, aluminum-alloy room filled with air at a pressure of 8.6 pounds per square inch or less. The fuselage is 130 feet 6 inches long, 14 feet 2½ inches deep and 12 feet 4 inches wide. Like the rest of the airplane, the fuselage is constructed so that it is as light in weight as possible, yet as strong as it needs to be to withstand all the stresses imposed by the most severe flying conditions encountered in airline flight. Added to this strength is a substantial safety factor.

Destined for very long service life, the fuselage is a "fail-safe" structure in every detail. If a crack were ever to develop at a critical stress point, at least one other part of the structure would be standing by to take the full load with strength to spare. Special metal bands called "tear-stoppers" are installed circumferentially inside the fuselage skin. Doors and windows are set in sturdy aluminum forgings, especially stressed.

The fuselage is constructed in three major sections: the control cabin, the main cabin, and the tail cone that supports the empennage—the fin, rudder, horizontal stabilizer and elevators.

Materials for the structure were carefully chosen for their strength under the type of structural loads 707 prototype flight tests showed would be encountered in service. Fabricated mainly of high-strength aluminum alloy, the fuselage also includes stainless steel and magnesium where the use of these materials is advantageous.

The Boeing fuselage design has been evolved step-by-step from the first pressurized transport in the world, the Boeing 307 of 1939. Other pressurized Boeing airplanes include the B-29, B-47, B-50, B-52, KC-97, KC-135 and Stratocruiser.

LARGE, SPACIOUS CABIN

From the passenger's point of view, a considerable attraction is the large, bright cabin. Cabins of earlier airliners resembled tubes. Not so this Jet Age cabin. It is broad and spacious; width of the floor averages 10 feet 8 inches. Its ceiling is more than seven feet from the floor. Its length is more than one and a half times that of a standard bowling alley. Except for the extreme back and forward ends, the cabin is constant in cross-section size. Into the carpeted floors of the cabin are recessed seattracks which permit seats and cabin partitions to be moved quickly, to change the space between rows of seats or the size of each cabin section.

HANDY PACKAGE

An innovation on Boeing jet airliners is the Passenger Service Unit. One of the packages of conveniences is fitted below the hat rack over each row of seats. Each Passenger Service Unit contains three reading lights; three individual fresh air outlets; a cabin attendant call button; illuminated seat row number; and "No Smoking—Fasten Seat Belt" sign. In alternating Service Units, a public address system speaker is installed through which can be broadcast announcements by crew members and recorded music. Not seen but ever ready in each unit is an oxygen mask for each passenger. Like the seats and partitions, Service Units can be moved when passenger cabin configuration is altered, so that no matter what class the cabin, or what the seat spacing, each passenger has a perfectly positioned service unit at his fingertips.

BETTER VIEWING

Eighty-eight windows consisting of 176 panes of stretched acrylic plastic and 88 panes of light Plexiglas make up a good part of the Boeing jet airliners' passenger cabin wall. With two windows on each side of each row of seats, even the passenger sitting on the aisle can look out on the landscape, seascape or cloudscape from his Jet Age vantage point. In flight, the outer pane of the three-pane window is under constant pressure, up to a maximum of 8.6 pounds per square inch, exerted by the air used in pressurizing the cabin interior. This pressure is equal to that exerted by water at 18 foot depth. Standing in reserve at all times, should the outer pane ever fail, is the middle pane, equally as strong as the outer. The inner pane is lightweight plexiglas. The windows, slightly tinted against glare at high altitude, are set in a strong aluminum forging which is securely fastened to the frame of the airplane. Each window is equipped with an opaque sliding window-blind. All pressure panes are tested to more than 12 pounds per square inch. Individual panes selected at random have withstood up to five and one-half tons per square foot pressure in tests.

PUZZLE DOOR

How can a door be opened outward which is larger than its doorway and fits as a plug inside the doorway? Four such doors are fitted on the Boeing jet airliners, two passenger entry doors on the left side and two galley service doors on the right side. When closed, the outward opening plug-type door seals the pressurized air in the cabin. It is opened outward by turning the handle which folds the door's upper and lower edges inward and rotates the door outward, edge first, through the doorway. Simple and fool-proof in concept and design, the door has been flight-proved and ground-tested. In one series of trials, a door was tested under extremely high pressures, tested in a cold chamber to make certain it could be opened even with a coat of ice covering it, and opened and closed more than 25,000 times in a life test. In service, a Boeing jet airliner would have to travel more than 25,000,000 miles before each door would be opened and closed 25,000 times.

BUILT-IN SILENCE

Sound-proofing surrounds the passengers on the Boeing jet airliner. The walls float on rubber to isolate them from outside vibrations and are lined with molded sound-proofing material. The rubber-backed carpets on the floors were chosen for sound-absorbing qualities as well as beauty and wearability. The ceilings are topped by high-density Fiberglas sound-proofing board two and one-half inches thick. Even the underside of the hat racks is covered with acoustical padding. The sound-proofing material deadens the sound of the engines and the sound of the air rubbing over the outside skin of the airplane at 10 miles per minute. It also absorbs the sound of air that is moving into the cabin to maintain pressure and air-condition the large fuselage. Behind the quietness of the cabin were tests carried out with the Boeing jet transport prototype. Pin-hole microphones were fitted into the skin of the experimental airplane to determine the level of sound caused by air friction on the skin. Sound level measurements also tested the sound-absorbing qualities of various types and thicknesses of sound-proofing material. Two tons of sound-proofing material are used in the cabin.

