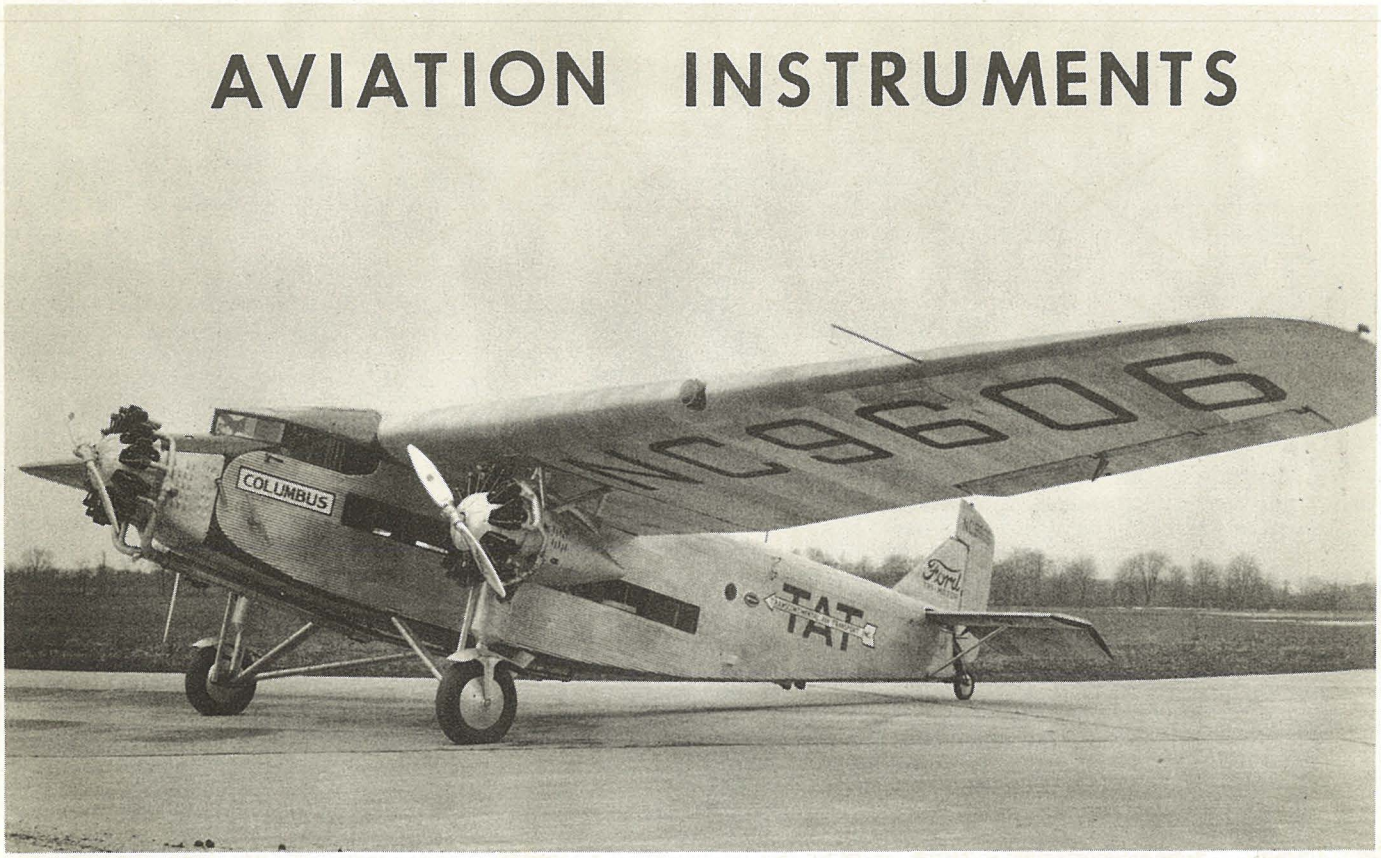
AVIATION INSTRUMENTS



The famous Ford "Trimotor", the CITY OF COLUMBUS, delivered to Transcontinental Air Transport 20 Nov. 1928 and used by Col. Charles Lindbergh as his flying office. It was a model 5-AT-4, S/n 4. (Ref. Larkins: "The Ford Story", p. 53.) Photo - Ford Motor Company.

PART 2

By ROBERT J. SCHEPPLER

THEIR USAGES DURING THE GOLDEN AGE OF SPORT 1928-1938

After Lindbergh's New York-Paris flight, the Dole race from California to Hawaii, won by Art Goebel with William Davis, and various other notable distance flights in the year 1927, the American public suddenly became air conscious. This was what the airframe, engine and instrument designers had been hoping for. Investment money became available and many designers' dreams became reality. Aircraft names such as Curtiss, Fokker, Ford, Travel Air, Stinson, and Waco became well known and in a lesser way, Pioneer, Sperry, and AC Spark Plug began to come to the front in the aircraft instrument field.

Higher powered engines and multi-engined aircraft became more common with a resultant increase in instrumentation. The number of licensed and student pilots jumped from 1,500 to 11,000 during the year 1928. Over seven million miles of air mail flying was scheduled with approximately 97% completed during 1928. This year marked the beginning of true long-range planning for use of aircraft by the Air Corps, airlines, and commercial users. It was the beginning of a period of extensive scientific testing, when the theories developed during the 20's could be tried and proven. Names in the news included Lee Gelbach, Jimmy Collins, Jimmy Doolittle, Roscoe Turner, Steve Wittman, Art Chester, Rudy Kling, Claude Cessna, Benny Howard, Jimmy Wedell, Doug Davis, Jimmy Mattern, Wiley Post and many others. The list of aviation greats who started on their climb to fame and success, as well as those who gave their lives, during these years is almost endless.

Some of the new instruments brought into use during the decade were fuel flow meters, air distance recorders, ice warning indicators, supercharger gages, manifold pressure gages, and operational versions of automatic pilots which were later to become universally accepted to the point that American pilots called them "Elmer" and the British pilots called them "George".

