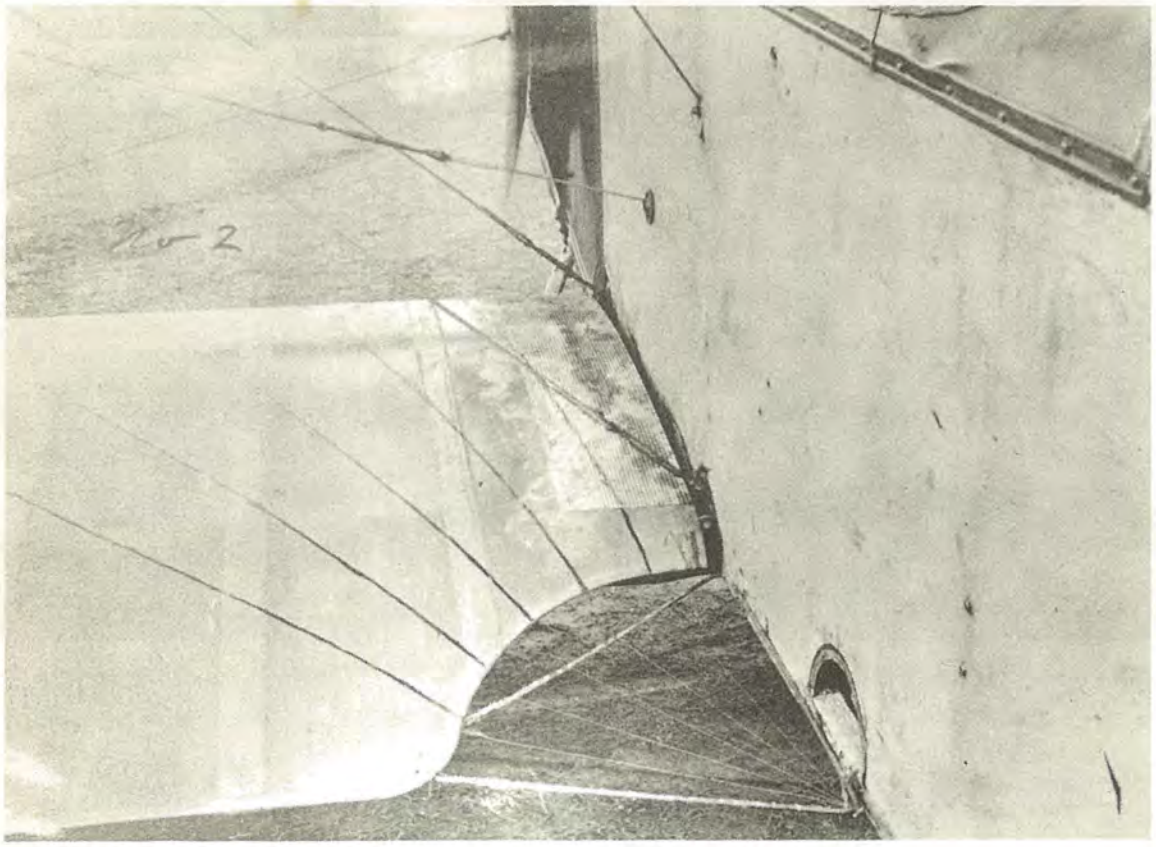
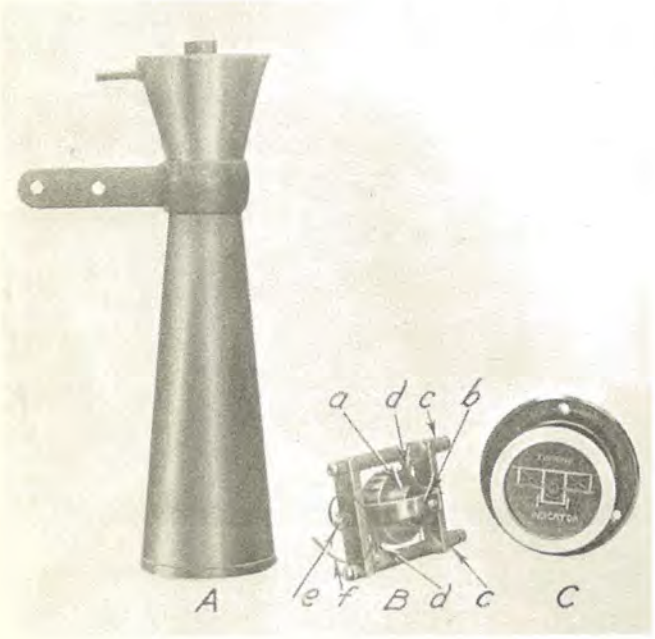
AVIATION INSTRUMENTS

A BRIEF HISTORY - PART 1

By ROBERT J. SCHEPPLER



External drift indicator lines on lower wing of Curtiss JN4-D. Used to estimate cross winds. Approximately 1919. (Original McCook Field photo, courtesy of Air Force Museum.)



3. The first pictorial display of an aircraft shape on the face of an instrument to show aircraft attitude. This was introduced by Sperry in 1919. (Photo - A.F. Museum)

INTRODUCTION

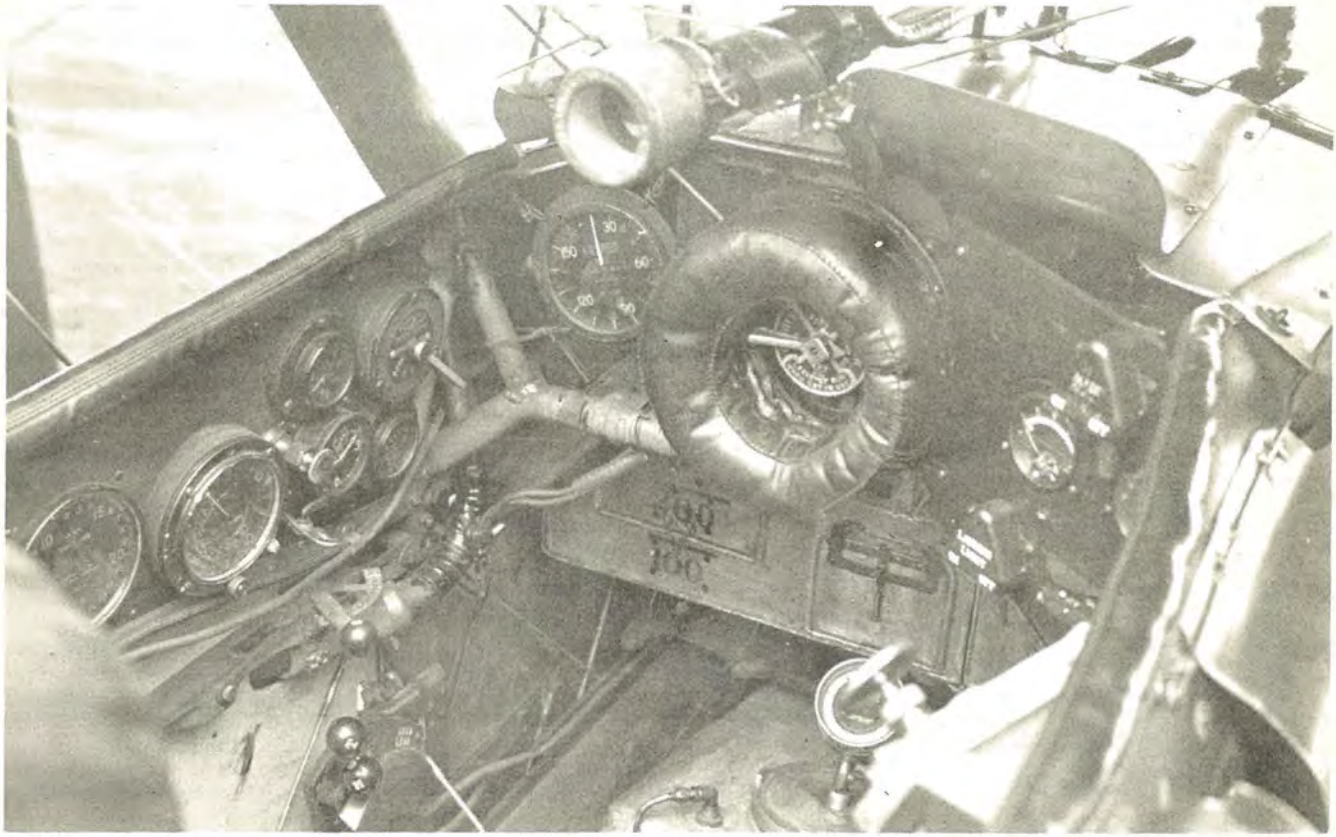
No history of aircraft instrumentation could be called complete unless it covered the many years of preparation for flight, research and development from the Middle Ages to the present. From the dawn of history, man has strived to conquer the air and it was realized by some at an early date that the problem of navigation through the air would require new and unknown instrumentation. The most interesting phase of any historical epic is always the chapter entitled, "Success At Last". I therefore will dwell only on the development of aircraft instrumentation for manned, heavier than air vehicles between the years 1903 to the present, with a short prophesy of things yet to come.

