



Douglas DC-3

AVIATION INSTRUMENTS

PART 3 By ROBERT H. SCHEPPLER

This continues the very fine series on Aircraft Instruments begun by Member Robert Scheppler in the Fall, 1961 issue of the JOURNAL. Part IV, covering the Post-WWII period, will be presented later this year.

LIVING IN THE PAST 1939-1941

By 1939 it was evident that a world wide conflict was eminent and that aircraft would play a major part. This had been frequently forecast in this country by men such as Generals Mitchell, Chennault and others, but the more outspoken aeronautical leaders were systematically discredited and removed from positions of responsibility. Because of America's isolationism the European instrument designers, especially those in Germany, entered World War II far advanced in the state of the art over those of this country. While the development of military instrumentation in this country lagged, equipment fortunately was being developed commercially by airlines such as United, American, and Pan American in cooperation with the components companies such as Bendix, Sperry, and Kollsman.

Naval aviation training had for years stressed navigation and use of instruments. This was necessary due to the type of navigation required for long overwater flights, the location and return to moving aircraft carriers, and location of moving targets during simulated missions. However, the air arm of the Navy on the whole was small and inadequately equipped.

The Army Air Corps, though somewhat better equipped, devoted less attention to navigation training, relying almost exclusively on visual reference to known landmarks and known radio aids. The fallacy of these methods had earlier been demonstrated in 1934 when the Army Air Corps was ordered to fly the airmail routes in place of commercial airlines. Though approximately two-thirds of the existing routes were eliminated, and midway in the fiasco all night flying was banned, within two months twelve pilots were dead, many more injured and many Air Corps aircraft were lost. The methods of training and much of the equipment remained unchanged until some of the lessons learned by our allies between 1939 and 1941 were finally heeded.

During the early years of World War II, 1939-1941, little new instrumentation was introduced to United States aircraft. Many refinements and alterations of existing instruments were made, and the instrument panels of military aircraft became overcrowded and difficult to use. With a trend toward four-engine bombers and some change toward twin-engine fighters, the number of individual instruments became excessive. Typical engine instruments in a four-engine bomber consisted of:

4 Tachometers	4 Fuel Pressure Gages
4 Oil Temperature Gages	1 Ammeter
4 Manifold Pressure Gages	4 Oil Pressure Gages
4 to 8 Fuel Level Gages	1 Voltmeter
4 Fuel Air Ratio Gages	1 Engine Synchronizer Gage
4 Fuel Flow Gages	4 Carburetor Temperature Indicators
1 Cylinder Head Temperature Gage	

In addition there were many general purpose instruments such as:

Suction Pressure Gage for Venturi Pressure
Outside Air Temperature Gage
Flap Position Indicator
Landing Gear Position Indicator
Oxygen Flow Indicator
Elevator Tab Position Indicator
Hydraulic Pressure Gage
Oxygen Pressure Gage
De-Icing Pressure Gage

Then there were the navigation instruments, many of which were duplicated on both pilot's and co-pilot's sides of the instrument panel.

Magnetic Compass - Standby	Altimeter
Turn and Bank Indicator	Airspeed Indicator
Automatic Pilot (Gyro Horizon and Directional Gyro)	Radio Compass Indicator
Rate of Climb Indicator	Clock



Gyro Flux Gate Compass. This instrument, developed by Pioneer Instrument Co., was eventually installed on most military aircraft and provided the most accurate direction-indicating device up to WWII. (Photo - Eclipse - Pioneer Div., Bendix Corp.)

Finally, there were between fifty and one hundred additional controls, switches, and lights for actuating or indicating the conditions of various systems such as propeller feathering, cabin air pressurizing, radio equipment, intercom equipment, navigating and operating lighting system, and various standby electrical, hydraulic and pneumatic systems.

All the above instruments were either of two standard sizes: 1-7/8 inch or 2-3/4 inch diameter. The Sperry Gyroscope Co. pioneered in the standardization of instruments working in conjunction with the Air Forces and the Civil Aeronautics Administration. The 1-7/8 and 2-3/4" diameter dial size and the use of white numerals on black dials had previously been standardized. At this time the items requiring standardization were lettering on dials, illumination, cover glasses, name

Northrop "Delta" (Courtesy of Charles Mandrake)

plates, and overall dimensions. Progress was made on these items which helped considerably during the next few war years when the quantities of instruments required could not have been built without standardization.

