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CYLINDER-HEAD COOLING BY MEANS OF A SHIELD IN THE EXHAUST PASSAGE

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SUMMARY

Tests were run on a single-cylinder, air-cooled engine with a Wright C9GC cylinder to determine the improvement in cylinder-head cooling that can be obtained by building into the exhaust passage an insulating shield designed to protect the valve-guide boss and the exhaust-passage walls from the exhaust gas. The test results showed an appreciable improvement in cooling of the exhaust-valve-guide boss, of the guide bushing, and of the valve seat. At a power output of 91 indicated horsepower, the temperature of the valve-guide bushing was reduced 48° F; that of the valve seat, 24° F; and that of the valve-guide boss, 82° F with the original shield and 57° F with the repaired shield. At this power the same guide temperature existed at a cooling-air pressure drop of 3 inches of water with the shield as at a pressure drop of 22 inches of water without the shield. The cooling-air pressure drops required for equal temperatures of the seat at this power were 3 inches of water with the shield and $7\frac{1}{4}$ inches of water without the shield. There was no perceptible loss of power because of the use of the shield.

INTRODUCTION

In the course of research on cylinder cooling at increased power outputs, it was found that the heat load imposed upon the exhaust valve was excessive at higher than rated power. Corrosion and deformation of the exhaust valve resulted. Reduction of the temperature of the outside of the cylinder head by increasing the mass flow of cooling air was found to be relatively ineffective in reducing the operating temperature of the valve (reference 1). Inasmuch as a large portion of the heat removed from the valve passes through the valve guide and the valve-guide boss, it was thought that the flow of heat from the valve might be increased by reducing the flow of heat from the exhaust gas to the valve-guide boss. Other investigators (references 2 and 3) have pointed out the importance of cooling the valve guide as a means of improving valve performance.

This report presents the results of comparative tests run to determine the reductions in the temperatures of the exhaust-valve seat and guide that are attainable by the use of an exhaust-passage shield. The influence of the shield on the breathing capacity of the cylinder was also investigated.

Some of the data presented in this report have been previously published in reference 4, which dealt with the over-all problem of failures of exhaust valves. It is believed that the use of a shield in the exhaust passage offers sufficient possibilities to warrant the publication of all the applicable data obtained in these tests.

APPARATUS AND METHODS

An insulating shield (fig. 1) similar to the one described in reference 5 was fitted into the exhaust passage of a standard Wright C9GC cylinder. The shield, made of 1/16-inch sheet Inconel, was hand-formed in four pieces to fit and entirely cover the exhaust passage. The exhaust passage was covered with powdered asbestos held by porcelain insulating cement. The asbestos served to prevent contact of shield and cylinder-head material. The pieces of shield were gas-welded in place to form a one-piece shield. The edge of the shield near the insert of the exhaust-valve seat was then peened into a previously cut annular groove to make a gastight seal and to form a smooth surface. The opening in the shield through which the valve stem passed was sealed by peening the shield against the exhaust-valve-guide boss. Gas leakage and lack of support at this point caused the eventual failure of the shield. The shield was not attached to the cylinder-head material except by peening into the groove near the insert of the valve seat and by forming tightly against the valve-guide boss and against the head material at the passage exit.

The cylinder, equipped with the exhaust-passage shield, was mounted on a single-cylinder crankcase. The cylinder bore was $6\frac{1}{8}$ inches and the crankshaft used had a stroke of 7 inches. The compression ratio was 6.7. The principal components of the test apparatus are shown diagrammatically in figure 2. Standard test-engine equipment was used for measuring engine torque, engine speed, fuel consumption, cylinder temperatures, and fuel-air ratio. A separately driven centrifugal blower supplied the cooling air. Thermocouples were located in the exhaust-valve guide, near the seat insert, and in the exhaust-valve-guide boss (fig. 1).

Tests with and without the shield were conducted to determine the effect of the shield on the temperatures of the exhaust-valve-guide bushing and the exhaust-valve seat and on engine power over a range of manifold pressures. Brake mean effective pressure and mass flow of cooling air were separately varied while the remaining factors were held constant. The tests covered a range of powers from 36 to 236 indicated horsepower and a range of cooling-air pressure drops across cylinder from 4 to 31 inches of water. The cooling-air jackets used for all tests were similar to the jacket described in reference 6. For all tests the engine speed was held at 2000 rpm and the fuel-air ratio was held at 0.08.

During the tests the shield failed by splitting at the edge of a welded seam. No asbestos remained behind the shield. The shield was repaired without replacing the asbestos and the tests were continued until the shield again failed. The shield was then removed and the comparative tests were run.

The friction horsepower was determined by motoring the engine at test values of inlet-air pressure while oil pressure, oil temperature, engine speed, and cylinder temperatures were held at values as close as possible to those obtained under power conditions.

