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RESEARCH MEMORANDUM

ALTITUDE-CHAMBER PERFORMANCE OF BRITISH ROLLS-ROYCE NENE II ENGINE

IV - EFFECT OF OPERATIONAL VARIABLES ON TEMPERATURE DISTRIBUTION AT COMBUSTION-CHAMBER OUTLETS

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RESEARCH MEMORANDUM

ALTITUDE-CHAMBER PERFORMANCE OF BRITISH ROLLS-ROYCE NENE II ENGINE

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SUMMARY

Temperature surveys were made at the combustion-chamber outlets of a British Rolls-Royce Nene II engine. The highest mean nozzle-vane temperatures and mean gas temperatures were found to occur at a radius approximately 75 percent of the nozzle-vane length from the inner ring of the nozzle-vane assembly. Variations in engine speed, jet-nozzle area, simulated altitude, and simulated flight speed altered the temperature level but did not materially affect the pattern of radial temperature distribution.

INTRODUCTION

The temperature distribution at the combustion-chamber outlets of a turbojet engine may be considered as one criterion of combustion-chamber performance. Inasmuch as nozzle vanes and turbine blades are affected more by local gas temperature than by average gas temperature, the temperature distribution should be considered in the combustion-chamber design. After the design parameters have been selected, the effect of operational variables on the temperature distribution must be considered. Data showing the effect of operational variables on the temperature distribution obtained with the combustion chamber operating as a component of the British Rolls-Royce Nene II turbojet engine under simulated altitude conditions are presented herein.

The altitude performance of the British Rolls-Royce Nene II turbojet engine has been determined in an investigation conducted in an altitude test chamber at the NACA Lewis laboratory (references 1 to 3). During a part of the investigation, radial temperature surveys were made at the combustion-chamber outlets of three combustion chambers. These temperature surveys, together with surveys obtained during a static sea-level investigation with three different size jet nozzles (18.75-in. diameter, 17.79-in. diameter, and 21.88-in. diameter), are presented herein. The radial temperature distribution along the leading edge of the nozzle vanes is presented for ranges of engine speed and jet-nozzle diameter for two altitudes and two flight speeds. Radial distribution of gas temperature at the combustion-chamber outlets, as measured by bare chromel-alumel thermocouples, is also presented for the sea-level conditions.

INSTRUMENTATION AND PROCEDURE

The turbojet engine used in this investigation is rated at 5000 pounds thrust at static sea-level conditions at a rotor speed of 12,300 rpm with an 18.75 -inch-diameter jet nozzle. The engine was mounted on a sea-level pendulum-type test stand (fig. 1) for a part of the investigation and in an altitude chamber (fig. 2) for the investigation at simulated-altitude conditions. The engine, altitude chamber, and general instrumentation are described in reference 1.

Four chromel-alumel thermocouples were installed on the leading edge of each of the nozzle vanes downstream of combustion chambers 1 and 2. (See fig. 3 for numbering of combustion chambers.) Figure 4(a) shows the location of these thermocouples. The position of the nozzle vanes with respect to the combustion-chamber outlets is shown in figure 4(b). The thermocouple leads were brought to the outer circumference of the nozzle ring through passages drilled in the vanes in order to minimize interference with the flow of gas between the vanes.

Gas temperatures at the combustion-chamber outlet were measured by bare chromel-alumel thermocouples located in combustion chambers 2 and 3. Five temperature-measuring rakes, radial with respect to the axis of the engine, were located across each outlet. Each rake consisted of five thermocouples equally spaced, as shown in figure 4(a). Figure 4(c) shows the circumferential location of the temperature-measuring rakes.

In addition to the temperature-measuring rakes in two of the combustion-chamber outlets, single thermocouples of the bayonet type were installed at the center of each of the other seven outlets. The thermocouples and the rakes are shown in figure 3.

The turbojet engine was operated at sea-level conditions with three different jet-nozzle sizes: (a) 18.75-inch diameter (design area), (b) 17.79-inch diameter (90-percent design area), and (c) 21.88-inch diameter (136-percent design area). The engine speed was varied with each jet nozzle from idling speed to a speed limited by the attainment of maximum allowable tail-pipe temperature, as specified by the manufacturer. Temperatures were recorded at each engine speed.

Because of limited facilities, the gas-temperature rakes were removed prior to the simulated-altitude runs but temperatures indicated by the nozzle-vane thermocouples were measured over a range of engine speeds at a simulated altitude of 30,000 feet and ram-pressure ratios corresponding to flight speeds of 0 and 620 miles per hour. In all runs at altitude, the 18.75-inch-diameter jet nozzle and a minimum engine speed of 10,000 rpm were used.

TEMPERATURE DISTRIBUTION

Gas temperature. - Typical data obtained from the rakes mounted in the outlets of the two combustion chambers are shown in figure 5. These data were recorded for a rotor speed of approximately 12,300 rpm under static sea-level conditions and with the 18.75-inch-diameter jet nozzle. The average values for all recorded gas temperatures in combustion-chamber outlets 2 and 3 were 1446° and 1466° F respectively. The temperatures at the centers of combustion-chamber outlets 2 and 3 were 1460° and 1424° F, respectively, which are within 42° F of the average temperature of the respective outlets.

The variation in centrally measured outlet gas temperatures over a range of engine speeds from 4000 to 12,000 rpm with the 17.79-inch-diameter jet nozzle at static sea-level conditions is presented in figure 6. An average curve is also shown in this figure. The temperature distribution from combustion chamber to combustion chamber at the center point approached uniformity above an engine speed of 10,000 rpm, showing less than 125° F deviation from the average temperature. The data obtained at engine speeds below 10,000 rpm showed considerable disparity among the temperatures indicated. This condition may have been caused by differences in fuel-air ratio of the several combustion chambers at low engine speed.

Nozzle vanes. - Typical nozzle-vane temperatures are presented in figure 7 for conditions of design-speed static sea-level operation with the design-area jet nozzle. The general temperature pattern for the nozzle vanes downstream of combustion chamber 2 (fig. 7(b)) is in agreement with the gas-temperature pattern (fig. 5(a)). The temperatures in the nozzle vanes downstream of combustion chamber 1 (fig. 7(a)) are not as uniform as those of 2.