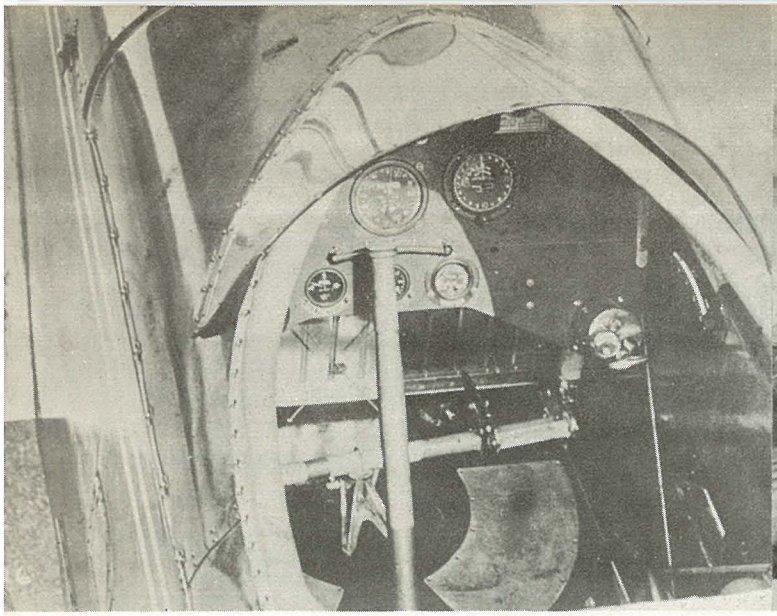
An important innovation was the appearance, on some larger aircraft, of the flight engineer. His duties were primarily to monitor engine instruments and control engine operation. This practice was introduced by Pan American Airlines in their Sikorsky and Martin "Clipper Ships" of the early 30's.

In the late 20's and early 30's a few significant steps in instrument design were taken. Instruments were standardized on 1-7/8 and 2-3/4 inch diameters, and the old system of black numerals on white dials gave way to white numerals on black dials. At a slightly later date numerals and pointers were standardized in size and shape.

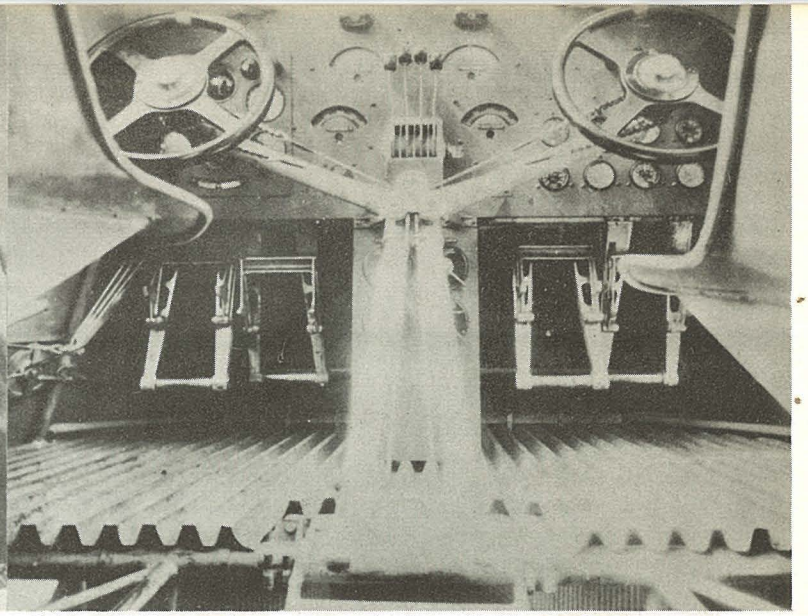
At this point it is interesting to note that the shape of instruments progressed through a complete cycle of evolution. Between 1903 and the mid 20's they were circular in shape with curved dial indications. Between the mid 20's and early 30's there appeared many rectangular shaped instruments with vertical faces. From the late 30's through the mid 50's circular shapes again predominated while from the mid 50's to the present the vertical shapes have become common once more.

Standard Air Corps instrumentation in 1929 specified the following:

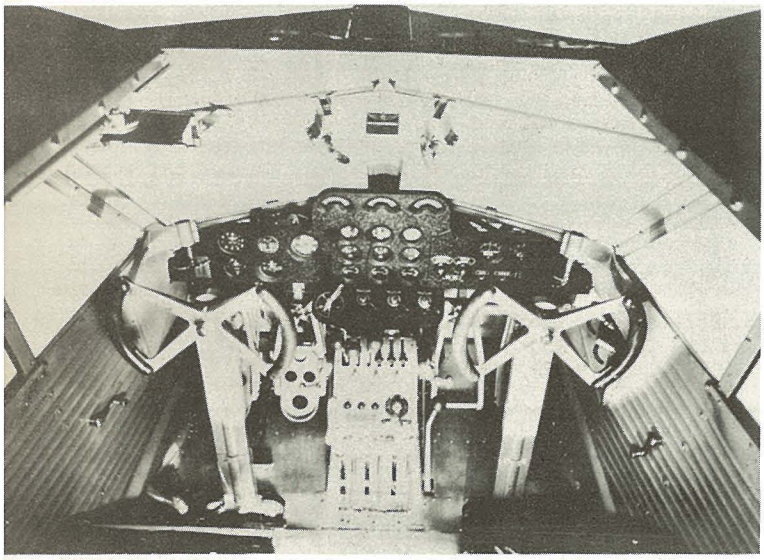
ENGINE	NAVIGATION
Tachometer	Airspeed Indicators
Thermometer	Turn Indicator
Pressure Gauges	Inclinometer
Fuel Level Gauges	Compass



M-2 Mailplane cockpit shows neat uncluttered panel. Photo - Douglas Aircraft Corp.



Fokker F-32 panel was very simple. F-32 was four-engined transport of early 1930's. Photo - Western Air.



Boeing Model 80A transport airplane had best design of instrument panel to date. Photo - Boeing Airplane Co.

Altimeter
Clock
Rate of Climb
Ground Speed and Drift Indicator

A flight indicator was sometimes used which consisted of a combination turn and bank and pitch indicator in a vertical mounting.

