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ACR No. E4H10

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NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

WARTIME REPORT

ORIGINALLY ISSUED

August 1944 as

Advance Confidential Report E4H10

SUPERCHARGED-ENGINE KNOCK TESTS OF METHYL tert-BUTYL ETHER

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NACA

WASHINGTON

E-215

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ADVANCE CONFIDENTIAL REPORT

SUPERCHARGED-ENGINE KNOCK TESTS OF METHYL tert-BUTYL ETHER

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SUMMARY

Data that show the knock-limited performance of methyl tert-butyl ether were obtained from tests made in a 17.6-cubic-inch-displacement engine under supercharged conditions. The performance of pure methyl tert-butyl ether was compared with that of S-2 reference fuel. Tests for temperature sensitivity, speed sensitivity, and lead susceptibility were made on a blend of 20 percent methyl tert-butyl ether and 80 percent S-2 reference fuel.

At the only conditions under which pure methyl tert-butyl ether was examined, the ether produced knock-limited indicated mean effective pressures 87 and 90 percent greater than those of S-2 reference fuel at fuel-air ratios of 0.100 and 0.075, respectively.

INTRODUCTION

Tests at various laboratories have shown that methyl tert-butyl ether has an exceptionally high antiknock value. Its use in aviation fuels, however, would be as a blending agent and as such could be considered as a substitute for isopentane.

The data presented in this report are for the purpose of extending the information on the antiknock characteristics of methyl tert-butyl ether. Knock-limited performance tests were conducted at the Aircraft Engine Research Laboratory of the NACA on blends of methyl tert-butyl ether and S-2 reference fuel in a supercharged 17.6 engine at two engine speeds and two inlet-air temperatures.

TEST CONDITIONS AND APPARATUS

Test conditions. - The tests were run at the following engine conditions:

Speed, rpm	1800, 2700
Compression ratio	7.0
Inlet-coolant temperature, °F	250
Inlet-air temperature, °F	150, 250
Spark advance, deg B.T.C.	33

Apparatus. - The engine used for these tests is a single-cylinder test engine. The stroke is $3\frac{1}{4}$ inches, the bore is $2\frac{5}{8}$ inches, and the displacement is 17.6 inches.

1. An aluminum piston was made in order to obtain a compression ratio of 7.0. This piston was not soduim-cooled.

2. An AFD 3-C injection elbow was installed on the engine. Fuel was injected into the elbow parallel to the flow of air. Schematic diagrams of the fuel-injection system and the inlet-air system are shown in figures 1 and 2, respectively.

3. The engine was coupled to a 30-horsepower dynamometer.

4. Knock was detected by a cathode-ray oscilloscope and an electromagnetic pickup.

Three types of spark plug were used in tests on pure methyl *tert*-butyl ether. It was impossible to obtain a knock curve with a Champion C34S or a Champion RJ-2 spark plug. In both cases preignition and afterfiring occurred before knock was obtained. A hot spot developed with the RJ-2 spark plug, and the engine fired steadily for about 3 minutes with the ignition switch off. In this particular case the engine showed no tendency to "run away" when the power was raised or lowered by changing the air flow to the engine. A Champion RJ-24 spark plug was installed and no preignition or afterfiring occurred.

TEST RESULTS

Data for S-2 reference fuel, methyl *tert*-butyl ether, and a blend of 20 percent ether plus 80 percent S-2 reference fuel are presented in figure 3. At a fuel-air ratio of 0.075, the 20-percent blend produced approximately 16 percent more knock-limited power than S-2. Pure methyl _tert_-butyl ether produced 90 percent more knock-limited power than S-2 at the same fuel-air ratio. At a fuel-air ratio of 0.100, the 20-percent blend increased the knock-limited power by 31 percent and the pure ether, by 87 percent. The knock-limited power expressed as percentage of S-2 is presented for the 20-percent blend and for methyl _tert_-butyl ether in table I.

The indicated specific fuel consumption for the 20-percent blend was the same as that of S-2 reference fuel; the fuel consumption of the pure methyl _tert_-butyl ether was, however, very different. The fuel-consumption curve for the ether crossed the curve for S-2 at approximately 0.083 fuel-air ratio. (See fig. 3.) At fuel-air ratios above 0.083, methyl _tert_-butyl ether had a lower fuel consumption than S-2; therefore, at rich mixtures the ether has the two advantages of increasing the knock-limited power and decreasing fuel consumption. For example, at a fuel-air ratio of 0.100, methyl _tert_-butyl ether produced 87 percent more knock-limited power than S-2 and had a fuel consumption 6 percent lower.

The effect of inlet-air temperature on the knock-limited performance of the 20-percent blend is shown in figure 4. At a fuel-air ratio of 0.070, the knock-limited power increase was 41 percent for a 100° F decrease in temperature; at a fuel-air ratio of 0.100, the knock-limited power increase was 29 percent for a 100° F decrease in temperature.

It has been noticed at this laboratory that the indicated specific fuel consumption tends to increase for lean mixtures as the inlet-air temperature is raised in both the 17.6-cubic-inch-displacement engine and the CFR test engine. In figure 4 this change is about 7 percent at a fuel-air ratio of 0.070. The data shown in the curves of figure 4 were obtained on the same day.

Changes in engine speed affected the indicated-mean-effective-pressure curve of the 20-percent blend of methyl _tert_-butyl ether only at very lean and very rich mixtures. (See fig. 5.) The high fuel consumption at 1800 rpm may have been caused by low combustion efficiency. Engine operation at this speed was decidedly irregular.