The thermocouple readings at each radius for the two combustion chambers were averaged to obtain a mean radial pattern of temperature distribution for each engine speed. The resulting radial temperature distribution is shown in figure 8 for the gas in the combustion-chamber outlets and for the leading edges of the nozzle vanes. Curves were made for operation at several engine speeds under static sea-level operation of the turbojet engine with the 18.75-inch-diameter jet nozzle.

The highest mean gas temperatures and mean nozzle-vane temperatures occurred at a radius approximately 75-percent of the nozzle-vane length from the inner ring of the nozzle-vane assembly (fig. 8). The radial temperature gradients in the nozzle vanes were not as great as those in the gas stream. Variation in engine speed from 10,000 to 12,300 rpm altered the temperature level but did not materially affect the radial pattern of temperature distribution.

Effect of change in jet-nozzle area. - The variation in mean temperature along the radial distance from the inner to the outer circumference of the nozzle rings for the nozzle vanes was selected as representative of the effect of change in jet-nozzle area on temperature distribution. The pattern of temperature distribution was unaffected by change in jet-nozzle size over the range of engine speeds investigated (fig. 9). When the 21.88-inch-diameter jet nozzle was used, however, the locations of peak temperature were not as clearly defined. Data were not obtained for an engine speed of 10,500 rpm with the 136-percent design-area jet nozzle.

Effect of changes in altitude and flight speed. - The variation in mean temperature along the leading edge of the nozzle vanes was examined to determine the effect of change in altitude and flight speed on temperature distribution. The pattern of temperature distribution along the leading edge of the nozzle vanes is essentially the same at an altitude of 30,000 feet as at sea-level (fig. 10). At an altitude of 30,000 feet, the same pattern is noted at a flight speed of 620 miles per hour as that at 0 miles per hour. The pattern of temperature distribution along the leading edge of the nozzle vanes may therefore be considered independent of altitude and flight speed.

SUMMARY OF RESULTS

An experimental investigation of radial temperature surveys at the combustion-chamber outlets and on the leading edges of the nozzle vanes was made on a British Rolls-Royce Nene II turbojet engine. The peak of the mean radial patterns of temperature distribution of both the gas and the nozzle vanes occurred at a radius approximately 75 percent of the nozzle-vane length from the inner ring of the nozzle-vane assembly.

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Variations in engine speed, jet-nozzle area, simulated altitude, and simulated flight speed altered the temperature level but did not materially affect the radial pattern of temperature distribution.

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REFERENCES

1. Barson, Zelmar, and Wilsted, H. D.: Altitude-Chamber Performance of British Rolls-Royce Nene II Engine. I - Standard 18.75-Inch-Diameter Jet Nozzle. NACA RM E9I23, 1949.

2. Armstrong, J. C., Wilsted, H. D., Vincent, K. R.: Altitude-Chamber Performance of British Rolls-Royce Nene II Engine. II - 18.41-Inch-Diameter Jet Nozzle. NACA RM E9I27, 1949.

3. Grey, Ralph E., Brightwell, Virginia L., and Barson, Zelmar: Altitude-Chamber Performance of British Rolls-Royce Nene II Engine. III - 18.00-Inch-Diameter Jet Nozzle. NACA RM E50A31, 1950.

