# THIRTY-EIGHTH ANNUAL REPORT

OF THE

# NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

## 1952

INCLUDING TECHNICAL REPORTS
NOS. 1059 to 1110

UNITED STATES
GOVERNMENT PRINTING OFFICE
WASHINGTON : 1954

For sale by the Superintendent of Documents, U. S. Government Printing Office, Washington 25, D. C. Price $8.75 (buckram)

# SOME EXAMPLES OF RESEARCH ACTIVITY

## NEW ALTITUDE TEST FACILITIES AID IMPROVEMENTS OF TURBOJETS

During the summer of 1952 a new research tool was put into use at the NACA's Lewis Flight Propulsion Laboratory. What made the event of great importance was that it came at a time in the world race for air supremacy when bigger, more efficient powerplants are sorely needed for tomorrow's airplanes. Except for this new facility, the United States would not now have the research equipment so necessary for study, through their full range of power and altitude, of the largest turbojet engines now being developed.

Termed the Propulsion Systems Laboratory to distinguish it from other, smaller engine testing facilities at the Lewis Laboratory, the new equipment marks another milestone in a successful, 9-year effort by American research, first to catch up with the turbojet revolution, and then take the lead. Throughout this period, the NACA has continually increased the capacity of its altitude facilities to enable testing the more powerful engines under development.

Prior to World War II, although interest was shown in the United States in theoretical considerations of the possible adaptation of the long-known prinicple of jet reaction for use in aircraft, virtually all development effort in this country had been concentrated upon designing piston engines with more power and better fuel economy for the long-range fighters and bombers upon which American air defense plans were based.

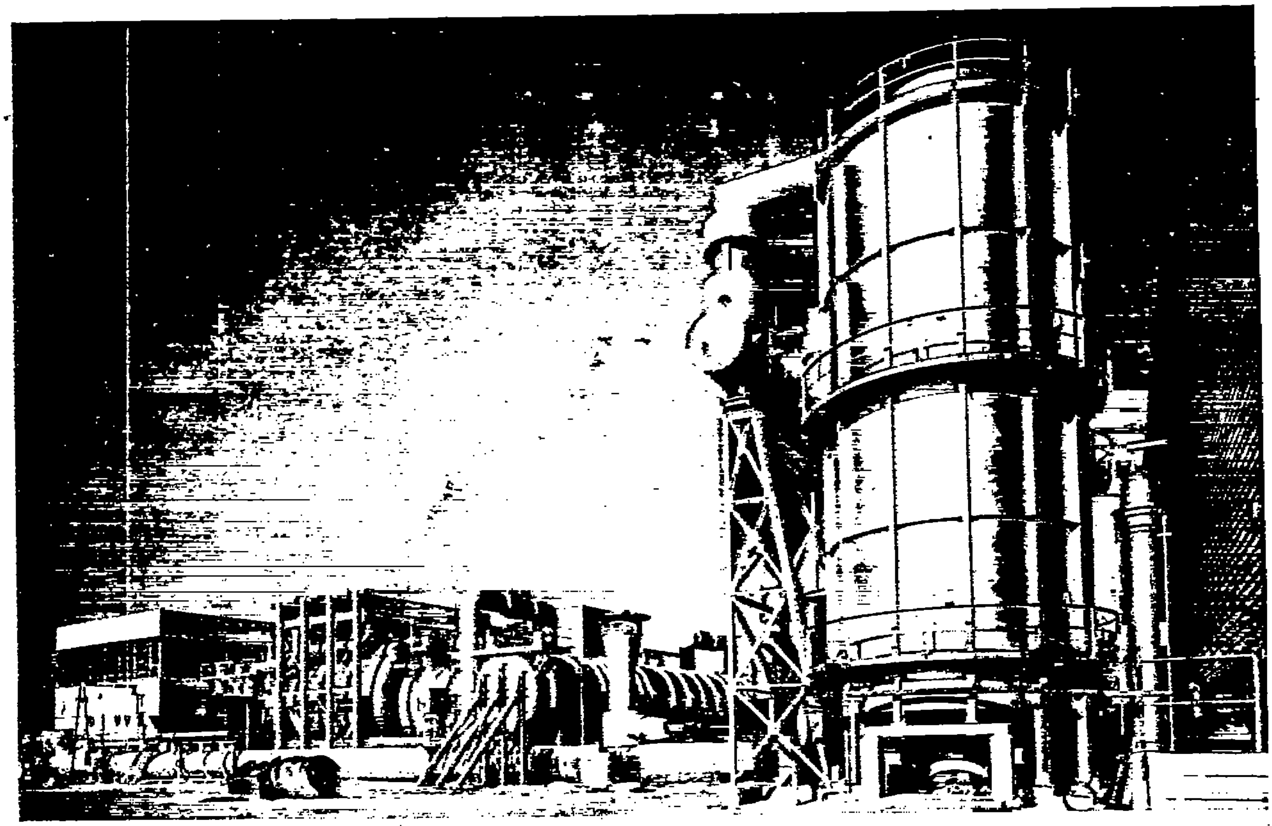
In both Germany and Great Britain, the need for more powerful engines for short-range, high-performance interceptor aircraft made the idea of turbojet engines very attractive, despite the handicap of high fuel consumption. In 1941, even before American involvement in the war, Great Britain made available to the United States the Whittle engine. American production and improvement of this first British turbojet was assigned to the General Electric Co., while the nation's aircraft research and production establishments were kept at the more immediate task of providing the improved piston engines needed to win World War II.