EFFECTS OF EXHAUST-PASSAGE SHIELD ON ENGINE-OPERATING CHARACTERISTICS

Temperatures

The exhaust-passage shield effectively lowered the temperatures of the exhaust-valve seat, the guide boss, and the guide bushing, as shown in figures 3 and 4. The temperature of the cooling air was higher when the cylinder was tested without the shield than during the tests with the shield; therefore, a correction to the observed cylinder temperatures was necessary. Data presented in figure 4 of reference 7 indicate that an increase of 1° F in the temperature of the cooling air will raise the temperature of the head approximately 0.8° F. The observed temperatures have been corrected to conform to a common cooling-air temperature on this basis and their variations with changes of power and with changes of cooling-air pressure drop $\sigma\Delta p$ are shown in figures 3(b) and 4(b), respectively, where $\sigma\Delta p$ is equal to the static-pressure drop of cooling air multiplied by the ratio of the average density of the cooling air to the density of air at a pressure of 29.92 inches of mercury and a temperature of 70° F.

Figure 3(b) shows that the following reductions in corrected temperatures resulted from the use of the shield: that of the valve-guide bushing was reduced 48° F, from 530° F to 482° F; that of the valve seat was reduced 24° F, from 404° F to 380° F; that of the guide boss was reduced 82° F, from 599° F to 517° F, when the shield was first installed, and 57° F, from 599° F to 542° F, after the shield had been repaired; that of the rear spark-plug bushing was reduced 8° F, from 361° F to 353° F.

Figure 3 shows that the temperatures of the valve seat and the guide bushing were approximately the same with the original shield which had asbestos behind it and with the repaired shield which had no asbestos. The valve-guide boss, however, was hotter without asbestos, perhaps because the shield touched the boss near the thermocouple. The effect of the shield failure is shown in figure 3 by the sudden rise in temperatures. The extremely high temperatures are probably due to gases, guided by the broken shield, that impinged on the valve-guide boss and passage wall.

The tests with variable power (fig. 3) were run with a cooling-air pressure drop Δp of 16 inches of water. With a pressure drop of this magnitude, additional quantities of cooling air are comparatively ineffective in reducing cylinder temperatures; therefore, if the temperature reduction effected by the use of the shield were to be accomplished by increasing the cooling-air flow, extremely high pressure drops would be required. The tests with variable cooling-air pressure drop were run at 91 indicated horsepower; the results are shown in figure 4. The following table shows values of cooling-air pressure drop $\sigma\Delta p$ in the operating range that would give equal temperatures with and without the shield.

	Cooling-air pressure drop required, $\sigma\Delta p$ (in. H_2O)	
	With shield	Without shield
Corrected guide temperature, 530° F	3	22
Corrected seat temperature, 441° F	3	$7\frac{1}{4}$

Volumetric Efficiency

Figure 5 shows that the shield in the exhaust passage did not sufficiently impede the flow of exhaust gas to cause a perceptible reduction in engine power. No difference in the manifold pressure required for a given indicated mean effective pressure, with or without the shield, is apparent.

SUMMARY OF RESULTS

An analysis of the test data taken in comparative tests of a standard Wright C9GC cylinder with and without an exhaust-passage shield shows that:

1. The exhaust-passage shield appreciably reduced the temperatures of the exhaust-valve-guide boss, the valve-guide bushing, and the valve seat. At a power output of 91 indicated horsepower the temperature of the exhaust-valve-guide bushing was reduced 48° F; the temperature of the valve seat, 24° F; and the temperature of the valve-guide boss, 82° F with the original shield and 57° F with the repaired shield.

2. At 91 indicated horsepower the use of the shield reduced the temperature of the exhaust-valve guide the same amount as increasing the cooling-air pressure drop from 3 to 22 inches of water. The cooling-air pressure drops required for equal temperatures of the valve seat at this power were 3 inches of water with the shield and $7\frac{1}{4}$ inches of water without the shield.

3. The exhaust-passage shield did not sufficiently obstruct the passage of exhaust gases to cause a perceptible reduction in the power of the engine.

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REFERENCES

1. Sanders, J. C., Wilsted, H. D., and Mulcahy, B. A.: Operating Temperatures of a Sodium-Cooled Exhaust Valve as Measured by a Thermocouple. NACA ARR No. 3I06, 1943.

2. Young, Vincent C.: Aircraft-Engine Valve Mechanisms. SAE Jour., vol. 44, no. 3, March 1939, pp. 109-116.

3. Colwell, A. T.: The Problem of Valve-Stem and Valve-Head Deposits. SAE Jour., vol. 47, no. 3, Sept. 1940, pp. 358-366.

4. Sanders, J. C., Mulcahy, B. A., and Peters, M. D.: Some Factors Affecting Failures of Exhaust Valves in an Air-Cooled Cylinder. NACA ARR No. 4A19, 1944.