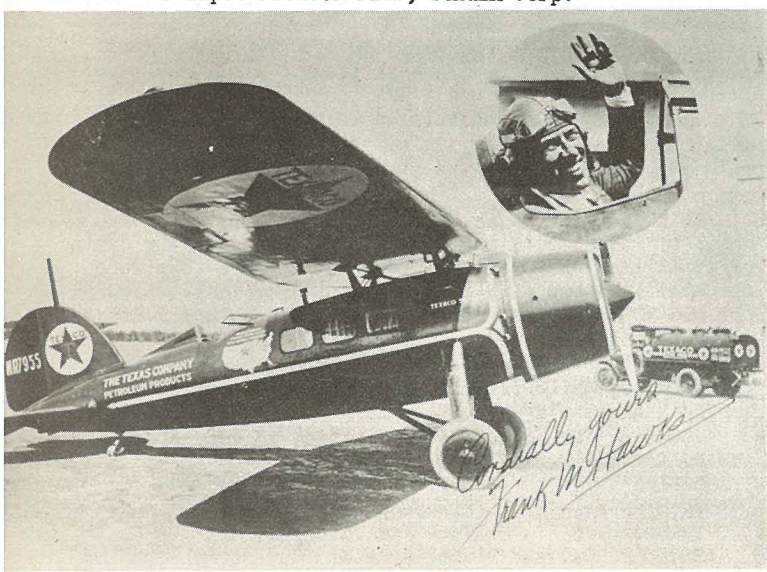
Between the years 1928 and 1938 the rate of aircraft development increased faster than even the most optimistic forecasters had predicted. At the beginning of this period the experienced air traveler rode in luxury in a Boeing 80A or a Ford "Trimotor" at the fabulous speed of 110 mph. Army, Navy, and the Marine Corps pilots protected the country in their Keystone B-7 bombers and Boeing F4B-1 fighters. By the end of the period the United States airlines were flying schedules throughout the world in fast reliable Douglas DC-3's and Boeing flying boats while the services had gone on to Boeing B17's and Seversky P-35's.

Distance flights of a spectacular nature were by this time becoming frequent occurrences. Some of the more notable were:

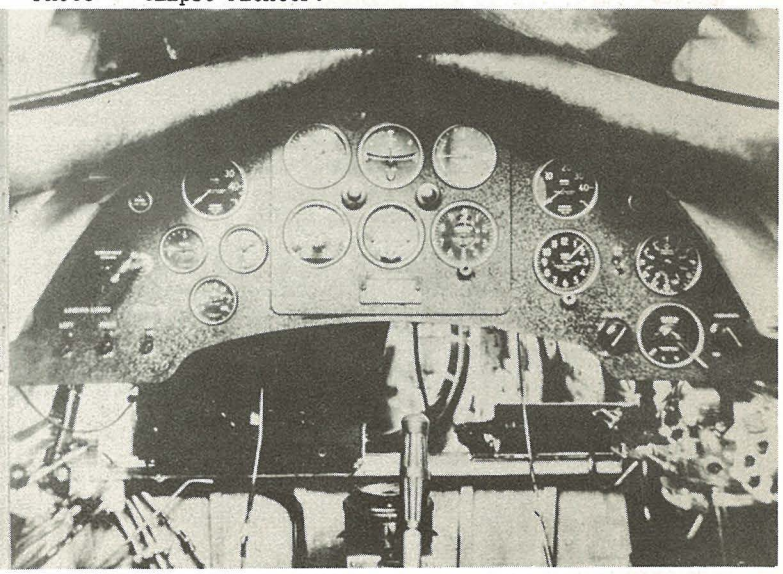
1929 June 28-29 Round-trip transcontinental flight made by Capt. Frank Hawks in a Lockheed "Air Express" in 40 hours, 4 min.

1931 June 23-July 1 Wiley Post and Harold Gatty, in a Lockheed "Vega", the WINNIE MAE, flew

Capt. Frank Hawks and his Lockheed "Air Express". Photo - Eclipse-Pioneer Div., Bendix Corp.



Instrument panel of Frank Hawks' "Air Express". Photo - Eclipse-Pioneer.



around the world in 8 days, 15 hours, 51 minutes. (1)

1932 May 20-21 Amelia Earhart flew solo across the Atlantic from St. Johns, New Brunswick to Londonderry, England in a Lockheed "Vega". (2)

1933 July 1 - Aug. 12 Italo Balbo of Italy led a group of 23 Savoia Marchetti seaplanes from Orbetello, Italy to Chicago, Illinois and return.

1933 July 15-22 Wiley Post flew solo around the world his Lockheed "Vega", the WINNIE MAE, in 7 days, 18 hours, 49 minutes. It was equipped with an automatic pilot.

1933 July 15 Floyd Bennett, using an automatic pilot, flew 15,596 miles in 7 days, 18 hours and 49.5 minutes. In the excitement generated by Wiley Post's flight of the same date this achievement was overlooked in the general press.

1934 Feb. 18 Jack Frye and Eddie Rickenbacker set a 13 hour, 4 min. cross country record in a Douglas DC-2.

1935 Nov. 22-29 Capt. Edwin Musick, Pan American Airlines, flew from San Francisco to Manila in the CHINA CLIPPER, a Martin Flying Boat, to initiate Pan Am's trans-Pacific commercial route.

1936 June 7 An all instrument transcontinental flight was made by Maj. Ira Eaker from New York to Los Angeles.

1936 Oct. 21 Pan American Airlines initiated weekly commercial passenger flights from San Francisco to Manila, via Honolulu, Midway, Wake, Guam.

1938 July 10-14 Howard Hughes and crew flew around the world in 3 days, 19 hours.

Two significant events separated by barely eight years highlight the rate of instrument development:

1929 Sept. 2 At Mitchell Field, Long Island, Lt. Jimmy Doolittle completed a 15 minute flight in fog. Later the same day he used a cockpit hood and repeated the flight with Lt. Ben Kelsey as passenger and check pilot. The plane was a Consolidated NY-2 sponsored by the Guggenheim Foundation. It contained an artificial horizon, gyro direction indicator, and sensitive altimeter, as well as the standard instruments.

1937 Aug. 23 Completely automatic landings were demonstrated at Wright Field by Capt. C. Crange with two passengers.

Though considerably new instrumentation was introduced during the 1928-1938 period, as much or more progress was made in improvement of the old standbys such as compasses, airspeeds, engine gages, and altimeters.

