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1948 INSPECTION OF THE LEWIS FLIGHT PROPULSION LABORATORY

THE STATUS OF AIRCRAFT PROPULSION SYSTEMS

by

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The high-speeds currently obtained by research and military aircraft is a measure of our knowledge concerning the laws of aerodynamics and flight propulsion, and of the extent to which this knowledge has been applied to the design of a particular aircraft. It is truly astounding that in a short period of 1 year the Air Force and Naval Aviation have flown a research airplane at a speed in excess of the speed of sound and a production model military fighter airplane at 670 miles per hour. The fundamental knowledge that makes possible this high-speed performance was obtained from a cooperative research and development program of the Air Force, Naval Aviation, the aircraft industry and the NACA. The necessary research work on this program was started by the Committee in 1942. The high speeds obtained in 1948 are the culmination of this research effort.

In 1942 the jet engine in this country was classified as top secret. At the request of the Durand Committee, which was the group then in charge of jet-engine research, the NACA was asked to investigate the heat release of a combustion chamber for a special jet engine. The results obtained showed that a heat release in excess of one million Btu per hour per cubic foot per atmosphere could be obtained. The Committee is now investigating a combustion-chamber design having a heat release of 50 million Btu per hour per cubic foot per atmosphere, which is more than five times that of current jet engines. Possible methods of cooling nonstrategic metals to temperatures at which they will have good strength characteristics is a companion research project to the one on combustion.

Most of the current jet engines have multistage axial-flow compressors, can-type or annular -type combustors, and single or multistage turbines. The thrust developed by these jet engines is from 3500 to 6500 pounds. The jet engines use a 30-70 mixture (by volume) of methyl alcohol and water to obtain increased thrust for take-off. In engines having centrifugal compressors, the alcohol-water mixture is injected into the inlet of the compressor. With the axial-flow compressor, no satisfactory method of injecting the mixture into the compressor inlet has been found because the compressor blading throws the alcohol-water mixture onto the compressor case. The mixture is therefore injected into the combustion chamber. This method of injecting the alcohol-water mixture gives a 20 percent increase in jet thrust. Although the consumption of the liquid mixture is high during take-off, the necessary additional injection equipment is relatively light in weight. No great weight penalty is imposed during the flights because the alcohol-water mixture is used up during the take-off.

For additional thrust increase at take-off and for certain flight maneuvers fuel may be burned in the tail pipe. Thrust increases as high as 40 percent at sea-level conditions and 80 percent at an altitude of 30,000 feet and a flight Mach number of 0.9 have been obtained using this method. The burning of additional fuel in the tail pipe requires the installation of a fuel-injection system and flame holders. Every effort must be made to keep this equipment low in weight because it forms a permanent part of the aircraft. The aerodynamic resistance of the fuel-injection system and flame holders installed in the exhaust gas stream should be low. Maximum aerodynamic efficiency is only obtained with tail-pipe burning when a variable-area nozzle on the end of the tail pipe is used. This orifice may be two-position inasmuch as it simplifies the controls and results in only a small loss in thrust. The tail-pipe burner is now being considered an integral part of the jet engine by the engine designer and the manufacturer.

The fuel consumption of the jet engine has shown a slight decrease as engines of increased thrust have been developed. During a period of 5 years, the thrust of a jet engine has been increased from approximately 2000 pounds to 6500 pounds. At the same time the fuel consumption has been decreased from a value of 1.2 pounds per hour per pound thrust to a value of 0.95 pound per hour per pound thrust. Large improvements in fuel economy will only be obtained by operating at higher compression ratios and higher combustion gas temperatures. The Committee's research methods of attacking the problem of decreased fuel consumption will be explained during the inspection of the laboratory.

One of the most serious flight problems affecting the reliability of the present jet engine is the icing of the stator and rotor blades of the axial-flow compressor when operated in icing conditions. The research of the Committee has indicated several possible methods for decreasing the icing hazards of jet engines. At present the use of hot gases from the turbine inlet piped to the compressor inlet and discharged at right angles to the air flow seems to be the most practicable method of combating the icing hazard.

The jet engine in this country is still a power plant for military aircraft only. It is used in fighter aircraft or in medium-range high-speed bombers. The reliability of the jet engine is reflected in the relatively short service life and in the large number of replacement parts which must be provided for military service. Although the latest design of jet engine has not been in flight service long enough to compile service records on the reliability of the engines, the indications are that the latest designs show a great improvement in reliability as compared with the first service jet engines. The recent successful flight of a squadron of F-80's across the Atlantic Ocean in 5 hours and 15 minutes is proof that the jet engine is becoming a reliable aircraft power plant.

There are a number of research problems that must be solved before the turbopropeller engine has a place in the aircraft propulsion picture. These problems include the attainment of high propulsion efficiency in an engine which has a high thrust per unit weight at altitude and a satisfactory solution of the engine and propeller control problem. During your inspection of the laboratory the Committee's methods of attacking these research problems will be discussed.

The Rocket Engine is a specialized type of power plant that is unique for certain applications where high velocities, high acceleration, compactness, or flight outside the earth's atmosphere are desired. Only after intensive research on fuels and controls can a boosted rocket be expected to have a range sufficient to reach any point on the earth's surface. Through the sponsorship of the military services knowledge of the basic physical characteristics of high energy fuels, their combustion characteristics, and methods of handling, storing, and using the fuels are being obtained. The German rocket V-2 used in World War II developed a specific impulse of approximately 200 pounds thrust / (lb. fuel)/(sec). The combustion characteristics of new fuels having specific impulses approximately $1\frac{1}{2}$ times that obtained from the combustion of alcohol with oxygen as used in the V-2 rocket are being studied at this laboratory. The relative range obtained with these new fuels will be approximately 3 times greater than that of the German V-2 rocket.

The latest reciprocating engine delivers take-off power in excess of 4000 brake horsepower. The reciprocating engine is still the only aircraft power plant with which the extreme ranges required by the military service can be obtained. The use of turbines for extracting energy from the exhaust gases has resulted in a design having exceptionally low specific fuel consumption. In 1945, the decision was made to concentrate the Committee's research effort on jet engines. It was believed that the engine manufacturers themselves would be able to develop the reciprocating engines without further assistance from the Committee. That this decision was sound is shown by the increase in power with low specific fuel consumption obtained from the latest designs of military reciprocating engines.

For a number of years, the Committee's altitude wind tunnel was the only research facility in which the performance of a complete jet engine could be investigated at altitudes from sea level to 50,000 feet and inlet-air temperatures as low as -35° F. During the past year the Committee has completed the installation of two 10-foot diameter altitude chambers in which the performance of jet engines can be determined. These additional research facilities will greatly relieve the work load of the altitude wind tunnel and provide additional facilities for the Committee's programmatic research on jet engines.

The ram jet is the only type of power plant that shows promises of supplying the tremendous power necessary to drive aircraft in the atmosphere at extremely high speeds. The Committee has had under construction at this laboratory since May 1945 a supersonic wind tunnel having a throat that measures 8 - by 6-foot. This tunnel will permit studying the aerodynamic and combustion characteristics of ram jets to a Mach number of 2.0. During your inspection of the laboratory you will be shown this unique research facility.