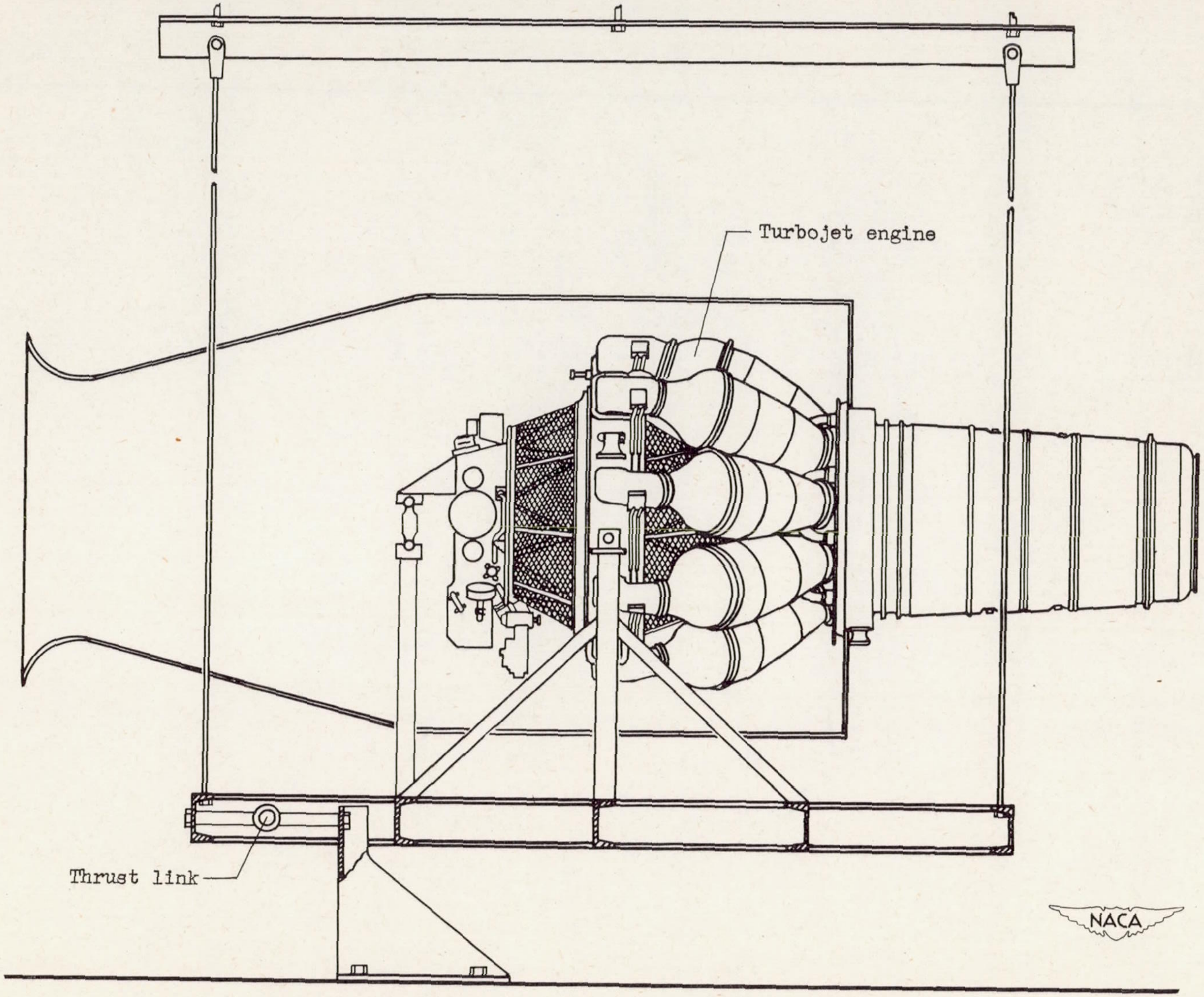


Figure 1. - Sketch of turbojet engine mounted on sea-level pendulum-type test stand.

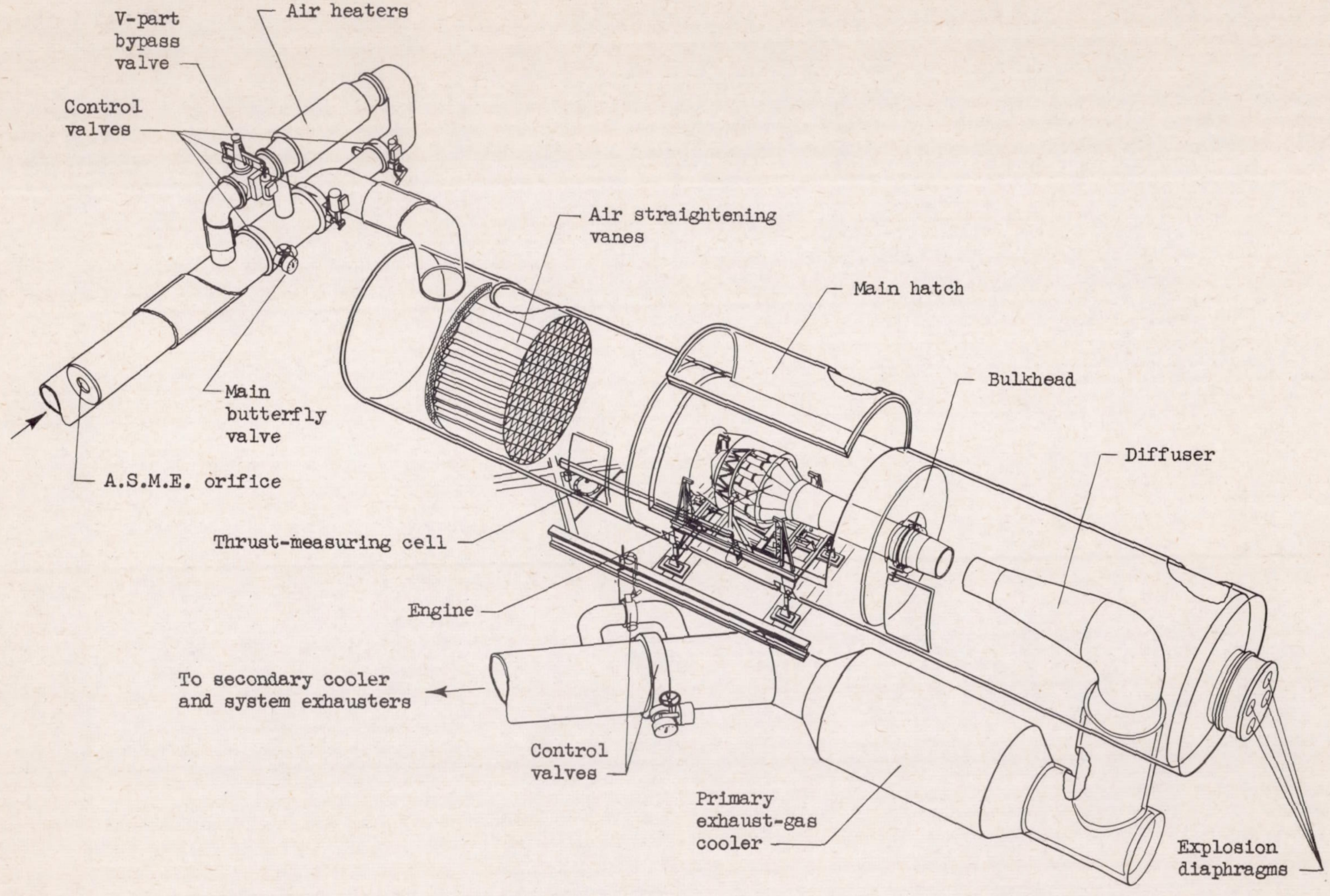


Figure 2. - Altitude chamber with engine installed in test section.