Gyroscopes or "gyros" of various types became more prevalent. All gyros consist, basically, of a free-spinning wheel which can rotate about one or more axes. The wheel or rotor is either electrically or air driven. One type of gyro is freely suspended, allowing the aircraft to rotate about it while it maintains a fixed path or attitude in space. This type is used for directional gyros and artificial horizons. The second type makes use of an attribute of a gyro known as "precession", which is the resistance or torque set up by the spinning gyro when any change is made in its plane of rotation. The torque or force of resistance is measured and shown on a dial as an indication of a change in attitude of the aircraft. This type is used in turn and bank indicators and in automatic pilots. The automatic pilot consists of three gyros, each one sensitive to one particular plane of motion of the aircraft, i.e., roll, yaw or pitch. If an aircraft drifts off its course or starts to sideslip, these gyros start to precess. This sets up a signal which varies with the degree of precession. The signal is picked up electrically and fed into the aircraft controls through relays and electrical drive motors. In this way a corrective action of the particular control, aileron, rudder, or elevator, is produced which returns the aircraft to its original course. Once returned to course the signal from the gyro decreases effectively to zero and the aircraft maintains a fixed line of flight until again disturbed. It should be noted that an automatic pilot in its true sense is not an instrument but a control. Most automatic pilots have instruments connected in their circuit to enable the pilot to visually determine that the autopilot is functioning correctly. These instruments are usually an artificial horizon and a directional gyro.

Fuel measuring and flow indicating equipment was developed and refined during the years 1928-'38. The old types of fuel level gages, consisting of a float and a direct reading rod, were relegated to the smaller single-engine sport-type aircraft and were replaced in larger craft with various types of electrical indicating gages. This was necessary first because of the greater wing spans of aircraft and therefore the requirements to indicate fuel level in remote wing tanks, and secondly because of the greater number of individual fuel tanks in the larger aircraft. At the same time fuel flowmeters were developed to tell the pilot the rate of fuel consumption for each individual engine. These consisted of transmitters and indicators which measured the actual rate of flow to the engine and displayed it in "gallons per hour" to the pilot.

Supercharger gages and manifold pressure gages were introduced. These consisted of pressure gages (reading in inches of mercury-Hg.) connected to the intake manifolds of the engines. They are used by the pilot as an indication of engine horsepower output. Before the early 30's engines equipped with fixed pitch propellers were controlled by use of a throttle. With the introduction of controllable pitch propellers the engine rpm was determined by the propeller control setting and the actual horsepower output was determined by the throttle position. The manifold gage showed the pilot the actual intake manifold pressure being produced in the engine and from this he was able to properly position the throttle. Other specialized instruments also made their debut: distance recorders, ice warning devices, and indicators to enable the pilot to synchronize two or more engines to the same speed.

During this decade aircraft design steadily advanced. Landing flaps and retractable landing gear were two of the most noteworthy changes. Position indicators were needed, and developed, to show the position of landing flaps and landing gear to the pilot since he could not visually check them from the cockpit. These indicators were electrically operated, by means of switches on the landing gear or flap, and usually presented a pictorial display along with red and green lights to indicate actual position of the items.

Toward the end of this period another major change in instrument design began to be noticed. This was the transition of much of the normal instrumentation from mechanically to electrically driven types. The change became necessary as engines were being mounted at greater distances from cockpits and many more indicators were being required in aircraft. Pressure gages for hydraulic, pneumatic, oxygen, oil and fuel systems could no longer be practically operated by direct lines thruout the aircraft due to the weight involved and in some cases the safety hazard which would be produced by their use. Electrical indicators were the answer. Once introduced, the acceptance of these instruments was rapid

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(1) Post & Gatty - JOURNAL of A.A.H.S., Vol. 2 No. 1, p. 28; Vol. 3, No. 3, p. 172; Vol. 3, No. 4, p. 221.

(2) Amelia Earhart - Ibid, Vol. 2, No. 1, p. 7.

and widespread. Another big change was evident in the lighting of instruments. In 1928, a panel with 2 or 3 lights such as used by Lindbergh in 1927 was a rarity. What little night flying was being done in the late 20's was done with the aid of a pocket flashlight. By the end of this period commercial and military instrumentation was lighted by separate lights on the panel or by integral lights within the individual instruments.

To illustrate the instruments in use during this period and also the rapid change in these ten years, the following typical aircraft and their instruments are listed:

1928 Douglas M-2 Mailplane, Photo No. 1
Airspeed indicator, Zenith altimeter 0-24000; B-2 compass, Waltham 8-day clock, fuel pressure gage 0-10 psi, Van Sicklen tachometer, inclinometer, Boyce thermometer.

1928 Fokker F-32, Photo No. 2
Pilot's panel - Altimeter, compass, airspeed indicator, turn indicator, inclinometer, clock.
Copilot's panel - 4 oil temperature gages, 4 oil pressure gages.
Center panel - 4 tachometers, semi-circular in shape.

1928 Ford "Trimotor", Photo No. 3
Pilot's panel - See figure I - Altimeter, compass, turn and bank indicator, airspeed indicator, clock, rate of climb indicator, and tachometer, oil pressure gage, oil temperature indicator for center engine only.
Pilot's compartment - Rear Top Wall - gas gages. Strut mounted on each outboard engine, oil temperature gage, oil pressure gage, tachometer.
Passenger compartment - Usually an altimeter and airspeed indicator.

1928 Boeing 80 and 80A, Photo No. 4
Pilot's panel - Altimeter 0-15,000 ft., rate of climb indicator, turn and bank indicator, airspeed indicator 40-160 mph, (note both R of C. and T. & B. were 2" instruments)
Center panel - 3 tachometers, (dial type, semi-circular) 3 air pressure indicators 0-10 psi, 3 oil temperature indicators, 3 oil pressure gages.
Copilot's panel - Ammeter, voltmeter.

1929 Lockheed "Air Express", Photos No. 5 & 6.
2 fuel gages 0-40 gals., fuel pressure 0-10 psi., oil temperature gage 0-100°C., airspeed indicator 60-240 mph., turn and bank indicator, rate of climb indicator, tachometer 600-2400 rpm., radio compass, sensitive altimeter, clock, direction indicator.

1931 Taylor Cub E-2 Granddaddy of all Taylor and Piper Cubs.
Standard instruments - airspeed indicator, fuel level (float and stick), altimeter, oil pressure gage, oil temperature indicator, tachometer.
Optional - Compass.

