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Downing, R. M.
Finger, H. B.


Power Plants, Reciprocating (6)
Induction and Supercharging (2)
Superchargers - Performance (91003)

RM-E6J18

Effect of three modifications on performance of auxiliary-stage supercharger for V-1710-93 engine

National Advisory Committee for Aeronautics, Washington, D. C.

U.S. Eng. Restr. 19 photos, graphs, drwgs


Three modifications of the auxiliary-stage supercharger for the V-1710-93 engine were designed and tested as part of an investigation to improve the power output and the altitude performance of the engine. A 12-vane diffusor was substituted for the standard 11-vane diffusor, and a vaneless discharge passage and a modified scroll were designed to increase the flow capacity of the supercharger. With the 12-vane diffuser installed and the carburetor replaced by an adapter, the equivalent volume flow at the peak efficiency point was increased 25% at the lowest speed investigated and 9.5% at the highest speed.


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RM No. E6J18

# RESEARCH MEMORANDUM



for the

Air Materiel Command, Army Air Forces

## EFFECT OF THREE MODIFICATIONS ON PERFORMANCE OF AUXILIARY-STAGE SUPERCHARGER FOR V-1710-93 ENGINE

By Richard M. Downing and Harold B. Finger

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Cleveland, Ohio



NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

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# EFFECT OF THREE MODIFICATIONS ON PERFORMANCE OF AUXILIARY-STAGE SUPERCHARGER FOR V-1710-93 ENGINE

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## SUMMARY

Three modifications of the auxiliary-stage supercharger for the V-1710-93 engine were designed and tested as part of an investigation to improve the power output and the altitude performance of the engine. A 12-vane diffuser was substituted for the standard 11-vane diffuser, and a vaneless discharge passage and a modified scroll were designed to increase the flow capacity of the supercharger and thereby to increase the performance at the high volume flows required by the engine.

With the 12-vane diffuser installed and the carburetor replaced by an adapter, the equivalent volume flow at the peak efficiency point was increased 25 percent at the lowest speed investigated and 9.5 percent at the highest speed. When the carburetor was used, any increase in equivalent volume flow was masked by choking in the carburetor. A small decrease in the peak adiabatic efficiency resulted from using the 12-vane diffuser. At the high volume flows where the supercharger is required to operate, the performance was improved by the 12-vane diffuser.

With the vaneless discharge passage, the surge-free range of the supercharger was increased 35 percent at the lowest tip speed investigated by increasing the maximum air flow. The maximum air flow at high tip speeds was again limited by choking in the carburetor, which masked the effect of the vaneless discharge passage on the maximum air flow. At the high volume flows near the operating point of the supercharger, the performance with the vaneless discharge passage was better than that with the standard 11-vane diffuser. At the low volume flows the standard 11-vane diffuser gave better performance. The modified scroll gave performance characteristics that were practically the same as those of the standard scroll except at high tip speeds, where the peak performance was improved.

## INTRODUCTION

At the request of the Air Materiel Command, Army Air Forces, an investigation to improve the altitude performance of the V-1710-93 engine has been conducted at the NACA Cleveland laboratory. Much of the research has been directed toward improving the performance of the auxiliary-stage supercharger. The performance of the standard auxiliary-stage supercharger installation at sea level is reported in reference 1, which also evaluates the effects on supercharger performance of the losses introduced by the carburetor and inlet elbow; the sea-level performance is compared with that at an altitude of 29,000 feet in reference 2. The results of an experimental investigation to determine the cause of the losses produced by the carburetor and inlet elbow is presented in reference 3. As a result of these investigations of the inlet components, the standard configuration of the engine was altered to place the carburetor between the two stages of supercharging instead of before the auxiliary-stage supercharger. The results of an investigation to reduce the losses due to the inlet elbow are presented in reference 4.

The results of the investigation of modifications to the induction system of a V-1710 engine (reference 5) and of the investigations of references 1 and 2 indicated that a significant improvement in the performance of the engine could be obtained by increasing the flow capacity of the auxiliary-stage supercharger and thereby increasing the efficiency and the pressure ratio at the operating point of the engine. The standard 11-vane diffuser was replaced by a 12-vane diffuser and later by a vaneless discharge passage to increase the flow capacity of the supercharger. The outlet of the standard scroll was changed from an elliptical to a circular cross section to give a better flow distribution from the scroll into the engine-stage supercharger and thus to improve the efficiency of the unit. The performance of the modified supercharger was investigated over a wide range of operating conditions.

## MODIFICATIONS

The standard auxiliary-stage supercharger for the V-1710-93 engine is completely described in reference 2. The standard impeller was used in combination with three modifications of the diffuser and scroll: a 12-vane diffuser, a vaneless discharge passage, and a modified scroll.

The 12-vane diffuser. - A 12-vane diffuser (part No. 41710) was designed and fabricated by the engine manufacturer to increase the capacity of the supercharger. The outside diameter of the 12-vane and the standard 11-vane diffusers were the same ($17\frac{1}{2}$ in.) but the vane-entrance angle was increased from $4\frac{1}{2}^{\circ}$ for the standard diffuser to $13^{\circ}$ for the 12-vane diffuser to reduce the angle of attack of the vanes at the high flow rates.

Vaneless discharge passage. - Elimination of the diffuser vanes appeared as a possible means of increasing the capacity of the supercharger by increasing the unrestricted flow area. In order to keep the modified diffuser within the dimensional limits specified by the standard scroll, the vaneless discharge passage was limited to a convergent throat section $17\frac{1}{2}$ inches in diameter. The rear wall of the passage was flat and the front-wall profile was a circular arc. The supercharger with the vaneless discharge passage is shown in figure 1.

