NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

WARTIME REPORT

ORIGINALLY ISSUED
June 1942 as
Memorandum Report

COOLING IN CRUISING FLIGHT WITH LOW FUEL-AIR RATIOS

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WASHINGTON

NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

MEMORANDUM REPORT

for the

Army Air Forces, Materiel Command

COOLING IN CRUISING FLIGHT WITH LOW FUEL-AIR RATIOS

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INTRODUCTION

Single-cylinder dynamometer tests (references 1 and 2) have shown that engine cooling and fuel economy at cruising powers can be improved by operation at fuel-air ratios leaner than those provided by the usual automatic lean carburetor settings. Inasmuch as improvements of the cooling and the fuel economy are attractive means for increasing the range, the possibilities of realizing similar gains with a conventional multicylinder engine installation have been investigated by tests of a Pratt & Whitney R-1830-43 engine mounted in a B-24D nacelle in the full-scale wind tunnel.

The engine temperatures, the baffle pressure drops, and the fuel consumptions were measured for engine operation at about 0.6 of rated power for values of the fuel-air ratio from 0.056 to 0.090. The lower of these fuel-air ratio values is only slightly above the leanest mixture for smooth engine operation while the upper value is rich. In automatic lean the carburetor that was tested provided a fuel-air ratio of about 0.072 at cruising power. The power was limited to about 0.6 of the normal engine rating to hold the brake mean effective pressure below the detonation limit for the 100 octane fuel used. With a better fuel the tests could have been extended to higher powers.

APPARATUS AND TESTS

The full-scale wind-tunnel equipment and methods of operation are described in reference 3. A Pratt & Whitney R-1830-43 engine with a normal rating of 1100 brake horsepower at 2550 rpm equipped with a General Electric turbosupercharger and Hamilton Standard constant-speed propeller was installed for the tests in a modified B-24D production nacelle (fig. 1).

The baffle pressure drop for each engine cylinder was determined from the difference between the total pressure at the baffle inlet and the static pressure at its outlet (fig. 2).

Temperatures of the rear spark-plug gaskets, the cylinder bases, the carburetor inlet air, and the accessories were measured with a self-balancing potentiometer. The fuel-air ratio was determined from Orsat analysis of samples of the exhaust gases taken in the tail pipe to the turbosupercharger using a chart for conversion to fuel-air ratio. The standard instrumentation required for the engine operation included a sensitive tachometer and carefully calibrated flowmeter.

The basic tests were made with the propeller pitch, tunnel speed, and engine rpm fixed in order to maintain constant power at approximately 660 horsepower. Temperatures and fuel flows were measured with the carburetor set at automatic lean, with the mixture leaned to a fuel-air ratio of 0.060, and for an intermediate condition giving maximum head temperatures. Additional tests at fuel-air ratios of 0.056 and 0.090 were made at approximately the same power with the propeller governing. Factors affecting the cooling other than the fuel-air ratio were held as constant as practicable throughout the tests.

RESULTS AND DISCUSSION

The engine cylinder barrel and head temperatures measured with constant power at three different fuel-air ratios are shown in figure 3. The baffle pressure drops corresponding to these test conditions are shown in figure 4. A cross plot showing the variation of the head and barrel temperatures on cylinder 1 with fuel-air ratio is shown in figure 5. The temperatures measured at about the same power with the propeller governing are included on figure 5. The cylinder temperatures were corrected for small differences in the cooling air and carburetor air inlet temperatures for the reference temperature of 100° F by a 1° per degree correction on the head and a 0.5° per degree correction on the bases. The test temperatures were all within 10° of the reference. The variation of the specific fuel consumption with fuel-air ratio is shown in figure 6.

The results show that leaning the fuel-air ratio from the automatic lean setting of 0.072 to 0.056 decreased the number 1 head temperature 50° F and the base temperature 22° F (fig. 5). Similar temperature decreases were obtained on the other cylinders (fig. 3). The fuel consumption was likewise decreased from about 0.45 to 0.39 pound per brake horsepower hour (fig. 6).

The results indicate that the cruising range can be extended considerably by operating the engine at fuel-air ratios of 0.060 or below instead of at the richer mixtures provided by conventional carburetor settings. In addition to the direct increase of range resulting from the 12-percent lower fuel consumption, the decreased engine temperatures reduce the necessary cooling drag. For airplanes in which it is necessary to open cowl flaps to cool in cruising flight, the extension of range resulting from operation with closed flaps and lean mixtures may be as much as 50 percent.