1932 Boeing P-26A, Photo Nos. 7 & 8.
Combination voltmeter and ammeter, airspeed indicator 50-200 mph., sensitive altimeter, magnetic compass, A-2 turn indicator, tachometer 0-3500 rpm., clock, combination engine gage, temperature 0-100°C, oil pressure 0-200 psi, and fuel pressure 0-10 psi., supercharger gage 0-7" Hg. vacuum and 7" to 23" Hg. pressure.

1933 Boeing 247D, Photo No. 9.
Copilot's panel - 2 fuel pressure gages 0-10 psi, 2 oil pressure gages 0-120 psi, 2 tachometers 0-2500 rpm, 2 oil temperature indicators - 32 to +212°F.
Pilot's panel - Wheel position indicator, outside air temperature gage - 20 to +120°F., 2 fuel quantity gages 0-136 gals. and 0-70 gals., cylinder head temperature gage (dual).
Center panel - Auto pilot, directional gyro, artificial horizon, airspeed indicator 60-220 mph., turn and bank indicator, rate of climb indicator, altimeter, clock, radio range indicator.

1933 Boeing F4B-4 and P-12E, Photo Nos. 10 and 11.
F4B-4 - Supercharger pressure gage - 10" to 20" Hg., altimeter 0-35,000 feet, fuel pressure gage 0-10 psi., turn and bank indicator, oil pressure gage 0-200 psi., oil temperature gage 0-100°C., airspeed indicator 50-220 mph, tachometer 0-3000 rpm., fuel sight gage 0-50 gals.
P-12E - Airspeed indicator 80-230 mph., turn and bank indicator, altimeter 0-35,000 ft., tachometer 0-3500 rpm., clock, fuel pressure gage 0-10 psi, oil pressure gage 0-200 psi., oil temperature indicator 0-100°C., auxiliary fuel gage 0-50 gal.

1933 Douglas DC-1, Photo No. 12.
All blind-flight and primary-flight instruments in center of panel. Compass, clock, manifold pressure gages and tachometers on pilot's panel. Secondary engine instruments on copilot's panel. In these installations, as may be seen in the photograph, many instruments were set at an angle. This allowed all pointers of similar instruments to be horizontal when in proper operating position thus mak-

