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ALTITUDE WIND TUNNEL AT AERL

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I don't know why I was chosen to make this talk—the men who know all about it are sitting here in case you want to ask any questions. They are A.W. Young and L.L. Monroe who wrote the Design and Performance Specifications [reference 1] and carried through the design.

The Altitude Wind Tunnel is unique from several standpoints. It is the first of its kind and it is the only one of its kind that we know about. It is unique also in that it is the most costly grouping of equipment combined to test a single engine. It probably requires more power to test one single engine than any other facility existing.

The purpose of the Altitude Wind Tunnel is to test an aircraft engine as installed in an airplane at altitudes.

The need for this tunnel was foreseen by a selected group of experts, comprising a special committee on engine research facilities, who recommended the components of the Aircraft Engine Research Laboratory. Mr. Kemper was a member of that committee and was a staunch proponent of the Altitude Wind Tunnel.

The size of this tunnel was determined by the consideration that it accommodates full-size aircraft engines driving flight propellers. For engine testing it is impossible to substitute a scale model for a full-size engine. Not only is a scaled engine design impractical but in the same time required to develop a model engine the full-scale engine could be constructed. On this premise the size of the Altitude Wind Tunnel was established. When the tunnel is completed, 3000-horsepower engines complete with all accessories and component systems may be investigated and performance and cooling characteristics determined at preselected altitudes in advance of actual flight.

The size of the flight propeller required for a 3000-horsepower engine fixed the diameter for the tunnel test section at 20 feet. The maximum altitude that could be reproduced in the tunnel—a direct result of the temperature and density decrease with altitude [the specific volume of air doubles between 30,000 and 45,000 feet)—was give careful consideration and was highly influential in determining the cost of the equipment. The temperature altitude at which the tunnel is designed to operate is 30,000 feet, and the shell is strong enough to simulate pressure altitudes of 50,000 feet.

The maximum speed of the tunnel air stream is 500 miles per hour at 30,000 feet. At lower altitude the maximum air spec will be less, approaching 345 miles per hour at sea level.

In actual use the tunnel is an intermediary between dynamometer calibration and flight tests. Nothing takes the place of final flight tests. There are, however performance data that it is desirable to know before an airplane is flight-tested and that cannot be determined in “Flying laboratories,” particularly power-plant performance at speeds and altitudes in excess of those attainable by the Flying Laboratory. This information can be determined in the Altitude Wind Tunnel. In addition, the tunnel allows us to control air conditions manually and reproduce any desired temperature and pressure combination for consecutive or repeat tests—a condition that is not available in flight testing and a consideration that results in much delay in flight testing.

Figure 1 represents the wind tunnel showing diagrammatically the steel shell, the office and shop building in front of the test section; the Exhauster Building to the left of the small end of the tunnel; the Refrigeration Building, the Make-Up Air Buildings, and the cooling tower grouped to the right of the large end of the tunnel.

An artist’s conception is shown of the external appearance of the steel shell and office and shop building in figure 2. The steel shell follows conventional wind tunnel design practice with a few significant exceptions. In the first place, the shell required thicker material than the conventional tunnel structure inasmuch as it must resist collapse from external pressures when the tunnel is operated at 50,000 feet altitude conditions. Secondly, the steel must be of a special alloy to retain its strength at the low temperatures encountered under high –altitude temperatures. In the third place, provision must be made to accommodate a heat exchanger, an intake-air duct, and an exhaust-air scoop that are not normally parts of an aerodynamic wind tunnel.

The design of the steel structure was done at Ames Aeronautical Laboratory and the type of steel selected in accordance with recommendations of the contractor. The steel structure is anchored at the test section and supported at the four elliptical corner rings through steels rollers on concrete piers in such a manner as to provide for movement in any direction to accommodate expansion and contraction of the steel shell. To minimize heat losses the shell will be provided with an insulating layer of glass wool which is in turn protected by a 1/3 inch steel cover. An 18,000 horsepower motor to drive the propeller is located externally to the tunnel on a foundation on the rear corner of the Exhauster Building and drives the tunnel propeller through an extension shaft sealed in the tunnel shell and provided with flexible couplings to allow for the movement of the tunnel shell. The driving motor is provided with a modified Kramer system of speed control. A 31-foot diameter 12-bladed propeller is used. The blades are wooden and were designed and constructed at Langley Memorial Aeronautical Laboratory. The propeller is protected against injury from failed parts within the tunnel by a bronze screen secured to the turning vanes just upstream of the propeller.