The lead response of the 20-percent blend to 2.0 milliliters of tetraethyl lead is shown in figure 6. The maximum increase in knock-limited power was obtained between fuel-air ratios of 0.070 and 0.075. This increase was about 52 percent. The minimum increase in power was about 42 percent at a fuel-air ratio of 0.100.

SUMMARY OF RESULTS

Results of knock-limited performance tests on methyl tert-butyl ether, pure and blended, in a supercharged 17.6 engine may be summarized as follows:

1. Methyl tert-butyl ether has high rich- and lean-mixture performance from antiknock considerations. At a fuel-air ratio of 0.100 methyl tert-butyl ether increased the knock-limited indicated mean effective pressure 87 percent over that of S-2 reference fuel at an engine speed of 2700 rpm and an inlet-air temperature of 150° F and 90 percent over that of S-2 at a fuel-air ratio of 0.075.

2. A blend of 20 percent methyl tert-butyl ether and 80 percent S-2 reference fuel increased the knock-limited indicated mean effective pressures by 31 and 16 percent over that of S-2 at fuel-air ratios of 0.100 and 0.065, respectively, at the conditions given in paragraph 1.

3. At fuel-air ratios greater than 0.083, the indicated specific fuel consumption of methyl tert-butyl ether was lower than that of S-2 reference fuel. A 20-percent blend of methyl tert-butyl ether with S-2 showed the same indicated specific fuel consumption as S-2 at all fuel-air ratios tested. These data are from knock-limited curves, which may not agree with data at constant manifold pressure.

4. For the 20-percent blend, a decrease of inlet-air temperature from 250° F to 150° F increased the knock-limited indicated mean effective pressures 29 and 43 percent at fuel-air ratios of 0.100 and 0.065, respectively.

5. Increasing the engine speed from 1800 rpm to 2700 rpm increased the knock-limited indicated mean effective pressure at fuel-air ratios lower than 0.075 and higher than 0.085.

6. The 20-percent blend had high lead response. For a 2.0 ml addition of tetraethyl lead per gallon, the knock-limited indicated mean effective pressures were increased by 42 and 52 percent at fuel-air ratios of 0.100 and 0.065, respectively.

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TABLE I - KNOCK-LIMITED PERFORMANCE OF METHYL tert-BUTYL ETHER EXPRESSED AS PERCENTAGE OF INDICATED MEAN EFFECTIVE PRESSURE OBTAINED WITH S-2 REFERENCE FUEL

[17.6 engine; compression ratio, 7.0; inlet-air temperature, 150° F; inlet-coolant temperature, 250° F; spark advance, 33° B.T.C.; engine speed, 2700 rpm]

Fuel-air ratio	20 percent methyl tert-butyl ether and 80 percent S-2	Methyl tert-butyl ether
0.060	118	------------
.065	116	------------
.070	116	------------
.075	116	190
.080	119	183
.085	121	173
.090	123	170
.095	128	176
.100	131	187
.104	133	211