Modified scroll. - The elliptical cross section of the standard scroll outlet was changed to a circular cross section of the same diameter ($5\frac{1}{2}$ in.) as the inlet to the engine-stage supercharger in order to give a smooth flow distribution from the scroll into the engine-stage supercharger. A circular outlet was bolted to the standard elliptical outlet and the scroll passage was faired into the modified section with sheet-aluminum inserts extending approximately $160^{\circ}$ around the scroll. The standard and modified scroll outlets are shown in figure 2. The area variation through the passage and outlet of the scrolls is shown in figure 3 for the standard and modified scrolls.

## APPARATUS AND INSTRUMENTATION

The setup for the present investigation was the same as for the investigation of the standard supercharger with the carburetor installed (reference 1). All runs were made in a supercharger test rig with the auxiliary-stage scroll as the collector. The impeller was driven by a 1000-horsepower induction motor in conjunction with a variable-speed magnetic coupling and a step-up gearbox.

The over-all measurements were taken in the inlet duct upstream of the supercharger and in the outlet duct downstream of the scroll outlet, as recommended in reference 6. Wall static-pressure taps were used for static-pressure measurements and pitot tubes were used for total pressures. All temperatures were measured with unshielded, calibrated, iron-constantan thermocouples in conjunction with a potentiometer and light-beam galvanometer. The volume flow of ambient air was measured with a sharp-edged thin-plate orifice and the refrigerated air was metered through an adjustable submerged orifice.

The accuracy with which all measurements were made is estimated to be within the following limits:

| | |
|---|---|
| Temperature, °F . . . . . . . . . . . . . . . . . . . . . . . | ±0.5 |
| Pressure, inches of mercury . . . . . . . . . . . . . . . . . . . | ±0.02 |
| Volume flow, percent . . . . . . . . . . . . . . . . . . . . | ±0.5 |
| Impeller speed, percent . . . . . . . . . . . . . . . . . . . . | ±0.5 |

## TESTS

All of the runs except those with the vaneless discharge passage were made with ambient inlet air because refrigerated-air services were not available. Testing under the actual operating altitude conditions is desirable, however, because the operating Reynolds number can be reproduced. In accordance with the standard procedure given in reference 7, an outlet total pressure of 10 inches of mercury above atmospheric pressure was maintained except at the lower tip speeds where it could not be obtained. The 12-vane diffuser installation was investigated with the carburetor installed and with the carburetor replaced by an inlet adapter, as described in reference 1, in order that the effect of the carburetor on the supercharger performance could be determined. The modified scroll and the vaneless discharge passage were investigated with the carburetor installed. The vaneless discharge passage was investigated at altitude conditions of 29,000 feet (9.29 in. Hg absolute and -45° F) in order that a comparison might be made with the standard 11-vane diffuser with altitude inlet conditions.

## RESULTS AND DISCUSSION

The over-all performance calculations were made by the method of reference 7. The performance of the three modifications of the auxiliary-stage supercharger is presented by the methods prescribed in reference 8, as a function of equivalent impeller tip speed.

The 12-vane diffuser. - Typical performance curves are shown in figure 4 for the standard 11-vane and the 12-vane diffusers with the carburetor installed and with a smooth adapter mounted upstream of the inlet elbow in place of the carburetor. The curves presented are for the equivalent impeller tip speed of 1073 feet per second. For a gear ratio of 6.85:1, this tip speed is approximately that obtained when the engine runs at rated speed. The peak adiabatic efficiency obtained with the 12-vane diffuser was slightly lower than that obtained with the standard 11-vane diffuser but the peak efficiency occurred at a higher volume flow; the same trend was observed in the pressure-ratio curves (fig. 4). Because of the increase in capacity at the peak efficiency and pressure-ratio points, the performance was improved at the high volume flows where the supercharger is required to operate. The potential increase in volume flow produced by the 12-vane diffuser was masked because the volume flow was limited by choking in the carburetor at the high tip speeds. At an equivalent tip speed of 1273 feet per second, the increase in capacity was negligible with the carburetor installed. With the carburetor replaced by the adapter, the increase in flow at the points of peak efficiency obtained by the use of the 12-vane diffuser varied from 25 percent at 683 feet per second to 9.5 percent at 1273 feet per second.

The peak performance characteristics of the supercharger are shown in figure 5. Over the range of speeds tested, the peak pressure coefficients obtained with the standard 11-vane diffuser were from 0.01 to 0.03 higher and the peak adiabatic efficiencies were from 0.01 to 0.02 higher than those obtained with the 12-vane diffuser except for the two lowest speeds tested. At an equivalent tip speed of 683 feet per second, the peak pressure ratios were the same for both diffusers, but at an equivalent tip speed of 1273 feet per second the peak pressure ratio for the standard 11-vane diffuser was approximately 0.10 higher than that of the 12-vane diffuser.

Although the peak performance was somewhat reduced by the 12-vane diffuser, the performance characteristics at the equivalent volume flow of 4400 cubic feet per minute required by the engine were improved. At volume flows greater than 4350 cubic feet per minute at an equivalent tip speed of 1073 feet per second, the performance of the 12-vane diffuser was more satisfactory than that of the 11-vane diffuser.

Vaneless discharge passage. - The curves in figure 6 were selected to compare the performance of the vaneless discharge passage and the standard 11-vane diffuser at the limits of the speed range investigated. The surge-free range of the supercharger with the vaneless discharge passage was increased 35 percent at the point of maximum flow over that of the standard 11-vane diffuser at an equivalent tip speed of 778 feet per second, the lowest speed tested. At 1459 feet per second the volume flow through the supercharger was limited by the carburetor; the volume flow was therefore almost the same for the standard 11-vane diffuser and the vaneless discharge passage.