This sixty year era can be divided into seven periods.

1. The Wright Era 1903-1907
2. Pre World War I 1908-1913
3. World War I 1914-1918
4. Between the Wars
   a. The Surplus Age 1919-1927
   b. Golden Age of Sport 1928-1938
5. World War II
   a. Living in the Past 1939-1941
   b. Wartime Development 1942-1945
6. Post World War II 1946-1960
7. The Future 1960-

Rear cockpit panel of 1919 Vought VE-7, McCook Field Project P-113, used by U.S. Navy. (Photo - McCook Fd. #4870, Air Force Museum #N58-D1-194)

Panel of Orenco PW-3, 1921. Compass was located in wing and airspeed indicator in front of windshield. (Photo - McCook Fd. #10311, Air Force Museum #N58-D1-195)



Cockpit of Thomas Morse MB-3A (Boeing-built), Project P-274, Approximate date 1921. The crash pad protection over the ignition switch was controversial at that era. Cramped quarters dictated placement of several main instruments in side of cockpit. (Photo - Wright Fd. #19864, A.F. Museum)

THE WRIGHT ERA 1903-1907

As almost everyone would tell you in 1903, man was never meant to fly or he would have been born with wings. Some, such as Bishop Wright of Dayton, Ohio, even went so far as to state that the subject of man's flying was blasphemy. Luckily for the world Bishop Wright's two sons did not adhere to this philosophy, and on December 17, 1903, they officially launched the world into the age of flight with a twelve second flight of one hundred twenty feet. They were followed almost immediately, or in some cases preceeded by others such as Lilienthal, Langley, Montgomery, Curtiss, Dumont, Bleriot, Huxley and many more.

Most of these early pioneers had little to gain and much to lose by devoting their time, money and, in almost all cases, their lives to the new field. Flying during this period was done for serious experimentation, thrills, advertising and personal satisfaction but not for travel. Therefore very little instrumentation was needed as all flights made were of short duration and within sight of the take off point. What few instruments were used were adapted from those previously used in laboratories or ships.

The following noteworthy flights were made:

1903-December Wright Brothers completed series of flights in straight line.

1904-Fall Wright Brothers completed flights including circular patterns.

1905-October 5 Wright Brothers flew 24 miles in 38 minutes.

1906-September 13 Santos Dumont made first flight in Europe (France).

1907-October 26 Henri Farman flew 21½ minutes with a passenger a cross country distance of 16 miles.

To illustrate the instruments in use during the years 1903 to 1907, the Original Wright Flyer had only:

Air Distance Indicator: Operation unknown.

Richard Anemometer: Wind driven vane type instrument manufactured by Richard Company. Normally used to determine wind velocity, but in this case it provided a rough measure of air speed.

Clock: Stopwatch-type used to time flight duration.

These instruments were mounted to the pilot's right on an interplane strut and were obviously considered only as secondary aides to flight. In addition, the Wrights attached a piece of tape on the foremost horizontal strut of the landing gear where it would be in direct view of the pilot. This piece of tape freely moving in the breeze indicated straight and level flight or skidding or slipping.

In a later model of the Wright Flyer, used by original barnstormers and first flying school operators, no instruments were mounted as standard equipment; those used during this period were relatively crude and were only for experimentation purposes.

PRE-WORLD WAR I 1908-1913

Early in 1908 the first age of the airplane came to an end and a second rapidly accelerating period began. It opened on January 20, 1908, with a request by the U.S. Signal Corps for bids for the construction of an airplane to Sec. No. 486, to carry a pilot and an observer at a speed of 40 mph. for one or more hours. Thus the practicability of the airplane was beginning to be suspicioned. It is significant that at no point in the specification is any mention made of instrumentation. With delivery of the first airplane to the U.S. Signal Corps the pace of aviation development quickened; longer and faster flights were made and long range plans were initiated to use it not only for thrills and experimentation but for personnel and mail transportation and warfare. Instruments were few and far between, used as auxiliary references only. The actual flight references required were the seat of one's pants, the wind in the rigging, the horizon and control "feel". The notable aerial events of these years bear out the increased use of aircraft.

1908-July 19 Bleriot crossed the English Channel from Calais to Dover in thirty-seven minutes. First international flight.

1909-August World's First International Aviation Meet held at Rheims, France. Stands accommodated 250,000 spectators. Contestants included Dumont, Bleriot, Latham, Paulham and Curtiss. Glenn Curtiss flying a ship of his own design won the Gordon Bennett Trophy Race at 47 mph.

1910-May 28 Glenn Curtiss flew from Albany to Governor's Island, New York, a distance of 142½ miles in two hours fifty minutes. The Hudson River was used as a guide. The equivalent boat trip took seven to eight hours.

1911-January 18 Eugene Ely landed and took off from a battleship deck thus demonstrating another future use of the airplane. On November 14, 1910 he had taken off of the battleship U.S.S. BIRMINGHAM but had not returned to it. (1)

1911-Sept. 17 Calbraith Rodgers, flying a Wright EX named VIN FIZ completed a trip across the country from New York to Pasadena, California without benefit of instruments. (2)

1911-October 9 Tarbox Automatic Pilot was demonstrated at College Park, Maryland. Method of operation and results of the demonstration are unknown, but it obviously did not perform satisfactorily as it was never further developed.

1912-January 10 Robert C. Fowler completed a trip from Pasadena to Jacksonville, Fla., a distance of 2,232 miles in 151 days without benefit of instruments. (3)

1912-April 16 Harriet Quimby, first U.S. Licensed woman pilot crossed the English Channel.

1912-June 11 Marcel Prevost set an international speed record of 111.73 mph in France.

Instrumentation on Bleriot's Channel Plane consisted of one fuel quantity gage, float-type, direct-reading, mounted on the right side of the combing forward of the pilot. It is notable that at least the instrument was mounted in front of the pilot for visibility's sake.

Many other aircraft made their debut in this period, but the instrumentation was left strictly to the discretion of the individual owners. This resulted in a "do it yourself" flyer in each case. Airspeed was of academic interest only, as there was little difference between cruise or landing speeds. If measured at all it was by means of a string attached within the pilot's view. This piece of string was actually the first generally accepted flight instrument. Its operation was simple, if it hung down the plane was at rest. If it was straight to the rear sufficient speed was being maintained. If it hung to either side it indicated a slip or skid. A somewhat later development consisted of a plumb bob with a rough mph. scale. Another common method of determining airspeed was to estimate by ear the various noises or the wind on the pilot's face.