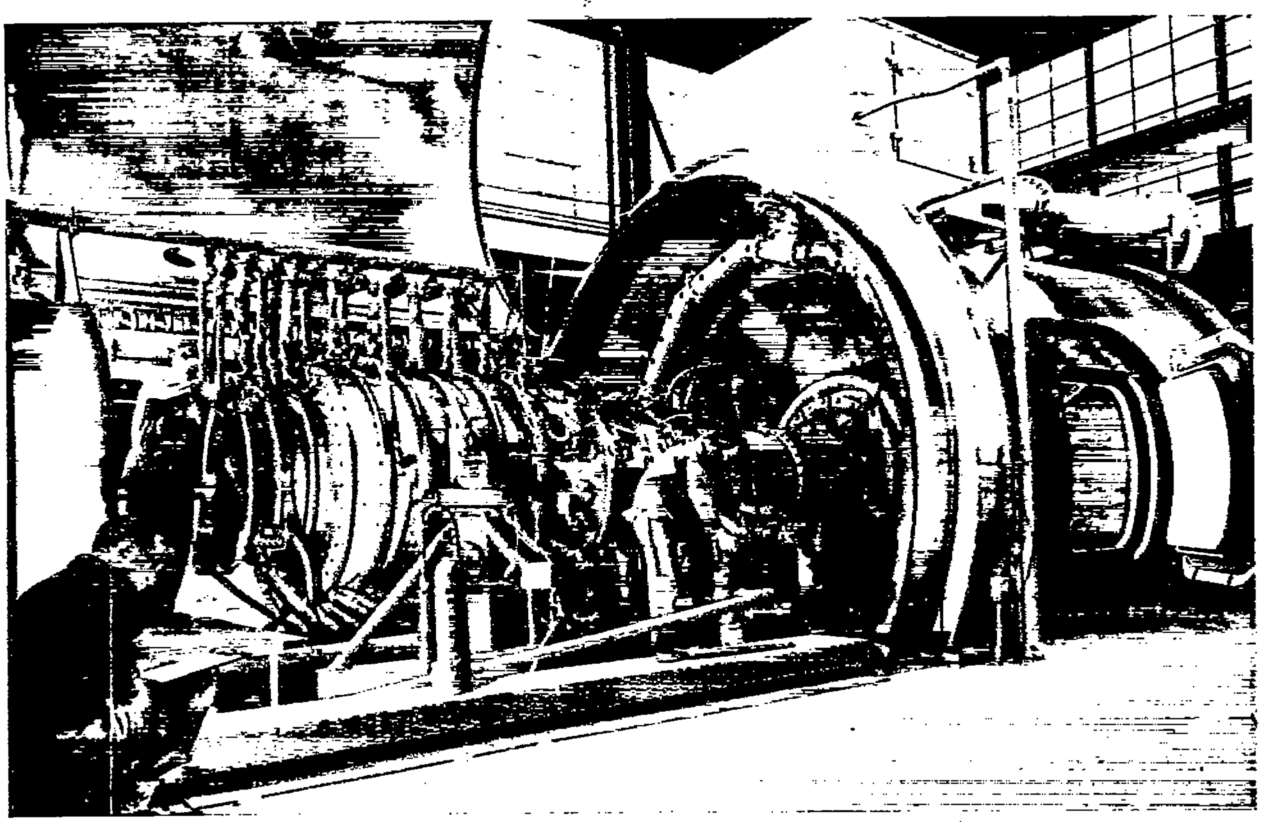
Construction of the Lewis Laboratory was authorized in 1940, and provided facilities, superior to those of any nation, for propulsion research. Previously, neither the NACA nor the aircraft engine manufacturers had been able to do more than test complete engines under sea level conditions, except in actual flight, but as the fighters and bombers of World War II continued to seek higher altitudes, it became imperative to perform extensive research on problems of high-altitude operation, to find solutions which could be applied quickly to current engines. Although some of this work could be done profitably in flight, the need was great for test equipment to enable study, under laboratory control with full instrumentation, of the operating characteristics of engines under conditions which simulated flight throughout the range of altitude and speed desired.