HOUSEWIFE'S DREAM

Colorful walls that are completely washable and removeable—this is a Jet Age feature in the Boeing jet airliner. Taken into account in selecting interior colors was the change in hue and deeper shadows due to the quality of light at high altitude. The walls themselves are made of aluminum alloy panels onto which silk-screened vinyl plastic is laminated. Fingerprints and stains can be removed with soap and water. If a panel is damaged it can be replaced. If a repair must be made to an item inside the wall, the necessary number of panels can be removed to carry out the repair. Formed after the silk-screened vinyl has been laminated onto the aluminum sheets, fabrication and installation of the wall panels is a "white-glove" operation at the Boeing plant and in airline overhaul shops.

HIGH LIGHTING

There's no glare up there in the Boeing jet airliner. Soft lighting is the rule in the passenger cabin. Main cabin lighting is provided by cove lights running the length of the passenger cabin on each side. Slim fluorescent lamps provide the light which is radiated through the translucent grille on the wall under the hat racks. Over the aisle are dome lights which throw a restrained white light. Late at night, when all other lights are out, the aisle dome lights shine midnight blue. Passenger reading lights are provided in the passenger service unit over each row of seats. In each lavatory, a white dome light provides for general illumination, while fluorescent lights are on each side of the mirror. The total number of individual electric lamps in the passenger cabin is more than 600, the precise number depending on the number of passenger seats provided.

CUSTOM ATMOSPHERE

From the thin cold air of high altitude, the Boeing jet airliner cabin air-conditioning and pressurization system makes an acceptably dense, comfortably warm atmosphere for the passengers. Unhampered by the decreasing air pressure at altitude, it maintains comfortable cabin temperature and a "cabin altitude" of 7000 feet at 40,000 feet actual airplane altitude. At 22,500 feet and lower, the passenger cabin pressure can be maintained at sea level.

Air for use in the cabin enters the airplane through small openings above each inboard engine inlet. Two turbo-compressors, one mounted on top of each of the inboard engines and powered by air bled from the engines, compress the fresh air. An alternate system makes use of the air bled from the compressor section of the engine. The air is ducted to two air-conditioning packs, one in each wingroot. There the air is conditioned to the required temperatures and excess moisture is removed. The air is then ducted into the cabin.

Temperature-controlled air flows upward inside the wall keeping it warm and enters the cabin through the same grilles behind which the cove lights are installed. Draft-free, it circulates across the cabin, up to the ceiling and finally downward, still warm, to be withdrawn from the cabin where floor and wall meet.

Pressurization is maintained by controlling the flow of air out of the airplane. Controls for the cabin pressurization and air-conditioning system are on the third crew member's panel in the cockpit. Automatic safety valves make it impossible for the cabin pressure to exceed safe limits.

OXYGEN FOR ONE

If the cabin altitude of the Boeing jet airliner were ever to increase to more than 14,000 feet, each passenger at that moment would be presented with his own personal oxygen supply to breathe while the airplane descended quickly to a lower altitude. Passenger oxygen masks are stowed in the Passenger Service Units above each row of seats. The oxygen line, leading from oxygen bottles in the aft cargo compartment to each mask, is charged the moment pressure decreases below that found at 14,000 foot altitude. A door in the Passenger Service Unit opens automatically and the masks drop out. The oxygen is turned on when the passenger pulls the mask toward his face. Directions for use of the mask are printed on the reservoir bag which is part of each oxygen set.

PUSH-BUTTON FLUSH

Lavatories in the Boeing jet airliner are equipped with flush toilets, which operate at the push of a button.

OBJECTIVE: GOOD WORKING CONDITIONS

Human engineering principles and the suggestions of airline pilots have been closely followed in painstakingly designing the Boeing jet airliner flight deck so that crews will be able to operate the airplane safely and easily under all conditions. Controls, instruments and displays are grouped logically, well within reach and view. Outside visibility is better than in any late model piston-engine airliner, and visibility on the flight deck at night is assured by the most advanced cockpit lighting system ever devised.

JET AGE SIMPLICITY

There are about 100 less controls, instruments and displays in the Boeing jet airliner cockpit than in the cockpit of late piston engine airliners. Much of the simplicity of the flight deck derives from the turbojet engine controls, which have been described as being "simple as a broomstick." Instead of mixture controls, pitch controls, supercharger controls, cowl flap controls and other piston-engine controls, the turbojet requires only a power lever. Instead of the vast spread of instruments required to check on the operation of a large piston engine, there are only five principal instruments for each of the turbojets. The engine instruments are situated in the center of the instrument panel directly above the engine controls, and the needles of all instruments are aligned when engine operation is normal.