Some instruments especially those for the engines, were combined; in place of four separate instruments, two would be used, each with two separate indicator hands suitably identified for the individual engines. Or, in place of four separate instruments, one dial with a four-position selector switch was used. These combined types of gages applied to tachometers, manifold pressure gages, fuel/air ratio gages and engine temperature gages.

Just prior to our entry into WWI the mechanisms used for instruments had changed considerably from the types originally designed and used for many years, and a few new ones began to make their appearance.

Pressure gages such as fuel, de-icing, oil and hydraulic were generally of two types, either Bourdon tube or electrical. The Bourdon tube type consisted of an expanding curved tube connected by direct line to the pressure to be measured. The movement of the tube was magnified and displayed by means of a pointer on a dial. This type of gage could not be used where a comparatively long connecting tube was required. For pressure gages and other instruments in installations involving long lengths, electrical indicators were used in which a pressure pickup device transmitted an electrical signal whose voltage was proportional to the pressure being measured, and this signal actuated a meter on the instrument panel.

Suction Gages such as vacuum and manifold pressure were of diaphragm or electrical types. The diaphragm type used a thin membrane or diaphragm to separate two different pressures. One of these pressures was a static or reference pressure while the other was the one being measured. The ratio of these pressures determined the amount of movement of the diaphragm which, in turn, was magnified and displayed on the instrument face.

Thermometers were of the vapor pressure or electrical types. The vapor pressure type used a sealed bulb to connect the point of measurement to the cockpit indicator. A liquid inside the bulb expanded and vaporized with increases in temperature. The pressure developed by the expanding gas in the sealed bulb and tube actuated the pointer on the instrument face.

Tachometer design had been standardized in two types, chronometric and generator voltmeter. The chronometric type was a form of watch-type mechanism which actually counted the revolutions for a one second period and displayed the result on the instrument face. This required a direct flexible drive between the engine and the instrument. In the generator voltmeter type the generator voltage output was measured by the voltmeter in the cockpit and displayed as revolutions per minute. A



variation of this, known as the "mag drag" type, was also used. It had the advantage of eliminating the overshoot and undershoot common to generator voltmeter types.

Fuel/Air Ratio Gages or Exhaust Gas Analyzers, as they were sometimes known, consisted of a series of small chambers thru which fine wires were laid to form a so-called "bridge circuit". Two of the chambers were open to the exhaust gases while two were sealed. The resistance of the wires in the sealed chamber was known and fixed, while that of the wires in the exhaust gas-filled chambers varied with the amount of different gases being exhausted by the engine. The two resistances were compared and the slight differences were measured by a galvanometer. The indication was shown as a ratio of air to fuel. Proper mixture was maintained by manipulation of the engine mixture controls to maintain a thirteen- or fourteen-to-one ratio of air to fuel.

Cylinder Head Temperature Gages were used on air-cooled engines as a means of determining the general temperature level within the engine. They were connected to the rear sparkplug of what was determined to be the hottest running cylinder in the engine. They consisted of a thermocouple (two electrical leads of dissimilar metals) joined at the engine connection and again at the instrument in the cockpit. Due to inherent properties of the metal, a very slight electrical current which varied with the temperature being measured would be set up in the wires. This slight current flow was measured by the cockpit instrument and indicated as a temperature.

An Engine Synchronizer consisted of a millivoltmeter, (a voltmeter which reads extremely small voltages) connected across the generators of two or more engines. These were the same small generators used for tachometer readings. The signals were balanced against each other so that when the engines were running at exactly the same speed, the dial on the millivoltmeter would read zero. In some cases the leads were connected across the engine magneto lines instead of generators.

Sensitive Altimeters had been developed by Kollsman Instrument Co. which were readable to 70,000 ft. This was merely an extension in range of existing instruments.