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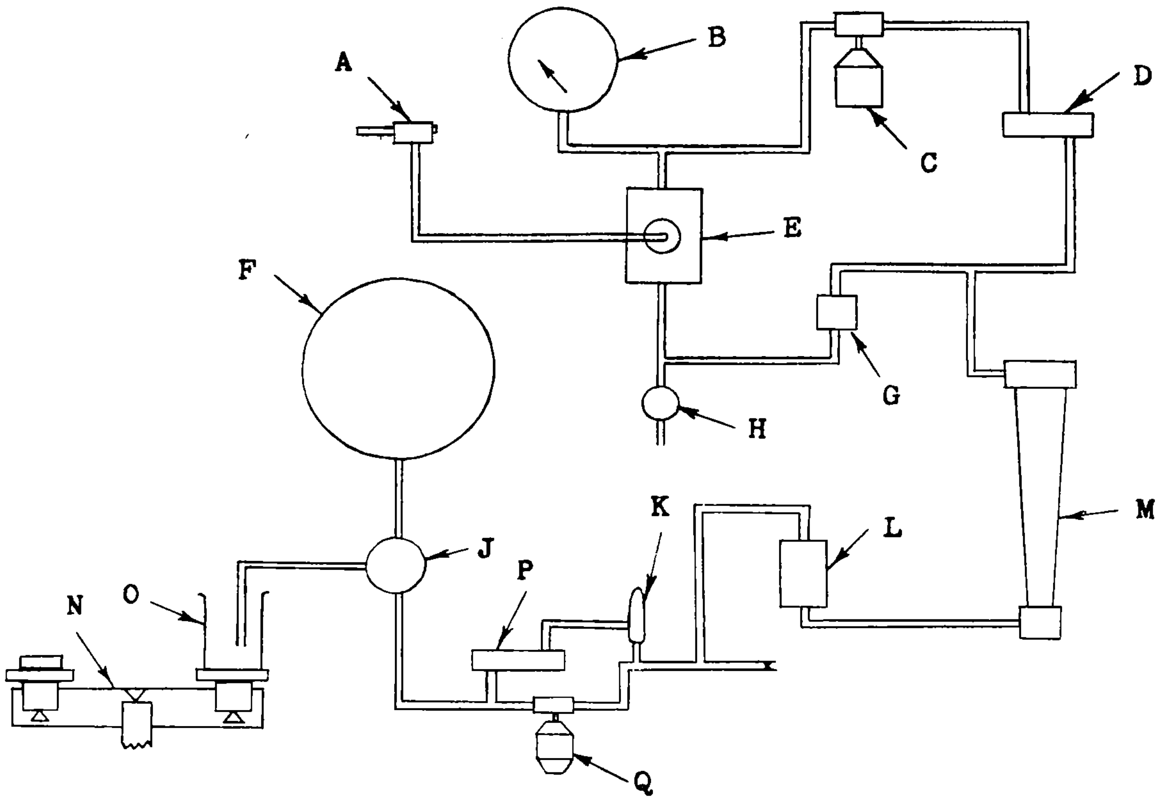
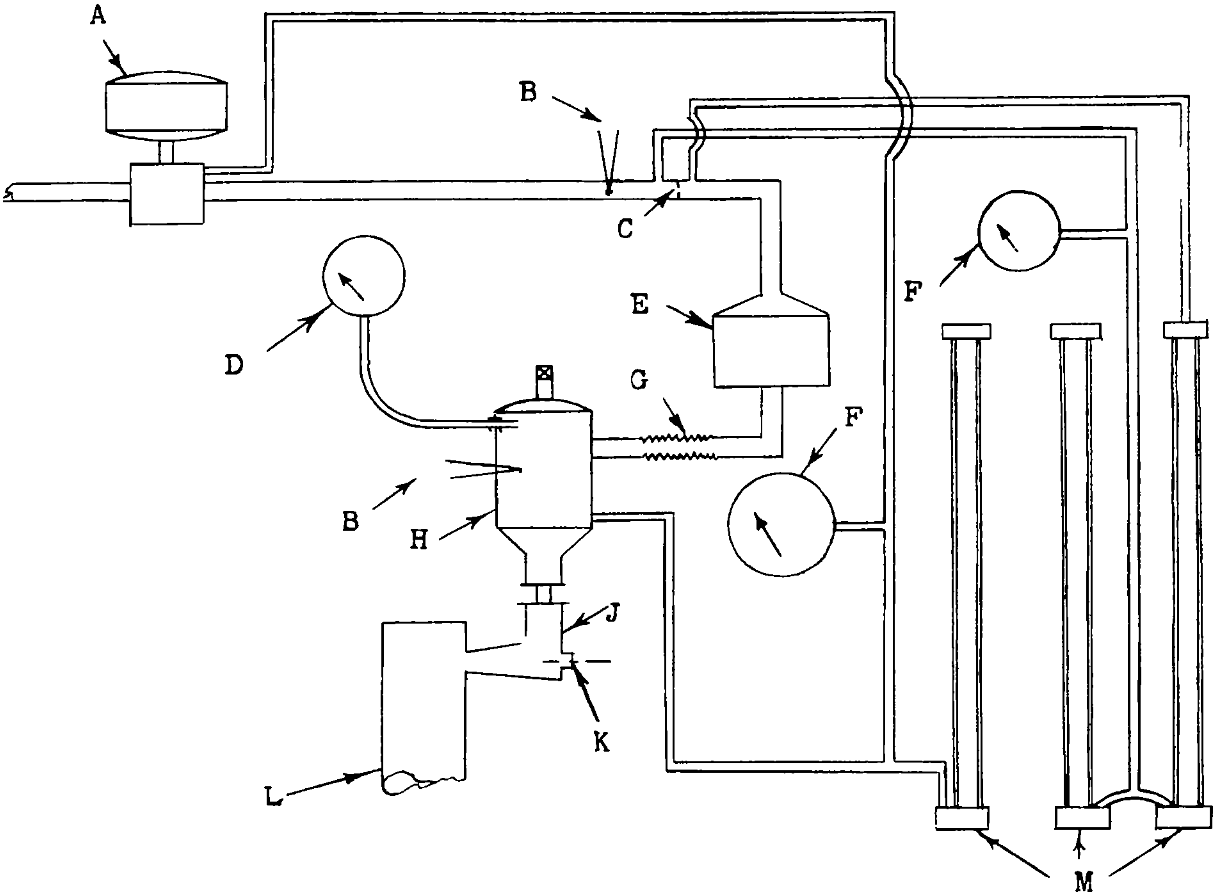


A Fuel-injection nozzle
B Pressure gage
C Circulation pump
D Fuel cooler
E Fuel-injection pump
F Fuel tank
G Fuel filter
H Glass surge chamber
J Three-way cock
K Pressure-relief valve
L Fuel filter
M Rotameter
N Balance
O Beaker
P Fuel cooler
Q Centrifugal pump

Figure 1. - Diagram of fuel system.



A	Pressure regulator	G	Flexible metal pipe
B	Thermocouple	H	Surge tank
C	Measuring orifice	J	Elbow
D	Dial thermometer	K	Opening for injection nozzle
E	Air preheater	L	Engine cylinder
F	Pressure gage	M	Manometers

Figure 2. - Diagram of inlet-air system.