Cruising flight at extremely lean fuel-air ratios will require adequate instrumentation and careful engine operation to avoid backfiring from over-leaning and detonation at higher brake mean effective pressures than those of the present tests (reference 2). The use of fuels with higher knock ratings will greatly simplify this type of operation.

CONCLUSIONS

1. The engine cooling and the fuel economy will be improved in the cruising power range by operation at fuel-air ratios of 0.060 or below instead of at the value of about 0.070 which is representative of present practice.

2. The cruising range will be considerably extended by operation at low fuel-air ratios, particularly if the cooling in cruising at present mixtures requires opening the cowl flaps.

Langley Memorial Aeronautical Laboratory,
National Advisory Committee for Aeronautics,
Langley Field, Va., June 18, 1942.

REFERENCES

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

2. Biermann, Arnold E., Corrington, Lester C., and Harries, Myron L.: Effect of Additions of Aromatics on the Knocking Characteristics of Several 100-Octane Fuels at Two Engine Speeds. NACA ARR, May 1942.

3. DeFrance, Smith J.: The N. A. C. A. Full-Scale Wind Tunnel. NACA Rep. No. 459, 1933.

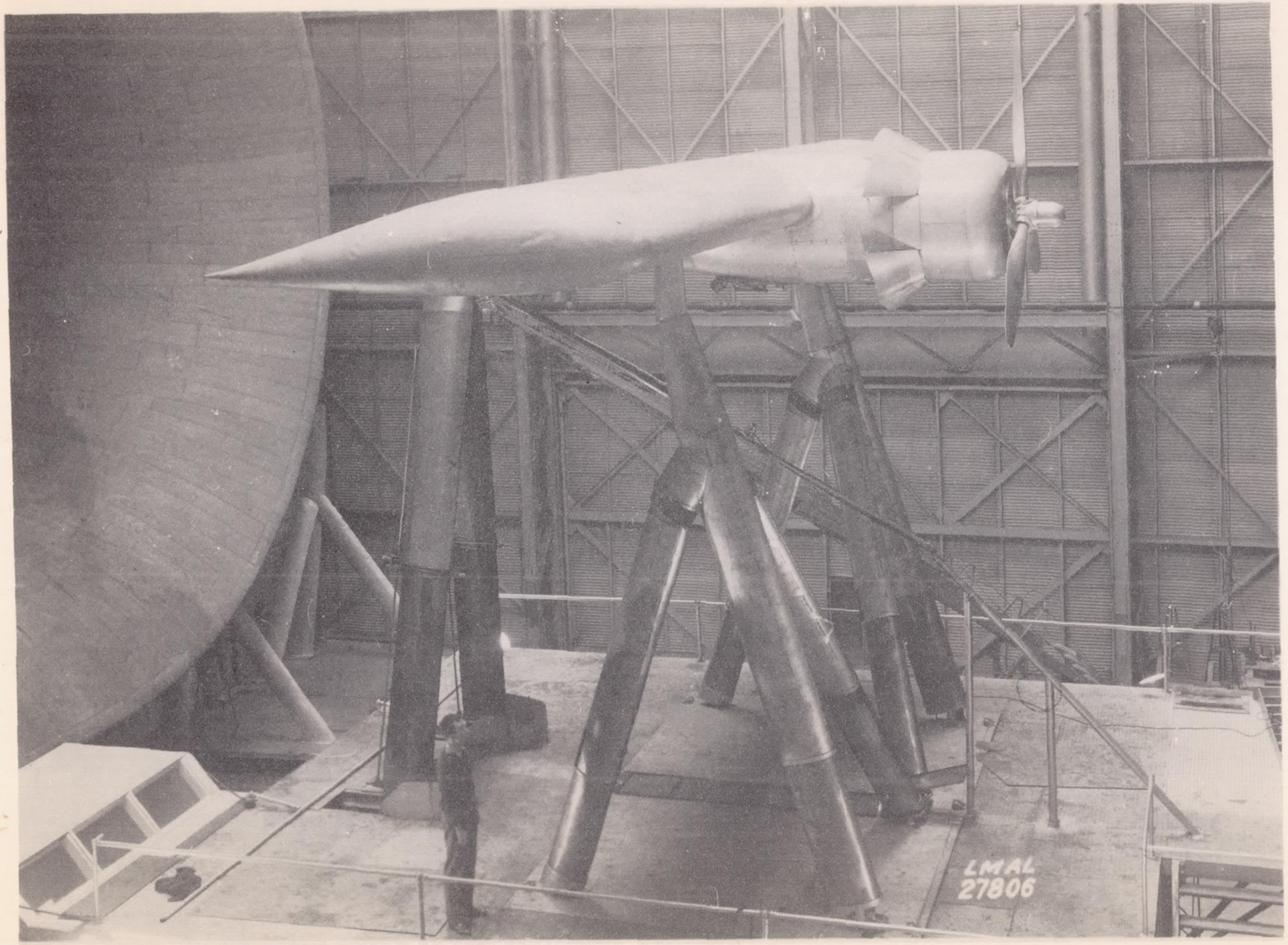
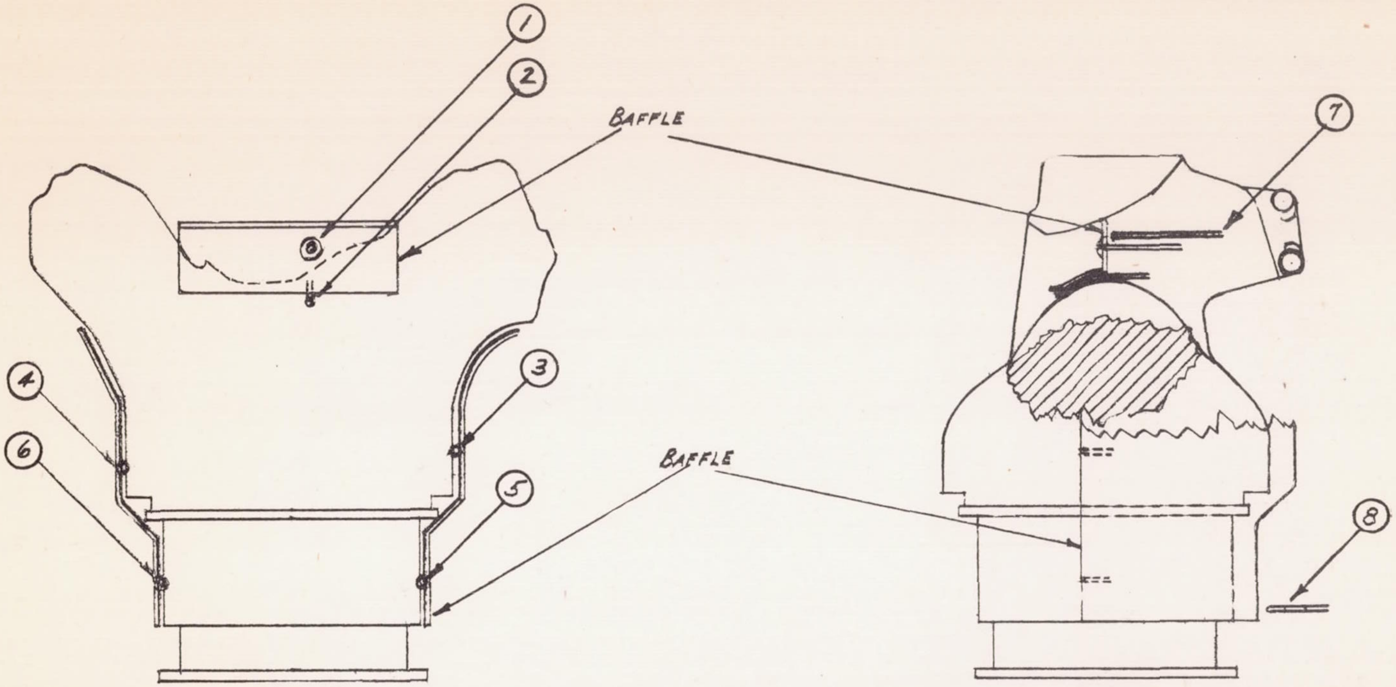
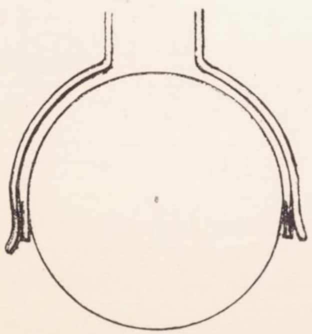


Figure 1.- Installation of 1830-43 engine and B-24D nacelle in the full-scale wind tunnel.