Rate of Climb Indicators were being altered to cover the higher rates of climb of military aircraft. Range was being extended from 0-2,000 fpm to 0 to 4,000 fpm and the scale on the instrument face was being changed to a logarithmic scale to provide wider graduations and therefore better readability at the slower climb or dive rates.

Airspeed Indicators for high speed aircraft were developed by Pioneer Instrument Co. which could be read from 50 to 700 mph. These instruments had a multi-revolution pointer and each revolution represented 100 mph. A large numeral, showing through a cutout in the face of the instrument, indicated the proper 100 graduation. This improved readability throughout the range considerably.

Engine Instruments of the remote-reading autosyn type were developed by Pioneer Instrument Co. The autosyn or transmitting device was a movable electrical coil unit which was moved or positioned by the pressure, temperature, vacuum, etc. being measured. Through an electrical circuit this autosyn positioned another autosyn in the cockpit indicator. The motion of the indicator autosyn was registered on the face of the instrument as a temperature or a pressure. The development of this type of remote readout was a major step in the over all instrument improvement picture.

Accelerometers were developed to serve as visual warning devices of the approach of dangerous accelerations. These instruments measured the gravity or "g" forces being exerted in a single plane. These instruments used a small weight mounted in the plane in which "g" forces were to be measured. Movement of this weight actuated a pawl and ratchet assembly which in turn moved

a pointer on the indicator face. Both negative and positive "g" forces could be measured with one pointer. Two additional pointers were usually incorporated on the dial face to show maximum positive and negative "g" forces encountered during a flight. These two pointers did not return to zero after displacement but remained at their maximum point of travel until manually returned to zero. This instrument was useful to the pilot to indicate forces on the aircraft in flight and was helpful to the ground crews to indicate maximum force experienced by the aircraft during any one flight.

A corresponding change was taking place in the lighting of instruments, as well as standardization. It had become the accepted practice to individually light each instrument. This increased the weight, took up additional space, and complicated the instrument design. The Grimes Co. developed a new ultraviolet lighting system that provided a soft light on all instruments from one or two main lights. At the same time the Kollsman Instrument Co. developed fluorescent lighting of both individual and groups of instruments. In both of these systems, complexity and weight was decreased while maintaining a lighting level suitable for night flying.

WAR TIME DEVELOPMENT 1942-1945

By 1941, the lessons learned in the early days of 1939 and 1940 were being used to produce better designs in both aircraft and instrumentation. Some United States aircraft producers had been supplying airplanes to the Allied Powers since before the war started, and their pipelines of information enabled them to take advantage of many of the improvements developed under combat conditions and incorporate them into the aircraft under current production.

While the standard instruments such as altimeters, rate of climb indicators, turn and bank indicators, airspeed indicators, etc. remained essentially the same, minor changes were made to facilitate mass production, reduce weight, decrease friction or increase reliability. However, some new instrumentation was developed to improve navigation accuracy. The more prominent of these are described here:

Gyro Stabilized Drift Meter. This improved drift meter developed by Pioneer Instrument Co. incorporated a gyro device which stabilized the instrument and enabled the pilot or navigator to take accurate readings even though the aircraft was not completely stable. However, use of this instrument was still dependent upon being able to sight on ground objects.

Gyro Flux Gate Compass. This was a major improvement in direction indicating instruments. It operated on the principle of measurement of the magnetic forces of the earth. The forces produced by a coil cutting thru the magnetic lines of force surrounding the earth were amplified and fed into an indicator. These minute electrical signals were converted in the indicator to direction signals.

Auto Pilot. Pioneer Instrument Co. started production on an all electric autopilot system using the flux gate compass, a torque amplifier and an electric turn and bank indicator. Corrective signals to the controls and control operation were also electrical. This was a big improvement over the older air-driven types as it was less susceptible to dirt, moisture, etc., and the gyros could be driven at a much higher speed, thus increasing their accuracy.

True Airspeed Indicator. Kollsman Instrument Co. developed a true airspeed indicator which compensated mechanically for changes in outside air temperature and air density. This eliminated the mental corrections which the pilot had to make using standard airspeed indicators.

Horsepower and BMEP Gage. Kollsman Instrument Co.

(Continued on Page 46)