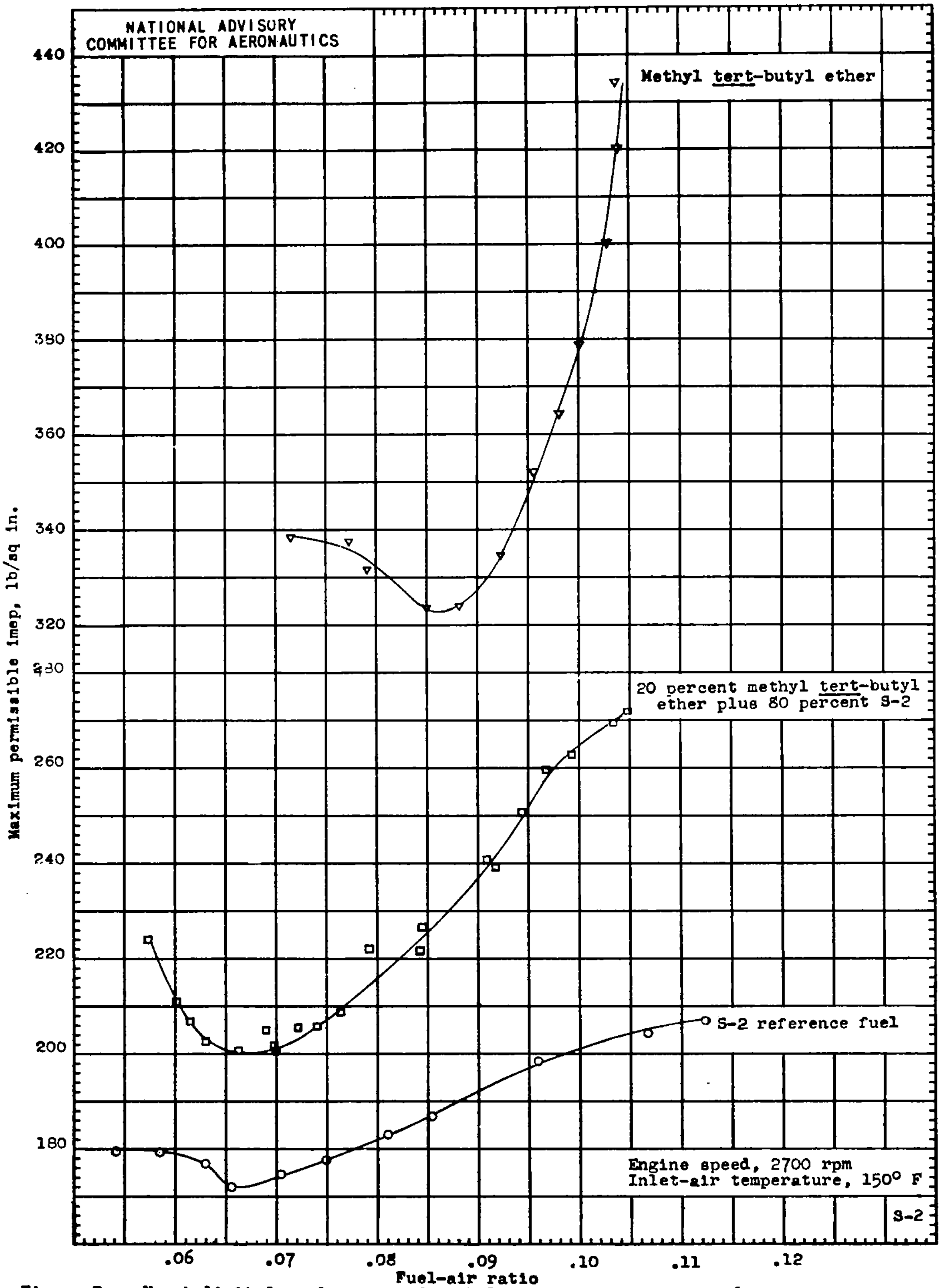


Figure 3. - Knock-limited performance of methyl tert-butyl ether. 17.6-cubic-inch-displacement engine; compression ratio, 7.0; spark advance, 33° B.T.C.; inlet-coolant temperature, 250° F; inlet-air temperature, 150° F; engine speed, 2700 rpm.