The peak performance characteristics of the standard 11-vane diffuser and the vaneless discharge passage are shown in figure 7. The difference in peak pressure coefficients decreased with an increase in equivalent tip speed from 0.10 at 780 feet per second to 0.03 at 1459 feet per second. The difference in peak adiabatic efficiency was approximately constant for the range of test speeds; the efficiency of the supercharger with the standard 11-vane diffuser was approximately 0.07 higher than that with the vaneless discharge passage. This difference in efficiency was probably caused by the sudden enlargement of the discharge passage into the scroll and could be reduced by a scroll designed for high air velocities. The peak pressure ratio of the standard diffuser was 0.10 to 0.15 higher than that obtained with the vaneless discharge passage. As in the case of the 12-vane diffuser, the peak performance characteristics of the standard supercharger are higher than those of the vaneless-discharge passage installation over most of the flow range. The performance of the supercharger at equivalent volume flows greater than 3000 cubic feet per minute was more satisfactory with the vaneless discharge passage.

Modified scroll. - Typical curves for the standard and the modified scrolls at the equivalent impeller tip speed of the auxiliary-stage supercharger for rated engine speed (fig. 8) show nearly the same adiabatic efficiencies and pressure ratios for both scrolls. The modified scroll collector produced no appreciable improvement in the performance of the auxiliary-stage supercharger up to equivalent tip speeds of 1061 feet per second (fig. 9). At tip speeds above 1061 feet per second, the peak performance of the supercharger with the modified scroll was higher than that with the standard scroll. At an equivalent tip speed of 1273 feet per second, the difference in peak pressure coefficient was approximately 0.03 and the difference in adiabatic efficiency was 0.04. The peak pressure ratio at the maximum speed was 0.15 higher with the modified scroll than with the standard scroll.

## SUMMARY OF RESULTS

The performance of three modifications - a 12-vane diffuser, a vaneless discharge passage, and a modified scroll - of the auxiliary-stage supercharger for a V-1710-93 engine may be summarized as follows:

1. With the 12-vane diffuser installed and the carburetor replaced by an adapter, the equivalent volume flow through the supercharger at peak efficiency was increased 25 percent at an equivalent tip speed of 683 feet per second, the lowest speed investigated, and 9.5 percent at 1273 feet per second, the highest speed investigated. With the carburetor installed, the air flow was limited and any increase was masked by choking in the carburetor. Over the complete range of tip speeds, the peak pressure coefficients, pressure ratios, and adiabatic efficiencies obtained with the 12-vane diffuser were slightly lower

than those of the standard 11-vane diffuser. At the high volume flows where the supercharger is required to operate, the performance was improved by the 12-vane diffuser.

2. At an equivalent tip speed of 778 feet per second and at the point of maximum flow, the surge-free range of the supercharger was increased 35 percent over that of the standard 11-vane diffuser by installing a vaneless discharge passage. At the high flows the pressure ratio and the adiabatic efficiency of the supercharger with the vaneless discharge passage were higher than those with the standard 11-vane diffuser. At high tip speeds the effect of the vaneless discharge passage on maximum air flow was masked by choking in the carburetor. The peak adiabatic efficiency was reduced approximately 0.07 over the range of speeds and the peak pressure ratio was reduced from 0.10 to 0.15 by using the vaneless discharge passage. The peak pressure coefficient was reduced 0.10 at the low speeds and 0.02 at the high speeds.

3. The modified scroll caused no appreciable change in the performance of the supercharger except at speeds above 1061 feet per second, where the pressure coefficient, the pressure ratio, and the adiabatic efficiency were slightly increased.

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## REFERENCES

1. Klein, Harold, and Downing, Richard M.: Tests of an Allison Auxiliary-Stage Supercharger for a V-1710-93 Engine. NACA Memo. rep., Army Air Forces, April 15, 1944.

2. Downing, Richard M., and Finger, Harold B.: Comparison of the Sea-Level and Altitude Performance of the Auxiliary-Stage Supercharger of the V-1710-93 Engine. NACA MR No. E6H07, Army Air Forces, 1946.

3. Benser, W. A., and Todd, D. J.: Losses Introduced by the Carburetor and the Inlet Elbow of the Auxiliary-Stage Supercharger of the Allison V-1710-93 Engine. NACA MR No. E4L15, Army Air Forces, 1944.

4. Todd, Donald J., and Graper, Fred E.: Effect of NACA and Bell Standard Inlet Elbows on Performance of Auxiliary-Stage Supercharger with Parabolic Guide Vanes for Allison V-1710 Engine. NACA MR No. E6B21, Army Air Forces, 1946.

5. Standahar, Raymond M., and Mizisin, John: Effect of Modifications to Induction System on Altitude Performance of V-1710-93 Engine. I - Effect of Increased Supercharging, Interstage Carburetor, Aftercooling, and Internal-Coolant Injection. NACA MR No. E6E20, Army Air Forces, 1946.

6. NACA Subcommittee on Supercharger Compressors: Standard Procedures for Rating and Testing Centrifugal Compressors. NACA ARR No. E5F13, 1945.

7. Ellerbrock, Herman H., Jr., and Goldstein, Arthur W.: Principles and Methods of Rating and Testing Centrifugal Superchargers. NACA ARR, Feb. 1942.

8. NACA Subcommittee on Supercharger Compressors: Standard Method of Graphical Presentation of Centrifugal Compressor Performance. NACA ARR No. E5F13a, 1945.