5. Towler, Clifford Owen: Cooling of Internal Combustion Engine. (Great Britain Patent Office no. 312,426, Jan. 24, 1939.) U.S. Patent Office 2,225,807, Dec. 24, 1940.

6. Pinkel, Benjamin: Heat-Transfer Processes in Air-Cooled Engine Cylinders. NACA Rep. No. 612, 1938.

7. Pinkel, Benjamin and Ellerbrock, Herman H. Jr.: Correlation of Cooling Data from an Air-Cooled Cylinder and Several Multi-cylinder Engines. NACA Rep. No. 683, 1940.

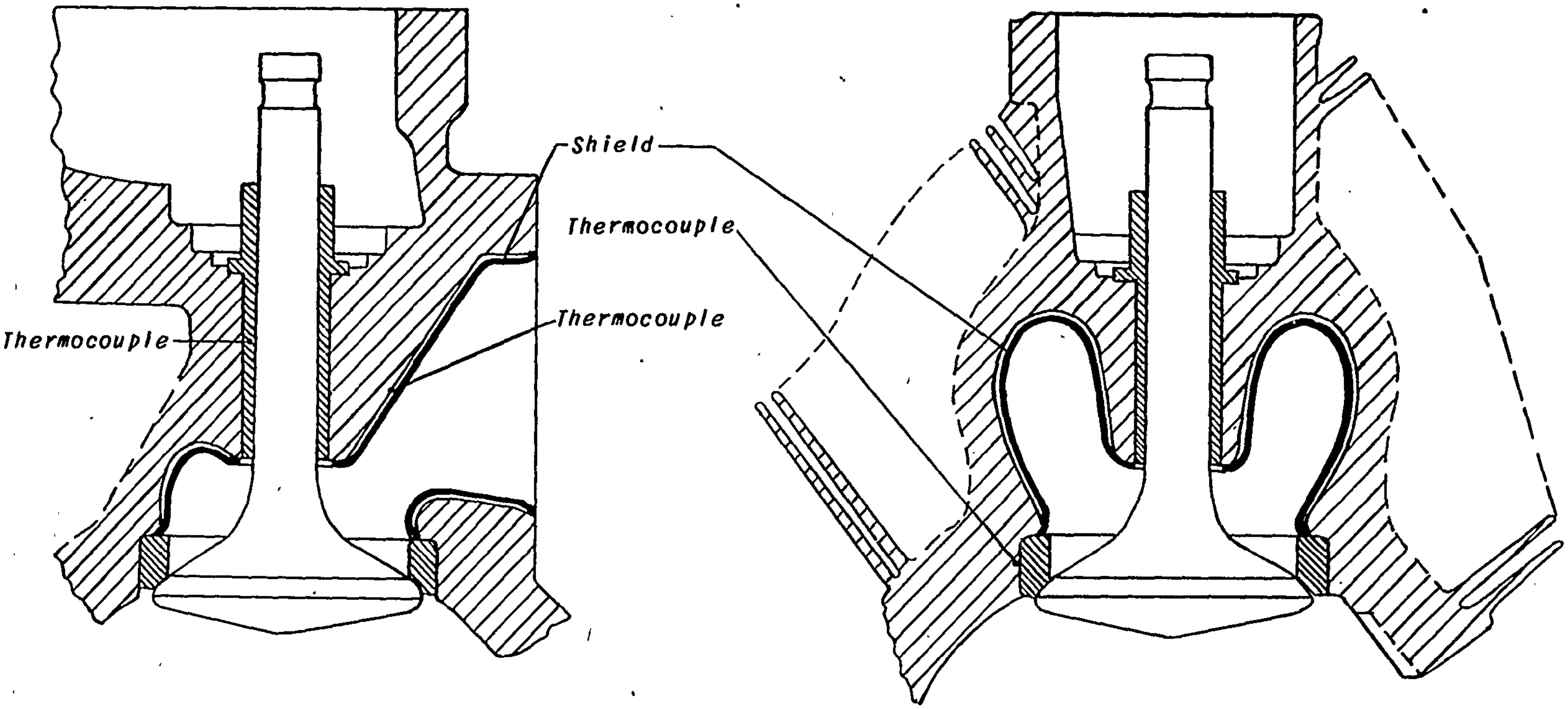

Figure 1. - Sections showing exhaust-passage shield and thermocouple locations.