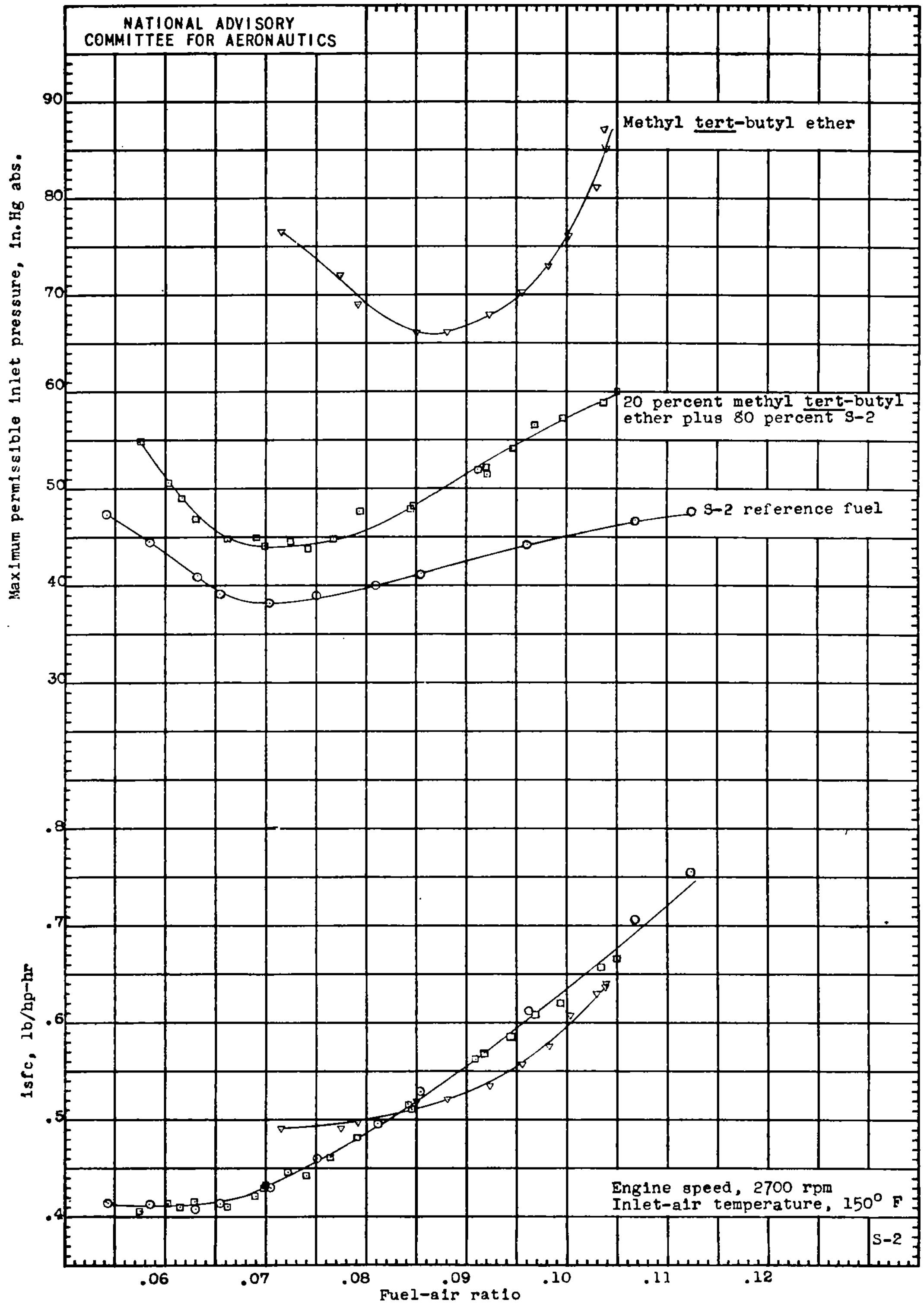


Figure 3. - Concluded. Knock-limited performance of methyl *tert*-butyl ether. 17.6-cubic-inch-displacement engine; compression ratio, 7.0; spark advance, 33° B.T.C.; inlet-coolant temperature, 250° F; inlet-air temperature, 150° F; engine speed, 2700 rpm.

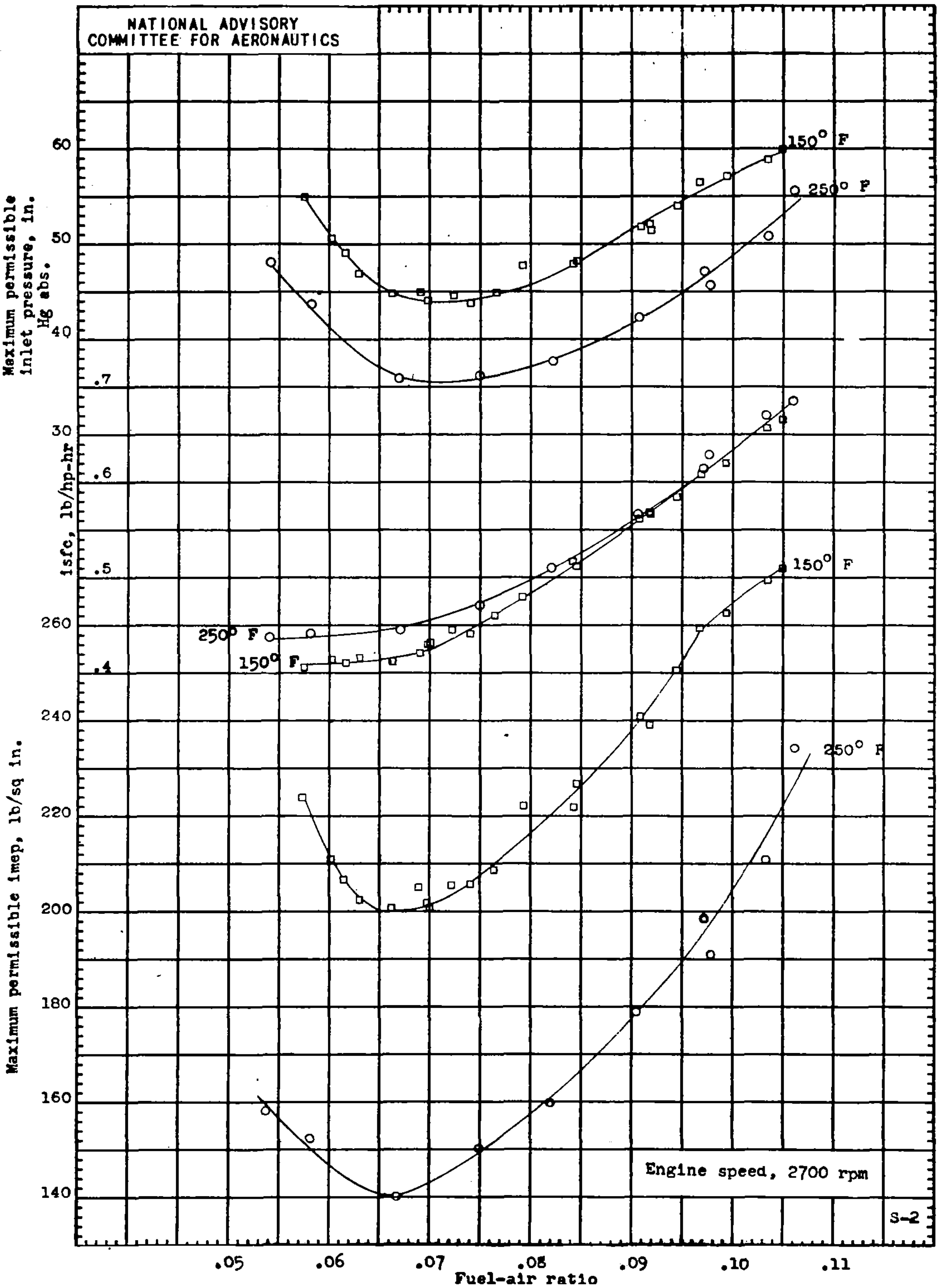


Figure 4. - Effect of inlet-air temperature on knock-limited performance. 17.6-cubic-inch-displacement engine; fuel, 20 percent methyl tert-butyl ether and 80 percent S-2; compression ratio, 7.0; spark advance, 33° B.T.C.; inlet-coolant temperature, 250° F; engine speed, 2700 rpm.