Attitude was shown by use of two spirit levels mounted at right angles to each other. One level, mounted horizontally in the cockpit visually displayed any tendency toward banking or rolling. The other level mounted parallel to the normal line of flight, visually displayed the tendency toward diving or climbing. These levels were surprisingly accurate and are still used, in principle, in the bank portion of present day turn and bank indicators.

Engine revolutions per minute (RPM) was determined, with practice, rather accurately by ear but was occasionally measured with a tachometer. RPM served as a rough indication of engine power. Most of the engines were of a class which either ran or refused to run so tachometers for the most part were not necessary. An occasional hand compass was carried but almost all cross country travel was by direct reference to landmarks, especially the railroad, which rapidly became known as the "Iron Compass". What few compasses were used were usually marine types which were not too satisfactory for aircraft use.

It can safely be said that up to this point almost all aircraft instrumentation consisted of either marine or automotive types altered as necessary to adapt them to aircraft use. As almost all flight was in a straight and level condition little or no adaptation was required. Consequently many of the instruments were merely removed from automobiles or boats and installed in the aircraft, usually in an inconvenient and always inaccessible corner of the cockpit.

During the latter years of this period between 1911 and 1913 the foreign aircraft designers seemed to develop a much greater appreciation of the eventual uses of the aircraft. More experimentation was conducted on instruments in France and England than in the United States. It was realized by some of the pioneers of this era such as Sopwith, Nieuport, Farman, Bleriot etc. that the speed, altitude and attitude of the aircraft must be accurately gauged before distance flying or any form of flying for serious motives could be accomplished.

By 1913 the well equipped European airplane boasted an airspeed indicator, operating from a Venturi or Pitot tube, an air driven, gyro-operated turn indicator, a level to indicate angle of bank and an altimeter of the aneroid barometer type. This group of instruments was almost identical to those in use in modern light aircraft of the present day except that the ranges of the instruments have been extended and various refinements have been made to eliminate friction in the mechanisms and thereby increase the accuracies of the indicators. The engine instruments consisted of a fuel level gage, an air-pressure gage to indicate pressure in the fuel line, a chronometric type tachometer, and a water thermometer. The air-pressure gage indicated the pressure in the fuel tank which was produced either by a pilot-operated hand pump, or engine-driven air pump, or both. The thermometer was only installed on water-cooled engines.

The equivalent typical American plane in most cases carried only an air-pressure gage and a fuel level gage. The main serious attempt at instrument development in the United States during this period was being carried on by Lawrence Sperry who, between 1912 and 1914, tested many gyro-operated control devices both in the United States and France. In June 1914 he flew a Curtiss Hydroplane in Paris, France to demonstrate an automatic stabilizer and thus win a 50,000 franc first prize in a contest sponsored by the French War Dept. This stabilizer contained gyroscopes connected by relays to electric motors which drove the elevators and ailerons. There was no automatic rudder control. During the demonstration Mr. Sperry stood in the aircraft cockpit with his hands in the air, with his mechanic standing on the lower wing, while they flew a straight and level flight path. From this beginning Lawrence Sperry, in 1916, developed a completely automatic airplane which was gyroscopically controlled. In addition to operating all controls by means of a group of four gyros he also directed the gyro operation by radio from the ground. This was the original "guided missile" or "Aerial Torpedo" as it was called. (5) The aircraft was 14 feet long and had a range of 50 miles at 90 mph. It was a biplane with a fixed skid landing gear. The United States Signal Corps was interested but from all reports the control system was not sufficiently damped and over-control resulting in severe oscillations was experienced. The entrance of the United States into World War I stopped development on this project for some reason rather than accelerating it.

The first crude forerunner of the instrument panel made its debut during this period when some of the more advanced European designers started grouping the instruments on a flat panel within the cockpit of the aircraft. This was by no means universal, and it was many years before any form of instrument panel or location became standardized.

Thus another stage of instrument development came to an end. It ended with a note of hope in that a few far-sighted designers and flyers were beginning to see the future uses of aircraft. These few also realized that instrumentation would soon play a large role in the overall development of aircraft.

WORLD WAR I 1914 - 1918

The World War I age of development literally opened with a bang. European designers were actually ready from an instrumentation standpoint for this event, when all peacetime uses of the airplane were forgotten. Within a short period aircraft were required for night flying, bombing, long range navigation and training of large numbers of crewmen. These requirements immediately meant that there must be a reasonable degree of interchangeability between instruments, weight had to be minimized, instruments capable of use on multi-engined aircraft were needed and weather problems had to be surmounted by reference to instruments.

The Allied aircraft in use in Europe during the first years of the War were usually equipped with a tachometer, airspeed indicator, fuel pressure indicator, inclinometer and altimeter. As the ranges of the flights were increased compasses were added, along with clocks. The Allied designers also rapidly agreed on the necessity of a panel for instrumentation mounting. The German aircraft of this era were usually not as well equipped, having only fuel pressure gages, tachometers, and compasses with few of the earlier models making use of actual instrument panels. Most of the instruments were haphazardly scattered about the cockpit.

Aircraft in America at this time were particularly lackingin instruments. To further emphasize this point I quote the following paragraphs from a report entitled "General Description of Instruments 1917" written by various members of the American Expeditionary Forces in France (File No. D13.23/22 Misc. Wright Field Museum). Speaking of the qualifications for aircraft instruments the author states "The first point about these is that they should be as much as possible standard so that if a pilot must move from one machine to another he can recognize the instrument that he had been accustomed to and his reading of it will therefore be facilitated"..... "Personally if a flyer really wants an inclinometer this office believes that a piece of string used in the usual way is as good as any inclinometer"...."A tachometer is the most important among all airplane instruments because very often a pilot's ear is not tuned exactly to his machine. This is not likely to occur among well trained pilots but is very likely to occur among the mass of untrained pilots which America must now use"... "Pilots must be taught very early in their course in flying to be capable of calibrating their own airspeed indicators, and it is suggested that you install this in your course in flying"...."Some pilots claim to be able to calibrate their airspeed indicators from the note given by the wire of the airplane. This again is subject to the wire being properly adjusted since slack wires will give a very much lower note than properly adjusted wires"...."Clocks. There are a number of different kinds of clocks good for use in the airplane. The main essential is that the dials should be luminous and that the clock should be sufficiently large in order

not to induce too many people to use them as pocket articles rather than to leave them on the airplane where they belong."

The above excerpts, typical of the report, clearly show how far American instruments were lagging behind those of their Allies and foes during the early stages of World War I. In 1915 the Army issued specifications for instruments stating that all aircraft except trainers should have an altimeter, an airspeed indicator, magnetic compass, air and oil pressure gages, gasoline gage, water thermometer, tachometer and clock. These specifications went unheeded for a number of years, but at least they represented a start.

Typical aircraft in use during World War I show the progress made both in types of instruments developed and in the uses to which they were put.

1916 Standard, Model J. American Trainer. 4 psi. Pressure Gage for fuel pressure.

1916-1918 Handley Page, O/400, British Bomber. Later used as airliner for day and night flying.
Pilot's Cockpit: tachometer, water temperature, oil temperature, oil pressure, ammeter, compass, airspeed indicator.
Bomber's Cockpit: altimeter, stop watch, air temperature, drift indicator. Note that the altimeter was mounted in the bomber's cockpit, evidently used only as a means of determining altitude during a bombing run.

1917-1918 Fokker Dr-1 Triplane -German Fighter. Carden (mfr's name) compass located at pilot's knee, tachometer at cockpit center, oil feed gage (sight glass) and ammeter at left side, fuel pressure gage at right side, fuel quantity gage on turtle deck between guns. The installation of an ammeter suggests that a radio, battery operated, was used in these planes as there was no other equipment requiring a battery.