Fortunately, these test facilities at the Lewis Laboratory, although designed specifically for piston-engine research, could be adapted quickly for study of the turbojet engine. It was because of this, in 1943 when it was no longer necessary for the NACA to concentrate its propulsion research effort on piston engines, that the tools were in hand with which to begin intensive research on the powerplant which would revolutionize the world of aeronautics.

Altitude facilities must duplicate in the laboratory the pressures and temperatures encountered at the altitudes and speeds simulated for the engines under test. Air pressure drops from 14.7 pounds per square inch at sea level to 3.5 pounds at 35,000 feet and to 1.7 pounds at 50,000 feet. At 100,000 feet it is down to 0.2 pound. Air temperature drops from the NACA standard of 59.5° F. at sea level to −67° at 35,000–100,000 feet. The air entering the engines of an airplane is subjected to a ram effect which causes a rise in both pressure and temperature. This ram effect becomes more pronounced as speed increases. For example, the ram effect experienced by an airplane flying at 35,000 feet at twice the speed of sound (M–2) would result in a pressure rise from 3.5 to 27 pounds per square inch, and in a temperature rise from −67° to 250° F.

At the Lewis Laboratory there are two kinds of altitude facilities suitable for testing of full-scale engines. In one, the Altitude Wind Tunnel, an engine may be mounted in a wing or fuselage section, and a study made of air flow around the outside of the engine as well as through it. When the tunnel was first used in 1944, it was for investigation of the operating characteristics of the General Electric I–16, that company's first improvement on the Whittle design, as installed in a Bell P–59. Originally, the tunnel could simulate a top speed of 500 miles per hour and an altitude of 30,000 feet, but within a relatively short time it became





(Upper) Exterior view of new facility at Lewis Flight Propulsion Laboratory where the largest turbojet engines now under development can be tested through their full range of power and altitude. (Lower) Interior view of altitude tank opened up to show test set-up for large-scale combustion tests.

necessary to duplicate altitude conditions of 50,000 feet. During 1952, the capabilities of the tunnel were again increased substantially, by raising the original capacity of the exhausters, which evacuate the test chamber to whatever degree of vacuum is required to duplicate conditions at the desired altitude, from 200,000 to 375,000 cubic feet per minute.

