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KNOCK-LIMITED PERFORMANCE OF BLENDS OF AN-F-28 FUEL CONTAINING 2 PERCENT AROMATIC AMINES - II

By Henry E. Alquist and Leonard K. Tower

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NACA

WASHINGTON

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NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

MEMORANDUM REPORT

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Army Air Forces, Materiel Command

KNOCK-LIMITED PERFORMANCE OF BLENDS OF AN-F-28 FUEL CONTAINING 2 PERCENT AROMATIC AMINES - II

By Henry E. Alquist and Leonard K. Tower

SUMMARY

Tests were conducted to investigate the effect of 2-percent additions of nine aromatic amines on the knock-limited performance of AN-F-28 (28-R) fuel. Knock tests were made on nine aromatic amines synthesized, or purchased and purified, at the Aircraft Engine Research Laboratory. The amines are: aniline, technical pseudocumidine, p-toluidine, o-toluidine, m-toluidine, N-methylaniline, N-ethyl-p-toluidine, p-tert-butylaniline, and cumidines (from synthetic cumene). The knock-limited performance of 28-R fuel with and without 2-percent additions of each of the aromatic amines was determined in a CFR engine under three sets of operating conditions (including F-4 conditions). The report presents information based solely upon the effect of the amines on the knock-limited power of 28-R fuel and does not consider other phases of the fuel problem.

The following results were obtained from this investigation:

1. Of the nine aromatic amines investigated, p-toluidine and p-tert-butylaniline gave the best over-all improvement in the knock-limited power of 28-R fuel at the three sets of engine conditions tested.

2. The aromatic amines that might be of interest as antiknock agents are p-toluidine, p-tert-butylaniline, technical pseudocumidine, m-toluidine, N-methylaniline, and cumidines.

INTRODUCTION

The data presented in this report are part of a general program being conducted at the request of the Army Air Forces, Materiel Command, to determine the effectiveness of aromatic amines as fuel additives.

This report, part II of a series of five reports presenting knock data on a total of 48 aromatic amines, includes test results on 9 amines. Limited data on one of them (aniline) were given in part I (reference 1). Knock in a CFR engine is the only criterion used in this report for evaluating the amines as additives in 28-R fuel. Reports, such as reference 2, dealing with the preparation and the physical and chemical properties of the amines are also being published by this laboratory.

This program is being conducted at the Aircraft Engine Research Laboratory of the NACA at Cleveland, Ohio. The data presented in this report were obtained during April 1944.

APPARATUS AND TEST PROCEDURE

Except for the cumidines and the technical pseudocumidine, the aromatic amines tested in this program were distilled through a fractionating column, and a narrow fraction (approximately 1° C) in the middle of the boiling range was selected. The preparation of the amines was carried on under the direction of Dr. W. T. Olson of the laboratory staff.

The knock tests were performed on a CFR (F-4) engine equipped with two independent fuel systems as described in reference 1. Inasmuch as this series of tests was a continuation of the program started in part I (reference 1) of this project, the procedure and the engine conditions were not altered. It was necessary, however, to use a different engine and operator for the second part of this program. The base stock, 28-R (AN-F-28) fuel, was chosen because of its availability to other laboratories.

The three sets of operating conditions, as discussed in reference 1, were used in these tests. They are as follows:

	Inlet-air temperature (°F)	Spark advance (deg B.T.C.)	Coolant temperature (°F)
F-4 method	225	45	375
Modification A	250	30	250
Modification B	150	30	250

At each of those sets of conditions, 0- and 2-percent additions of the aromatic amines were tested in 28-R fuel on the same day. Minor differences in the 28-R curves plotted throughout the project were observed.

DISCUSSION OF RESULTS

Figure 1 presents the 28-R data under F-4 conditions and the corresponding bracketing S-3 reference curves. The rich-region F-4 rating for this fuel is S + 1.42 ml TEL or 132 performance number.

The knock-limited performance data of the aromatic amines is shown in figures 2 to 10. Each figure compares the effects of the transition from severe to mild test conditions on blends of 0 and 2 percent aromatic amines and 28-R fuel.