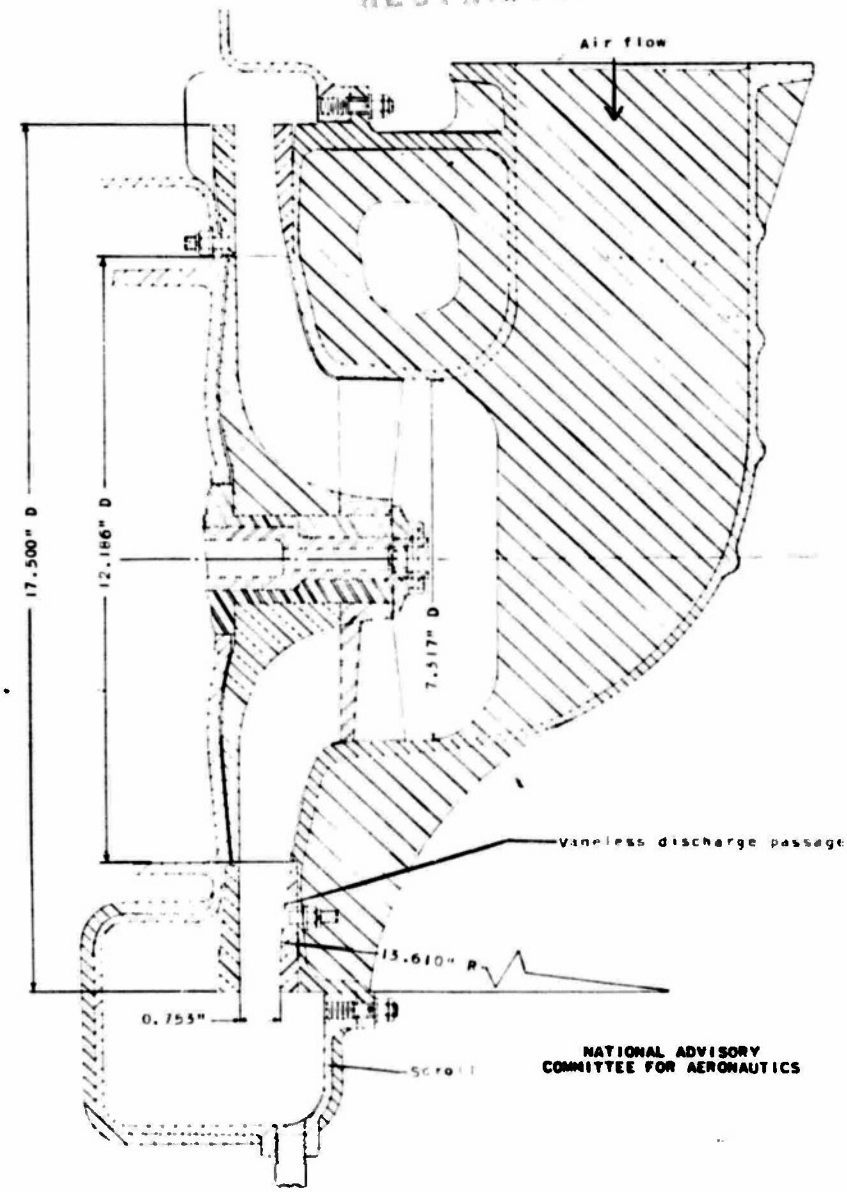


Figure 1. - Assembly of auxiliary-stage supercharger with vaneless discharge passage for V-1710-93 engine.

