Altitude Wind Tunnel Inspection Talks
October 8-10, 1947

Carlton Kemper, Executive Engineer, and William Fleming, Head of one of two Altitude Wind Tunnel (AWT) sections, gave talks at the first annual inspection of the NACA Flight Propulsion Laboratory. Kemper describes the overall research at the lab, and Fleming focuses on the AWT's contributions.

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MR. KEMPER'S TALK AT MORNING SESSION OF FIRST ANNUAL INSPECTION FLIGHT PROPULSION RESEARCH LABORATORY

This is the First Annual Inspection of the Cleveland Laboratory. Many of you, however, have attended the laboratory's specialized research conferences on compressors, turbines, combustion and have visited certain facilities at the laboratory. A brief statement of the laboratory's facilities that you will inspect today and some facts concerning the construction of the laboratory will be of interest to everyone.

The construction of the Flight Propulsion Research Laboratory was started in 1941. By a speed-up of construction, facilities were completed in 1942 so that the Committee could contribute effectively to the war effort by conducting necessary research requested by the Army and Navy on the powerplants used in military airplanes. The majority o f the laboratory facilities were completed in 1944. The laboratory was designed to include research facilities that would enable investigation of the scientific problems associated with reciprocating engines. The maximum power of the reciprocating engines for which the laboratory was facilities were provided was 4000 horsepower. The air facilities supplied 8 pounds of air per second at temperatures of -70 degrees Fahrenheit and altitudes of 50,000 feet.

One of the unique research facilities at this laboratory is the 20-foot Altitude Wind Tunnel. This tunnel was designed to permit the investigation of the reciprocating engine installations complete with flight propeller, cowling, engine controls, heat exchanges, and turbo-superchargers. The performance of the powerplant as a complete unit can be investigation for a range of flight conditions from a sea level to 50,000 feet altitude and for a maximum speed of 400 miles per hour (P-47). The tunnel, with no blocking has a maximum air speed of 520 miles per hour, an altitude limit of 50,000 feet and a minimum air temperature of -37 degrees Fahrenheit. The make-up capacity of the tunnel is 100 pounds per second.

With the advent of the jet engine in the United States in 1945, the decision was made to shift the emphasis in research at the Cleveland Laboratory from the reciprocating engine to the jet engine. The Altitude Wind Tunnel was the only facility in the United States that permitted the installation of the complete jet engine with fuselages and air inlets so that a study could be made of the combustion and performance characteristics under altitude conditions. All new jet engines have investigation in the Altitude Wind Tunnel at the request of the Air Material Command or the Bureau of Aeronautics, Navy Department. The operating time for this tunnel has been scheduled 8 to 12 months in advance since its completion.

The laboratory's research facilities have been converted and enlarged so that today we have an air-supply system of 80 pounds per second. This quantity is ten times that required for research of the 4000-horsepower reciprocating engine. Even this quantity is sufficient only to supply the demand of current jet engines. The new designs of jet engines now on the boards will require air supplies of approximately 400 pounds per second.

The new Compressor and Turbine Wing to the Engine Research Building completed in 1946 has research facilities that provide for compressors of 15, 000 horsepower and absorbing power for turbine developing 17,000 horsepower.

Of particular interest during your inspection will be the two new altitude chambers that can be used to investigate the performance of jet engines from sea-level to 50,000 feet altitude and at temperatures from 200 degrees Fahrenheit to -70 degrees Fahrenheit. These research facilities will greatly relieve the work load on the 20-foot Altitude Wind Tunnel and will speed up scientific research on the complete jet engine. The same air supply for the altitude chambers will be available for research on the component parts of the jet engines.

During your inspection today you will see only a limited number of the laboratory's research facilities, but you will obtain a good general view of these facilities and in many cases see the latest research data that have been obtained on the certain component parts of current jet engines.