Specialists in human engineering developed the layout of controls during design of the cockpit to make certain that every control would be within easy reach of even the shortest flight crew member. They also assured that there would be no confusion between controls. For instance, the landing gear control on the front panel is shaped like a wheel and is moved up and down; the wing flap control handle, airfoil-shaped like a wing flap, is well separated from the landing gear control handle and is moved forward and back. The controls least used are grouped on the ceiling panel above the pilots. Controls and displays for the airplane systems not operated by the pilots are situated on the third crew member's panel.

A GOOD LOOKOUT

The 10 windows in the Boeing jet airliner flight deck provide a vantage for the pilots unequalled in any airliner produced in recent years. Not only is the view good ahead; it is also commanding to the side and somewhat behind. Eyebrow windows in the cockpit roof provide the pilots with a view above the airplane, which is especially valuable during steeply banked turns. Anti-glare shields above the instrument panels keep distracting reflections off the windshield at night. The windshield and one window on each side are electrically heated to prevent both fog and ice. All other windows are electrically defogged. The ability of the inch-thick windshield, sliding side windows and "eyebrow" windows in the Boeing jet airliner cockpit to withstand being struck by birds at jet speeds has been demonstrated. At the F.A.A. Technical Development Center chicken carcasses, shot from a gun, bombarded the windows at velocities equal to jet cruising speeds.

EDGE LIGHTS AND WEDGE LIGHTS

During night operation, flight deck illumination on the Boeing jet airliner is provided by red lights since red lights do not interfere with the pilots' night vision. Actual flight instruments—those which indicate airspeeds, altitude, attitude and direction—are illuminated by edge-lighting, which casts a glow onto the face of the instruments from the entire circumference of the instrument. Engine instruments are illuminated by small wedge-shaped lights. In addition, separately controlled lights are provided for the various crew members' tables, for map-reading and for general illumination of the flight deck.

LIGHTS FOR DAYTIME SEEING

At high altitudes, the thin air does not radiate light as well as at lower elevations. If the jet airliner is flying over cloud, the pilot looking away from the bright clouds to the relative darkness of the cockpit would not be able to read the instruments unless special daytime lighting were included. For that reason, fluorescent white lighting is provided to illuminate the instrument panels, and all sources of flight deck illumination provide white as well as red light.

AIRPLANE WITH A BASEMENT

The Boeing jet airliner fuselage is a "double-bubble" although it doesn't at first glance appear to be. A crease line marks the passenger cabin floor. Below that is the "basement" which contains a number of "rooms." From front to rear, there is the nosewheel well, into which the nosewheel retracts; the electronics compartment; the forward cargo compartment; the airconditioning and electronic antenna bays; the mainwheel wells into which the main landing gear units retract; and the aft cargo compartment. The electronics compartment and forward and aft cargo compartments are pressurized by warm air exhausted from the passenger cabin. Special cooling air is directed into the electronic racks to maintain acceptable temperatures in spite of the heat generated by the radios and other electronic equipment.

HIGH CAPACITY STOREROOMS

The cargo compartments of the Boeing 720B jet airliner are greater in capacity than a medium-sized moving van. Total capacity is 1390 cubic feet. The forward cargo compartment is the same in cross-section throughout. This means that it may be equipped, for use of preloaded containers—special form-fitted units which are filled at the terminal with luggage, mail, parcel post or air freight and can be speedily loaded and unloaded from the airliner. The aft cargo compartment tapers toward the tail.

Cargo compartment doors—one each for the aft compartment and for the forward compartment—are on the right side of the airplane so that loading and unloading will not interfere with passenger boarding. The doors are plug-type which move inward and to one side of the doorway.

Cargo compartments are pressurized.

SWEPTBACK WINGS

GOOD LIFT FROM A NEW WING

The graceful wing of the Boeing jet airliner on which rides the fuselage and all it contains, gives the best "lift" ever given an airliner. So efficient is the wing that from its cruising altitude with all engines stopped it could glide more than 150 miles.

Not only is the speedy wing great at gliding, it is also able to fly closer to the speed of sound and to navigate more smoothly through "air bumps"—gusts and downdrafts—than that of any other airliner in service. Reason: the sweepback and flexibility.

The wing carries along with it the four jet engines, their fuel, the flying controls which bank or lean the airplane to the side, and the flaps which add lift at low speed.

BIG SUPPORT

In a straight line from tip to tip, the Boeing 720B wing span is 130 feet 10 inches—30 feet longer than the first flight of the Wright Brothers' first airplane. Total wing area is 2433 square feet. At its root, the wing chord, or width from front to back, measures 30 feet 9 inches and it tapers toward the tip to a width of 9 feet 4 inches.

The wing was designed according to "fail-safe" principles. It will support at least two and one-half times the weight of the airplane, plus a safety factor amounting to an additional one and a quarter times the airplane's weight.

High-strength aluminum alloy is used for the most part in construction of the wing. At its heaviest, on the underside of the wing, the skin is almost one-half an inch thick. "Honeycomb" of aluminum, cemented or bonded between thin sheets of aluminum to form a light-weight, very-high-strength material, is used in fabricating the trailing edge of the wing.