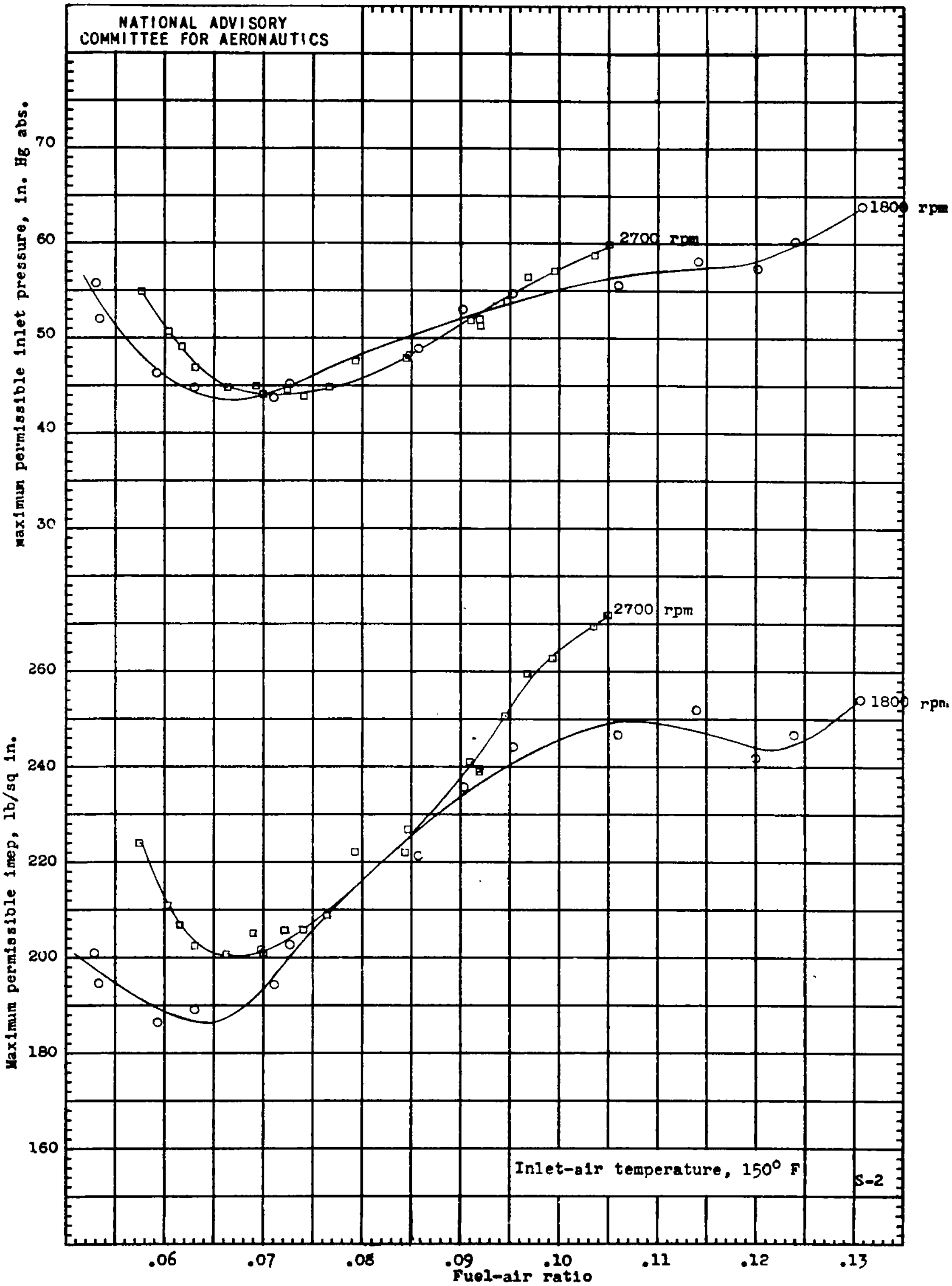


Figure 5. - Effect of engine speed on knock-limited performance. 17.6-cubic-inch-displacement engine; fuel, 20 percent methyl tert-butyl ether and 80 percent S-2; compression ratio, 7.0; spark advance, 33° B.T.C.; inlet-coolant temperature, 250° F; inlet-air temperature, 150° F.