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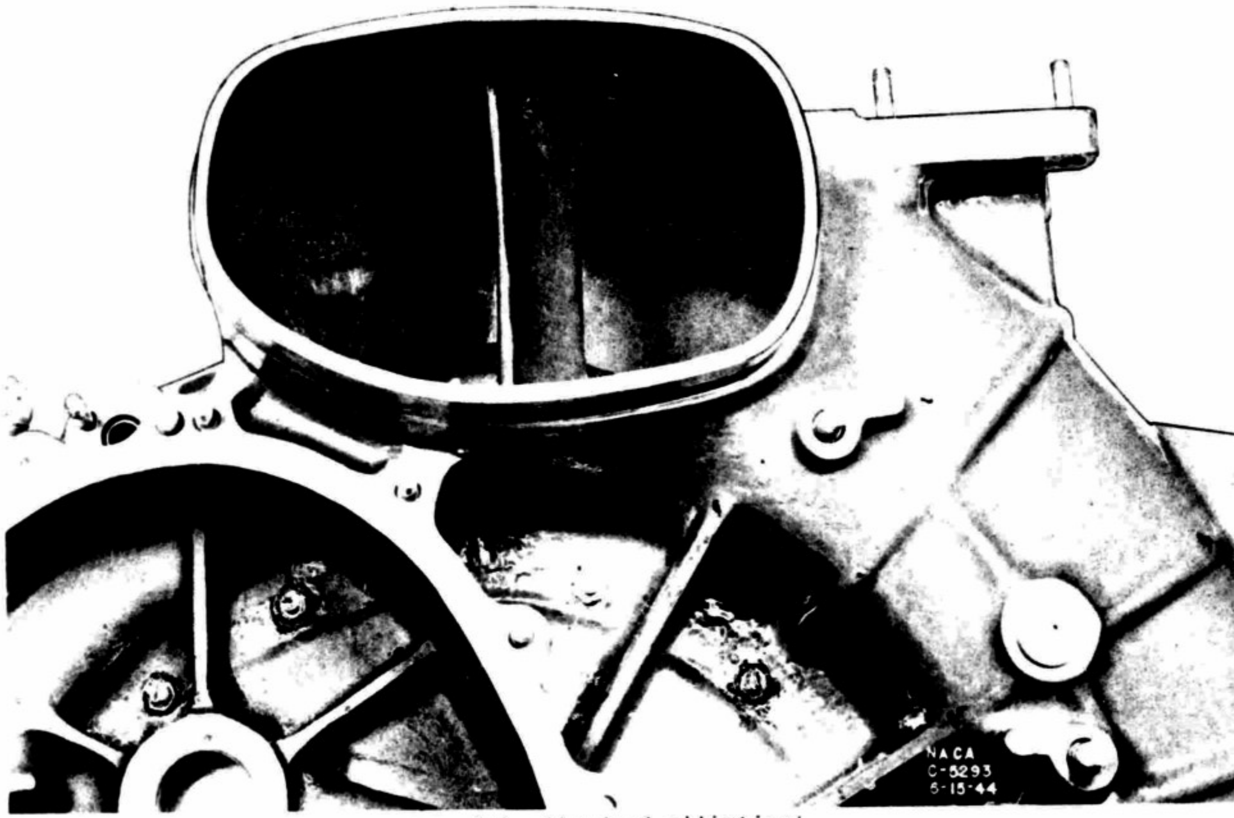
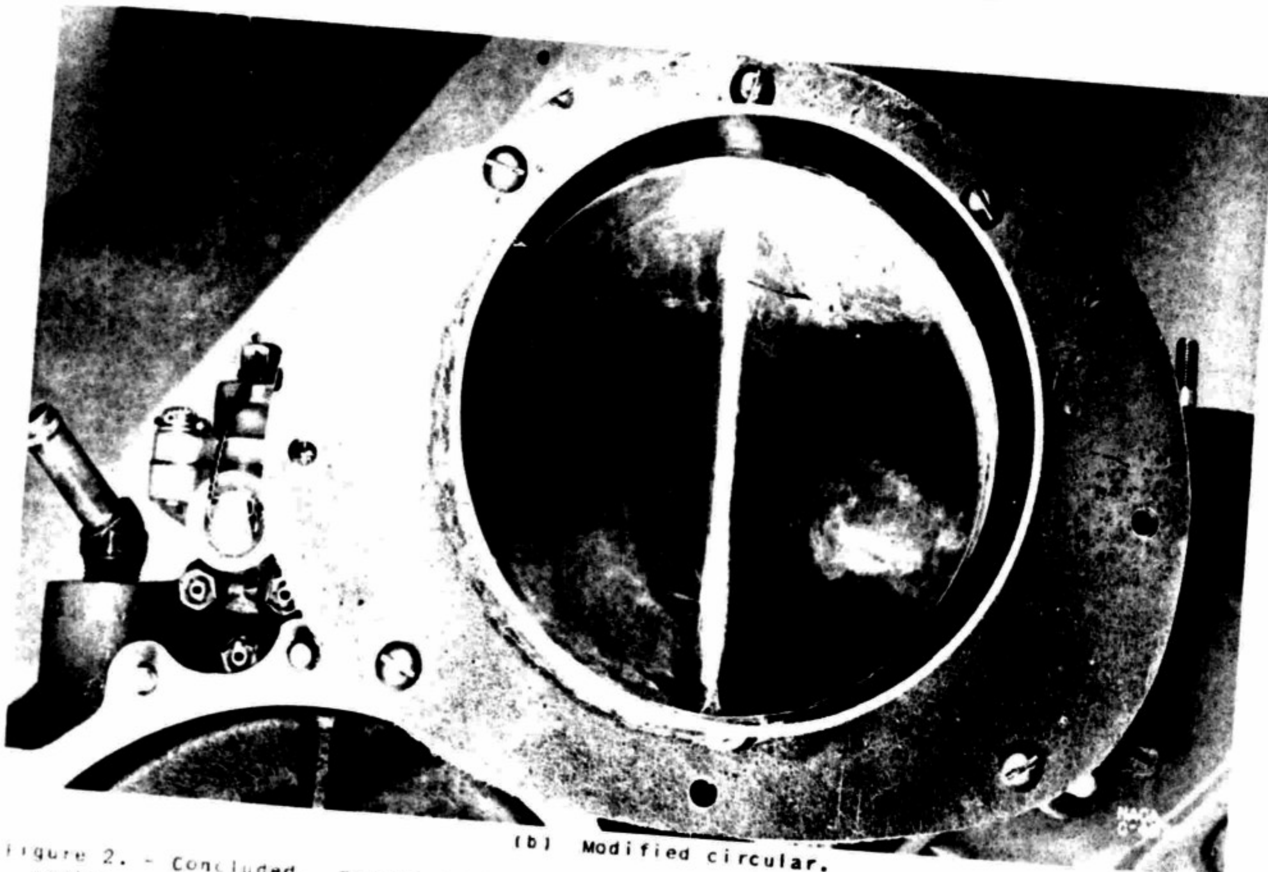



(a) Standard elliptical.

Figure 2. - Scroll outlets of auxiliary-stage supercharger for V-1710-93 engine.



(b) Modified circular.

Figure 2. - Concluded. Scroll outlets of auxiliary-stage supercharger for V-1710-93 engine.