FRONT

SIDE



SECTION THROUGH CYLINDER

	READING	LOCATION
1	TOTAL PRESSURE	BUTTON IN HEAD BAFFLE
2	TOTAL PRESSURE	BETW. FINS 9&10 (FROM INTAKE)
3	TOTAL PRESSURE	BETW. FINS 7&8
4	TOTAL PRESSURE	BETW. FINS 5&6
5	TOTAL PRESSURE	BETW. FINS 8&9
6	TOTAL PRESSURE	BETW. FINS 8&9
7	STATIC PRESSURE	1/4" FROM BAFFLE
8	STATIC PRESSURE	OPP. 4TH FIN FROM BOTTOM

NOT TO SCALE

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FIGURE 2.- THE LOCATION OF TUBES FOR THE BAFFLE PRESSURE MEASUREMENTS

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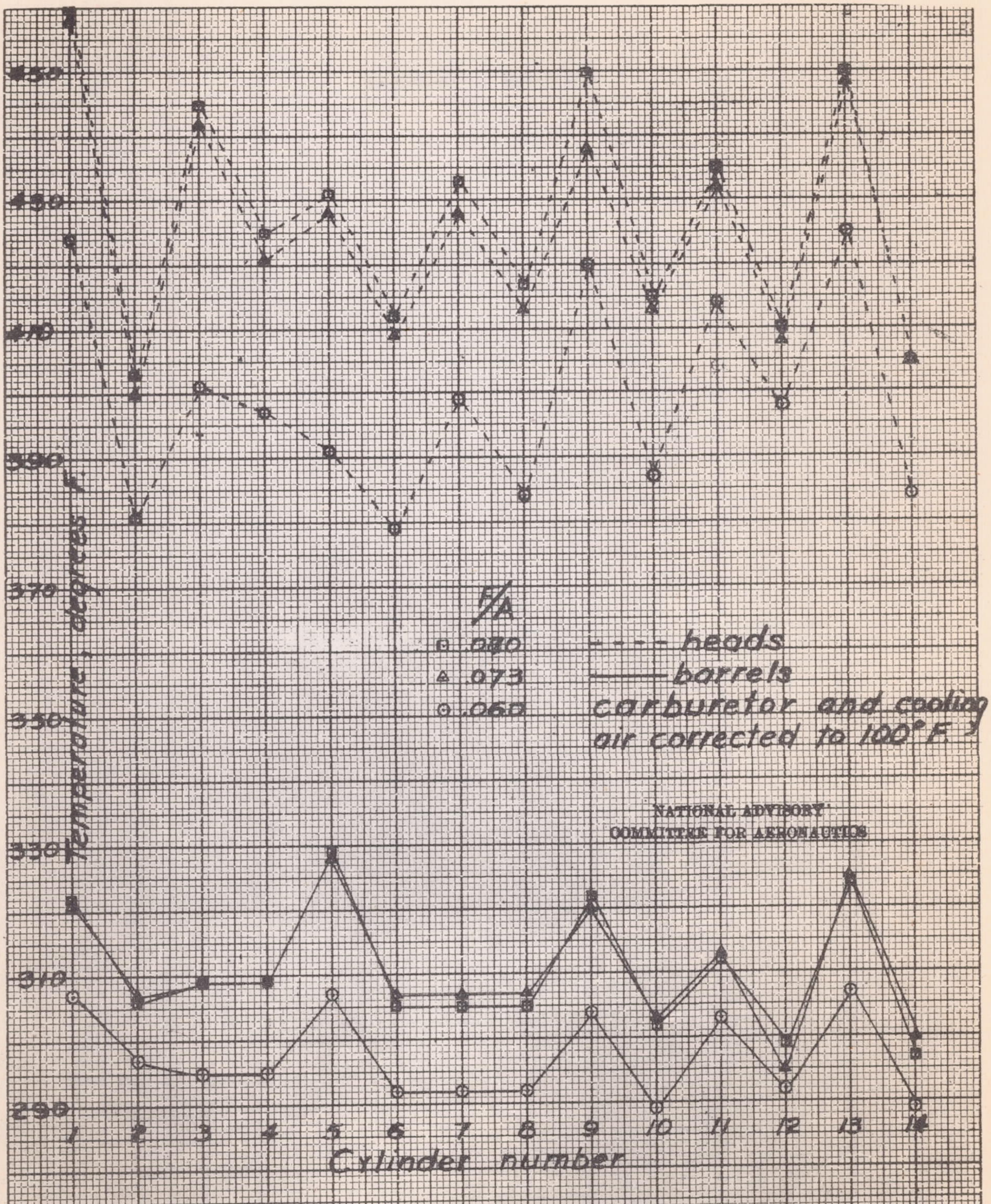