FLEXIBLE FLYER

The swept back flexible wing of the Boeing jet airliner makes possible greater speed in greater comfort. First such wing on any airliner, it is swept back at an angle of 35 degrees outboard of the engines nearest the fuselage, and at an even greater angle between the inboard engines and the fuselage. In addition, it is an aeroelastic structure so that it can move up and down as the airplane encounters rough air.

The thinner a wing, the better it can cut through air and the closer it can approach to the speed of sound. If a wing meets the air at a slant, it seems to the air to be less thick than it actually is. Thus the swept wing, with greater thickness and fuel capacity, can be as speedy a wing as a thinner wing that is not swept.

The addition of what engineers term a "glove," or extension, to the leading edge of the wing between the inboard engines and the body in the 720B further improves the wing's effectiveness and gives the airplane an additional boost in speed.

The Boeing jet airliner wing, in addition to being swept, is also flexible. Based on experience gained in Boeing B-47 and B-52 wings, the wing is designed so that as the airplane encounters a rising column of air—which produces the bump felt by the passenger—the wing will flex slightly, cushioning the bumps and making for a much smoother ride.

FUEL-FILLED WING

More than 14,700 gallons of aviation kerosene fuel—which is more than the capacity of 10 standard home fuel-oil delivery trucks—can be carried in the wing of the Boeing 720B. This amount of fuel would enable an automobile to circumnavigate the globe eight times. Four main tanks and two reserve tanks are "integral"—that is, the metal wing structure itself makes up the fuel tanks. The center wing tank is composed of a combination of integral and bladder-type cells. When the airplane lands after a long flight at high altitude, the chilled fuel remaining in the wing sometimes causes frost to form on the outside of the wing.

FLYING CONTROLS

CONTROL BY MANPOWER

The aileron and elevator controls of the Boeing jet airliners, which bank the airplane and make it climb and descend, are operated against the great force of the air at jet speeds with the help of the air itself. Proved in operation of the B-52 bomber and the 707 prototype, the ailerons and elevator controls make no use of electric or hydraulic servo motors. Instead they are designed so that air pressure set up in flight, applied to balance plates connected to the forward edge of the control surface and recessed internally, counterbalance the force of the wind stream on the control surface. Thus the control surfaces can be moved manually by moving small tabs on the trailing edge of each surface. The rudder is fully powered.

The flying controls are tailored to provide excellent aircraft control from the slowest speeds to the highest speeds the airliner will encounter. They have been designed according to "fail-safe" principles and incorporate improvements resulting from a continuing development program. Hydraulic gust-dampers, which cushion extreme movement of the control surfaces on the ground due to wind, take the place of control locks, so it is impossible for the aircraft to take off with its controls inoperative.

BANKING ON AILERONS AND SPOILERS

At high speed, small controls have as much effect as large controls do at low speeds, just as a finger held out of an automobile window at high speed produces as much drag as a hand held flat to the air stream at low speed. The unique lateral controls of the Boeing jet airliner—the controls which cause the aircraft to bank or lean to one side—can put "one finger" or a "hand" into the windstream.

The lateral controls are made up of two sets of ailerons, one half-way out on the trailing edge of the wing and the other at the wingtip. The inner set of ailerons operates at all speeds. The outer set operates only at low speeds, coming into play when the wing flaps are extended. This aileron system, in airliner use for the first time on the Boeing jet airliners, grew out of experience gained with the B-52 bomber.

Another airliner first in lateral controls is the use of spoilers. Hydraulically powered, the spoilers are hinged plates on the upper surface of the wing. Raised on one side, they "spoil" the lift produced by the portion of the wing on which they are fitted and cause the aircraft to bank in that direction. They are also used as speed brakes during descent and after landing.

NOSE UP, NOSE DOWN

There is little new about the swept-back "tail feathers" of the Boeing jet airliner except the nose-up, nose-down trimming device and the small ventral fin. In current non-jet airliners, trimming the airplane to fly with its nose up or down or level is done by means of small trim tabs on the back edge of the elevators. On the Boeing, the trimming is done by rotating the leading edge of the horizontal stabilizer either up or down. The pilot controls the trimming by means of a push-button on his control wheel. Manual control of the horizontal stabilizer is by means of a control wheel in the cockpit. The ventral fin under the tail adds to directional stability.

LIFT AND LET-DOWN

Wing flaps are larger in total area than the entire wing of the popular Cessna 170 private plane. New on Boeing jet airliners are small flaps along the wing leading edge. The wing flaps help increase the "lift" produced by the wing and permit the Boeing jet airliner to fly slowly during takeoff and landing.

It's a long way down from jet cruising altitude, and to make possible a swift descent, the landing gear can be extended at high speeds as speed brakes. Extended on both sides at one time, the spoilers are also used as speed brakes. Using landing gear and spoilers together as speed brakes, the Boeing jet airliner can descend at a rate of 15,000 feet per minute—nearly three miles per minute. Such a descent will seldom if ever be experienced by an airline passenger since it would only be made under highly unusual circumstances.