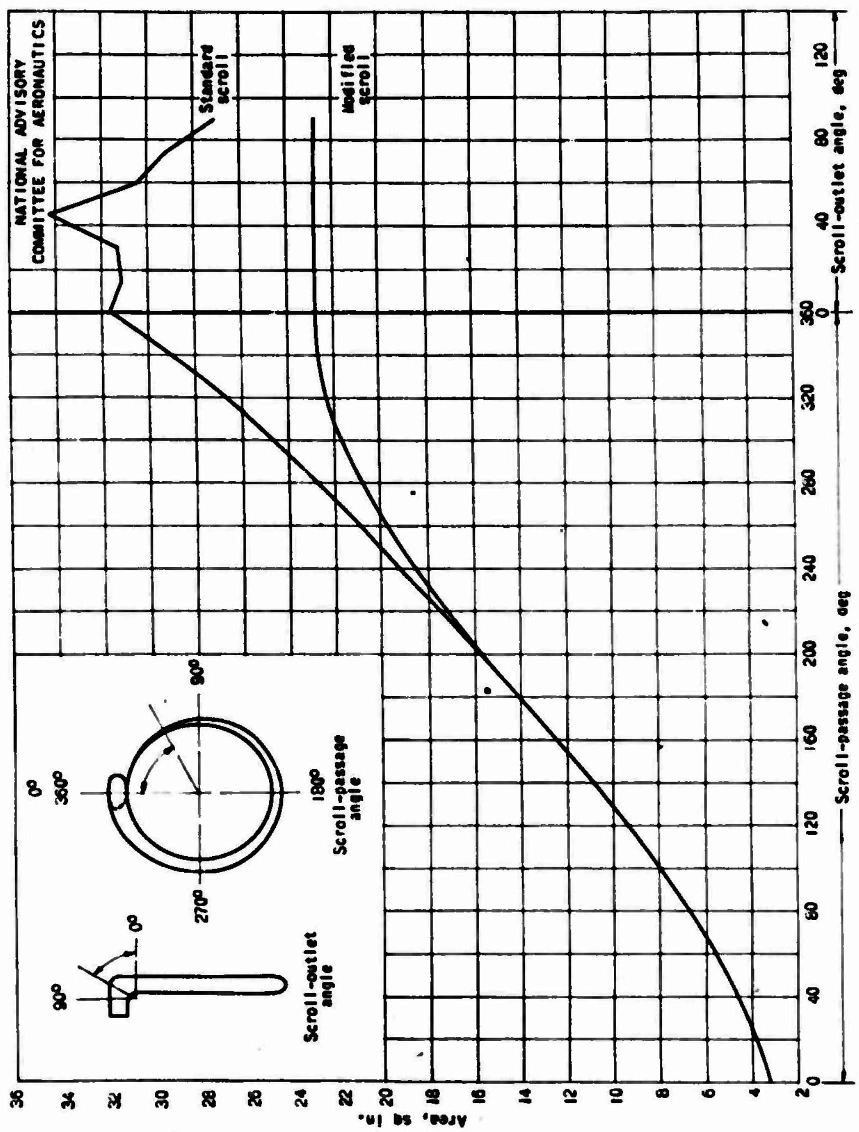



Figure 3. - Variation of area through scroll passage and scroll outlet of auxiliary-stage supercharger for V-1710-93 engine.

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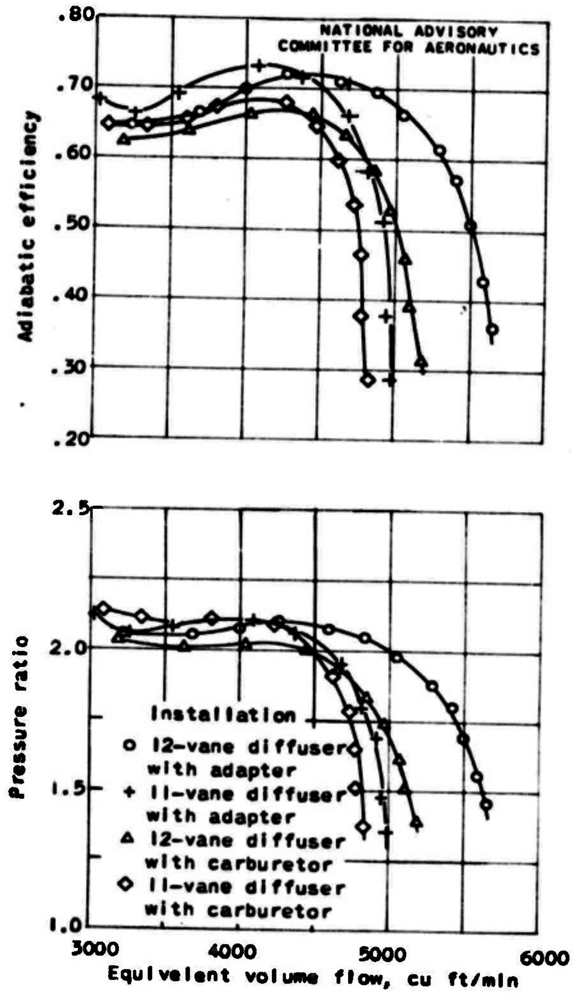



Figure 4. - Typical performance curves of auxiliary-stage supercharger for V-1710-93 engine with standard 11-vane diffuser and 12-vane diffuser at equivalent tip speed of 1073 feet per second.