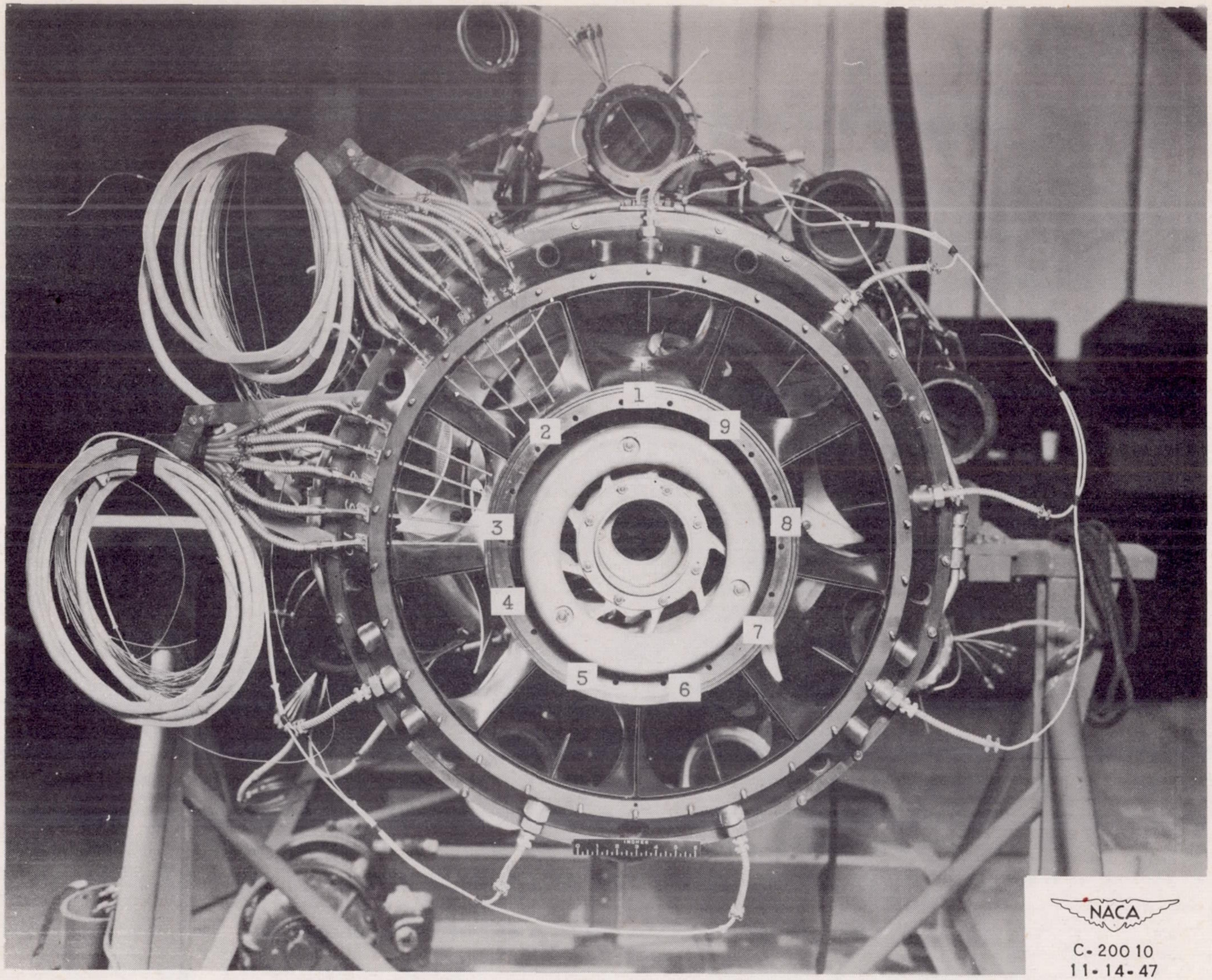
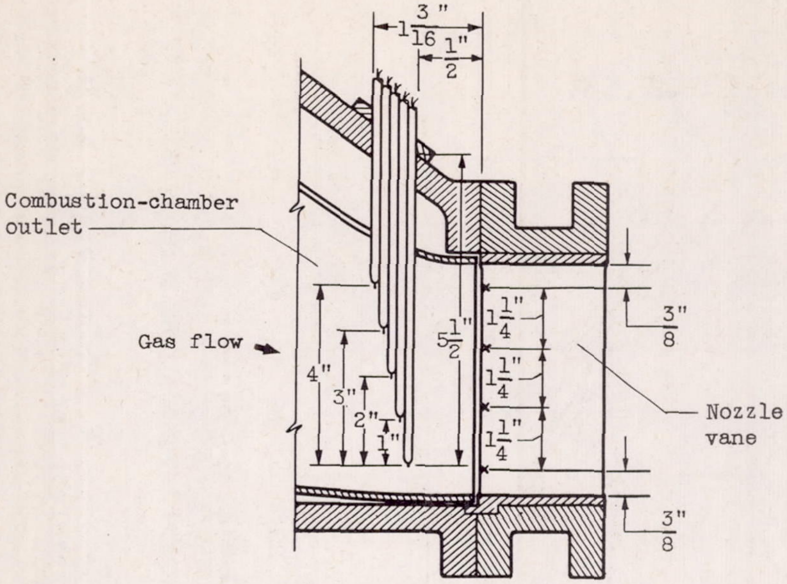
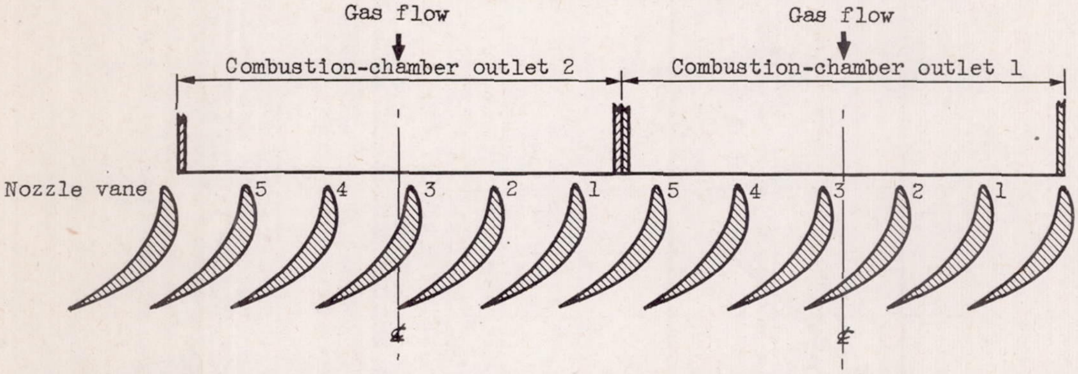


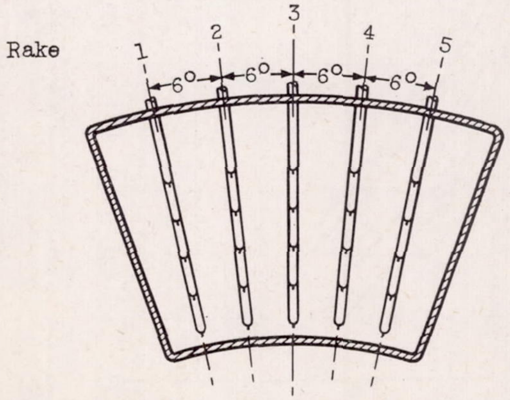
Figure 3. - Thermocouples installed in combustion-chamber outlets of turbojet engine.