Figure 5. - Distribution of the head and barrel temperatures on the 1830-43 engine installation for three fuel-air ratios. Constant power at 2230 rpm; β = 21° at 42-inch radius.

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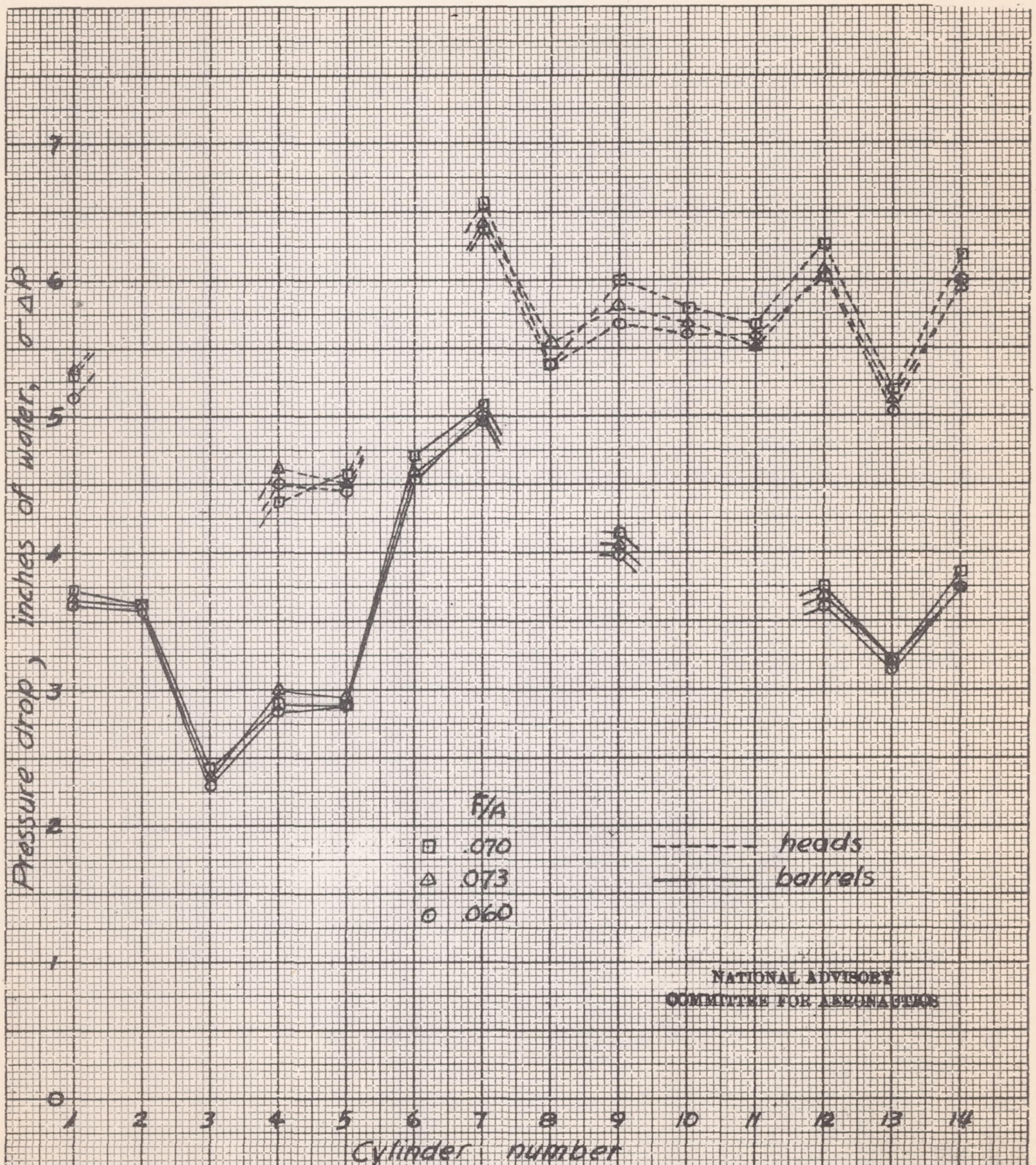

Figure 4. - Distribution of pressure drop across the cylinders of the 1830-43 engine installation for three fuel-air ratios. Constant power at 2230 rpm; β = 21° at 42-inch radius.