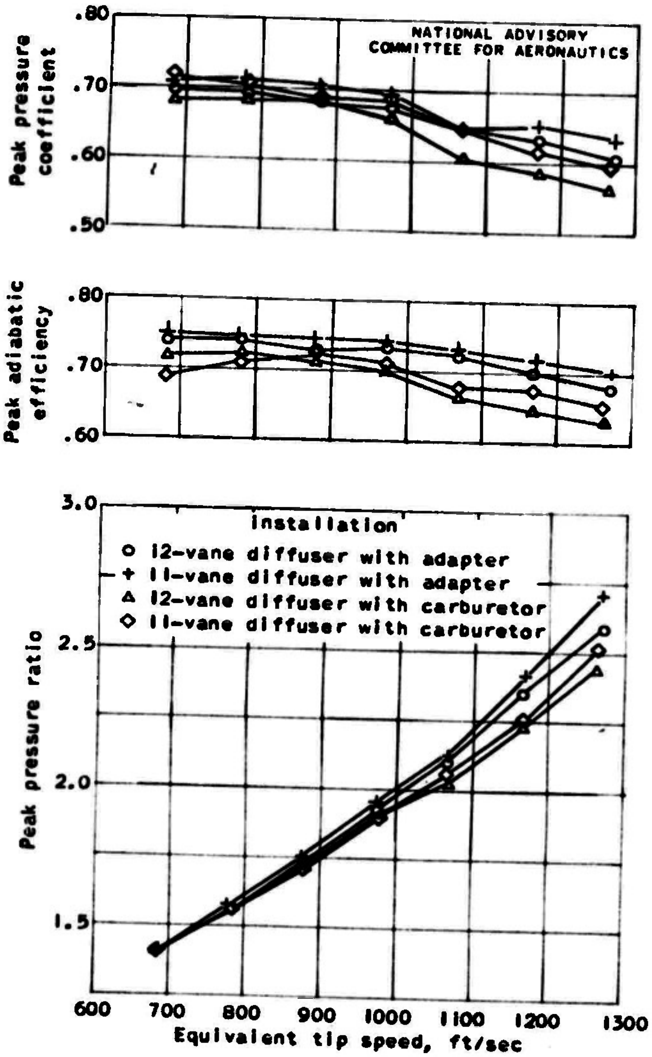
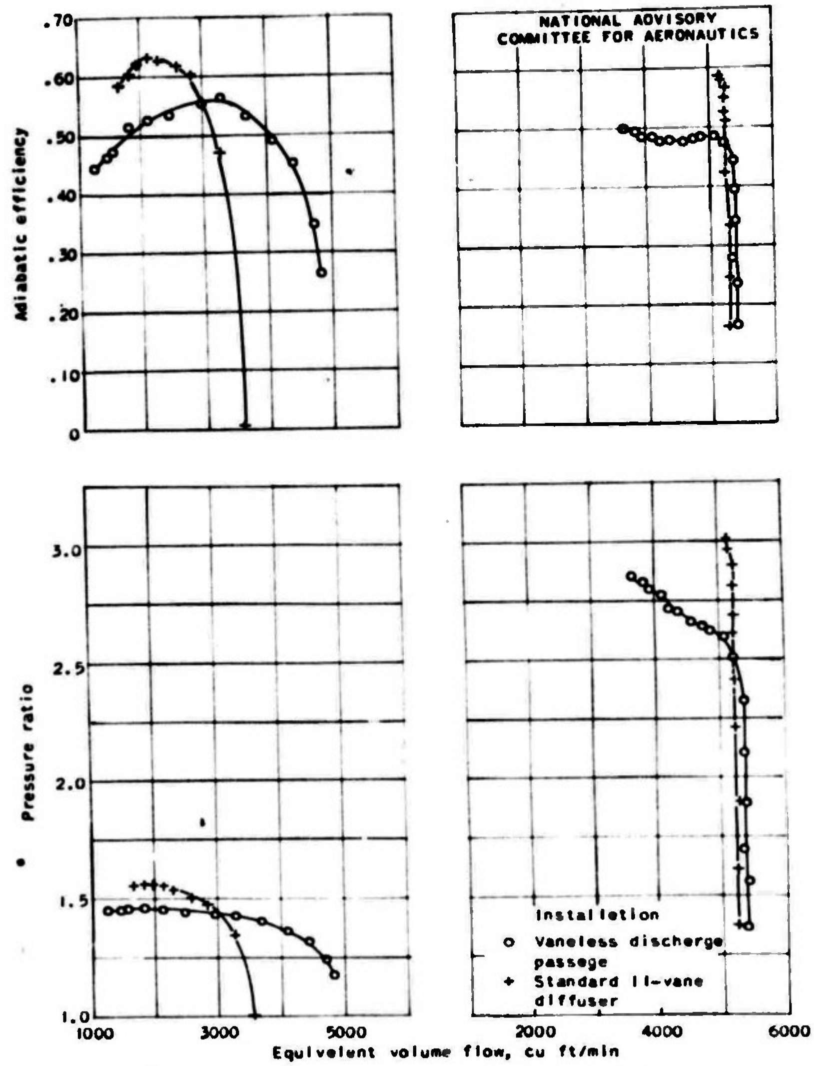



Figure 5. - Peak performance characteristics of auxiliary-stage supercharger for V-1710-93 engine with standard 11-vane diffuser and 12-vane diffuser at various equivalent tip speeds.




(a) Equivalent tip speed, 778 feet per second.

(b) Equivalent tip speed, 1459 feet per second.

Figure 6. - Typical performance curves of auxiliary-stage supercharger with carburetor installed for V-1710-93 engine with standard 11-vane diffuser and vaneless discharge passage at equivalent tip speed of 778 and 1459 feet per second at pressure altitude of 29,000 feet.

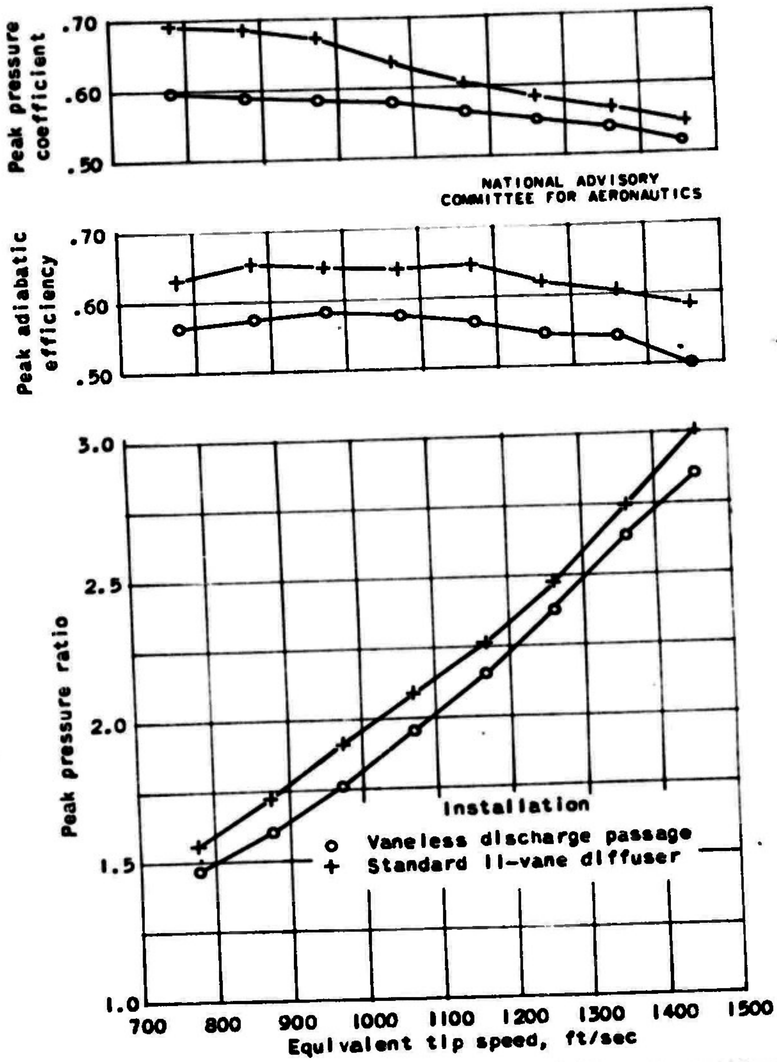



Figure 7. - Peak performance characteristics of auxiliary-stage supercharger with carburetor installed for V-1710-93 engine with standard 11-vane diffuser and vaneless discharge passage at various equivalent impeller tip speeds.