1917 Sopwith "Camel" - British Fighter. clock, altimeter, compass, two fuel pressure gages for two fuel tanks, tachometer, inclinometer, airspeed indicator.

1917 Friedrichshafen G-3 German Bomber. airspeed, altimeter, level-flight indicator, magnetic compass, and two each tachometers, air-pressure gages, water thermometers, and fuel quantity gages.

1917 Thomas Morse S4C - American Trainer. tachometer, air-pressure gage, fuel quantity gage, magnetic compass, airspeed indicator, barograph (recording barometer), air relief valve and air-pressure gage. The fuel system was pressurized to 3-4 psi. above atmospheric pressure. Relief valves were required to relieve internal pressure at altitude.

1918 Fokker D-7 German Fighter (Photo No. 1). tank fuel-pressure gage, auxiliary tank pressure gage, tachometer, compass.

1918 Martin Bomber-United States Twin-Engine Bomber (Photo No. 2). clock, altimeter, airspeed indicator, air temperature thermometer, and two each coolant temperature gages, fore and aft inclinometers, tachometers, and oil-pressure gages.

As World War I came to a close the great changes in aircraft and their instrumentation were very apparent. In every wartime period development of new weapons is greatly accelerated and most of the instruments improved or developed during this period were to find peacetime uses in the next decade. But at the same time much of the war-sponsored development in process at the close of 1918 was dropped for the usual reasons, lack of money, lack of interest and lack of foresight.

BETWEEN THE WARS, the Surplus Age 1919 - 1927

The general state of the art of aircraft instrumentation at the close of World War I was one of great promise. The requirements born of the war years resulted in design advances and more general acceptance of instruments for their intended uses. However the resultant design improvements had little time to be actually incorporated in great numbers in aircraft. Also the European instrument manufacturers were still far advanced over the American companies.

A description of the instruments in use in early 1919 is in order:

Altimeters using either a "D" spring or a helical spring movement linked to an evacuated bellows known as an aneroid were manufactured by a large number of companies, including Sperry, in the United States. These instruments operated on the principle of measurement of the differential pressure between the outside air and the near vacuum in the aneroid.

Rate of Climb Indicators were being put into limited use (manufactured by the Vigilax Company in France). Basically these instruments were similar to altimeters except that the bellows had a calibrated leak rate to allow the indicator to "zero" itself after a short period of level flight at any altitude.

Tachometers, mainly of the chronometric and centrifugal types, were manufactured by many companies including Van Sicklen, National Cash Register, Tel, Hamilton, Johns-Manville, Jones, Hoffenker, Reliance, Schaeffer and Budenberg, Adair and Star Corporations in the United States. Various other types, including air-driven magnetic, magneto, and liquid types were being made by Waltham, Stewart Warner, Tecto and Veeder Corporations in this country. In all cases these instruments counted the revolutions of the engine and thereby gave an indication of the power being developed.

Airspeed Indicators were made in all major countries with Foxboro, Sperry, Zahm, Van Sicklen, National Cash Register, Precision, King and Bristol being the principle manufacturers in this country. These instruments measured the difference in pressure between an impact pressure and a static pressure within the cockpit. The impact pressure was produced by the forward motion of the airplane and the ratio of these pressures varied with the aircraft speed.

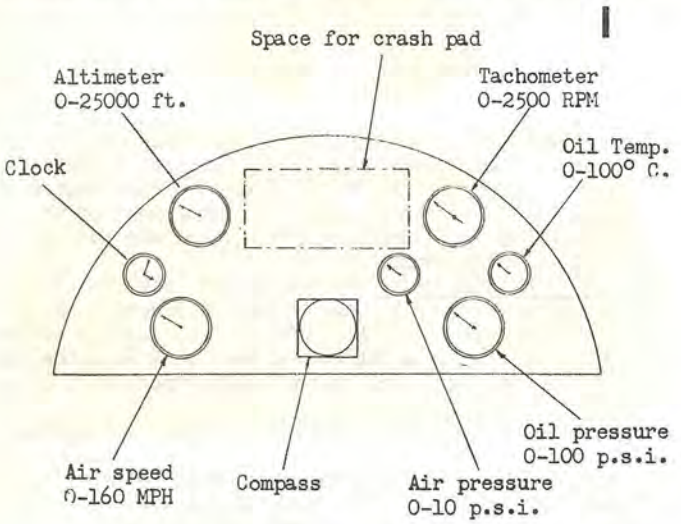
Compasses were not considered special instruments since they were merely adaptations of those made for marine use. In this country Sperry, Sherman, Moran, General Electric and Durkee were the leaders in the field. These instruments were adapted from marine-types by including additional damping mechanisms to minimize the violent oscillations experienced during flight. They had to be individually compensated for each installation due to the proximity of metal, rotating engine parts, and electrical devices in the aircraft, all of which influenced the magnetic operation of the instrument.

Inclinometers were popular in Europe for both fore and aft and lateral-attitude indications and were of both liquid and pendulum types. Surprisingly, only Sperry seemed to be active in their manufacture in this country. In the liquid types a ball incased in a liquid-filled tube tended to roll toward the end of the low side of the tube. This would indicate whether a wing was low or if the aircraft was diving or climbing. The pendulum-type consisted of a weighted pendulum suspended so that the top of the pendulum arm served as a needle on a graduated dial.

Other miscellaneous instruments such as gas gages and temperature and pressure indicators were universally manufactured with Taylor, Foxboro, Bristol, National Gage and Equipment, U. S. Gauge, Roberts and Triumph being the main contenders in the United States.

At this point it is interesting to note the emergence of companies in this field which are to this day leaders in the aircraft instrument industry. Names such as Sperry, General Electric, U.S. Gauge, and Foxboro are still active in this field while many of the others, though still in the instrumentation field, have diverged from the aircraft line.

Early in 1920 the typical instrument panel, as described by the American Society of Mechanical Engineers, consisted of the eight instruments shown in Figure I.



The A.S.M.E. pioneered in classifying instruments into nine basic categories:

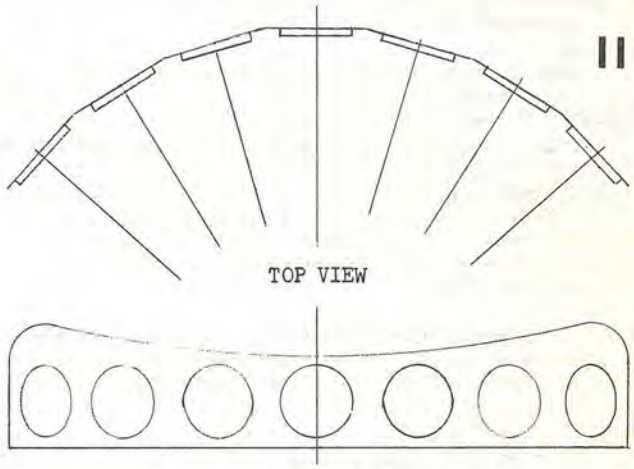
Altitude Indicators
  Altimeters
  Rate of Climb Indicators
Speed Indicators
  Airspeed Indicators
Direction Indicators
  Compass
  Turn Indicators, usually air-driven gyro-operated.
  Inclinometers
  Bank Indicators, (ball in curved tube type)
  Angle of Attack, a counterweighted wind vane with a scale to indicate angle
  Slip or Yaw Indicators, pendulum types, direct reading.
  Drift Indicators, either grid lines on wings or tail, or instrument mounted in cockpit floor
  Course Indicators, eventually included later types of compasses and course and distance computors
Tachometers.
Gas Indicators, including both fuel-level and fuel-flow meters.
Thermometers and Pressure Gages, including all types for fuel, oil, air, etc.
Timepieces, standard clocks, stopwatches and elapsed time clocks.
Oxygen Apparatus, quantity gages and flow indicators.
Balloon and Airship Instruments, including all instruments for lighter-than-air use. This covers many special types of inclinometers, gas pressure indicators, etc. that are more important for lighter-than-air use.