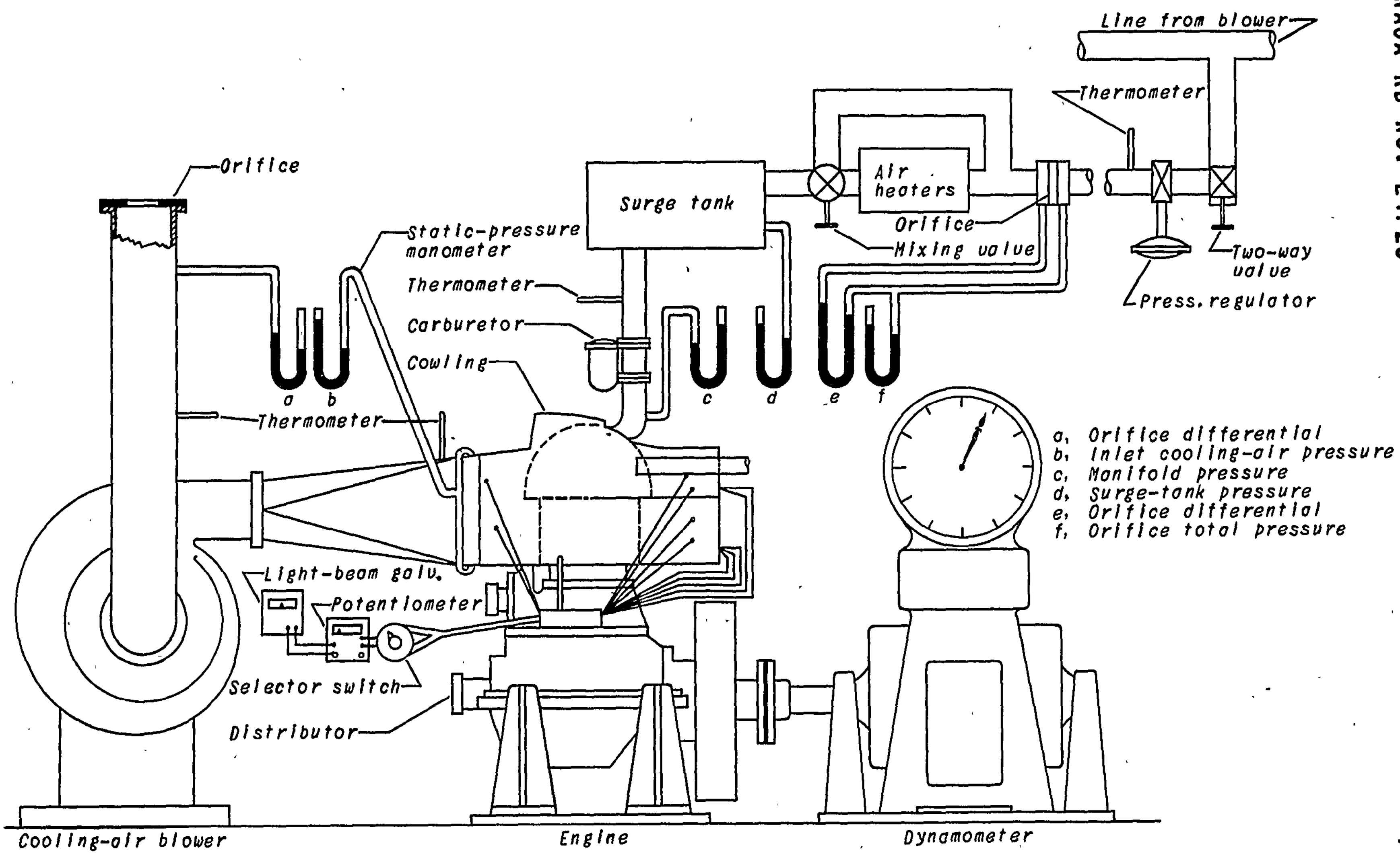

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