(a) Radial location of thermocouples.

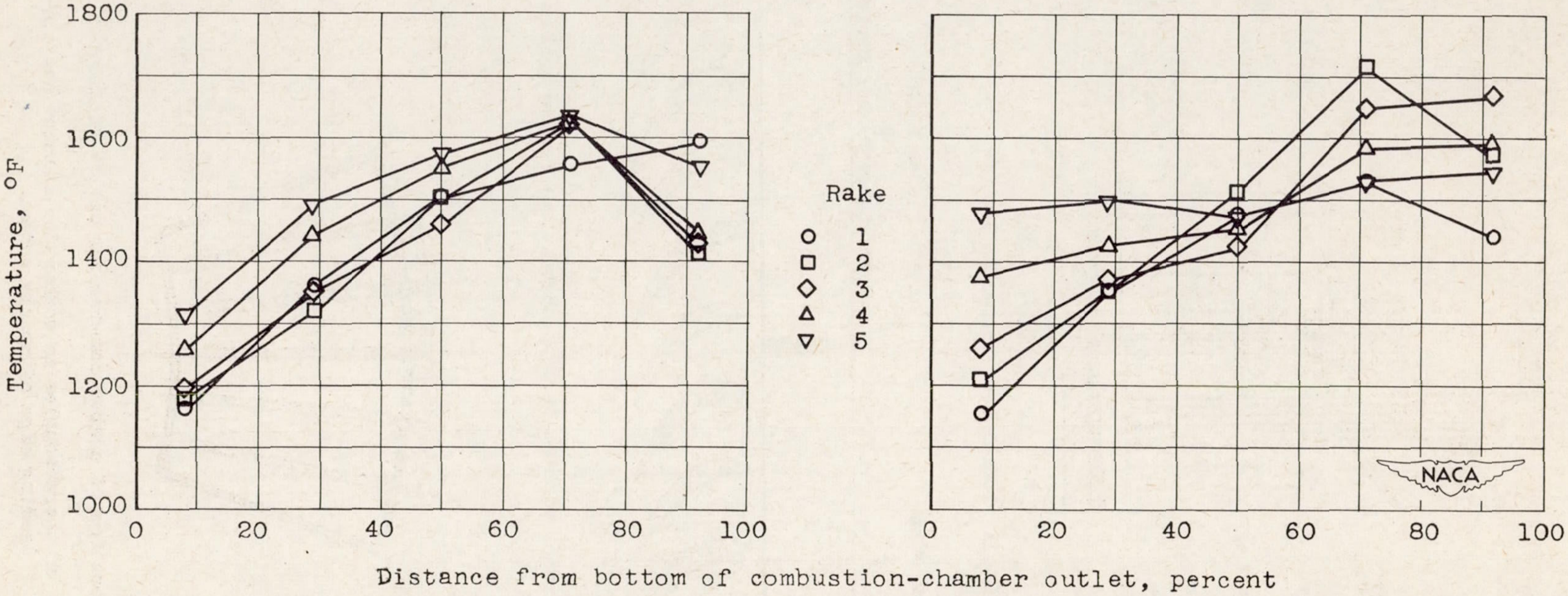


(b) Position of nozzle vanes with respect to combustion-chamber outlets.



(c) Circumferential location of combustion-chamber outlet thermocouple rakes.

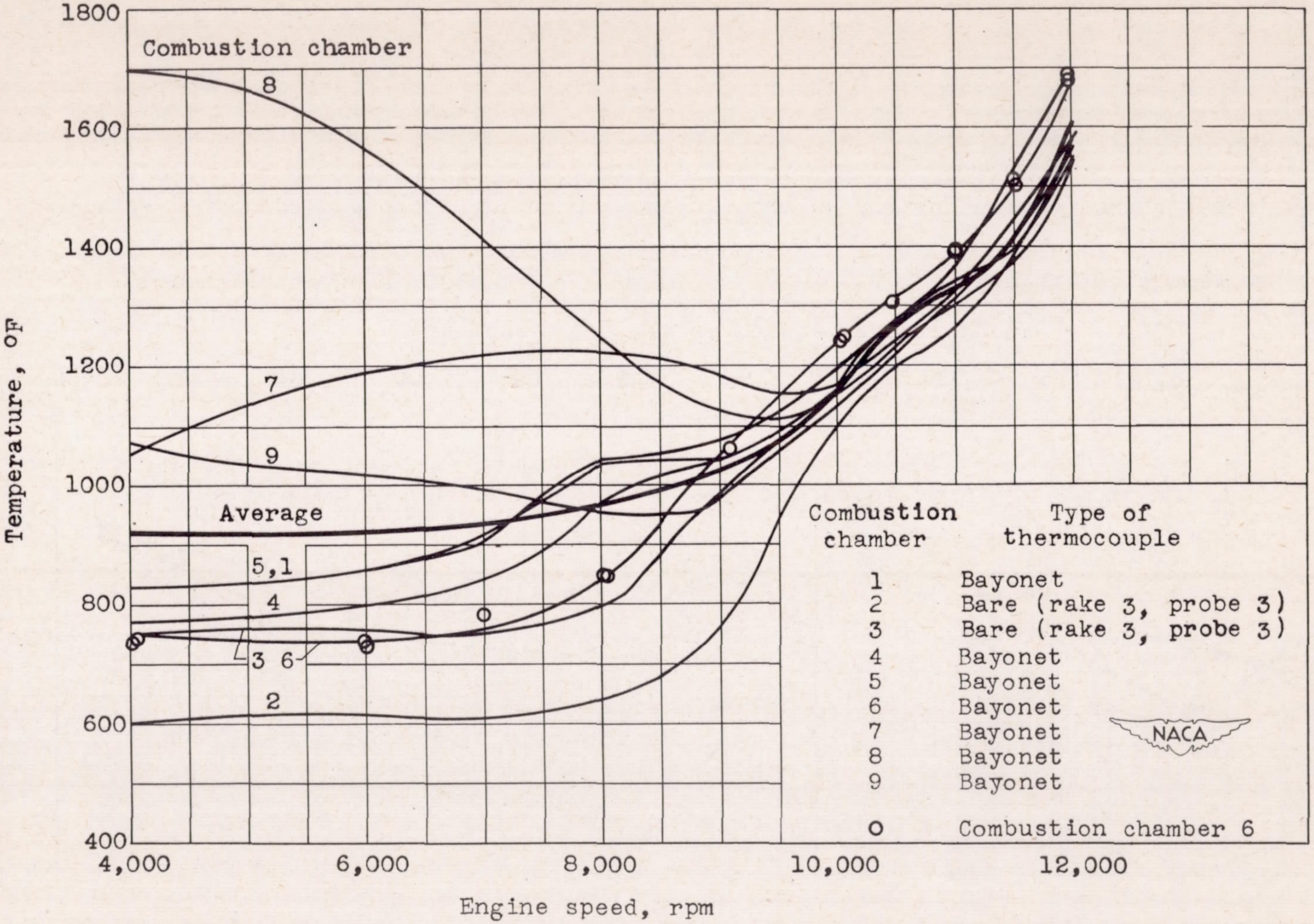
Figure 4. - Location of thermocouples in combustion-chamber outlets and on leading edge of nozzle vanes.