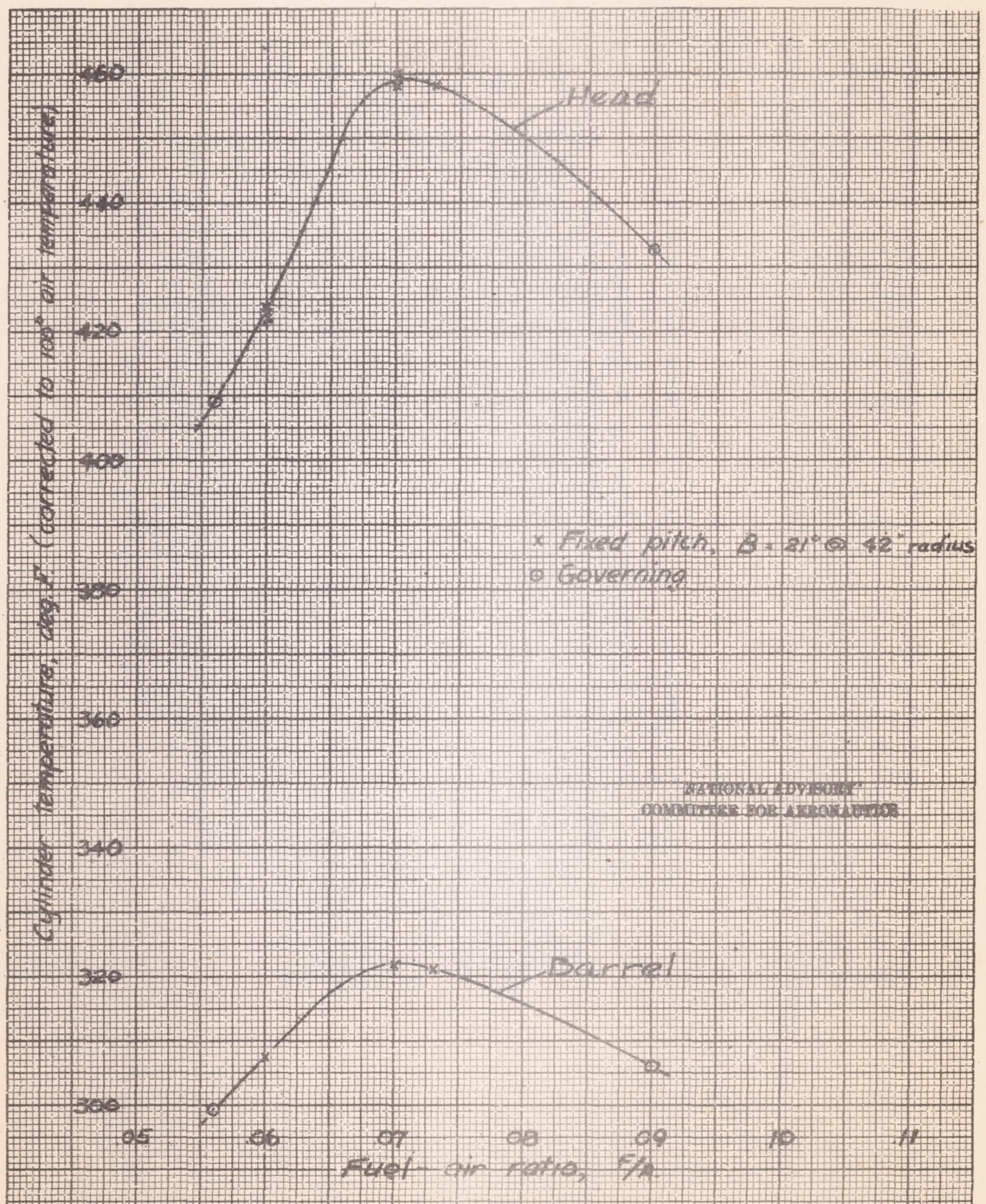

Figure 5. - Variation of the temperatures on cylinder 1 with fuel-air ratio at constant power output; approximately 660 bhp; 2230 rpm, 100° carburetor-air temperature.