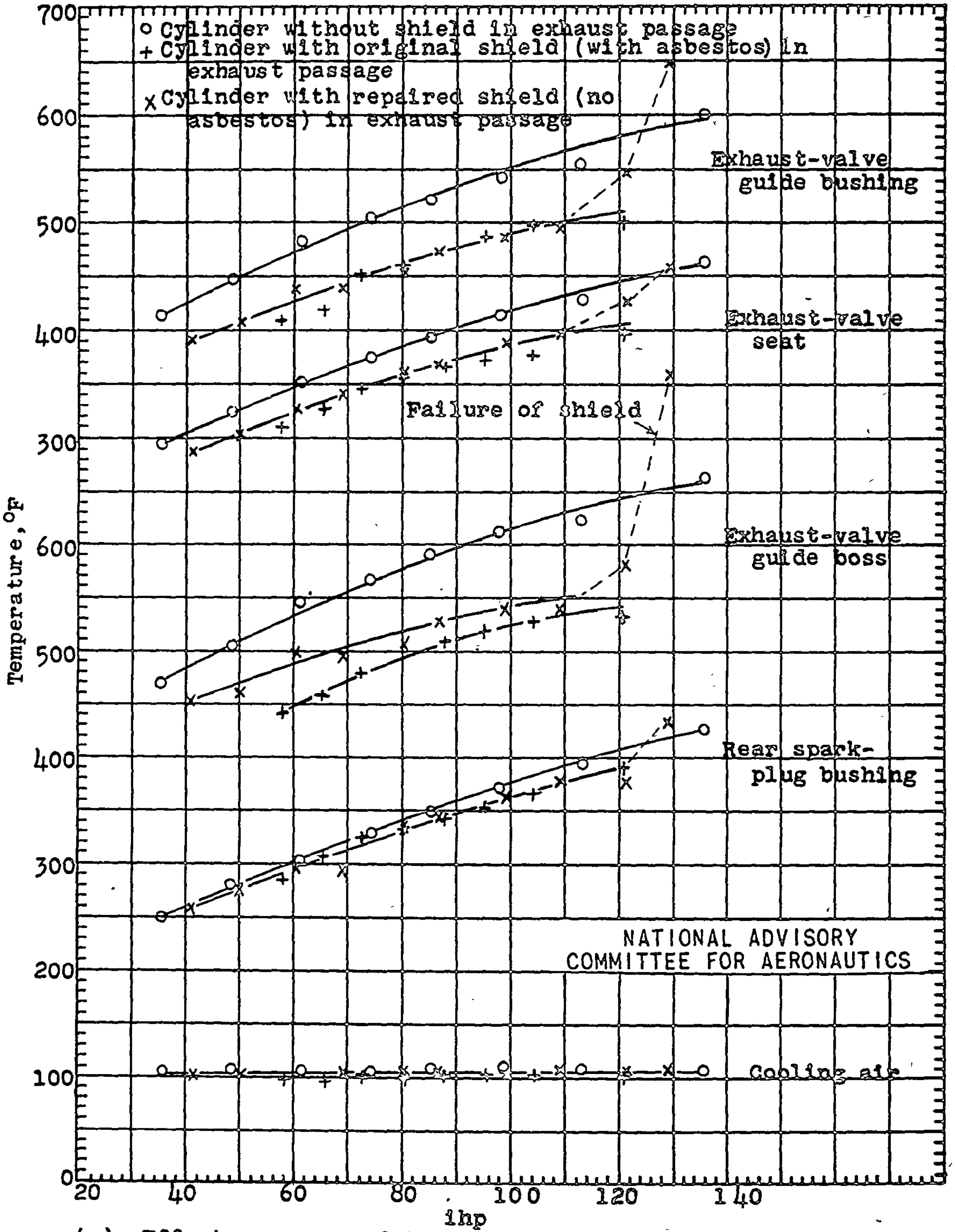
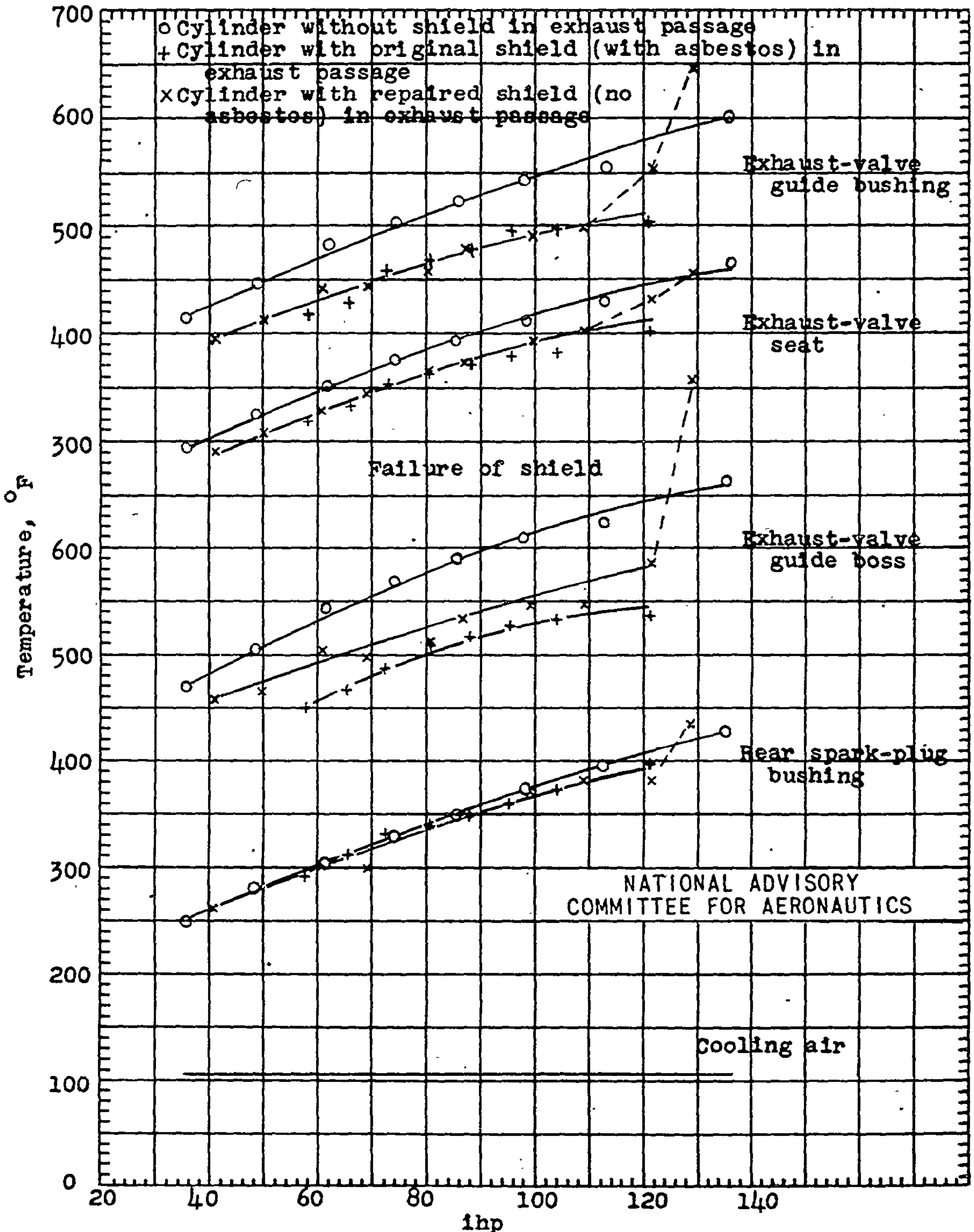
Figure 2. - Diagrammatic layout of equipment.