The test section proper is a steel cylinder 20 feet in diameter and 40 feet in length surrounded by a test chamber which connects the test section with the shop where the models are prepared for tests. Six component balances are provided in a sealed chamber beneath the test section and either on a trunion at the ends of the stub wind or on three supporting structures passing through the bottom of the test section. The top of the test section is hinged and may be opened by means of a motor-driven drum and cable arrangement in order to allow the model to be lowered into the test section.

Figure 3 shows an artists conception of a model being lowered into the test section from the overhead crane provided for that purpose.

Figure 4 shows a typical test section through the test chamber with a model in place supported at the stub wing tips using this type of model support. Controls for the engine are brought out through the trunion. Figure 4 also shows the balance frame and connecting linkage to the model balances. The mechanisms for changing the angle of attack of a model and for compensating for deflections in the balance frame are visible.

Figure 5 shows a typical section through the test chamber with the mechanism visible for opening the top of the test section. Ingress to the tunnel may also be had through the stairs leading to a small door in the bottom of the test section. From the observation platform the installed model may be observed, but not controlled, through windows in the top of the test section. The tunnel and the engine under test are both controlled from the sound-proof control room located below the observation platform. From this convenient location the operator with the help of assistants stationed in the Refrigerator Building and in the Exhauster Building is able to control the pressure temperatures and air speeds within the tunnel, the angle of attack of the model, and the operation of the engine and propeller mounted in the model by means of remote control. Instrumentation is provided to remotely indicate forces on the model in addition to the complete performance data of the test engine and its accessories.

Altitude pressures are maintained within the tunnel by means of four large reciprocating exhausters located in the Exhauster Building and connected by large ducts to a streamlined scoop just downstream of the model to be tested. Each compressor comprises four cylinders of 60-inch bore and 30-inch stroke and is driven by a 1750 horsepower constant-speed [133 rpm] electric motor. Exhaust from the compressor cylinders passes out of the building through eight horizontal pipes discharging into the atmosphere.

Inasmuch as the test engine is allowed to exhaust directly into the tunnel and would thereby contaminate the air duct from the carburetor air scoop by the wind stream, provision must be made to ventilate the tunnel. On the assumption that 40 percent of the exhaust gas could be directly removed from the tunnel by properly locating the exhaust scoop behind the test model, it was calculated that a rate of air exchange of 6000 pounds per minute would be adequate to maintain the contamination of the air stream at something less than 5 percent. Exhausters were accordingly chosen with the capacity sufficient for handling air at this rate. Inasmuch as the Engine Research Building, located directly across the road from the Altitude Wind Tunnel, is equipped with exhausters having one third the capacity required to ventilate the wind tunnel, the large reciprocating exhausters selected for the Exhauster Building, shown pictorially in Figure 6, have a capacity of only two thirds that required by the tunnel and operate in parallel with the Engine Research Building exhausters in full-load wind tunnel tests.

The ventilating air removed by the exhausters is replace by dried and refrigerated air and admitted into the tunnel through a pressure-controlled valve which is upstream of the tunnel heat exchanger and through a nozzle directionally controlled located at the converging section of the tunnel and adjusted for each test model to direct the entering air toward the carburetor air scoop by controlling the velocity within the make-up air nozzle to be equal to that passing by the nozzle. It is expected that an uncontaminated stream of fresh air will be obtained at the carburetor air scoop.