The spoilers are also used as speed brakes as soon as the airplane lands. Raised at that time, they place the full weight of the airplane on the wheels so that the wheel-brakes can be fully effective immediately.

THE JET AIRLINER'S SYSTEMS

ELECTRIFYING POWER

The Boeing jet airliner electrical system, radically different from the electrical systems on propeller-driven aircraft, produces enough 200-volt, 400-cycle alternating current to supply 80 houses. Changeover to alternating current, the type of current generally used in homes, resulted in a decrease in weight of the system since the size of wire required for the higher voltages weighs only one-fourth that required for low-voltage direct current systems used in earlier airplanes. This is an important weight saving in Boeing jet airliners, each of which contains 40 miles of electrical wiring, enough to wire 100 houses.

Four generators, one on each engine, supply electrical power. However, the electric system is ingeniously designed so that the airplane can be safely flown with only one of the four operating. A battery provides power for essential direct current equipment in case of failure of other sources.

The third crew member's panel contains controls and indicators for monitoring the electrical system.

FLUID ENERGY

Hydraulic pressure provides power to operate such things as the wing spoilers, the rudder, the wing flaps, landing gear retraction and extension, nose-wheel steering and wheel brakes. Two separate systems are employed, one powered by engine-driven pumps, the other by electrically driven pumps. Throughout the system, fire-resistant Skydrol hydraulic fluid is used.

GOOD UNDERSTANDING

On the ground, the Boeing jet airliner rolls along on 10 wheels, as fast as 180 miles per hour. Each main landing gear unit is made up of a four-wheel truck, and the nosewheel is a dual-wheel unit. Enough material is contained in the tubeless tires of the Boeing jet airliner's gear to produce 100 automobile tires, and the wheel base from nose gear to main gear is 50 feet 8 inches, five times the wheel base of a passenger car. The main landing gear units retract inward and are housed in the lower fuselage. The nose gear retracts forward and upward. Wheel-well doors close again around the extended or retracted landing gear to decrease drag. A feature of the Boeing jet airliner landing gear is the added hydraulic cushioning on landing provided by the 22-inch travel of built-in telescopic shock-absorbers. Piston-engine aircraft shock absorbers or oleo struts travel no more than 12 inches.

NON-SKID STOPS

Even on ice or snow, the Boeing jet airliner's wheels cannot skid when the brakes are applied. The jet airliner is fitted with a brake anti-skid system first developed by Boeing for the B-47 bomber. This senses the sudden decrease in wheel rotation that precedes a skid and releases the brake momentarily to stop the skidding, thus making possible maximum braking effort with minimum tire wear. Under normal landing conditions, the brakes on the Boeing jet airliner absorb enough energy to stop simultaneously 432 automobiles traveling at 50 miles per hour. During full braking, the brakes absorb enough energy to stop 970 automobiles. The brakes normally act under hydraulic pressure, with enough pressure retained in an accumulator for five operations of the brakes even after a hydraulic failure. A pneumatic system backs up the hydraulic system for emergency use.

BLACK BOXES

From the cockpit of a Boeing jet airliner, the pilots can receive person-to-person calls from the home office, can see 150 miles electronically through storms to spot other storms, can talk to ten positions in and around the airplane, and can guide the airplane accurately from takeoff to landing approach without seeing the ground. All this is made possible by the black boxes in the electronic racks at the forward end of the airliner's lower deck.

The person-to-person calls are carried out through SELCAL which rings a bell in the cockpit when the airline radio operator on the ground wishes to contact the flight crew aloft. The calls are then completed over the company's radio frequencies. The 150-mile "look-see," which penetrates storms, is through the "picture window" of radar. Any of ten different interphone outlets inside and outside the airplane can be used during preflight ground checks and, in flight, for crew communication.

Among other aviation radio equipment that is found on Boeing jet airliners is Very High Frequency (VHF) communication and navigation equipment; High Frequency (HF) communication and navigation equipment; and landing approach aids, including marker beacon receivers and Instrument Landing System (ILS) receivers. In the majority of cases, dual installations of radio equipment are carried. The passenger address system, including provisions for broadcasting restful music in flight, is also part of the electronics system.

The 14 antennas on the Boeing jet airliner are internal, flush, or low-drag types. Gone are wire antennas which, if they broke in flight at jet speeds, could damage the airplane. Blade-like antennas above and below the forward fuselage are for VHF communications and navigation.

So much heat is generated by the electronics that the racks in which the equipment is carried must be specially cooled. In flight, air from the air-conditioning system is directed through the racks; on the ground, a blower, which is turned on automatically, maintains the correct temperatures for the electronic equipment.

AUTOMATIC AVIATOR

A super-sensitive automatic pilot flies the Boeing jet airliner whenever the pilots wish. Not only will it hold courses and carry out turns to new headings, it will also hold given altitudes or follow selected radio beams. So sensitive is the autopilot that at 40,000 foot altitude it maintains height to within 50 feet. It immediately detects a divergence of six feet from the selected altitude and begins correction. Landing approaches in bad weather can be carried out by the automatic pilot when it is coupled with the Instrument Landing System beams transmitted by the ILS systems found at most major airports. The automatic pilot also senses a yaw or swing of the airplane's nose almost before it happens and corrects before passenger or pilots notice that the yaw has begun.