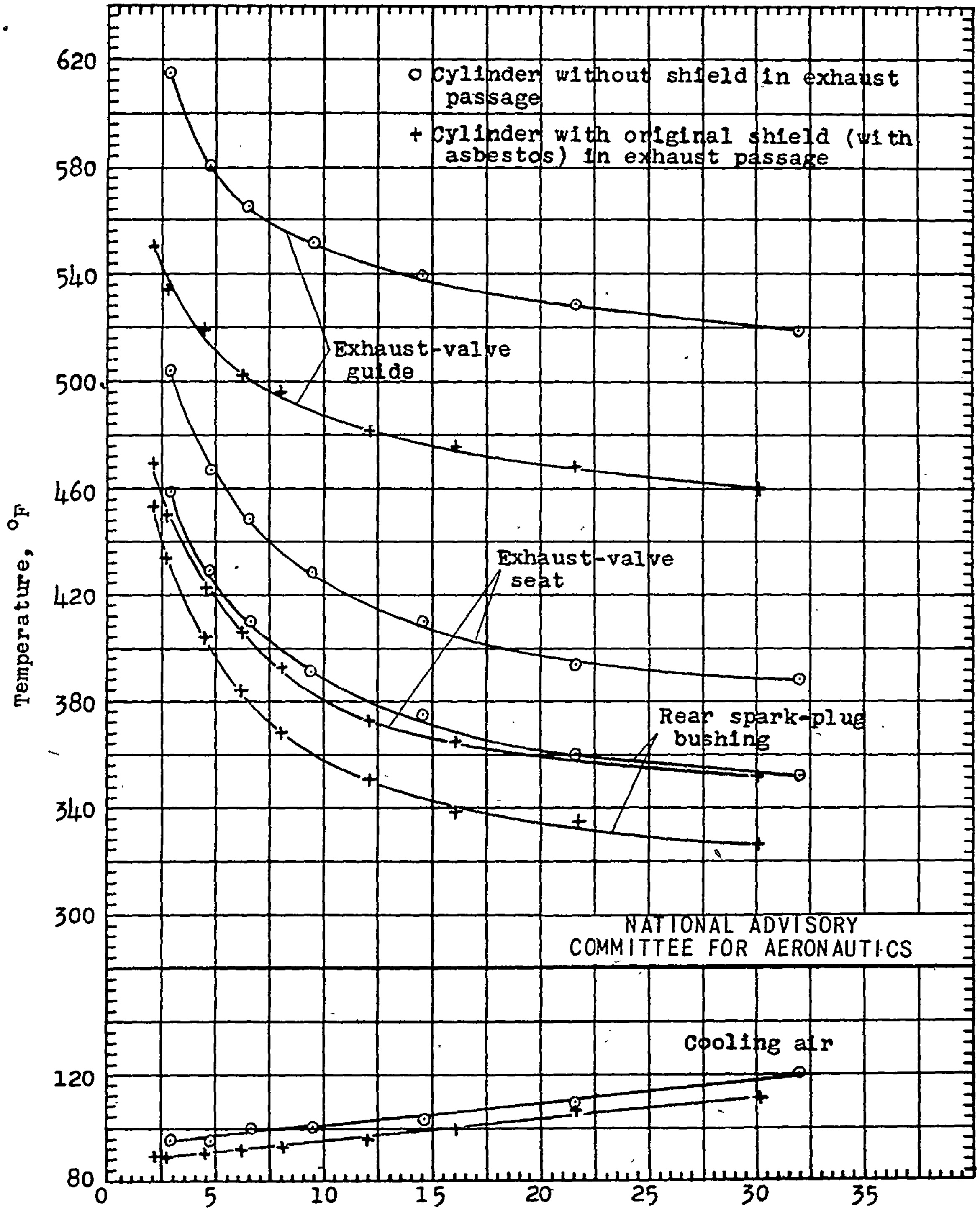
(a) Effect on measured temperatures.