Referring to Figure 1, the means for drying and refrigeration the make-up air is shown in the group of buildings to the rear of the Refrigeration Building. The entering air passes over primary cooling coils, which reduces such temperatures to about 40 degrees F saturated. It then passes through beds of activated alumina which absorbs the moisture to a dew point of -70 degrees F while increasing the air temperature somewhat. The dried air is then passed over secondary cooling coils which reduces the temperature to that within the wind tunnel. Provision is made for reactivating the absorption drier by passing air heated by steam coils through the alumina in a reverse direction to drive out the moisture. The reactivation cycle takes about 5 hours. The dried alumina is then cooled by chilling the steam coils and continuing to circulate air over the chilled coils and through the alumina beds. Refrigerant for the primary coils and the secondary coils is supplied by a group of York reciprocating Freon-12 compressors located within the Refrigeration Building. These compressors absorb 1500-horsepower and also serve to supply chilled water for the secondary exhaust coolers in the Engine Research Building and for air conditioning the Administration Building.

The main refrigeration of the wind tunnel is accomplished by means of a copper plate fin type of heat exchanger located in the 51-foot diameter end of the wind tunnel and connected to 14 Carrier refrigeration compressor and condenser units installed in the Refrigeration Building. Each compressor is driver by a 1500-horsepower constant-speed motor.

Figure 7 shows a section through the heat exchanger and indicates the zigzag arrangement of the coils adopted to provide an area of air flow through the coils approximately four times that of the tunnel cross section. The heat exchanger was arrived at after considerable deliberation and discouragement on the part of both the contractor and the laboratory personnel. In the selection of the heat exchanger the contractor engaged the services of the ablest refrigeration men in the industry and our own staff was ably augmented by the assistance of Mr. Eugene J. Manganiello.

Freon 12 is used as the refrigerating medium and is compressed and condensed into a liquid by the 14 Carrier units. The liquid is then pumped into the tunnel heat exchanger where it is evaporated and withdrawn by means of four large vapor returns through a flash cooler and distributing header to the suction side of the 14 Carrier rotating units. The typical section through the refrigerating system is shown in Figure 8. The actual temperature control of the tunnel is affected by the suction pressure within the heat exchanger which is controlled by setting of suction valves located between the flash cooler and the distributing header on the suction side of the refrigeration pumps. Variation in the refrigeration capacity of the system is accomplished by adding or subtracting compressor units. The heat removed is transferred to the surrounding air by water circulated from the refrigeration machinery to a large cooling tower.

The total refrigeration capacity provided would, if utilized for ice making, manufacture 10,000 tones of ice each 24 hours. When operating at full capacity, refrigeration machinery requires a circulation of over 20,000 gallons of cooling water per minute.

Provision is made for defrosting the heat exchanger by pumping Freon vapor through the coils. Special precautions are necessary to protect the heat exchanger in case of mechanical failure within the tunnel. For this purpose a bronze screen is attached to the turning vanes immediately upstream from the heat exchanger. It was thought desirable that means should be provided whereby the test section could be opened to atmospheric pressures and temperatures while maintaining dry air within the remainder of the tunnel. For this purpose an inflatable balloon has been provided in a housing at either end of the test section with a mechanism for lowering and inflating with dry air. By this means the test section can be effectively sealed from the remainder of the tunnel, provided, of course, pressures on either side of this sphere are equal.

Figure 9 is an artist's conception of the Refrigeration Building with the machinery visible in phantom. The vertical pumps in the foreground are those required for handling cooling water.

The tunnel is scheduled for completion early in the fall of 1943 and should supply this laboratory with a much needed facility and one not available elsewhere in the world. Its operation will be more complicated than any existing tunnel and its power requirement enormous. At full load it will require more than 50,000 horsepower to test a single engine at high altitudes. Its value to the development of new aircraft should far exceed any additional complications or power cost of operation.

REFERENCE

1. Young, A.W., and Monroe, L.L.: Design and Performance Specification for Altitude Wind Tunnel. Revised ed., June 15, 1943.

--*Text from NASA Glenn History Office files. Director's Files. Boxes 1B1/1B2 F.764*