HOT WINGS

Climbing or descending through clouds, the Boeing jet airliner may sometimes encounter super-cooled water droplets which could form a crust of ice on the leading edge of the wing and empennage and slow the airplane. To prevent this, hot air is bled from the engine and flows through small ducts inside the leading edge of the wing. Ice is also kept off the engine inlets by means of hot air from the engines. The tail fin and horizontal stabilizer are de-iced by "electric blankets" which form the leading edge. When icing conditions are encountered, the pilots are warned by the ice-detector which automatically turns on a light in the cockpit. The Boeing jet airliner anti-icing and de-icing systems have been tested in heavy icing conditions.

THE TESTING PROGRAM

PROVED BY PROTOTYPE

By virtue of the 707 prototype and thousands of hours of laboratory work, Boeing jet airliners can be truthfully described as "the most thoroughly tested airliners ever to enter service." The prototype, which has been flying since July, 1954, has been an invaluable test tool for Boeing engineers. First of all, the airplane proved the basic aerodynamic, stability and control excellence of the design. It went on to serve as a test bed for the systems and components to be put into the Boeing jetliners. Where developments were necessary, it was used to test and re-test improvements. As it piled up flight time, the prototype also accumulated performance data which made possible reliable forecasts of airliner operation costs on which the airlines could base their planning. Tests of sound levels produced by the airplane outside and inside aided in design of jet engine sound-suppressors and efficient cabin sound-proofing. Long-range flights on the nation's airways demonstrated the ability of Boeing jet airliners to fit into existing air traffic and to land and take off at existing airports. The veteran of American jet transports, with approximately 1500 demanding test hours in the air, is still fully employed at Boeing as a test airplane for aeronautical developments which may be applicable to future Boeing jet airliners.

BOTTOM OF THE ICEBERG

The testing of a new airplane has something of the "iceberg" concept about it. Only the flight-test program is visible. Below the surface are thousands and thousands of hours devoted to laboratory testing of every part and component in a wide variety of environments. Months before the prototype first lifted off the field at Renton, Washington, in 1954, engineers were busy testing the materials of the airplane. Wing and body panels were built and subjected to loads beyond those expected in flight. Highly accurate scale-models were tested in Boeing-owned wind tunnels. All systems were checked over and over on test benches and by electronic simulators. This work did not stop when the prototype took to the air. Laboratory tests continued simultaneously with flight testing.

Laboratory tests, for example, have subjected the nose gear to more than 8000 simulated normal landings, plus 5000 at twice normal loads. The main landing gear units have completed more than 8000 simulated landings. Both nose and main gear have undergone complete static structural tests. In a single test of a passenger cabin window selected at random, the pane was subjected to 10 pounds per square inch differential pressure 507,000 times. Normal maximum pressure is 8.6 pounds per square inch. In another test the same window was kept at 10 pounds per square inch differential pressure for 5000 hours. In yet another, the same pane's resistance to solvent was tested by dousing it with lacquer thinner and other solvent liquids and fumes and putting it under pressure for a total of 4000 hours continuously plus 400 cycles of pressurization. The unique and practical door of the jet airliner, which combines the advantages of the plug-type with the outward-opening door, was opened and closed more than 25,000 times during tests. These were only a few of the many component tests carried out.

SLICED, PUFFED AND BENT

The structure of the Boeing jet airliners, operating as it does under a demanding environment of speed and pressure differential, was carefully designed and then painstakingly tested under a guillotine, in a giant water tank and in a mammoth static test rig.

Extensive use was made of the multiple-load-path concept in designing the structure, and materials were selected for their resistance to tearing under the most demanding conditions. "Guillotine" tests, in which a giant knife was dropped through pressurized fuselage sections severing multiple load bearing members, proved the capacity of the other members to carry the loads and the ability of the tear-resistant metal skin to hold up even when the structure was damaged.

The structure was static tested to determine its ability to bear the loads for which it was designed. One hundred separate tests requiring 15 months were carried out and were climaxed by bending a wing until it broke. Before breaking, the wing underwent 110 per cent of the load for which it was designed, and it was designed to withstand the maximum it will be required to undergo under the most extreme flight conditions, plus a substantial safety factor.

To test the life of the fuselage structure, a section was placed in a water-filled tank for hydrostatic tests. Hydraulic pressure acting on the water in the fuselage simulated the cycles of pressurization which take place in flight. The fuselage section completed 50,000 "flights" in the hydrostatic tests. At four hours per flight, this would be equivalent to 200,000 flight hours or at least 100,000,000 miles. A Boeing jet transport pilots' cabin also underwent hydrostatic tests, exceeding 70,000 "flights."

GOVERNMENT APPROVED

Boeing jet airliners were the first to receive the stamp of approval of the United States government to carry passengers for hire. The certification was awarded just nine months after the first Boeing 707 airliner took to the air, and the first three 707's to come off the production line took part. Then, as variations of the basic type were developed, the differences were thoroughly tested by the FAA and certificated.