Just as World War I had resulted in great progress in the instrumentation field, the period following it resulted in a lag due to the large quantity of surplus aircraft and instruments that were readily available.

Two events during this period helped to maintain at least some degree of progress in the instrumentation field. They were the formation of an Aircraft Instrument Section at Wright Field and the establishment of the nucleus of the United States Air Mail System. According to Pamphlet No. 8, published by the War Dept. Air Service in 1919, instruments actually required for cross country flying were compass, airspeed, altimeter, clock and drift indicator. Magnetic compasses were used, with the better, more accurate types used on bombers and those of approximate accuracy used on fighters.

The year 1919 also marked the introduction of the first pictorial display of an aircraft on the face of an instrument to show aircraft attitude. This was introduced by Sperry and served as the real forerunner of all forms of modern day artificial horizons, attitude indicators, and three dimensional altitude and position indicating devices. The trend set with this instrument, in displaying a small aircraft on its face, will undoubtedly continue as long as instrumentation is used in aircraft. This instrument is shown in Photo No. 3 seen on Page 169.

During the years 1922 and 1923 the first types of vertical rather than round instruments made their appearance. These years also marked the introduction of the first combination, or engine gage, units which were also made into vertical scale types. It was realized during this period that the common compass was the most important navigation instrument as well as the least reliable. Another innovation of 1923 came in an attempt to keep instruments equally distant from the pilot and equally sized to increase readability. This is shown in Figure II. The idea never did catch on, as the slight advantage gained in readability was greatly offset by the increase in complexity of mounting.



HORIZONTAL VIEW (from pilot)

S.P.A.D. C.1 Type 81 INSTRUMENT PANEL

Note: A compass was not included and all instruments were of the same size.

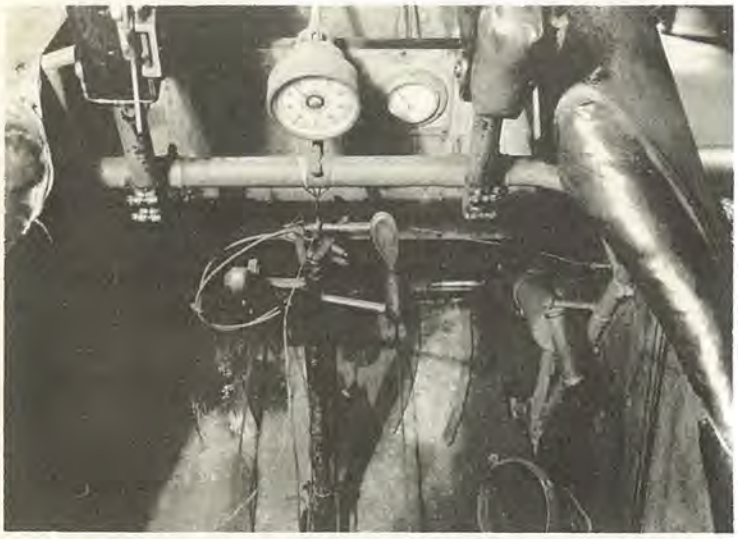
During this period the tendency still existed to consider instruments as supplementary references for the pilot and their indications were never believed over the instinct of the pilot. However a few pioneers, operating from the instrument development section at Wright Field, were proving the error of these assumptions. Some of the especially notable instrument flights made by these dedicated men included:

1923 Feb. 13 Dayton, Ohio to Langley Field, Va., 457 miles in 2 hours, 20 minutes in a DH-4.

1923 Sep. 6 Dayton, Ohio to Boston, Mass., 750 miles in 7 hours, 35 minutes at 7000 foot altitude. From Columbus, Ohio to the Hudson River there was no reference to landmarks. Final error was 12 miles south of course.

1923 Sep. 23 Dayton, Ohio to Fort Riley, Kan., 675 miles in 5 hours, 40 minutes. A total of three hours of this flight was completely on instruments. Final result was arrival exactly on course.

1924 Mar. 7 Dayton, Ohio to Mineola, N.Y, 575 miles in 3 hours, 45 minues with two and one half hours on instruments. Final result was ten miles south of course. The return



1. Cockpit of the Fokker D.VII which landed on the 1st Pursuit Group's advance field in France, October, 1918. (Photo courtesy of Air Force Museum.)

2. Pilot and bombardier cockpits in Martin MB-2 of 1921 configuration (1918 referred to in text). (Photo - McCook Fd. #8297, Air Force Museum #N58-D1-197)

trip was made five days later with a fifty mile per hour crosswind. Three hours of the six hour, ten minute flight were completely on instruments with arrival only eight miles north of course.

The above are only a few of the many flights made, which probably did more for the development of instrumentation than any other group either before or since, yet in most cases even the names of the men have not been recorded.

By 1925 serious attempts were underway to improve instrumentation. The following items were discussed in a Project Report #E-8-F entitled "Instrument Boards" which covered the work of the Instrument Development Group at Wright Field.

1922 May 4 Instrument board drawings were made up for night-flying Martin MB-2 plane P-222, No. 64201, which included the first two sets of tachometer and combination gage units of vertical type instruments. These were installed on May 26, 1922 in a DH-4 night flying plane.

1922 June 7 The Fokker transport, type T-2, plane P243, No. 64234, carried an altimeter, turn indicator, airspeed indicator, tachometer, oil pressure gage, water thermometer and clock. This plane is the same Fokker T-2 used by Kelly and McReady in their famous cross-country flight (now on display at the Smithsonian Institution in Washington, D.C.)

1923 Apr. 14 Vertical instruments installed in a DH4-B airplane.

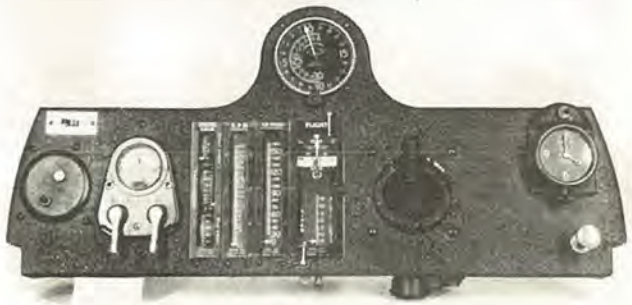
1923 June 1 First complete vertical instrument type board completed for DH-4 airplane. This board was eventually placed in General Mitchell's airplane. Instruments included were engine gage unit, tachometer, airspeed indicator, flight indicator and compass. All were of vertical types except the compass. A clock and altimeter of the usual type were used. A second panel of the same type was installed on General Patrick's personal airplane. Photo No. 4 shows the standard DH-4 panel

Reports from field locations showed vertical instruments were not satisfactory, nor were they considered as reliable as older types. Crash pads on the panel were considered as "a joke", and "taking up too much valuable space". Apparently there was considerable difference of opinion concerning this report as in other sections of this project report it is mentioned that various questionaires filled out by pilots indicated that all the instruments were operating satisfactorily and were a big improvement over the older types. To continue with excerpts from the report:

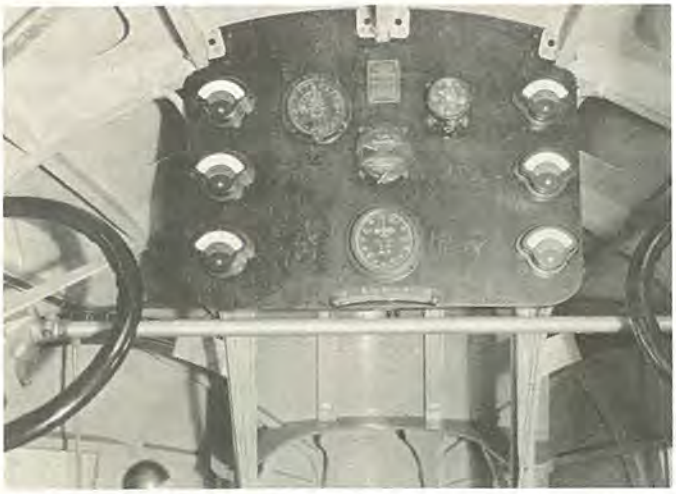
1924 Jan. 5 Instrument board designed for Barling bombers was disapproved by instrument section. Photos Nos. 6 & 7 show both pilot and observer's (or as presently known, engineer's) panels.

