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RESEARCH MEMORANDUM

ALTITUDE-IGNITION LIMIT OF A TURBOJET ENGINE USING A CONDENSER-DISCHARGE IGNITION SYSTEM

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NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

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SUMMARY

An investigation has been conducted in an altitude test chamber at the NACA Lewis laboratory to evaluate the altitude-ignition characteristics of a condenser-discharge ignition system installed on a turbojet engine.

With a fuel having a Reid vapor pressure of 1.1 pounds per square inch, ignition was obtained with 4.8 joules per spark at 6 sparks per second at an altitude of 55,000 feet and a flight Mach number of 0.6.

INTRODUCTION

An extensive research program is being conducted at the NACA Lewis laboratory for the purpose of increasing the altitude-starting limits of present-day turbojet engines. Results to date from this investigation are given in references 1 and 2. As part of this program, the altitude-ignition limits obtainable with a condenser-discharge ignition system were investigated. The altitude ignition limits of this system were evaluated at a flight Mach number of 0.6 on an axial-flow turbojet engine having tubular-type combustors.

APPARATUS AND PROCEDURE

A conventional turbojet engine was installed in an altitude test chamber where NACA standard atmospheric pressures were simulated at the outlet of the jet nozzle and standard NACA free-stream total pressures and temperatures were simulated at the engine inlet. Fuel was supplied to the engine at the same temperature as the inlet air.

The ignition unit used in this investigation was a condenser-discharge system which is shown schematically in figure 1.

Power is supplied at 115 volts and 400 cycles per second through a circuit containing condenser C_1 and the primary coil of transformer A. The output of transformer A is rectified and charges the two condensers, C_2 and C_3, which store the energy discharged at the spark gap. The discharge of the small condenser C_3 is stepped up by transformer B from 1100 to 15,000 volts which is sufficient to ionize the spark gap. After the gap has been ionized the large condenser C_2 discharges through the secondary winding of transformer B and supplies the high energy for ignition. The sparking rate is controlled by the capacity of C_3, the rate at which the charging resistor permits charging of C_3 and the breakdown voltage of the sealed triggering spark gap. A standard spark plug was connected to the ignition unit with a 6-foot coaxial ignition cable.

An alteration was made on the engine fuel system which consisted of replacing the standard duplex nozzles with smaller simplex nozzles rated at 5 gallons per hour at 100-pound-per-square-inch pressure. This change was made to insure good fuel spray characteristics at the low fuel flows encountered at high altitudes. In addition, the fuel flow control system was altered to permit more sensitive control with the low fuel flows at high altitudes. Fuel having a Reid vapor pressure of 1.1 pounds per square inch was used.

Instrumentation was installed to measure engine-inlet total pressure, inlet total temperature, exhaust static pressure, fuel temperature, and combustor-outlet temperature.

The procedure followed for each ignition attempt consisted of simulating altitude conditions, energizing the ignition system, and slowly opening the throttle until a predetermined fuel flow was attained. This fuel flow was determined by previous tests as the condition most favorable for ignition. Immediately after each short period of engine operation which followed a successful start, the combustor was subjected to a 2-minute cooling period and a 30-second cold fuel spray. This procedure was used to establish a poor environment for ignition.

In order to show the individual effect of joules per spark on the altitude-ignition limits, the spark repetition rate was held as nearly constant as possible (6 to 7 sparks/sec). The altitude-ignition limit was determined by maintaining a constant joules-per-spark input and increasing the altitude until ignition was no longer possible.

With the repetition rate held at 6 to 7 sparks per second, the ignition limit was determined at four values of C_2 condenser-discharge energy, 1.3, 2.6, 3.5, and 4.8 joules per spark. Corresponding energy levels dissipated in the spark gap were 0.9, 1.6, 2.4, and 3.0 joules per spark. This loss is approximately 30 to 40 percent of the energy input and is the sum of the losses in the ignition unit, the harness wiring, connectors, and spark plug electrodes.

RESULTS

The effect of condenser-discharge energy on the altitude-ignition limit at a flight Mach number of 0.6 is shown in figure 2. As the condenser-discharge energy was increased from 1.3 to 3.5 joules per spark, the altitude-ignition limit increased from about 42,000 to 53,000 feet. Ignition was obtained at an altitude of 55,000 feet when 4.8 joules per spark was used but did not necessarily constitute an altitude-ignition limit because starting attempts were not made above 55,000 feet. The practical operating limit of the engine at windmilling starting speeds and a flight Mach number of 0.6 is an altitude of 55,000 feet because only a negligible temperature rise in the combustor is obtained at higher altitudes. As compared with the 55,000-foot limit of the condenser-discharge system, the altitude-ignition limit of the standard engine configuration was approximately 15,000 feet.