Table I is a summary of the relative powers obtained by the additions of the aromatic amines. As was expected, the amines showed more sensitivity to a change of fuel-air ratio under F-4 conditions than under either of the two less severe conditions. The amines that gave the most desirable rich-region response under F-4 conditions were N-methylanilino, p-toluidine, and p-tert-butylaniline. p-Toluidine and p-tert-butylanilino were less sensitive to engine conditions than the other amines tested and showed the most consistent inprovement in the knock-limited power at all fuel-air ratios and engine conditions.

All the aromatic amines tested in this series showed good rich-mixture response at the modified conditions, but o-toluidine and technical pseudocumidine were not particularly effective at leaner mixtures. Lowering the inlet-air temperature from 250° F to 150° F resulted in a decrease in the relative-power rating at lean fuel-air mixtures for the o-, m-, and p-toluidines.

In most of the tests the indicated specific fuel consumption of the base stock was the same as the consumption of the base stock plus the aromatic-amine additive. In some cases the amine additive gave apparent economy changes, but so little material was available for check tests that the significance of these differences in indicated specific fuel consumption is questionable.

When sufficient quantities of test fuel were available, F-3 ratings were also obtained. These results are presented in table II.

SUMMARY OF RESULTS

The following results were obtained from tests of the antiknock effectiveness of 2-percent additions of nine aromatic amines to 28-R fuel under three sets of operating conditions in a CFR engine:

1. Of the nine aromatic amines investigated, p-toluidine and p-tert-butylaniline gave the best over-all improvement in the knock-limited power of 28-R fuel at the three sets of engine conditions tested.

2. The aromatic amines that might be of interest as antiknock agents are p-toluidine, p-tert-butylaniline, technical pseudocumidine, m-toluidine, N-methylaniline, and cumidines.

Aircraft Engine Research Laboratory,
National Advisory Committee for Aeronautics,
Cleveland, Ohio, June 26, 1944.

REFERENCES

1. Branstetter, J. Robert: Knock-Limited Performance of Blends of AN-F-28 Fuel Containing 2 Percent Aromatic Amines - I. NACA Memo. rep., April 17, 1944.

2. Olson, Walter T., and Kelly, Richard L.: The Low-Temperature Solubility of Aniline, the Toluidines, and Some of Their N-Allyl Derivatives in Aviation Gasoline. NACA Memo. rep., June 5, 1944.

TABLE I - SUMMARY OF ANTIKNOCK EFFECTIVENESS OF AROMATIC-AMINE ADDITIONS TO 28-R FUEL

F-4 Method: inlet-air temperature, 225° F; coolant temperature, 375° F; spark advance, 45° B.T.C.
Modification A: inlet-air temperature, 250° F; coolant temperature, 250° F; spark advance, 30° B.T.C.
Modification B: inlet-air temperature, 150° F; coolant temperature, 250° F; spark advance, 30° B.T.C.

Aromatic amines (2-percent addition to 28-R fuel)	Relative power = imep (aromatic amine plus AN-F-28) / imep (AN-F-28)											
	Fuel-air ratio											
	0.062			0.070			0.090			0.110		
	F-4 method	Modification A	Modification B	F-4 method	Modification A	Modification B	F-4 method	Modification A	Modification B	F-4 method	Modification A	Modification B
28-R (AN-F-28)	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Aniline	1.00	1.03	1.13	.97	1.07	1.15	1.03	1.12	1.15	1.09	1.11	1.14
Technical pseudocumidine	.96	1.02	1.03	.94	1.02	1.09	.99	1.11	1.09	1.06	1.08	1.13
p-Toluidine	1.05	1.08	1.02	1.06	1.13	1.11	1.09	1.13	1.12	1.11	1.14	1.11
o-Toluidine	.88	1.03	1.01	.92	1.03	1.04	.99	1.08	1.10	1.07	1.09	1.15
m-Toluidine	.98	1.15	1.09	.96	1.16	1.09	1.05	1.08	1.10	1.09	1.06	1.11
N-methylaniline	.93	1.11	1.10	.99	1.15	1.13	1.05	1.15	1.11	1.14	1.12	1.10
N-ethyl-p-toluidine	1.00	1.04	1.07	.98	1.06	1.06	.99	1.04	1.07	1.02	1.04	1.06
p-tert-Butylaniline	1.06	1.02	1.09	1.03	1.02	1.11	1.08	1.07	1.08	1.11	1.12	1.10
Cumidines (from synthetic cumene)	.83	1.08	1.06	.82	1.05	1.08	1.00	1.10	1.10	1.05	1.13	1.08