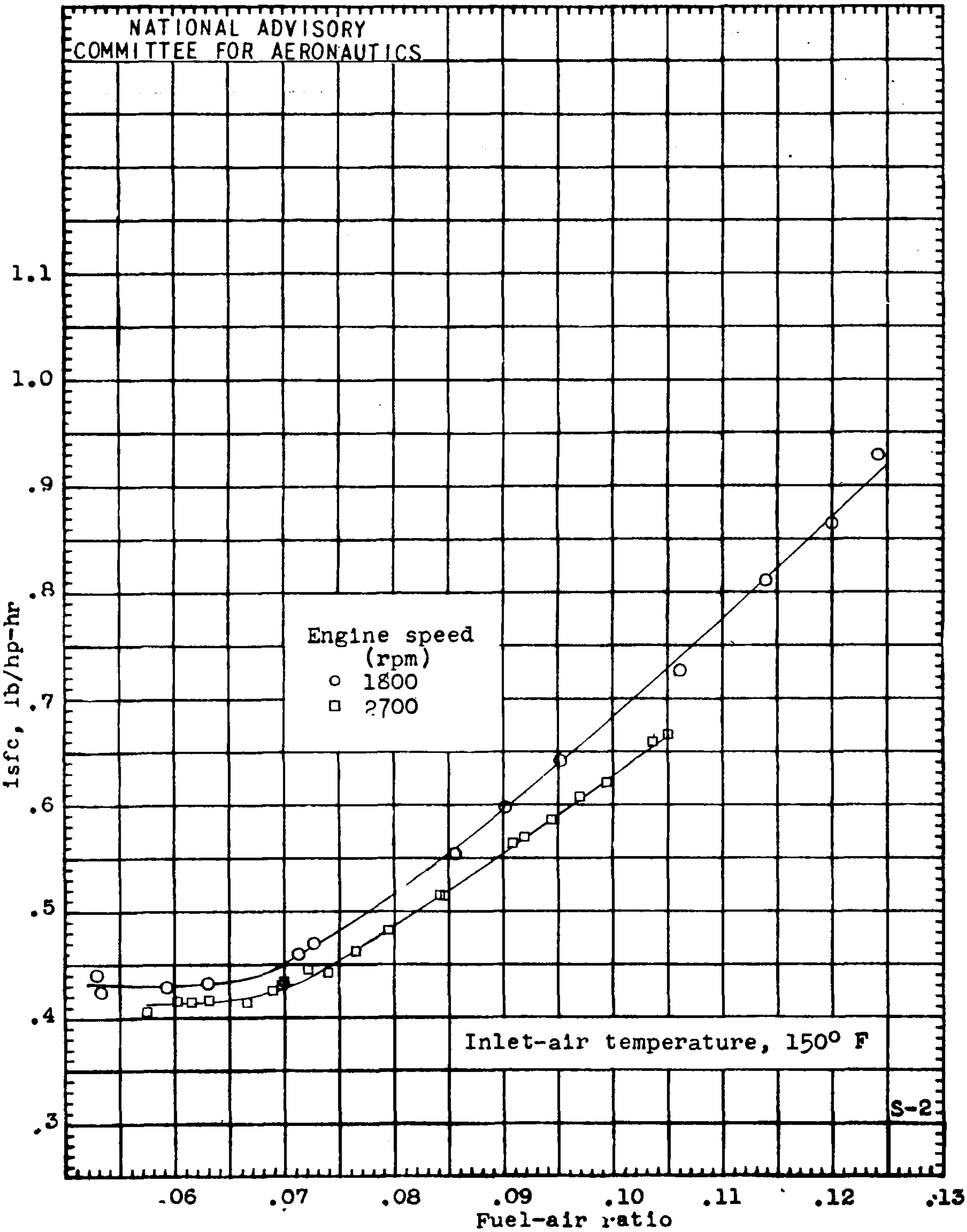


Figure 5. - Concluded. Effect of engine speed on knock-limited performance. 17.6-cubic-inch-displacement engine; fuel, 20 percent methyl tert-butyl ether and 80 percent S-2; compression ratio, 7.0; spark advance, 33° B.T.C.; inlet-coolant temperature, 250° F; inlet-air temperature, 150° F.