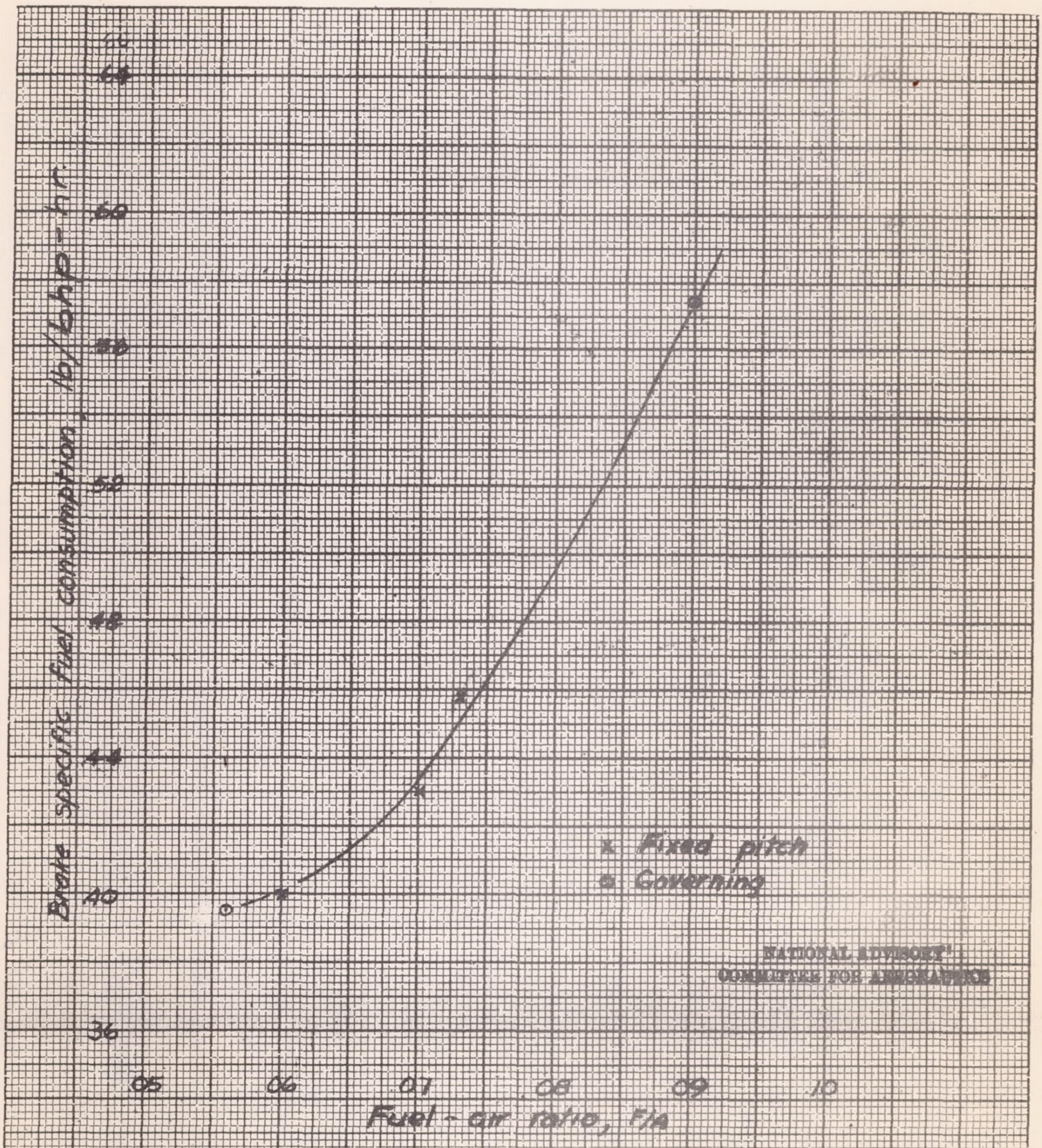

Figure 6. - Variation of brake specific fuel consumption with fuel-air ratio for constant power approximately 660 horsepower.