SUMMARY OF RESULTS

An investigation was conducted to evaluate the altitude-ignition characteristics of a condenser-discharge ignition system installed on a turbojet engine at a flight Mach number of 0.6 and using 1.1-pound Reid vapor pressure fuel.

Ignition was obtained at an altitude of 55,000 feet with the condenser-discharge ignition system using 4.8 joules per spark at 6 sparks per second.

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REFERENCES

1. Wilsted, H. D., and Armstrong, J. C.: Effect of Fuel Volatility on Altitude Starting Limits of a Turbojet Engine. NACA RM E50G10, 1950.

2. Foster, Hampton: Ignition-Energy Requirements in a Single Tubular Combustor. NACA RM E51A24, 1951.

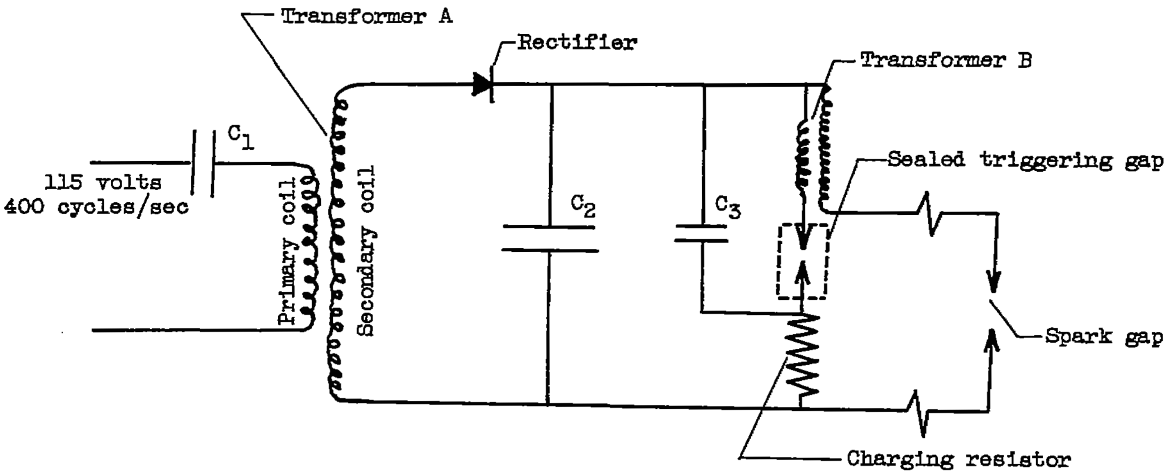

Figure 1. - Schematic diagram of condenser-discharge ignition unit.

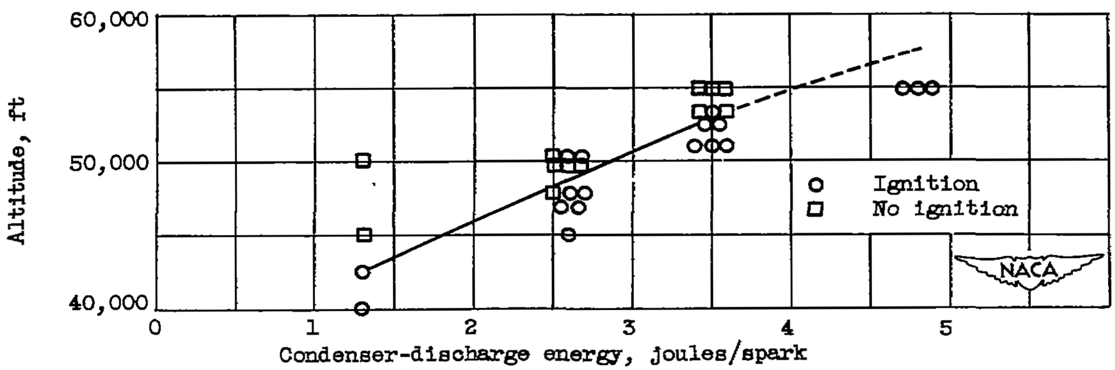

Figure 2. - Effect of condenser-discharge energy on ignition limits of turbojet engine using 1.1-pound Reid vapor pressure fuel at flight Mach number of 0.6.