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TABLE II - F-3 RATINGS OF 2-PERCENT BLENDS OF AROMATIC AMINES AND 28-R FUEL

Aromatic amines (2-percent addition to 28-R fuel)	F-3 Ratings	
	S-3 + ml TEL	Performance number
28-R	0	100
Aniline	.13	105
N-ethyl-p-toluidine	.05	102
p-tert-Butylaniline	.10	104
Cumidines (from synthetic cumene)	.15	106

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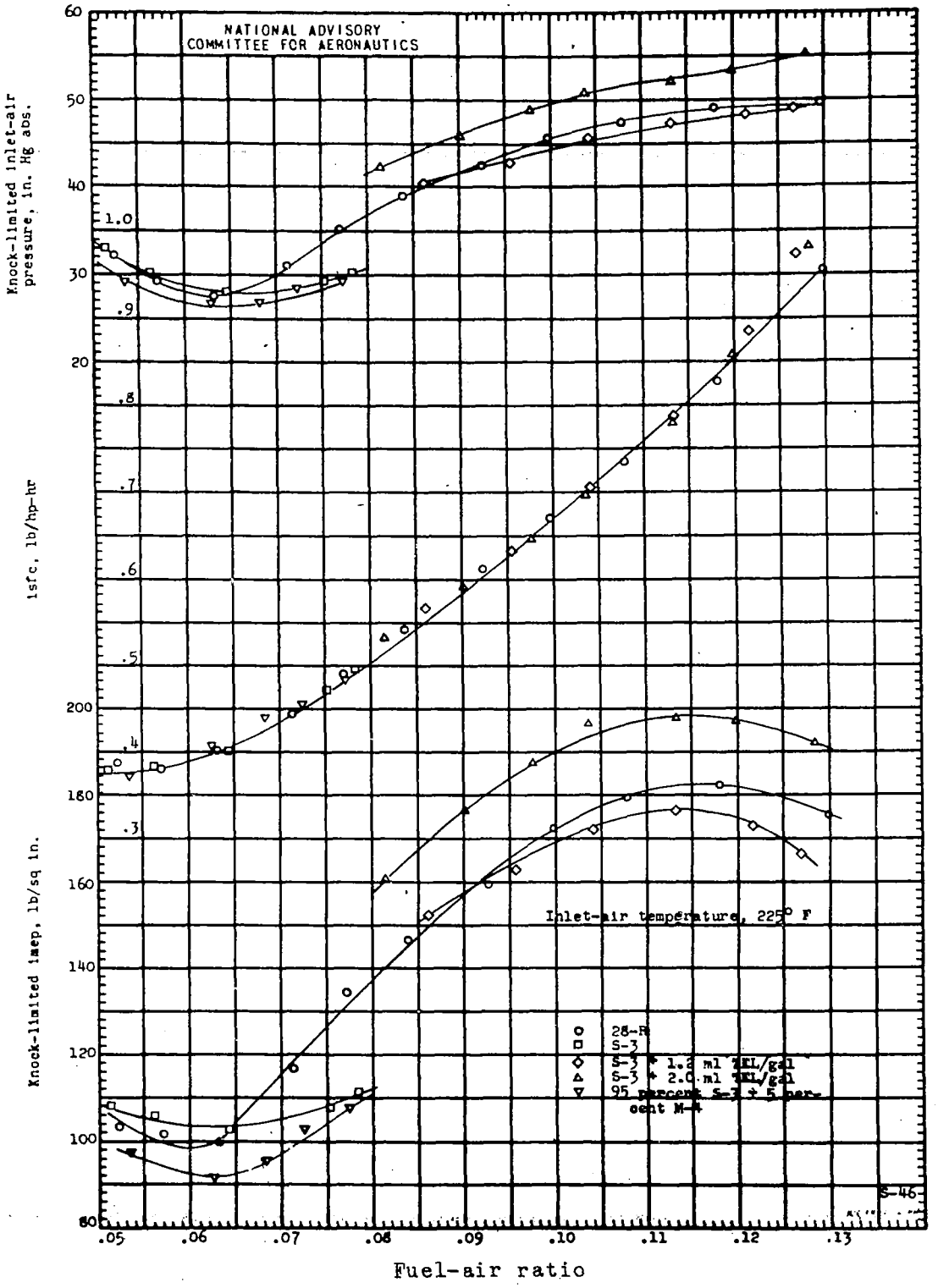
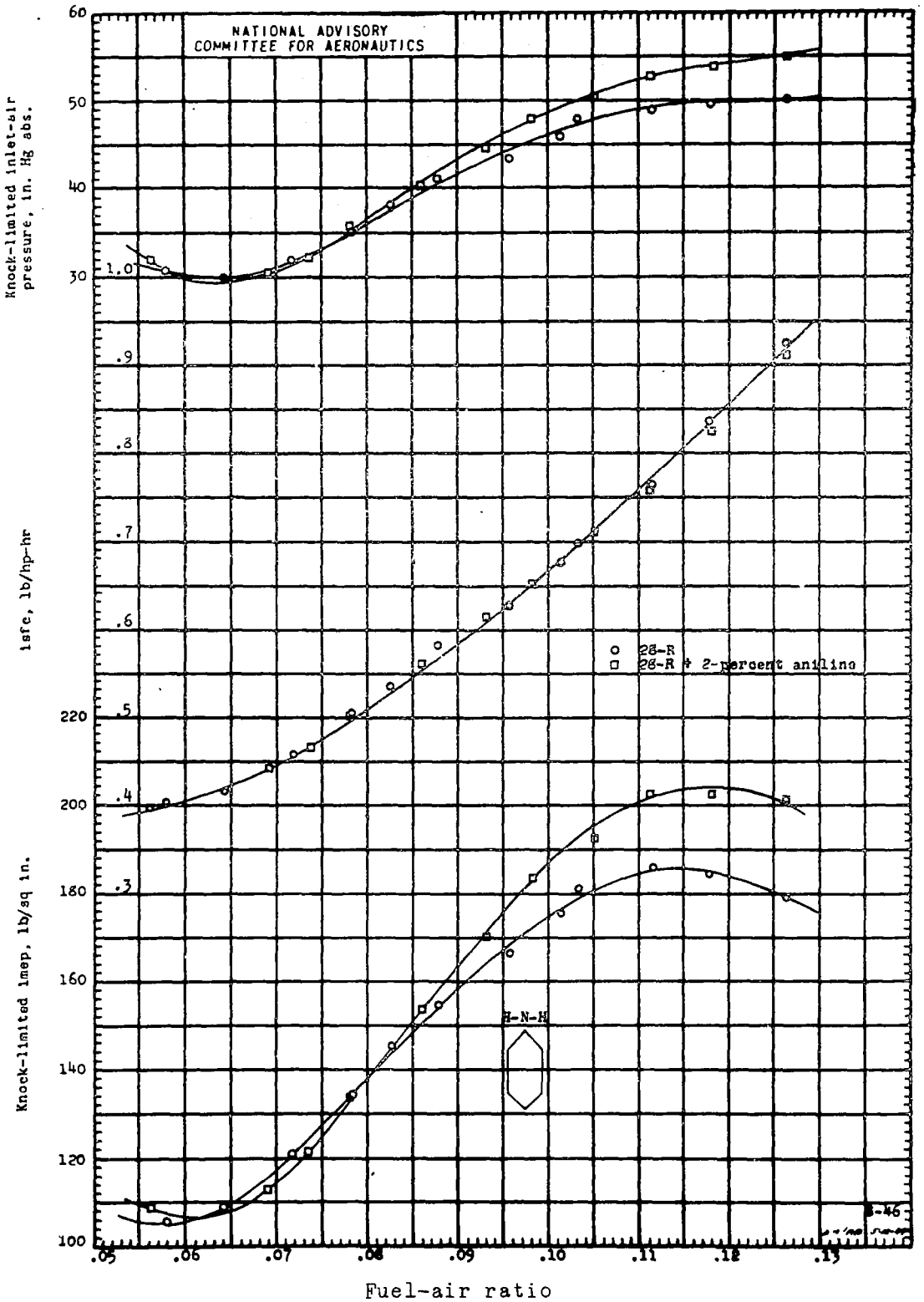
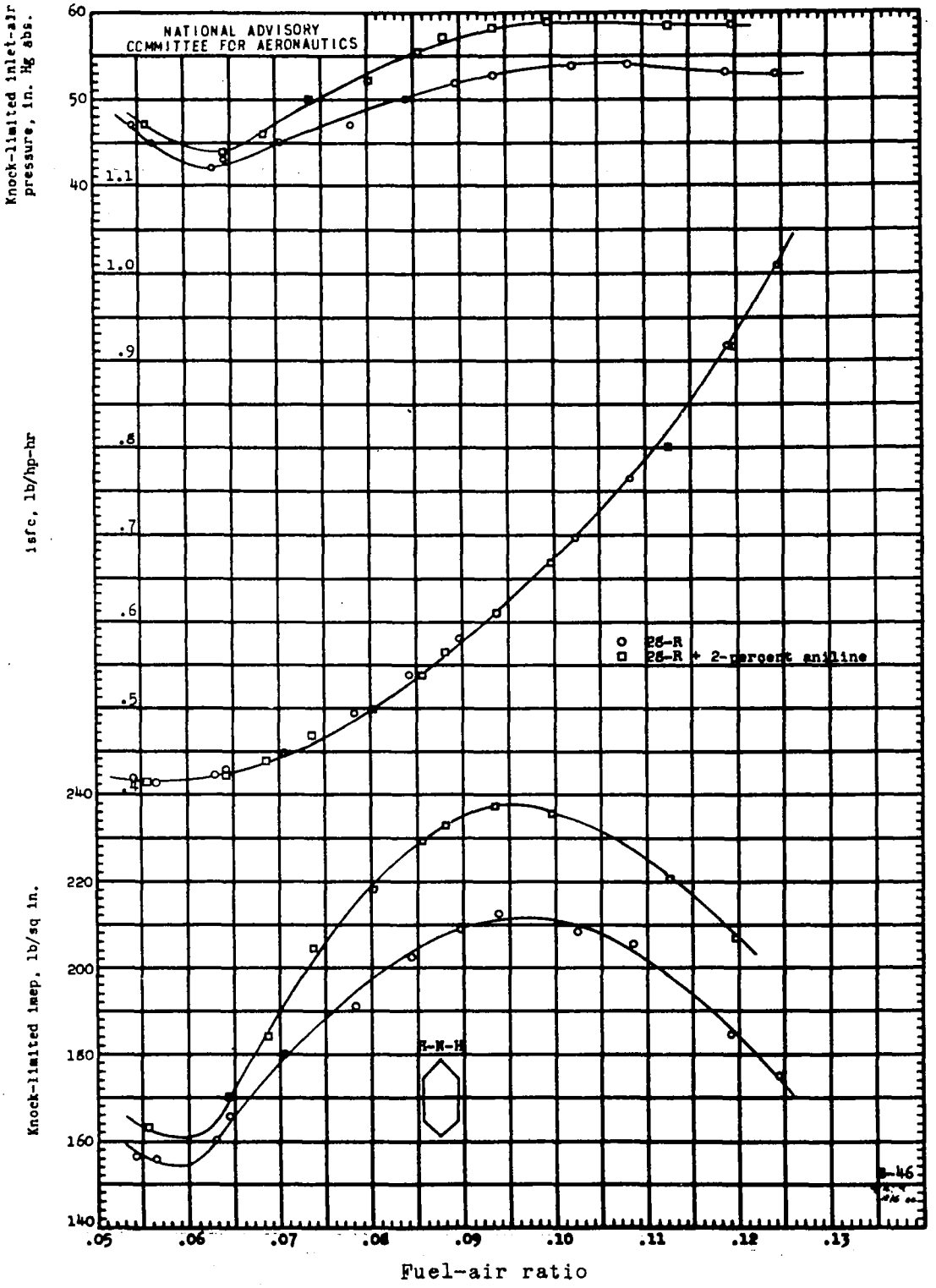