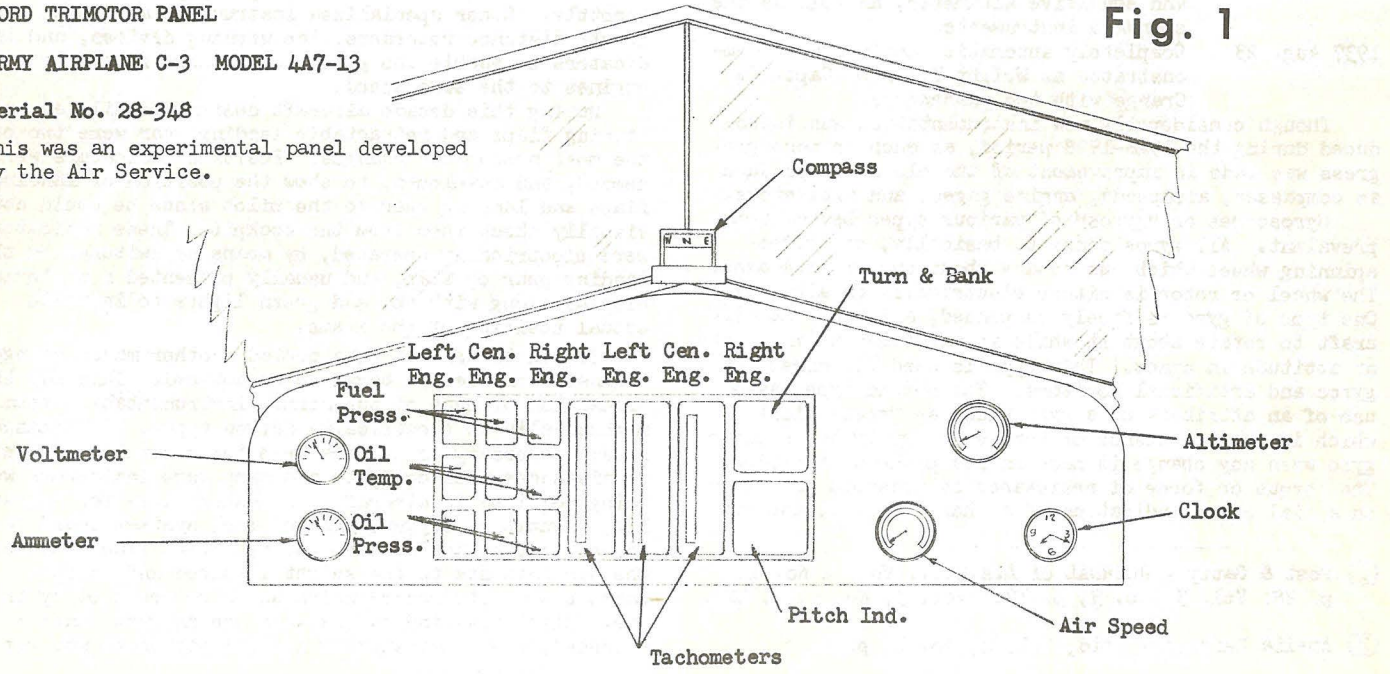
FORD TRIMOTOR PANEL

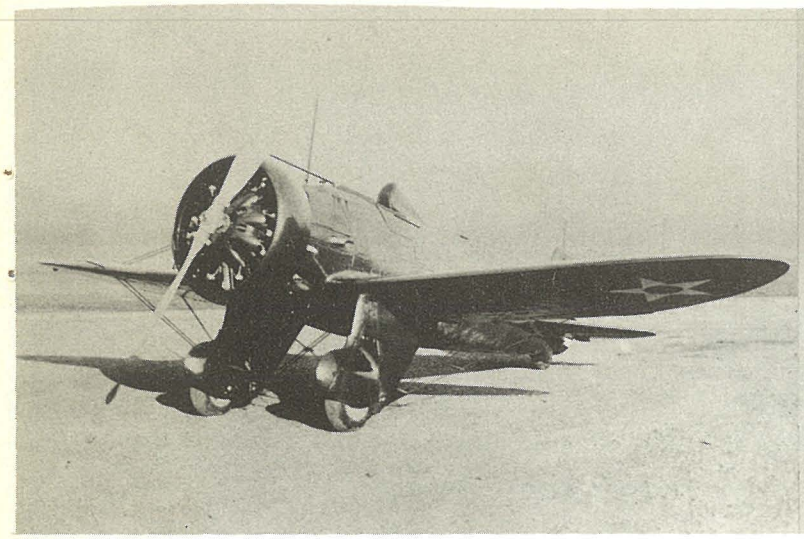
ARMY AIRPLANE C-3 MODEL 4A7-13

Serial No. 28-348

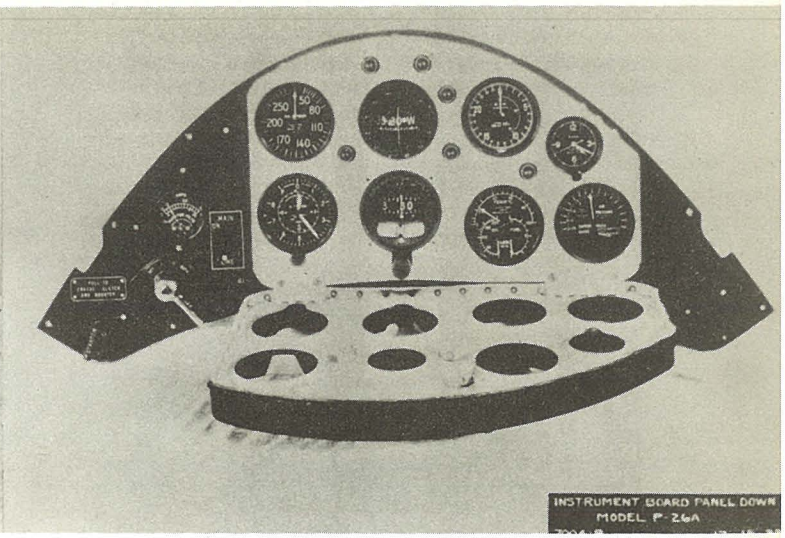
This was an experimental panel developed by the Air Service.

Fig. 1

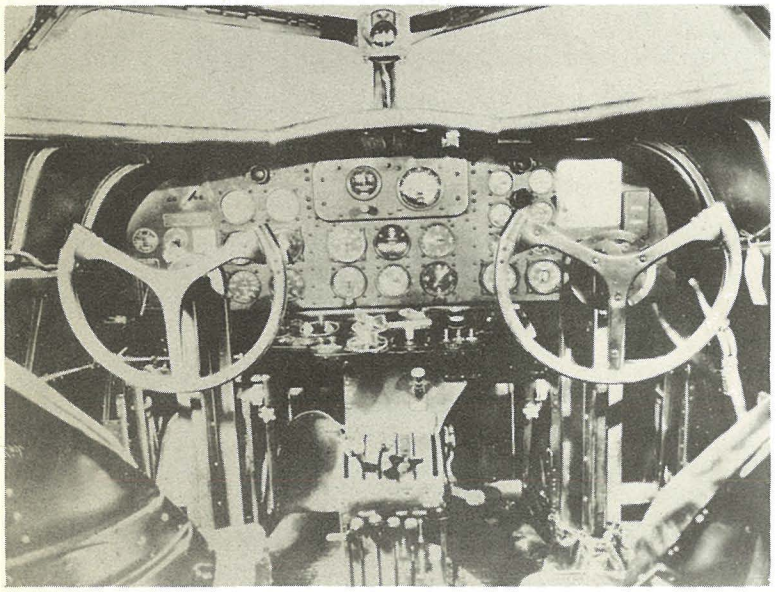




Boeing P-26A, the "Peashooter", still in use in 1941. This was No. A.C. 33-28. Photo - Wright Field #48665.



Instrument board of P-26A, typical of Service-adopted standard panels of 1930's. Photo - Wright Field #49593.



F4B-4 Cockpit. All instruments except fuel level tube grouped between gun mounts. Photo - Boeing No. 5653B.

Left - Cockpit of Beeing Model 247, first of modern all-metal low-wing transport airplanes. Photo - Boeing.

ing it easier to immediately spot any one instrument not indicating a normal condition.

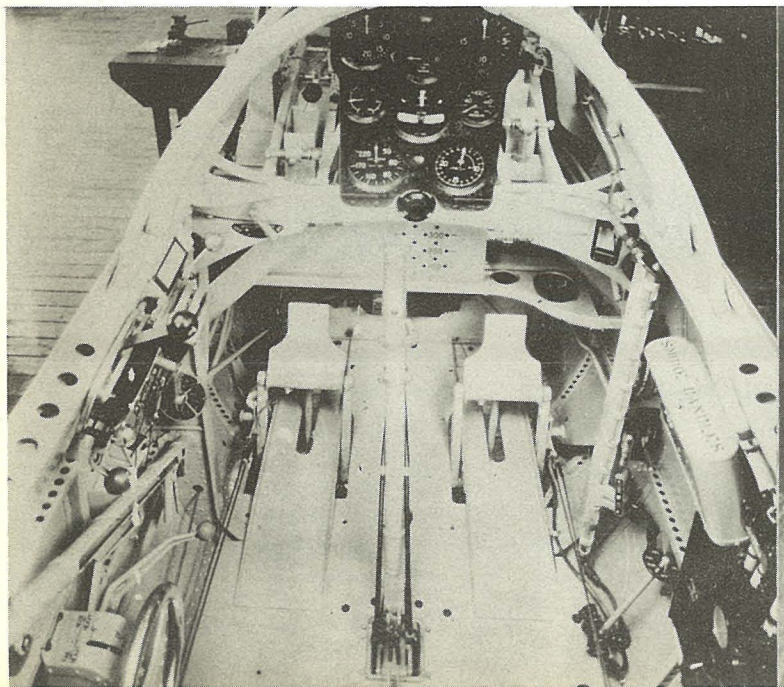
1934 Douglas DC-2.

The trend that was started in the DC-1 continued, with primary groups of instruments in the center, the main engine instruments on the pilot's side, and secondary instruments on the copilot's side. New instruments introduced on this airplane included electrical fuel quantity gages, electrical tachometers (voltmeter type), electrical temperature indicators, and a hydraulic-air operated auto-pilot (Sperry A-2).