(a) Combustion chamber 2.

(b) Combustion chamber 3.

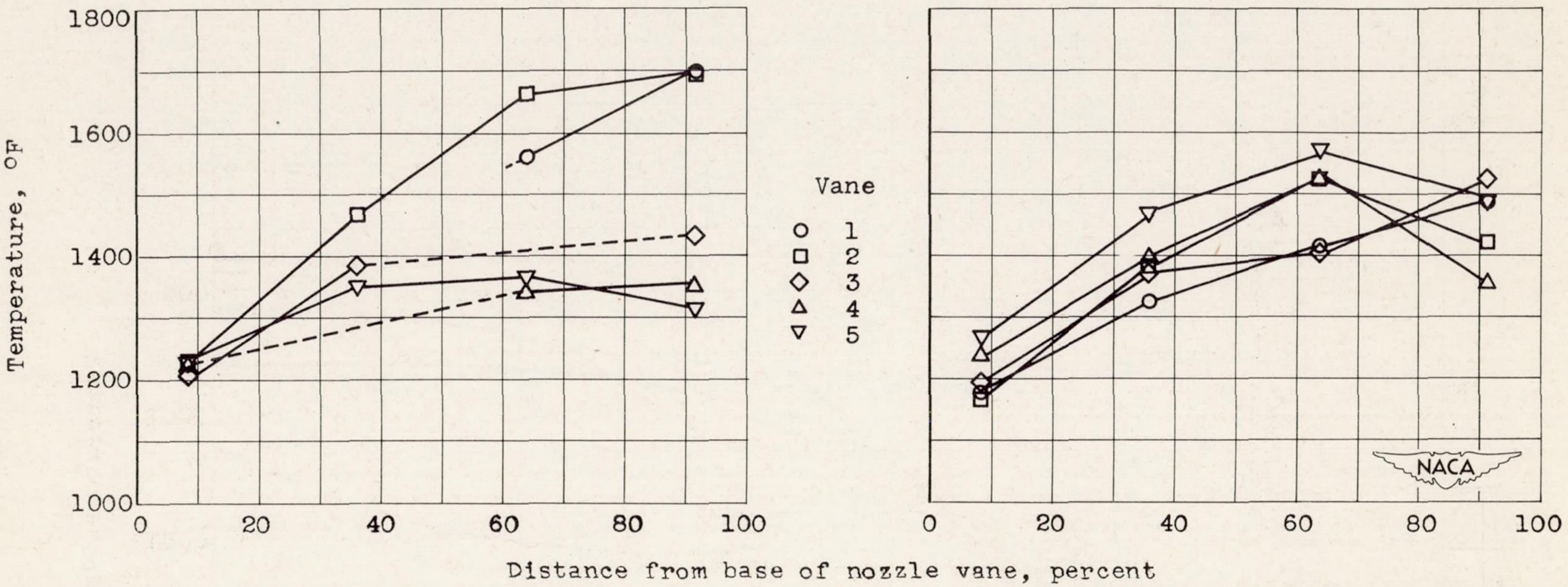
Figure 5. - Gas-temperature distribution at combustion-chamber outlet. Engine speed, about 12,300 rpm; 18.75-inch-diameter jet nozzle; static sea-level conditions.



Combustion chamber	Type of thermocouple
1	Bayonet
2	Bare (rake 3, probe 3)
3	Bare (rake 3, probe 3)
4	Bayonet
5	Bayonet
6	Bayonet
7	Bayonet
8	Bayonet
9	Bayonet