Figure 1. - Knock-limited F-4 performance of 28-R fuel and corresponding S-3 reference curves. Inlet-air temperature, 225° F; spark advance, 45° B.T.C.; coolant temperature, 375° F; engine speed, 1800 rpm; compression ratio, 7.0; oil temperature, 165° F.



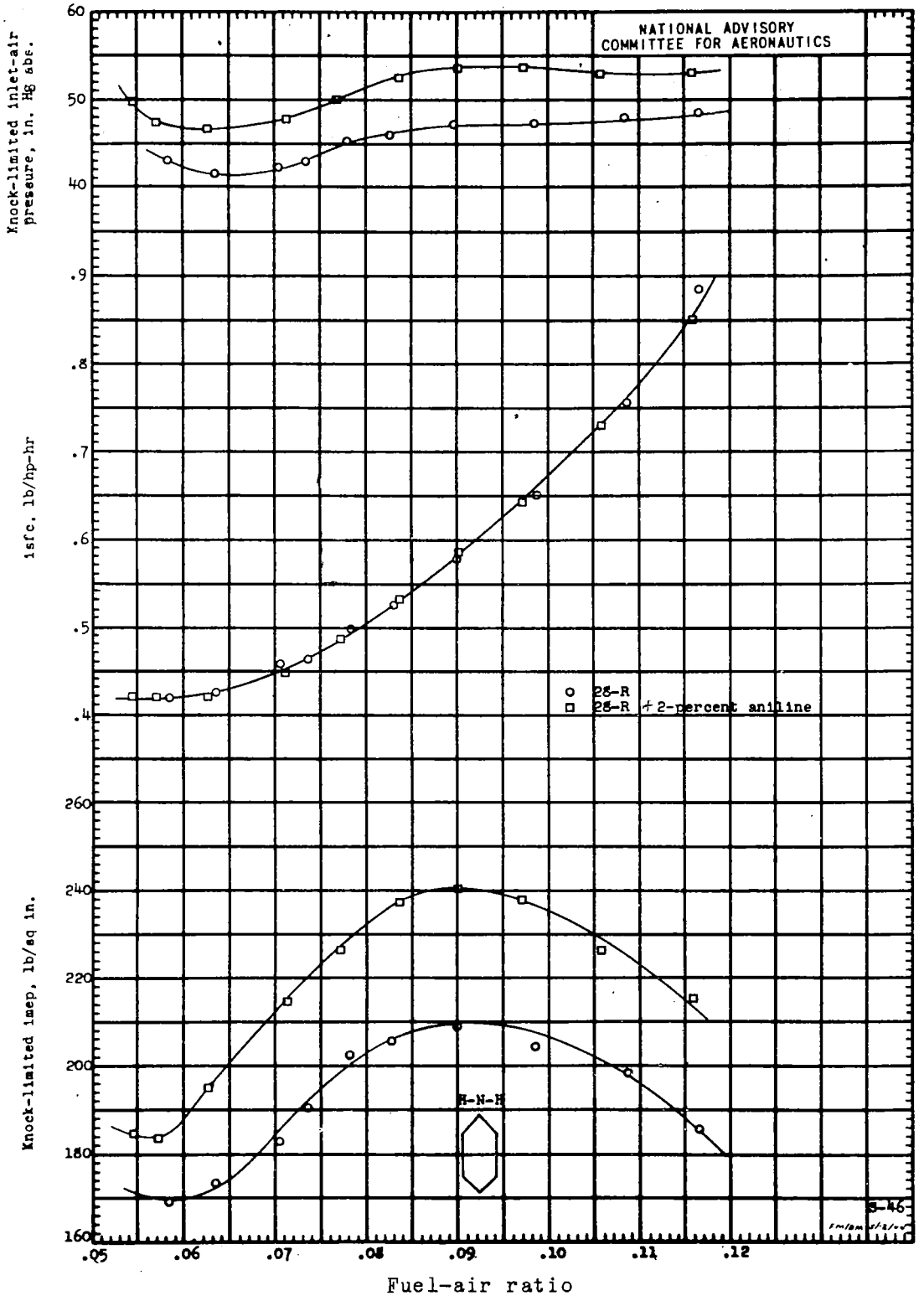
(a) Inlet-air temperature, 225° F; spark advance, 45° B.T.C.; coolant temperature, 375° F.

Figure 2. - Effect of addition of 2-percent aniline to 28-R fuel on knock-limited performance of a CFR engine. Engine speed, 1800 rpm; compression ratio, 7.0; oil temperature, 165° F.