ALTITUDE WIND TUNNEL RESEARCH
By William A. Fleming

The altitude wind tunnel was constructed for research on full-scale aircraft engine installations at altitude flight conditions. A plan view of the wind tunnel and its facilities is shown in Figure 72. In order to accommodate full-scale engine nacelles in the altitude wind tunnel, the test section was made 20 feet in diameter and 40 feet long. Since these engine installations were to be investigated at airspeeds between 400 and 500 miles per hour, it was necessary to install an 18,000 horsepower electric motor which drove a 32-foot diameter propeller. To simulate altitude conditions required both a reduced pressure and a reduced temperature within the tunnel. Reduction of the pressures in the tunnel requires four reciprocating-type exhauster unites which together absorb 7000 horsepower. Reduction of the temperature in the tunnel, to simulate temperatures encountered at high altitude flight conditions, requires a 21,000 horsepower refrigeration system for cooling the tunnel air. Because the engine exhausted directly into the tunnel test section, this meant that the air within the tunnel had to be constantly changed. Air at atmospheric pressure is dried, refrigerated, and then bled into the tunnel to replace the burned has exhausted by the engine. Induction of this additional air requires that the exhauster capacity not only be great enough to maintain the desired test altitude but that the exhausters also have sufficient capacity to handle the fresh air bled into the tunnel.

Work has been done in the altitude wind tunnel on both reciprocating and jet engines. Some of these have been investigated with complete wind nacelles or fuselages installations. Other engines have been installed in special nacelles constructed at this laboratory. Recent work in the altitude wind tunnel has been almost completely devoted to investigations of various types of jet engines.

Operational and performance data of the entire engine are determined at various altitude flight conditions, as well as the performance of the various engine components operating in the engine. Engine operations data include a number of phases: The operating range of the engine is established at various altitudes and it is determined whether the operating range is limited by high turbine temperature, faulty combustion, or other reasons. The windmilling drag of the engines is also determined; that is, the draft of an engine which is inoperative and which is allowed to windmill while in flight. Starting and acceleration characteristics of the engine are determined at all altitudes and the maximum altitude at which it is possible to start the engine is established. Investigations are made to test the ability of the engine fuel systems to compensate for changes in altitude and airspeed, in such a manner as to maintain a fixed engine speed for a given throttle setting at all flight conditions.

The operating range of a typical turbojet engine for a range of altitudes up to 50,000 feet is shown in the Figure 73. This figure is somewhat similar to one which was shown by the Combustion Research Branch. This figure, however, is the operational limits of the entire engine tested at altitude flight conditions, whereas the curve presented by the Combustion Research Branch was one for an individual combustion chamber operating at conditions simulating those within an engine in flight at high altitudes. It should be noted that at very high altitudes the operating range of the engine was greatly reduced from that at lower altitudes.

The windmilling drag of a turbojet engine in flight is presented in Figure 74. Here the windmilling drag is presented in terms of percent of maximum net thrust of the engine. As the airspeed is raised, the windmilling drag increases quite rapidly. At a speed of 500 miles per hour, the drag of the engine is 12.5 percent of the rated engine thrust at that flight condition.

Because the trend in aviation is to fly at ever-increasing speeds, the NACA is conducting a research program to increase the thrust of various types of jet engines. Some typical performance data obtained in the altitude wind tunnel which cover one phase of this program are presented in the next two figures. In Figure 75 is presented a comparison of the net thrust per unit frontal area obtained with a turbojet engine, a turbojet engine with tail-pipe burning and a ram jet engine. The curve shoes that the thrust of the turbojet engine increases only slightly as the airspeed is raised; however, the thrust of the turbojet engine with tail-pipe burning increases quire rapidly, and at an airspeed of 600 miles per hour the thrust with the tail-pipe burning is twice that obtained with the same turbojet engine and no tail-pipe burning. Thrust of the ram jet engine is considerably lower than that of the turbojet engine or that of the turbojet engine with tail-pipe burning at low airspeeds. However, at the airspeeds above 500 miles per hour the thrust of the ram jet increases quite rapidly and the ram jet equals that of the turbojet at about 630 miles per hour, and equals that of the turbojet engine with tail-pipe burning at a flight speed of about 920 miles per hour.

To complete the comparison of the three engines, the specific fuel consumption is presented in Figure 76. This figure shoes that the specific fuel consumption for the turbojet engine increases slightly with airspeed and is lower than that of either the ram jet or the turbojet with tail-pipe burning at all airspeeds. The specific fuel consumption of the turbojet engine with tail-pipe burning is somewhat high than that of the turbojet engine at all airspeeds, decreasing slightly at low airspeeds, and remaining uniform at airspeeds above about 300 miles per hour. The specific fuel consumption for the ram jet is very high at lower airspeeds and decreases rapidly as the airspeed is raised. At speeds as high as 1000 miles per hour, however, the specific fuel consumption of the ramjet is considerably higher than that of the turbojet or turbojet engine with tail-pipe burning. Improvements of combustion efficiency in the ram jet engine and the turbojet engine with tail-pipe burning will further lower the specific fuel consumptions of these engines.

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