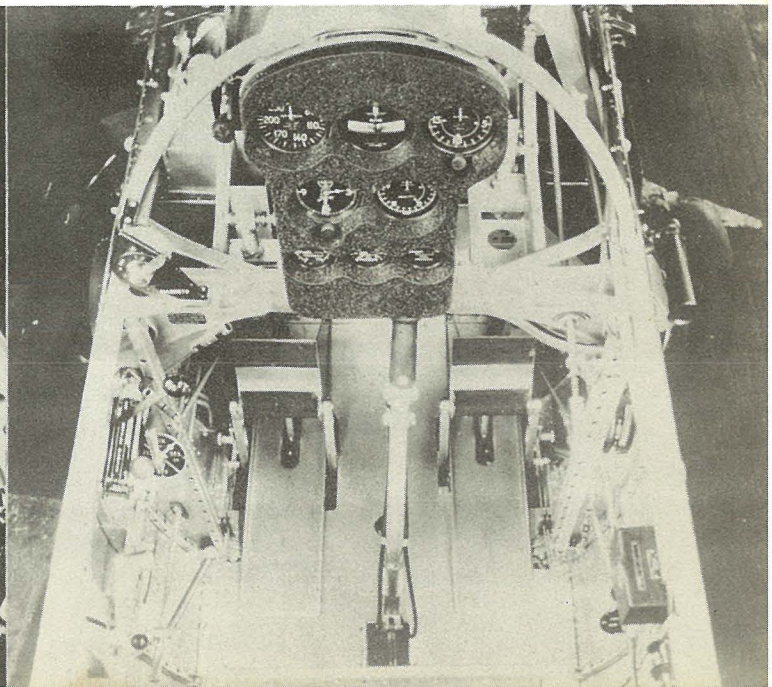
1935 Douglas DC-3, Photo No. 13.

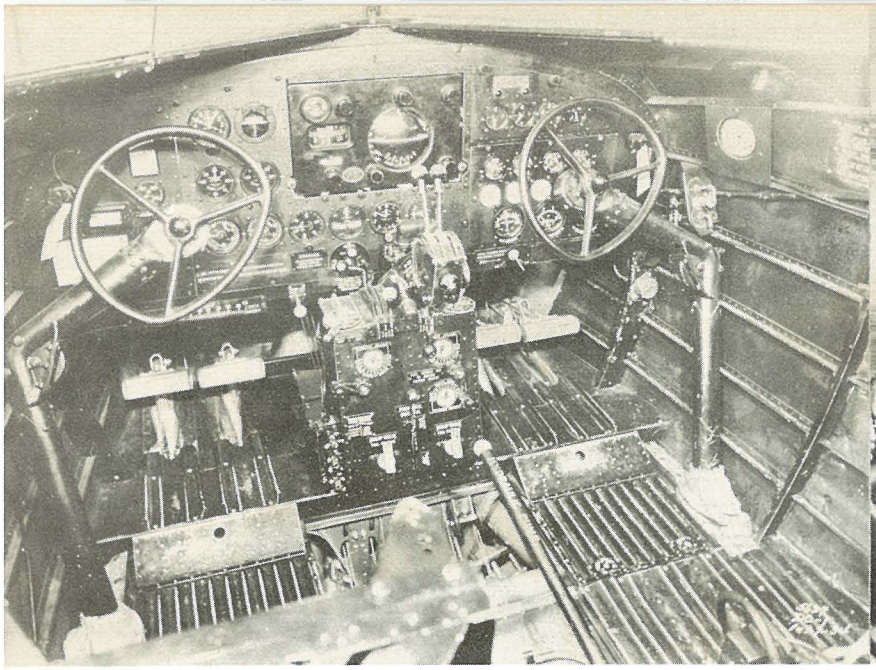
Over 10,000 of the DC-3/C-47 type were produced. The instrumentation varied with different purchasers. The photo shows a typical installation for American Airlines. The main change from the DC-2

(Continued on Page 285)

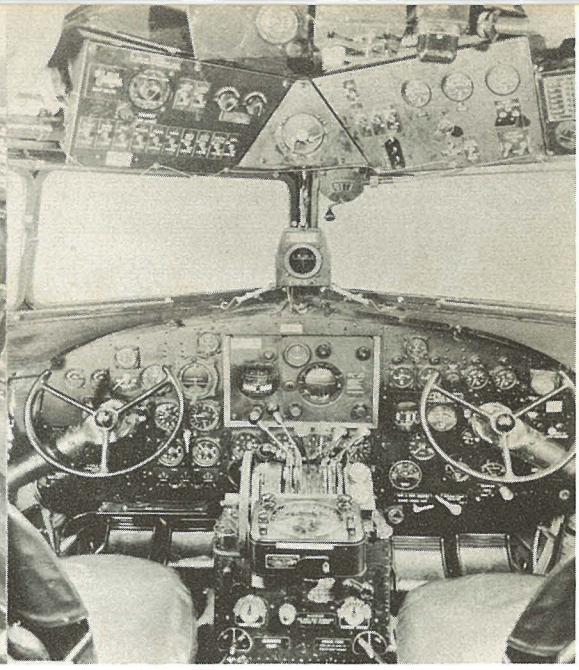


P-12E cockpit, similar to F4B-4. Fuel level tube at right of pilot's leg. Photo - Boeing No. 4862B.