1925 July 18 Lt. McCready of "Dawn to Dusk" cross-country flight fame, condemned the verti-

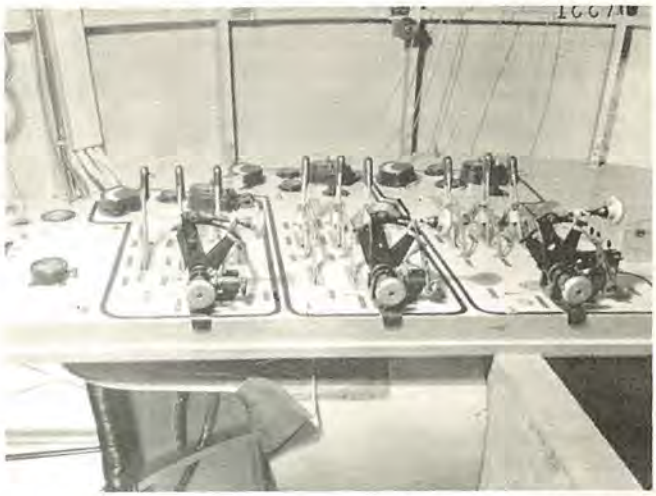
4. Panel of production type DH-4. In Photo No. 5 at right is shown the advanced design panel installed in



General Mitchell's DH-4. A duplicate was in Gen. Mason Patrick's. (Photos - A.F. Museum.)



6. Barling Bomber, pilot's panel. The absolute minimum of instruments and the complete dependency of the pilot upon the observer undoubtedly caused dangerous delay in the relay of commands and possible errors.



7. The observer's panel, to right of pilot, was poorly arranged, with some controls moving horizontally, others vertically. (Photos - McCook Fd. Nos. 16667 & 16670 respectively, from Air Force Museum.)

cal scale instruments.

1925 Dec. 9 Plans were made to install vertical instruments in a P-I-A airplane.

1925 Dec. 10 Instrument board for Fokker CO-4, airplane P325, No. 23-1209, for fog flying use, will use vertical instruments.

1925 Dec. 11 Elias Bomber had vertical scale instruments installed (later replaced with conventional).

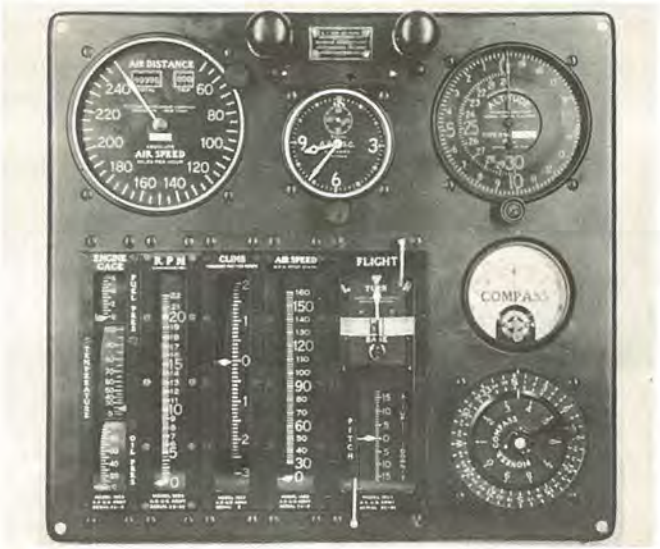
1925 Dec. 15 Pioneer Instrument Company given contracts for vertical scale instruments. Photo No. 8 shows the panel delivered on this contract. An interesting sidelight shows up in the report regarding this particular panel. It seems that the specification called for a particular identifying nameplate to be attached to this panel and Pioneer Instrument Company, wishing to receive recognition, added a plate identifying themselves as the manufacturer. Many paragraphs are used in the report to criticise them for this action and to detail the instructions for removal of this extra plate.

1926 Feb. 26 Huff-Daland LB-1 Bomber proposed with instruments on the engine nacelles within view of the pilot instead of on an internal panel. This was an attempt to lick the problems associated with instrumentation on remote outboard engines, as the instruments of this age had to be directly connected with the point of measurement. This same system was very successfully used in later years on the Ford Trimotor airplanes. It also served to eliminate any possible error of the pilot in mistaking the various readings of the instruments for different engines.

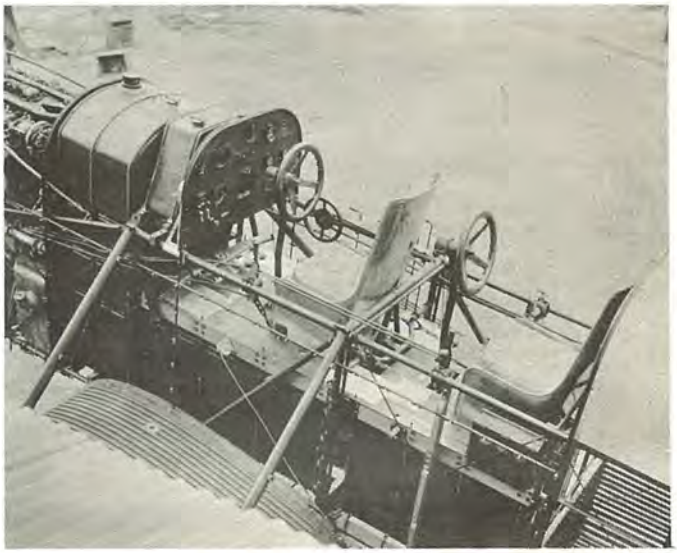
1926 Apr. 19 Attempts were made to standardize on bomber instrument panels.

1926 Apr. 27 Considerable repercussions on proposed use of vertical instruments but every dissenting opinion was based on the large number of circular instruments in the Air Corps' stock.

1926 Oct. 25 First reports completed on Curtiss XP-3 pursuit plane, P451, covering first vertical instruments in pursuit aircraft. In-



8. The Pioneer Instrument Co. vertical panel, neat, easy to read and advanced in design. (Photo - A.F. Museum.)



9. The Douglas World Cruiser under construction. (Photo - Douglas Aircraft Co. No. SM181229.)

cluded were 0-3000 RPM tachometer, engine gage unit type A-2 with 0-200 PSI oil pressure and 0-240 MPH airspeed indicator, and an engine supercharger unit.

1927 Feb. 1 Specification No. 1602 for Curtiss P5 pursuit plane disapproved vertical instruments.

Following is the closing quote from the same report: "Instrument Boards before the opening of this project were of minor importance in the design and construction of airplanes. Heretofore instruments were the last parts of the airplane to be installed. Not a great deal of thought was given to the best visible location as well as systematic grouping. Since this project was started the Air Service has awakened to the fact that it is of great importance to have instruments in proper grouping. In the last two years the Equipment Section has been called in on conferences and has supervised the design and construction of many instrument boards."