Figure 3.- Effect of an exhaust-passage shield on the temperatures of the exhaust-valve seat, guide bushing, guide boss, and rear spark-plug bushing. Wright C9GC cylinder; fuel-air ratio, 0.08; engine speed, 2000 rpm; cooling-air pressure drop, 16 inches of water.



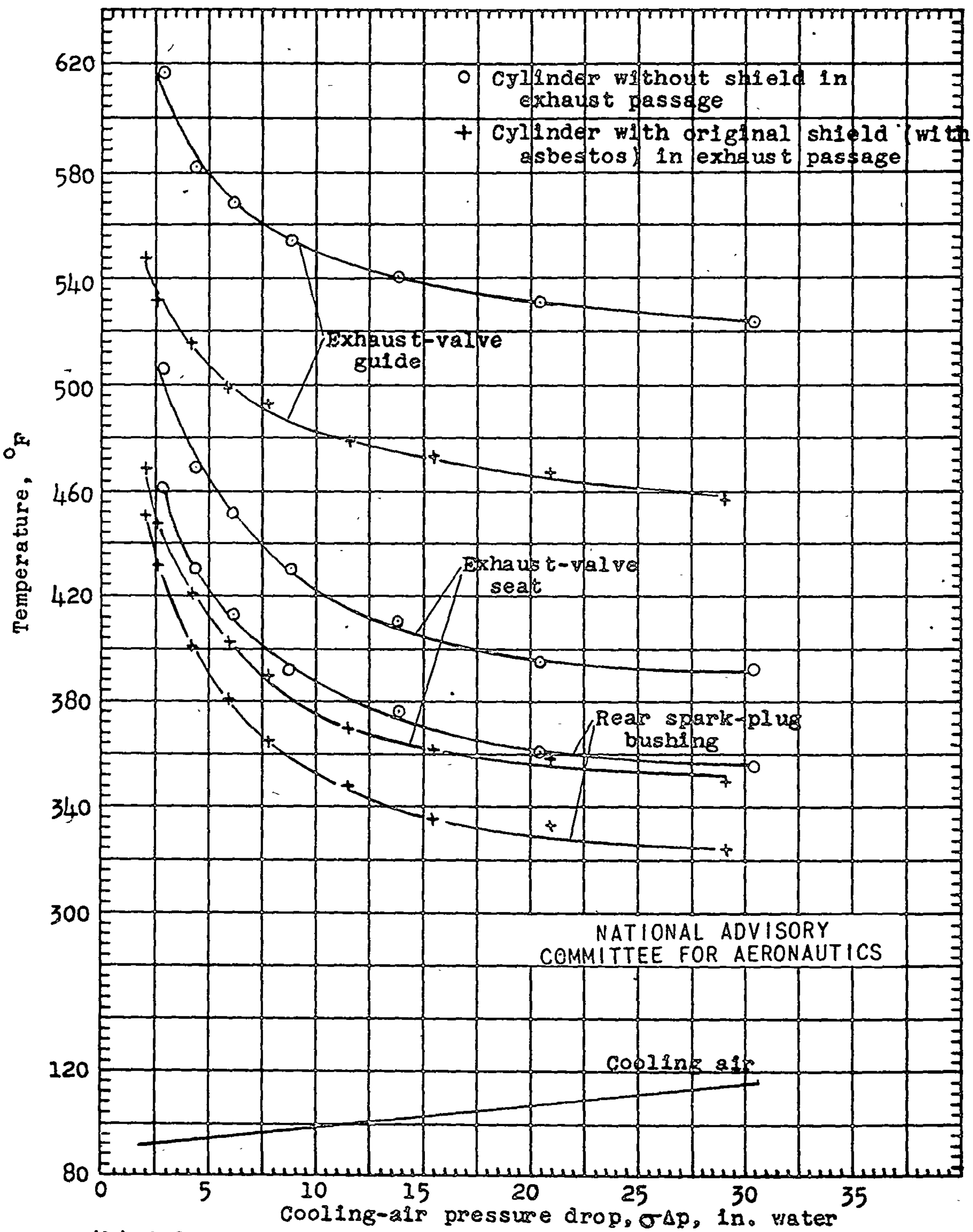
(b) Effect on corrected temperatures.

Figure 3.- Concluded. Effect of an exhaust-passage shield on the temperatures of the exhaust-valve seat, guide boss, and rear spark-plug bushing. Wright C9GC cylinder; fuel-air ratio, 0.08; engine speed, 2000 rpm; cooling-air pressure drop, 16 inches of water.