○ Combustion chamber 6

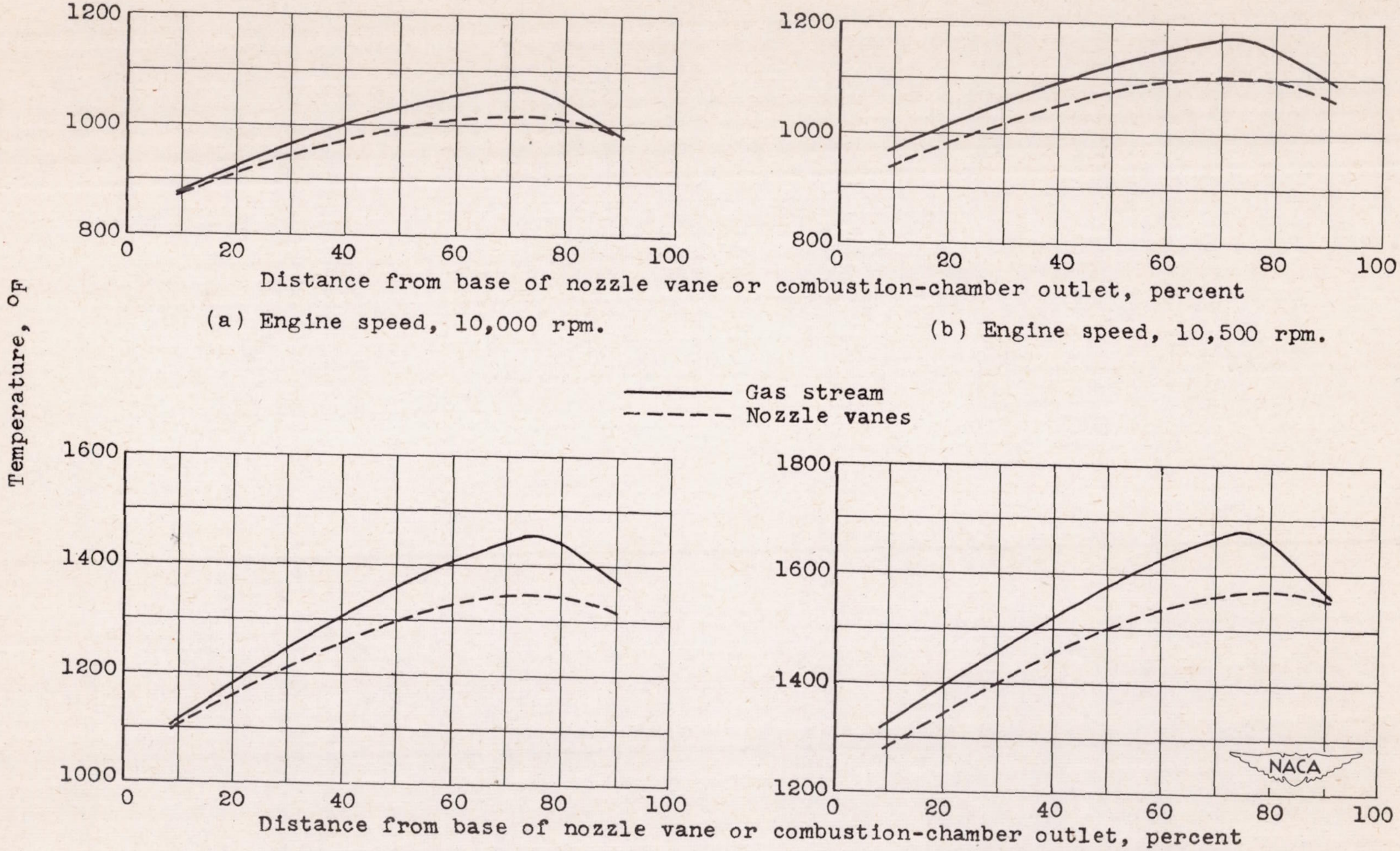
Figure 6. - Temperature of each combustion-chamber outlet as measured by centrally located thermocouple at various engine speeds. 17.79-inch-diameter jet nozzle; static sea-level conditions. Typical data shown for combustion chamber 6.



(a) Combustion chamber 1.

(b) Combustion chamber 2.

Figure 7. - Temperature distribution on leading edge of nozzle vanes. Engine speed, about 12,300 rpm; 18.75-inch-diameter jet nozzle; static sea-level conditions.



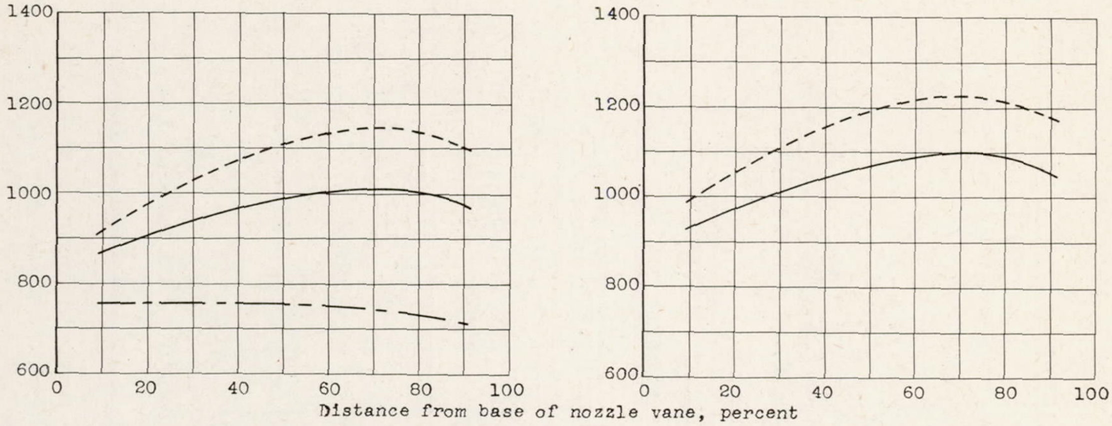
(a) Engine speed, 10,000 rpm.

(b) Engine speed, 10,500 rpm.

(c) Engine speed, 11,600 rpm.

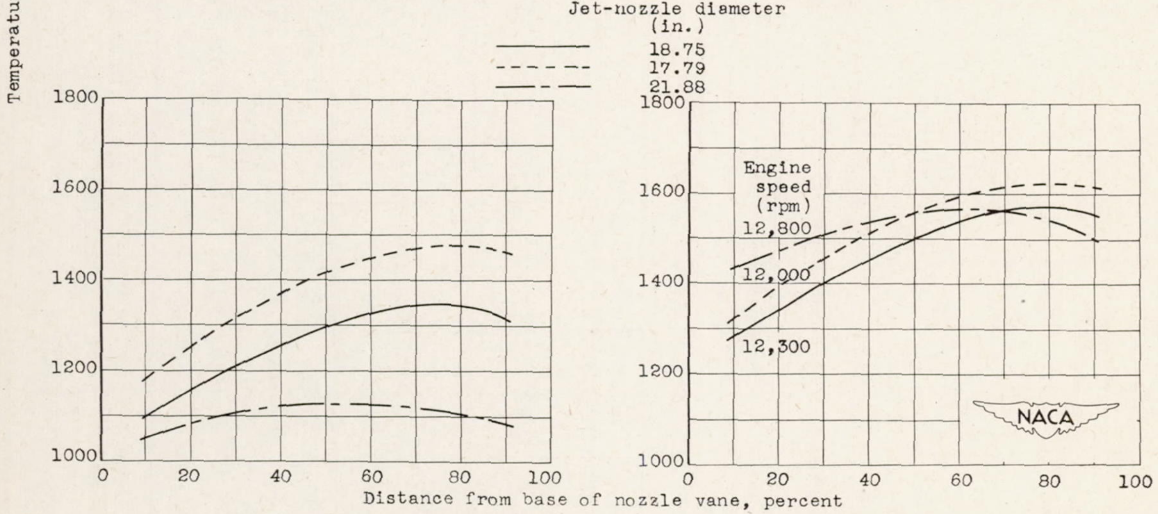
(d) Engine speed, 12,300 rpm.