Some of the particularly notable flights of this period between 1919 and 1927 follow:

1919 May 8-31 Trans Atlantic crossing by Lt. A. C. Read and crew from Rockaway Beach, New York to Plymouth, England in the NC-4, 53 hours, 58 minutes flying time and a total distance of 4514 miles.

1919 June 14 First non-stop Atlantic crossing made by Capt. J. Alcock and Lt. A.W. Brown in a converted Vickers "Vimy" bomber from St. Johns, Newfoundland to Clifden, Ireland; 1890 miles in 16 hours 12 minutes.

1920 July 6 First flight entirely guided by radio compass was completed. A Navy F-5-L seaplane left Norfolk, Va., flew 95 miles directly to the battleship U.S.S. OHIO and returned to Norfolk without previous knowledge of the vessel's location. The radio compass is not actually a compass but rather a direction indicator connected to a loop antenna which could be tuned in by sound to radio signals originating from various points. By the use of various radio stations at known locations accurate navigation could be accomplished.

1920 Sep. 8 Transcontinental mail route, combination plane and train, from New York to San Francisco was completed.

1921 Feb. 22-23 Cross-country air mail inaugurated, flying both night and day.

1922 Sep. 4-5 Lt. J. H. Doolittle flew from Pablo Beach, Fla. to San Francisco, Calif. in 22 hours, 35 minutes.

1923 May 2-3 Lts. J.A. McCready and O.G. Kelly in the Fokker T-2 flew non-stop from New York to San Diego in 26 hours, 50 minutes.

1924 April 6-Sept.28 Round-the-World Flight from Seattle to Seattle using Douglas "World Cruisers" was made by Lts. Smith, Nelson, Arnold, and Harding; 26445 miles in 175 days, or 368 hours flying time.

1926 May 8-9 Richard Byrd and Floyd Bennett in a Fokker Trimotor flew over the North Pole.

1927 May 20-21 Non-stop flight from New York to Paris made by Charles Lindbergh in a Ryan Monoplane; 3610 miles in 33 hours, 30 minutes.

1927 June 28-29 Lts. A.F. Hegenberger and L.J. Maitland flew the Fokker C-2 trimotor from San Francisco to Hawaii. Instruments included radio compass, directional radio receiver (an improved version of the radio compass) earth inductor compass, and all standard instruments. Total flight covered 2407 miles in 25 hours, 50 minutes. However all radio aids became inoperative a short time after takeoff and the old reliable dead-reckoning navigation proved adequate.

1927 Aug. 16-17 A.C. Goebel and Lt. W.V. Davis flying a Travelair 15 won the Dole Oakland-to-Honolulu Race.

To illustrate the instruments in use during the years 1919 to 1927 the following aircraft are indicative:

1919 DH-4. See Figure III

1921 Curtiss Flying Boat, NC-4 (U.S.Navy)

Pilot's Instruments - Remote engine instruments for each engine.
Navigator's Instruments - drift indicator, airspeed indicator, compass, air distance indicator

1924 Curtiss "Falcon" O-1 (U.S. Army Observation Plane)

Oil temperature, engine-coolant temperature, and fuel quantity gages, airspeed indicator, magnetic compass, 8-day clock, oil-pressure gage, tachometer, turn and bank indicator, voltmeter and ammeter.

1925 Douglas DWC "World Cruiser", Photo No. 9

Pilot's Cockpit - ammeter, voltmeter, 0-100°C. Coolant temperature, oil temperature, 0-120PSI oil-pressure, 0-6 Psi fuel pressure, 0-2000 RPM. tachometer, earth inductor compass, (Experimental Model developed by Bureau of Standards, Aeronautical Instrument Co., and Pioneer Instrument Co.), magnetic compass, turn, bank, and pitch indicator with vertical scale, 0-10,000' altimeter, 0-160 MPH airspeed indicator, and clock. Fuel-level gage was mounted on the cowling.

Observer's Cockpit - magnetic compass, airspeed indicator, clock, and galvanometer used with the earth inductor compass. No drift meter was installed, however lines were painted on the top of the horizontal stabilizers to enable the observer to estimate drift in degrees.

1925-1931 Boeing 40A and 40B Mailplane, Photo No. 10

Airspeed indicator, compass, turn and bank indicator, tachometer, oil pressure, oil temperature, and fuel-pressure gages, clock, rate-of-climb, altimeter, ammeter.

1927 Ryan "Spirit of St. Louis", Photo No. 11

Lighted instrument panel with earth inductor compass, altimeter, tachometer, turn and bank indicator, airspeed indicator, 8-day clock, oil pressure, oil temperature, air pressure, fore and aft level, and transverse level gages. This was probably the most advanced single engine instrument panel in 1927.

At this point it might be interesting to note the cablegram sent by Lindbergh after completing his historic flight.

"PARIS MAY 26, 1927 FILED 4:25P.
PENINSCO N.Y.
PIONEER INSTRUMENT CO.
745 LEXINGTON AVE., BKLYN.
ALL INSTRUMENTS FUNCTIONED PERFECTLY DURING ENTIRE FLIGHT. I WAS LESS THAN FIVE MILES OFF COURSE ON IRISH COAST DUE LARGELY TO EARTH INDUCTOR COMPASS.
C.A.LINDBERGH"

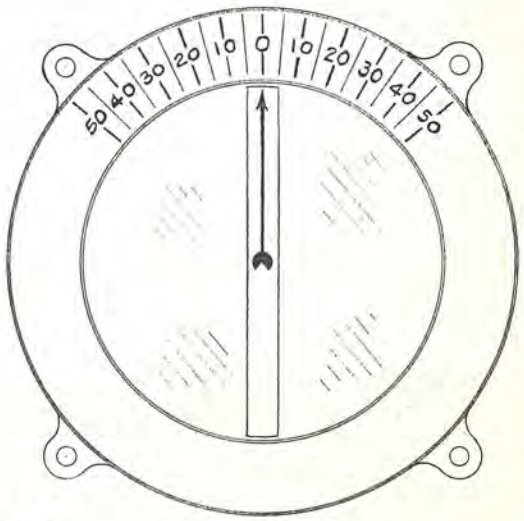
Five miles error after 3610 miles represents an accuracy of 1/10 of 1%. This shows that instruments were truly coming into their own, not as navigational aids to the "seat of one's pants, the wind in the rigging, the horizon and control feel", but as navigational requirements for all forms of distance flying.

Two instruments not previously described have made

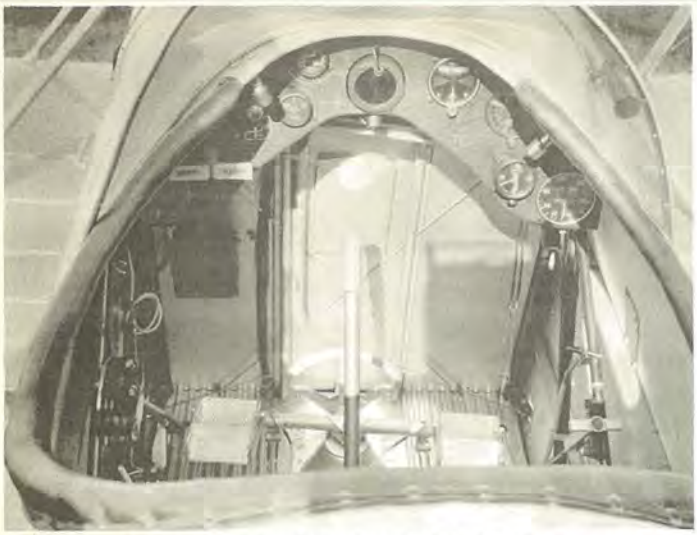
III "PILOT'S COCKPIT D-H-4-B FULLY EQUIPPED" was the title of this photoprint supplied by Capt. Truman Weaver, USAF. The DH-4B was in use in the Air Service from 1918 to early 30's. The photo was originally McCook Fd. #6545 A.S., later renumbered 11513, and had been prepared by C.C. Culver, Lt. Col., A.S.

their appearance during these years, the drift indicator and the earth inductor compass. A drift indicator is a device which, in its simplest form, consists of a series of angular lines on the aircraft which the pilot or navigator can use to sight objects on the ground. During flight the ground object will appear to follow one of the angular lines. By noting which line is followed the angle of drift can be estimated. These lines are usually spaced at 5° intervals so accuracy to better than 5° is strictly by estimate and by pilot experience. The latter versions of this instrument consisted of a sight gage with angular lines mounted in the cockpit floor. The pilot could look directly below the aircraft thru the sight glass and read the angle of drift on the instrument. Fig. IV shows a typical floor-mounted drift gage.