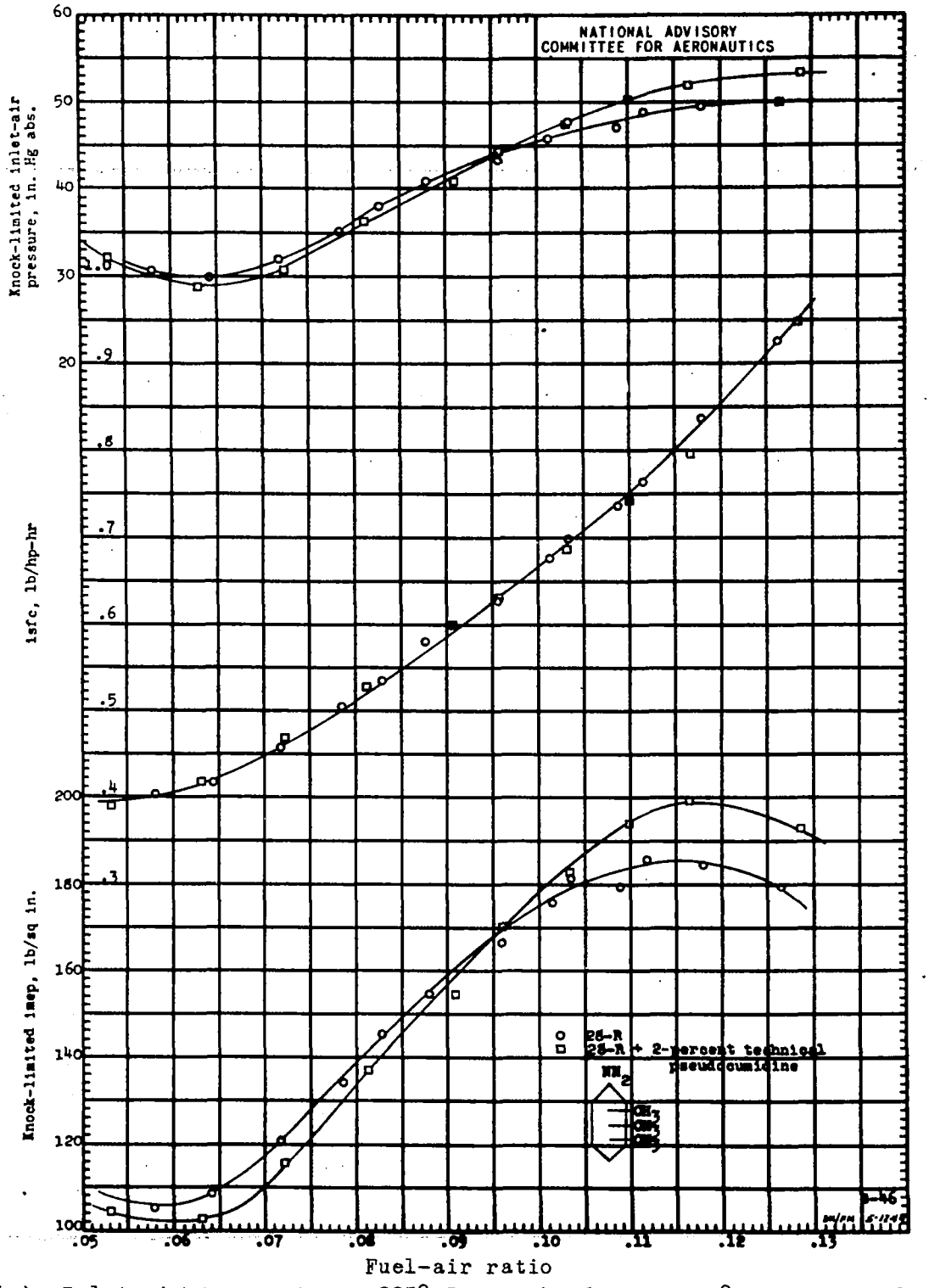
(b) Inlet-air temperacure, 250° F; spark advance, 30° B.T.C.; coolant temperature, 250° F.

Figure 2. - Continued. Effect of addition of 2-percent aniline to 28-R fuel on knock-limited performance of a CFR engine. Engine speed, 1800 rpm; compression ratio, 7.0; oil temperature, 165° F.