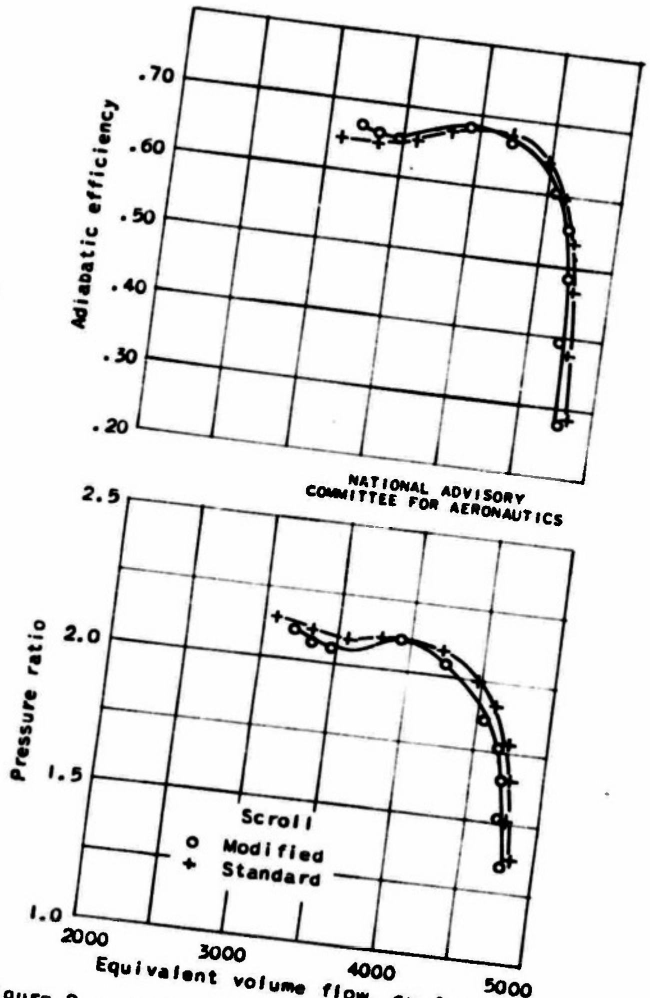



Figure 8. - Typical performance curves of auxiliary-stage supercharger with carburetor installed for V-1710-93 engine with standard and modified scroll at equivalent tip speed of 1073 feet per second.

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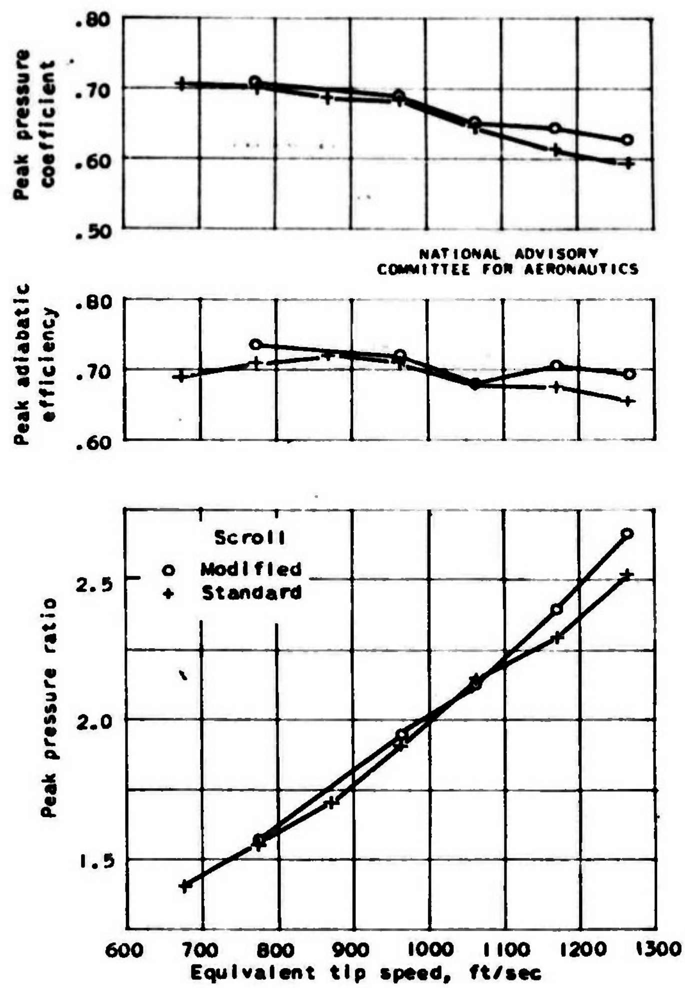


Figure 9. - Peak performance characteristics of auxiliary-stage supercharger with carburetor installed for V-1710-93 engine with standard and modified scrolls at various equivalent impeller tip speeds.

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ABSTRACT

Three modifications of the auxiliary-stage supercharger for the V-1710-93 engine were designed and tested as part of an investigation to improve the power output and the altitude performance of the engine. A 12-vane diffusor was substituted for the standard 11-vane diffusor, and a vaneless discharge passage and a modified scroll were designed to increase the flow capacity of the supercharger. With the 12-vane diffuser installed and the carburetor replaced by an adapter, the equivalent volume flow at the peak efficiency point was increased 25% at the lowest speed investigated and 9.5% at the highest speed.

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