Boeing jet airliners involved in FAA tests have logged a total of more than 3600 hours in the air. Of this total, more than 1300 hours were actually spent in FAA testing, while the remaining time was logged on Boeing flight tests. In the course of the FAA tests, the airplanes reached a maximum true airspeed of 670 miles per hour and a maximum Mach number of .95, or 95/100ths of the speed of sound. Maximum altitude reached was 45,500 feet.

During Boeing tests and FAA certification flights, 143,500 feet of oscillograph paper and 795 miles of magnetic tape have been used to record test data; 36,350,000 data points were actually analyzed by Boeing engineers and supplied to the FAA. More than a million air miles have been flown by the Boeing 707 prototype and the Boeing jet airliners used in FAA certification tests. This is equal to four times the distance to the moon.

FACTORY AND FLIGHT

BUILDING THE BOEING

Boeing jet airliners, as carefully built as any machines ever made, are constructed on a base of paper work. They start as engineering designs. Production plans are then made on the basis of the design. These plans precede delivery of the airplane by two years. They set out in writing and drawings, on 450,000 pieces of paper, every single operation involved in the fabrication, assembly and inspection of a Boeing jet airliner and where and in what sequence it will be carried out. Schedules also are established which must be met so that the close coordination of the complex assembly effort can be maintained. Decisions are made as to what production tools—precision jigs and fixtures—will have to be fabricated. After consideration of available company production facilities, it is decided what parts of the airliner must be produced by other manufacturers. The complex and careful production planning for current jet airliners began even before the first jet airliner was sold.

As planning progresses, Boeing Transport Division representatives begin placing orders for materials, parts and assemblies for the jet airliners. These are produced in all parts of the United States—and engines and electronic equipment for some of the jet airliners are produced abroad.

Soon work on small sub-assemblies begins. Parts flow together as human skill is applied. The high standard of quality which is a tradition in Boeing plants is attained and maintained through careful inspection and relentless quality control. Quality of materials and workmanship and the operation of each part, component, assembly and the airplane as a whole is checked throughout production. The airplane is completed in stages, growing as parts, components and assemblies are brought together and equipment is installed. Finally it is rolled out, undergoes pre-flight preparations and takes off into the element for which it was destined.

TRAINING FOR EXPERTS

The thorough training of airline personnel in the maintenance, servicing and operation of Boeing jet airliners begins at the Boeing Training School in Renton. There the airline's instructors receive the basic knowledge of the airplane and its care and feeding that they will pass on to other airline personnel. Instructor pilots, too, receive their initial Boeing jet airliner ground instruction at the Boeing school. They then proceed to the Boeing Flight Center where test pilots give them transition training on the airplanes themselves. Thus the experience accumulated in six years of jet transport flying is passed on to the people who will operate the advanced airliners on the air routes of the world.

SPARES AND SERVICE

To keep the jet airliners flying, the Boeing Airplane Company Transport Division has set up an engineering service section which is a veritable fund of jet knowledge and a spare parts provisioning system which operates at jet speed. The service section, whose representatives are assigned to airlines operating Boeing jet airliners and are backed up by the technical staffs of the entire Boeing organization, can thus provide the assistance necessary to help the airlines solve operations, maintenance or servicing problems. The service engineers also produce the handbooks and technical publications which aid the airlines in operating and maintaining their jets.

Airplanes on the ground are useless, so the Boeing spares organization has been set up to supply needed spare parts with the utmost speed. IBM methods—including the fabulous Ramac "mechanical brain"—are employed to expedite the filling of spare parts orders.

BOEING JET AIRLINER GLOSSARY

Jet Airliner—A propeller-less airliner powered by jet engines.

Jet or Turbojet Engine—A precision engine which takes in air at its front end, compresses it, adds fuel to it and ignites the combination and exhausts to the rear, past turbines and out the tailpipe, the gasses produced. Since, according to Newton's Third Law, for every action there is an equal and opposite reaction, the gases thus exhausted react against the engine and produce forward thrust. A toy balloon blown up and then released is a rudimentary jet engine.

Turbofan Engine—A jet engine which operates on the same principle as the turbojet, but utilizing a third stage, or fan, in place of a portion of the compressor. The turbofan engine provides more power with lower fuel consumption resulting in a faster, more economical airplane.

Thrust—The force produced by a jet engine, expressed in pounds. At sea level, one pound of thrust equals one horsepower at 375 miles per hour.

Pod—The part of a Boeing jet airliner containing the jet engine and its accessories. On each Boeing jet airliner four pods are suspended on struts forward and below the wing.

Strut—The streamlined pylon on which each jet engine pod is suspended forward and below the Boeing jet airliner's wing.

Spoilers—Hinged plates attached to the top of the jet airliner's wing and hydraulically raised and lowered. Raised on one side only by movement of the pilot's control wheel, the spoilers help bank the airplane. Raised on both sides simultaneously by movement of the speed brake control lever in the cockpit, they act as speed brakes during flight, to slow the speed of the airplane or to enable it to descend quickly without gaining speed. Used thus, they set up a slight harmless vibration felt by the passengers. The spoilers are also raised after landing to "spoil" the lift produced by the wing so that the weight of the airplane is immediately placed on the wheels, making the wheel brakes fully effective.