(a) Effect on measured temperatures.

Figure 4.- Effect of variation in cylinder-head cooling on the temperatures of the exhaust-valve guide, valve seat, and rear spark-plug bushing. Wright C9GC cylinder; fuel-air ratio, 0.08; engine speed, 2000 rpm; power output, 91 indicated horsepower.



(b) Effect on corrected temperatures.

Figure 4.- Concluded. Effect of variation in cylinder-head cooling on the temperatures of the exhaust-valve guide, valve seat, and rear spark-plug bushing. Wright C9GC cylinder; fuel-air ratio, 0.08; engine speed, 2000 rpm; power output, 91 indicated horsepower.

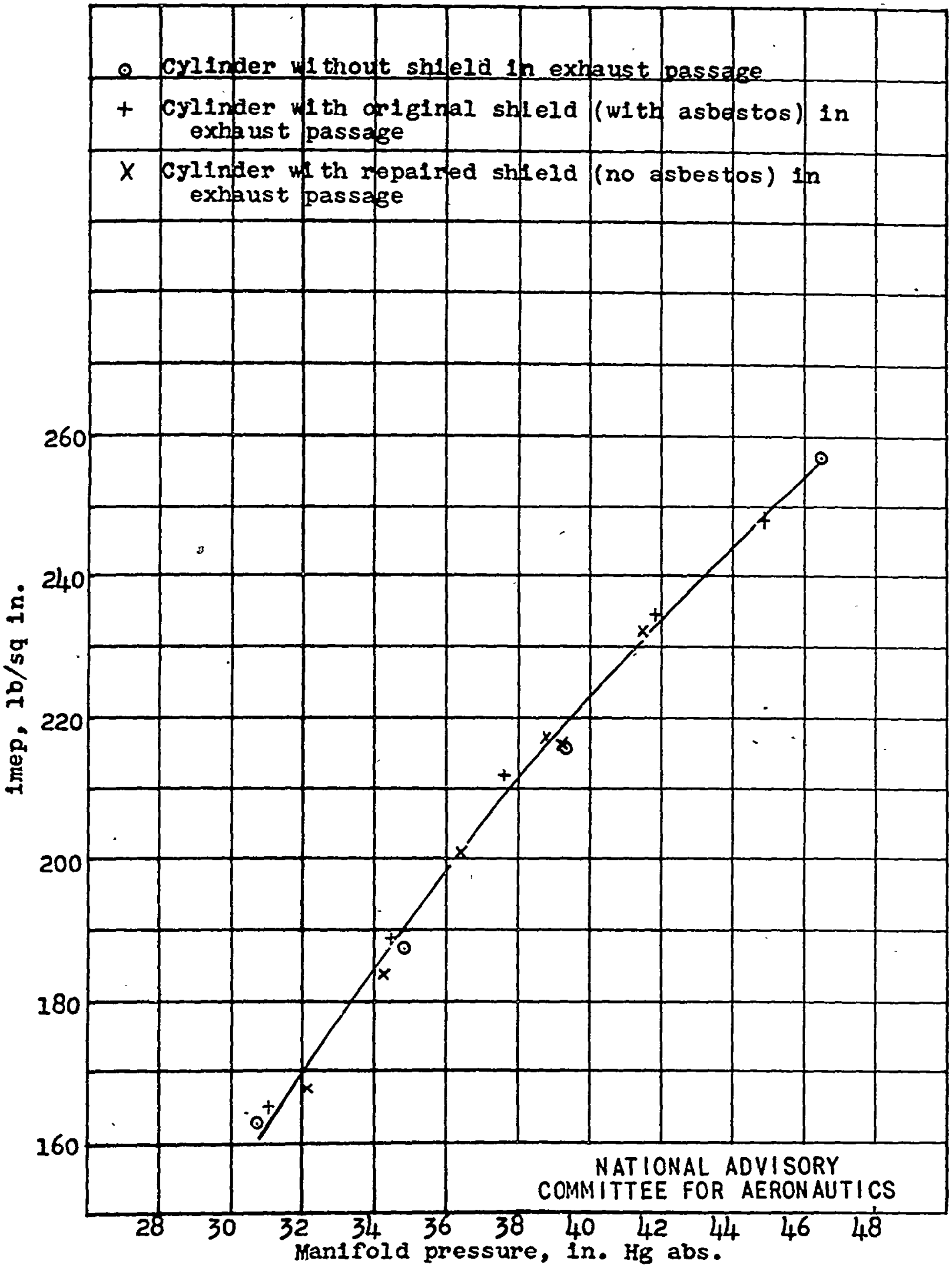


Figure 5.- Relation between manifold pressure and indicated mean effective pressure with and without exhaust-passage shield. Wright C9GC cylinder; fuel-air ratio, 0.08; engine speed, 2000 rpm; cooling-air pressure drop, 16 inches of water.