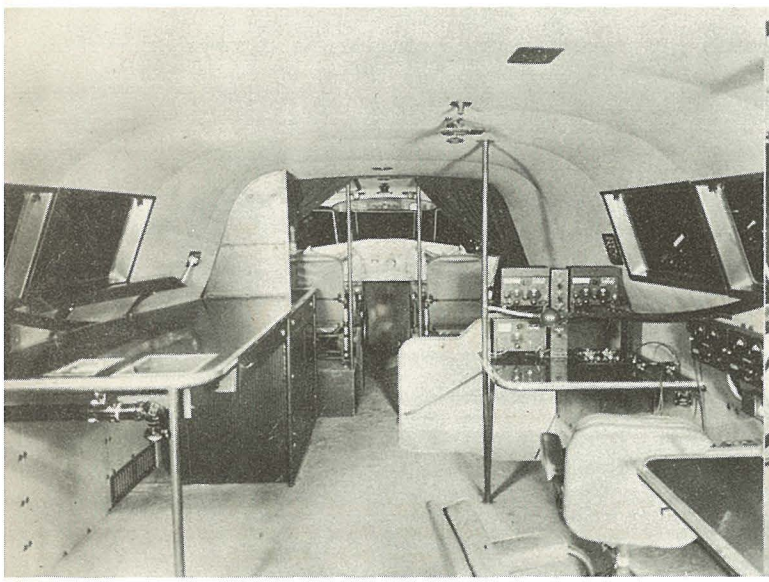




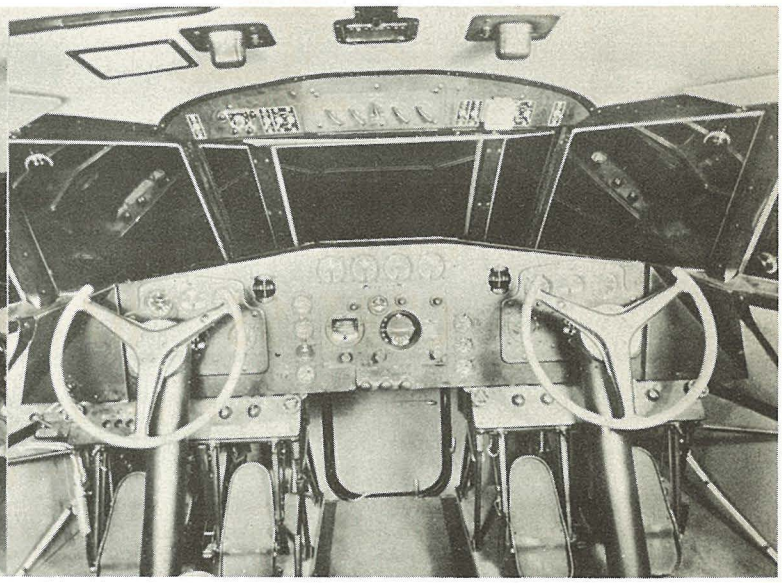
Prototype Douglas DC-1 panel, a definite trend toward separate pilot/copilot duties. Photo - Douglas Aircraft.



The later DC-3 panel, as used by American Airlines. Photo - American Airlines.



Spacious flight deck and comfortable working conditions featured in Boeing 314 Flying Boat. Photo - Boeing.



Closeup of the Boeing Model 314 instrument panel shows minimum pilot instrumentation. Photo - Boeing.

Douglas DC-4 Prototype. Photo - United Air Lines.

Engines (Continued from Page 258)

cerning the early days at Wright and P & W A; for photographic and literature assistance from N. L. Mead, Public Relations Manager of Curtiss-Wright; for similar assistance from Frank Murphy, Public Relations Director at Pratt & Whitney Aircraft; to Roy Cross and Charles Mandrake, A.A.H.S. Members, and to Philip Hopkins of the National Air Museum. Appreciation is also expressed for criticisms from Frank L. Greene and my wife, Caroline.

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ABOUT THE AUTHOR

Harvey H. Lippincott, a member of AAHS, is also founder and President of the CONNECTICUTT AERONAUTICAL HISTORICAL ASSOCIATION formed by Connecticut Members of the American Aviation Historical Society with the very considerable interest of the aviation industry in that state. An example of Member Lippincott's leadership is found in the description of the latest meeting of the C.A.H.A. in the Society Affairs column of this JOURNAL, Page 279. He is currently employed as an Installation Performance Engineer in the Sales Department of Pratt & Whitney Aircraft at East Hartford, Conn. His historical interest plus 18 years of association with P & W A, has given him a deep appreciation of the aircraft engine developments related here.

Instruments (Continued from Page 265)

in instrumentation was the use of the "mag drag" electrical tachometers. These instruments used a magnetic coupling device which limited overshoot and increased the accuracy.

1937 Boeing 314, Photo Nos. 14 and 15.

Pilot's panel - Turn and bank indicator, rate of climb indicator, compass, turn and bank (standby) artifical horizon, altimeter, airspeed indicator, compass (standby).
Copilot's panel - Duplicate of pilot's panel.
Center panel - Gyro pilot, 2 tachometers (dual types) 2 manifold pressure for venturi, clock, flap indicator, 2 oil pressure gages (dual types), 1 oil temperature gage with selector switch, air temperature gage. (Note: The total of 5 compasses, including one in the Gyro Pilot, indicated that these were still considered the most unreliable of instruments.)

1938 Douglas DC-4 Prototype, Photo No. 16.

In general this panel followed the lead of the DC-1, -2, & -3 but included instrumentation for four engines. The panel and the entire airplane were frequently altered as airline trials were run. The DC-4 prototype was eventually sold to Japan.

It can be seen that in ten short years from 1928 to 1938 many advances had been made. Sport aircraft instrumentation had changed little, though the reliability and accuracy of the instruments used had increased. But commercial transport aircraft instrumentation had advanced considerably due to the changeover from single-engine to two- and four-engine aircraft and to the improvements in design and increased requirements necessitated by changes in the basic aircraft types. In 1928 commercial air transports carried 8 or 10 unlighted instruments. By 1938 commercial aircraft carried 30 to 40 lighted instruments, many of which were dual types.

Military aircraft had likewise progressed during this decade from panels containing 15 to 20 unlighted instruments to ones containing 30 to 40 for single-engined aircraft and 60 to 80 on the most advanced four-engined bombers. It must be stressed however that both the advanced military aircraft and their instrumentation were in many cases still in prototype stages. Most of the operational aircraft in use in 1938 were of 1930 to 1933 vintage, actually little different from those of the 1918 to 1920 period.

The stage was now set for history to repeat itself with another World War. Time would tell whether the American instrument designers had learned enough since the First World War to cope on even terms with those of the Axis powers.

CHANGES OF ADDRESS
(Continued from Page 282)

John T. WIBLE, 2152nd Comm Squadron, APO 235, San Francisco, Calif.

Ed WISCHNOWSKI, 2926 Porter St., N.W., Washington 8, D. C.

Douglas WOOD, 421 E. 82nd Street, New York 28, N.Y.