Figure 8. - Temperature distribution in gas stream of combustion-chamber outlet and on leading edge of nozzle vanes at several engine speeds. 18.75-inch-diameter jet nozzle; static sea-level conditions.



(a) Engine speed, 10,000 rpm.

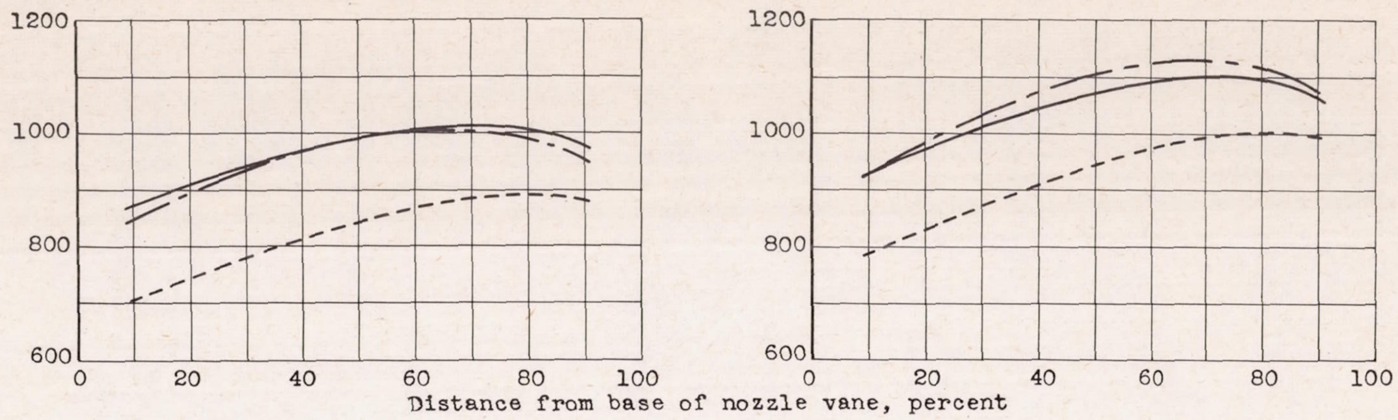
(b) Engine speed, 10,500 rpm.



(c) Engine speed, 11,600 rpm.

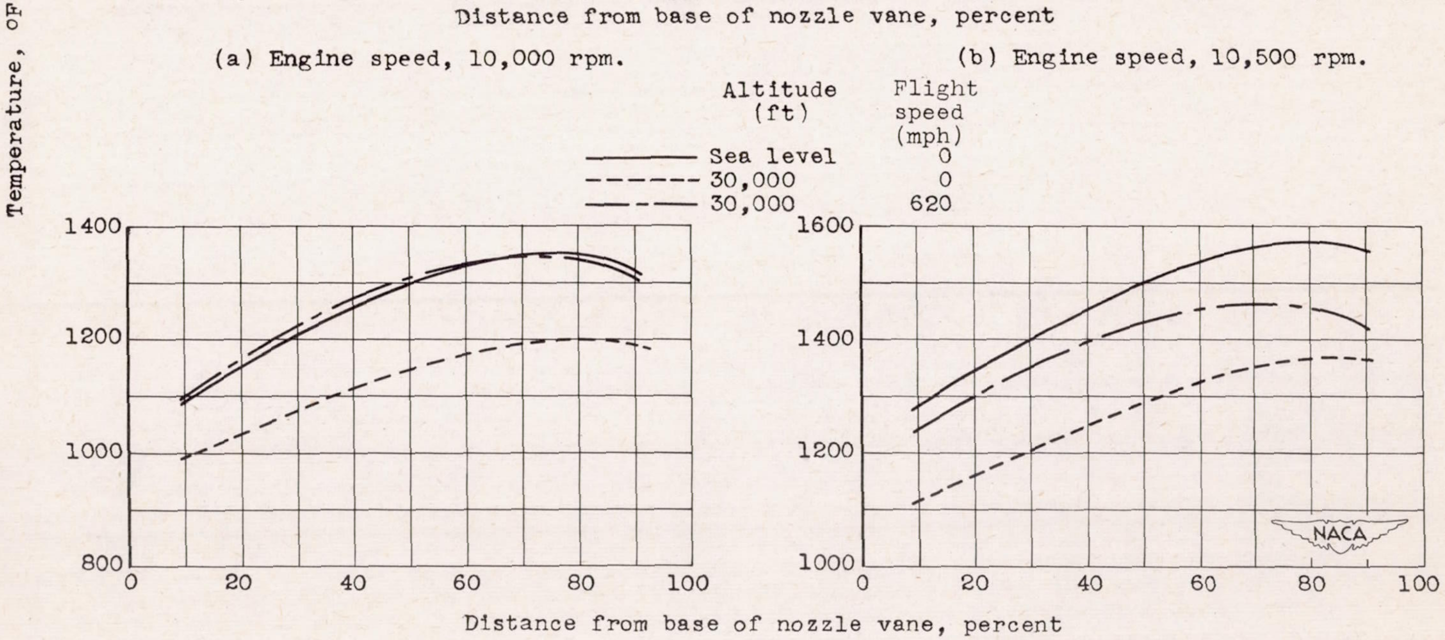
(d) Tail-pipe temperature-limited speed.

Figure 9. - Effect of change in jet-nozzle diameter on temperature distribution along leading edges of nozzle vanes at several engine speeds. Static sea-level conditions.



(a) Engine speed, 10,000 rpm.

(b) Engine speed, 10,500 rpm.



(c) Engine speed, 11,600 rpm.

(d) Engine speed, 12,300 rpm.

Figure 10. - Effect of changes in altitude and flight speed on temperature distribution along leading edge of nozzle vanes at several engine speeds. 18.75-inch-diameter jet nozzle.