The earth inductor compass was a new version of a compass originally invented jointly by the Bureau of Standards, Aeronautical Instrument Co. and Pioneer Instrument Co. It was further refined and marketed by the Pioneer Instrument Co. for many years. It consisted of three basic parts, an electrical generator, a controller and an indicator. The generator was mounted at a distant point in the aircraft, usually in the rear of the fuselage, where it would not be seriously disturbed by magnetic disturbances within the aircraft. The controller and indicator were mounted within the cockpit. The pilot set the required compass course on the controller which positioned the generator in relation to the known magnetic field of the earth. When the proper course was followed the indicator showed a zero reading. Deviation from the course showed on the indicator in terms of degrees to the right or left of the proper course. An interesting point concerning this instrument is that if a course 180° or exactly opposite to the course set on the controller was flown, the indicator would show zero or on course. Many years after this period Mr. "Wrong Way" Doug Corrigan steadfastly maintained that he reached Ireland from New York flying by mistake a course 180° from that which he intended. There may have been more to this claim than most people realized.



IV FLOOR MOUNTED DRIFT GAGE



10. Instrument panel of Boeing Model 40A Mailplane. (Photo - United Air Lines.)

With the close of 1927 another great era of aviation history ended. The infancy and childhood stages were behind. The stage was set and the world was almost ready for the next period - an adolescent time known later as the Golden Age.

TO BE CONTINUED

FOOTNOTES:

(1) See "The Birth of Naval Aviation" by George A. Hardie, A.A.H.S. JOURNAL, Vol. 6, No. 1, (Spring 1961) pp. 5-6.

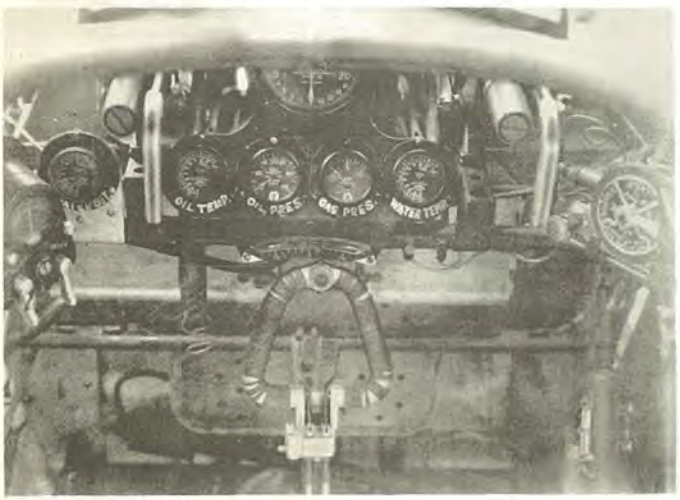
(2) See "Transcontinental U.S.A. 1911" by George Tweney, ibid., Vol. 6, No. 2, (Summer 1961), pp. 101-102.

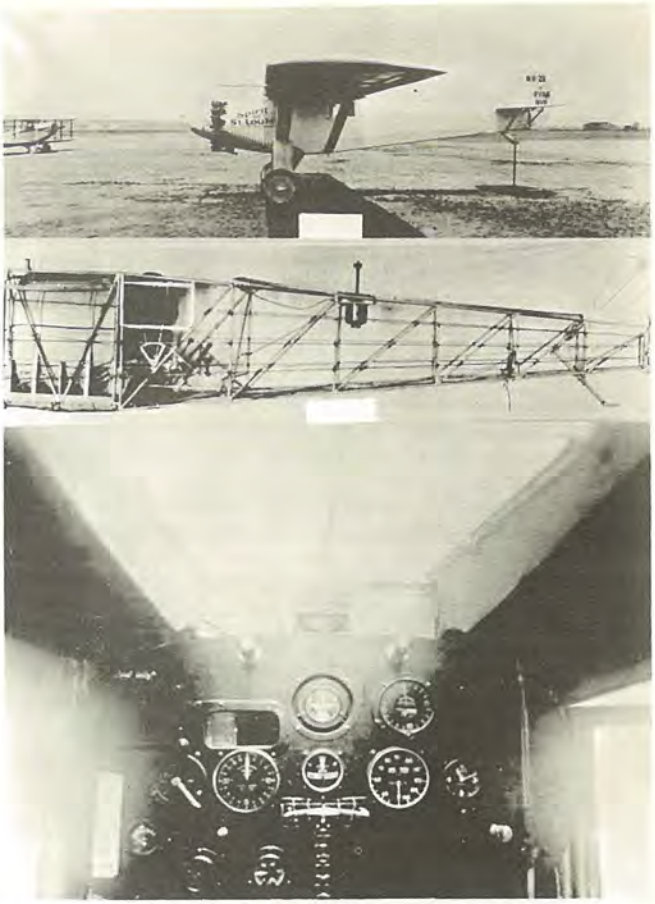
(3) A brief biography of Robert Fowler is given by Harold E. Morehouse in this issue. See "The Flying Pioneers".

(4) Ibid.

(5) See "The Aerial Torpedo" by Charles L. Keller, SPERRY ENGINEERING REVIEW, 1961. Issue and date unavailable.

Below - The instrument panel of the Engineering Division PW-1, 1921. (Photo - Original McCook Fd. #9729, later renumbered N58-D1-193. Courtesy of Air Force Museum.)





11. Interior of Lindbergh's Ryan, NX-211, "The Spirit of St. Louis". Excellent location and arrangement of instruments, and complete lack of forward visibility. (Photo - #7475 A.S., credit N.A.S.A.)

ABOUT THE AUTHOR

Robert H. Scheppler was born practically within sight of the original Teterboro, New Jersey, airport, where he developed a strong attachment for airplanes. He visited Teterboro Airport and witnessed many of the National Air Races held at Cleveland.

He graduated from Parks Air College in 1942 with a B.S. Degree in Aeronautical Engineering as well as A. & E. Mechanics Certificate and instructor ratings. Then followed a period of instruction for the Army Air Forces and work on the Manhatten Project at Oak Ridge, Tennessee. After the war he operated his own business, SCHEP'S AIREPAIR at Indiana, later moved to the newly formed Pioneer Central Division of Bendix in Davenport, Iowa, as Supervisor of the Test Equipment Dept. This Division manufactures all forms of flight instruments, life support equipment for aircraft and space vehicles, and sonic energy cleaning systems.

In addition to membership in the A.A.H.S. he has been a member of the Antique Airplane Assn., the Experimental Aircraft Assn., and various professional associations.

Interest in the history of aircraft instrumentation started with Bob about five years ago. He realized that there was a nearly complete lack of material available and that histories of aviation almost completely ignored the instrumentation. Major corporations had paid little attention to the advertising value of maintaining historical records. After two years of research the accompanying article was developed. It will be continued in the Winter JOURNAL.