The second type of altitude facility at the Lewis Laboratory for full-scale testing duplicates internal air flow conditions. This requires a ram air supply and a refrigeration system to duplicate the pressure and temperature conditions encountered over the range of flight speeds and altitudes desired. Exhausters subject the gases leaving the engine to a pressure equivalent to the altitude conditions being simulated, and also provide cooling. To permit operation of the several "tanks" at Lewis, exhauster capacity of 400,000 cubic feet per minute was provided, enabling simulation of operating conditions at altitudes of 60,000 feet and higher.

Because the turbojet engine is basically an air-heat machine, its production of greater thrust is limited by the amount of air it can handle efficiently. In the few years this type of powerplant has been under development, its air-handling capabilities have increased enormously. The earliest engines handled hardly 25 pounds of air per second; turbojet powerplants now in full production require 100 pounds of air per second or more, and tomorrow's engines will be even more voracious. During this same brief period the production of useful thrust has increased correspondingly from 1,500 pounds or less to more than 6,000.

This rapid increase in the amount of air required by the more powerful turbojet engines has had the effect of forcing a similar scaling up of the machinery required to operate altitude testing facilities. At the Lewis Laboratory this increase in requirements has been met in two ways.

First, the existing exhauster equipment has been connected by a system of cross piping, which enables the exhausters to be operated collectively as a unit or individually. Similarly, the refrigerated air and combustion air production equipment has been linked for pool operation. From a central station the control engineer can readily supply the test cells with their particular air requirements.

Second, a new research facility, the Propulsion Systems Laboratory, was constructed. Incorporating many improvements both in the altitude exhaust vacuum system and in the other process systems needed to provide altitude conditions, the new equipment has its own exhausters with a total capacity of 825,000 cubic feet per minute, which may be connected with the other exhauster equipment at the Laboratory.

Such facilities are vital in the investigation of the aircraft engines of today and tomorrow. Without them altitude research would be reduced to a crude cut-and-try projection of information gained either from tests at sea level, or flight test which is becoming less practicable as engine performance potentials exceed the performance capabilities of test-bed airplanes. Used effectively these laboratory facilities can contribute greatly to the further improvement of the powerplants specified for the faster, higher flying aircraft of tomorrow.

## FLUTTER PROBLEMS PRESENT NEW CHALLENGE TO RESEARCH SCIENTISTS

Flutter, which had been effectively restrained if only imperfectly understood in pre-World War II days, has reappeared to challenge the best efforts of both the aerodynamicist and the structures specialist. Today's airplanes, with their very thin, swept wings, fly at or near the speed of sound, and maneuver at very high altitudes. But their gains in performance have been at the cost of greater susceptibility to flutter.

Flutter was a serious problem in World War I and for years afterwards. It manifested itself frequently during dives, sometimes so violently as to cause the airplane to disintegrate in flight.

Basically, flutter is vibration of some part of an airplane, excited by the imposition of air loads. Most early cases of flutter affected one of the airplane control surfaces, such as the aileron, and a cure was found by the addition of mass balance to the affected part. In the 1930's, Theodorsen delineated the fundamental mechanism of flutter, and methods were developed for calculating safe design limits. With increasing use of all-metal construction, the relatively slow airplanes of the day, when designed on a strength basis only, were sufficiently rigid and sturdy to escape the occurrence of flutter. However, at the much faster speeds of today's airplanes, and with the thinner, heavier and more flexible construction now used, airplanes must be designed for flutter as well as for strength right from the beginning.

The flutter problem has become more complex and difficult in the postwar period as designers seek to use extremely thin wings on airplanes to be flown ever faster, ever higher. In attacking the problem, the vibratory characteristics of the structure have to be studied together with the nature of the air loads imposed on the structure. It is necessary to consider the vibrational characteristics of many different types of wings. The thin wing, which does not remain undistorted in its own plane, introduces a new complication. Once, it was sufficient to consider only the more simple vibrational characteristics. Now, it is being found that unless the flutter analyses take into account as many as possible of the characteristics, the results will be seriously in error.