Aeroelastic Wing—A swept wing which flexes slightly in rough air, cushioning the effect of the "air bumps."

Swept Wing—A wing that slants backward from wing-root to wingtip. The sweep of the wing has the aerodynamic effect of making the wing seem more thin than it actually is as it moves through the air, thus enabling it to cut through the air more easily and approach closer to the speed of sound, while still being thick enough to have the necessary volumetric capacity for fuel.

Manual Flight Controls—Flight controls that are operated by the pilot without the aid of servo motors.

Internally Balanced Controls—Controls designed so that air pressures set up in flight are applied to balance plates connected to the forward edge of the control surface and recessed internally forward of the control surface. This counterbalances the force of the wind stream on the control surface, which can then be moved manually by moving small tabs on the trailing edge of each surface. Not only are the internally balanced controls simple and foolproof, they also become progressively more difficult to move as the airspeed increases. This prevents them from being moved too quickly at high speeds.

707 PROTOTYPE—America's first jet transport, from which all Boeing jet airliners have been developed. The 707 prototype has been flying since July, 1954.

PASSENGER SERVICE UNIT—A unit fitted below the hat rack over each row of seats which contains reading lights, fresh air outlets, loudspeaker, cabin attendant call button, emergency oxygen masks and "No Smoking—Fasten Seat Belts" sign.

LEADING-EDGE FLAPS—Small flaps along the wing leading edge. Flush with the underside of the wing during cruising, they are extended during takeoff and landing, to maintain the excellent lift characteristics of the wing even at the lowest flying speeds.

THRUST-REVERSER—A device installed immediately forward of the tail pipe on the rear of each engine and also just aft of the fan duct in turbofan engines which directs part of the engine thrust forward after landing to help slow the airplane, just as reversing the propeller pitch does on other airliners. When the engine power is increased after landing, it is to increase the re-directed engine thrust and brake the airplane.

BOUNDARY LAYER TURBULENCE—Eddies in a thin layer of air against the airplane's outer skin, caused by the airplane moving through the air. Boundary layer turbulence causes the low sound in the jet airliner's cabin at cruising speed which resembles the sound of a stream heard at a distance.

SPEED BRAKES—Devices to slow the airplane aerodynamically in flight and after landing. The wing spoilers of Boeing jet airliners serve as speed brakes in flight and after landing. The landing gear can be lowered at 370 miles per hour indicated air speed to serve as additional air brakes.

INTEGRAL FUEL TANKS—Fuel tanks made by sealing the structure into a liquid-tight container. Wings of Boeing jet airliners contain integral fuel tanks.

ANTI-SKID BRAKES—Wheel brakes including devices which sense the sudden decrease in rotation that precedes a skid and release the brakes momentarily to prevent skidding.

FAIL-SAFE DESIGN—Design which takes into account the failure of any part, however unlikely failure may be, and ensures that it will not interfere with the safe operation of the remainder of the airplane.

"GUILLOTINE" TESTS—Tests of the Boeing jet airliner structure in which large steel blades were dropped through pressurized fuselage sections to test the ability of the structure to maintain its integrity and the skin to resist tearing even after undergoing damage.

STATIC TESTS—Ground "torture" tests which proved the ultimate strength of the airplane's structure under simulated flight conditions.

HYDROSTATIC TESTS—Pressure tests of the Boeing jet airliner fuselage carried out in a water tank. The tests prove the life of the airplane structure under load cycles simulating actual operation.

MACH NUMBER—Named for Austrian physicist Ernst Mach, Mach number describes the relation of the speed of an object to the speed of sound, Mach 1. Thus Mach .90 is 90/100ths the speed of sound. The speed of sound varies with temperature and altitude. At sea level it is about 760 miles per hour; at 35,000 foot altitude it is about 660 mph.

SHOCK OR COMPRESSION WAVES—Waves formed by the pile-up of air at the point where the air reaches the speed of sound in relation to the airplane. A harmless phenomenon in a well-designed modern airplane, these waves first form when the airplane itself is still traveling considerably below the speed of sound but the air moving over curved portions of the airplane attains the speed of sound. The waves are sometimes visible on the wing as thin lines of light and dark which parallel the leading edge of the wing.

JET STREAM—A narrow band of very high-speed wind, usually found at altitudes from 20,000 to 40,000 feet. These winds generally blow from west to east and reach speeds as high as 250 miles per hour.

STRATOSPHERE—The portion of the atmosphere above approximately seven miles altitude, in which the atmospheric temperature remains relatively constant at about 65 degrees below zero, and only thin ice clouds form. Jet airliners fly in or just below the stratosphere.

TROPOSPHERE—All the atmosphere below the stratosphere. In the troposphere, the temperature decreases rapidly with altitude, clouds form, turbulence is present and the weather is active. Jet transports climb quickly through the weather disturbances in the troposphere and generally fly at the upper limits of the troposphere or in the stratosphere, above virtually all of the weather.