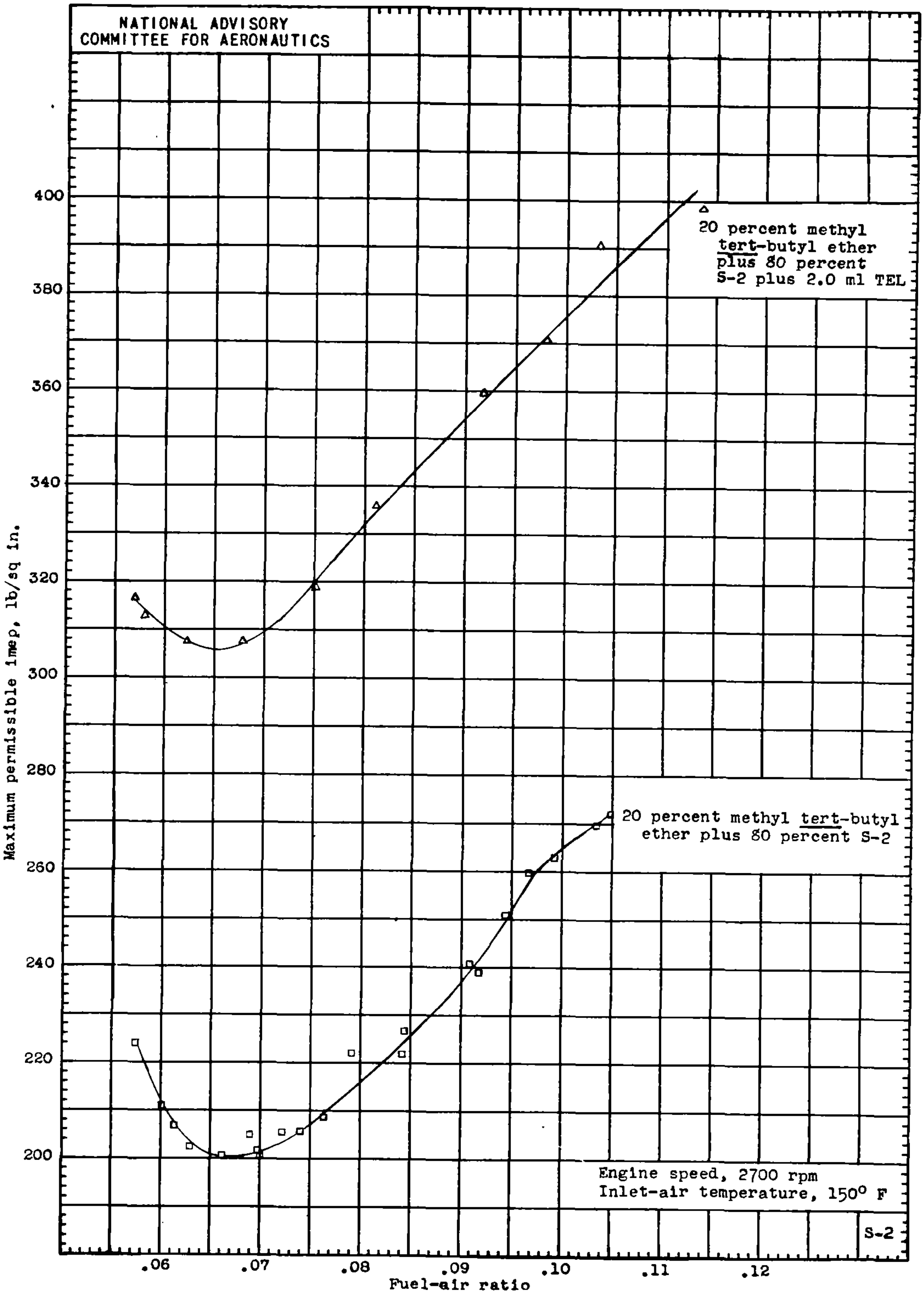


Figure 6. - Effect of tetraethyl lead on knock-limited performance. 17.6-cubic-inch-displacement engine; compression ratio, 7.0; spark advance, 33° B.T.C.; inlet-coolant temperature, 250° F; inlet-air temperature, 150° F; engine speed, 2700 rpm.

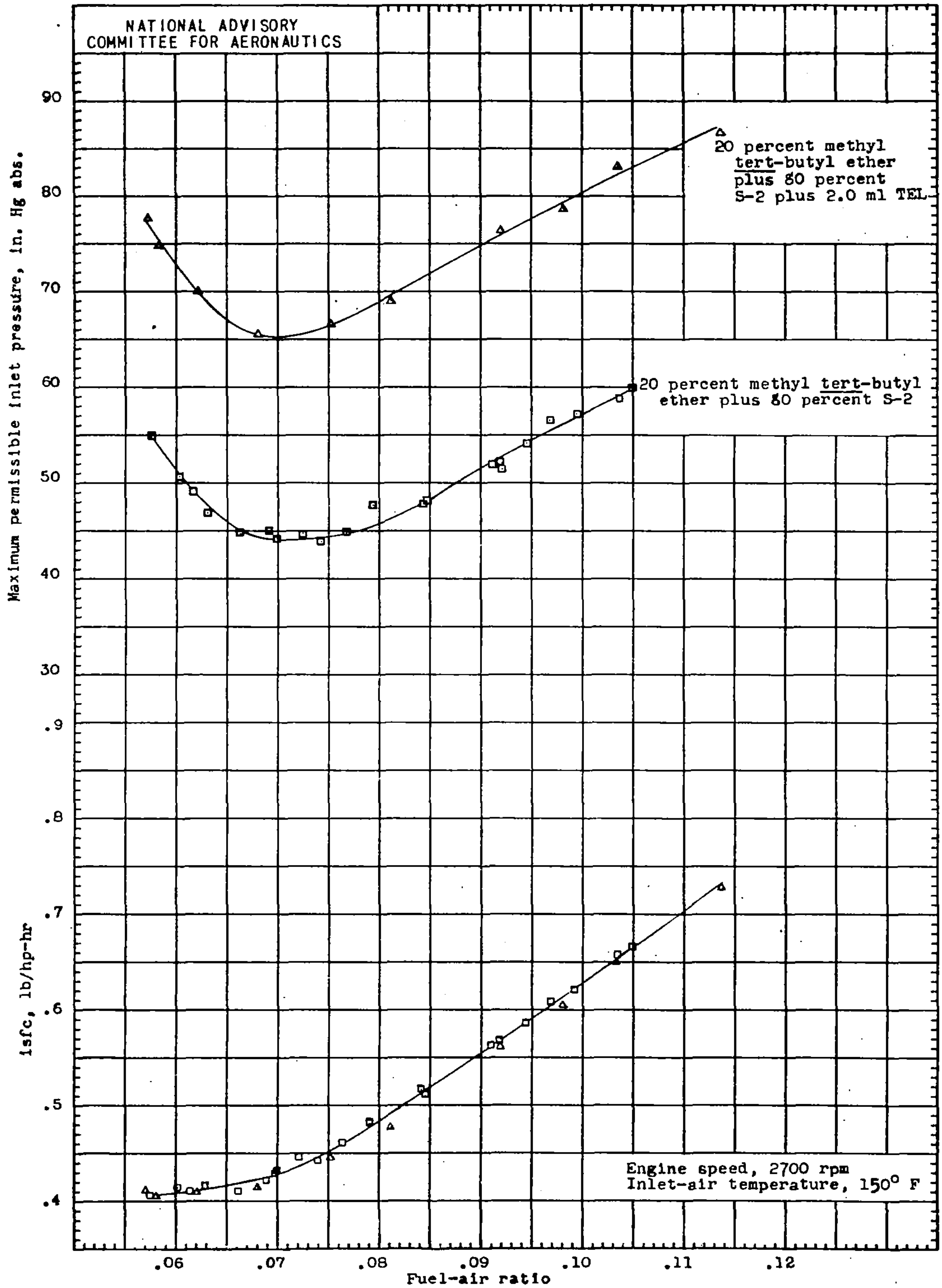


Figure 6. - Concluded. Effect of tetraethyl lead on knock-limited performance. 17.6-cubic-inch-displacement engine; compression ratio, 7.0; spark advance, 33° B.T.C.; inlet-coolant temperature, 250° F; inlet-air temperature, 150° F; engine speed, 2700 rpm.