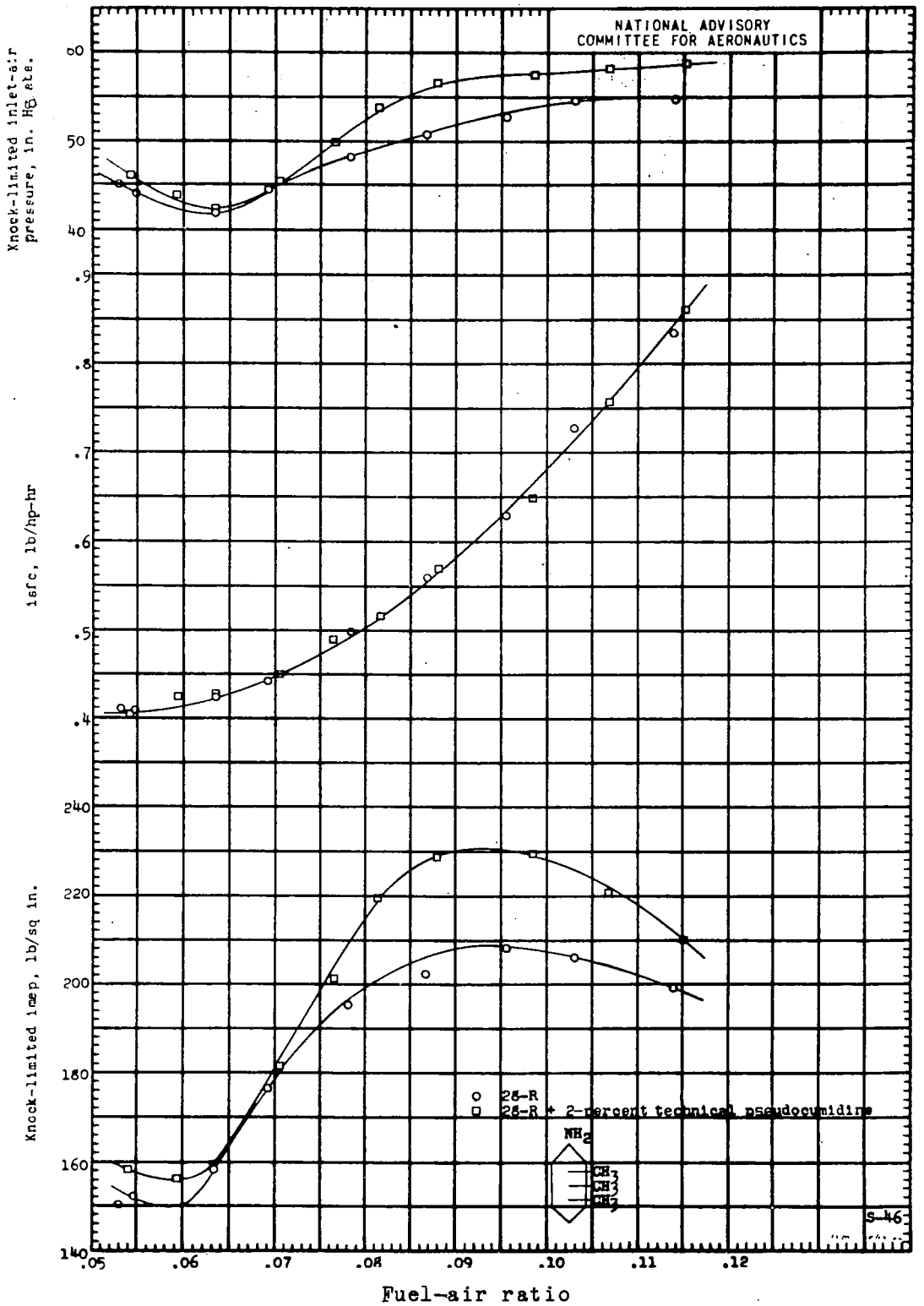
(c) Inlet-air temperature, 150° F; spark advance, 30° B.T.C.; coolant temperature, 250° F.

Figure 2. - Concluded. Effect of addition of 2-percent aniline to 28-R fuel on knock-limited performance of a CFR engine. Engine speed, 1800 rpm; compression ratio, 7.0; oil temperature, 165° F.



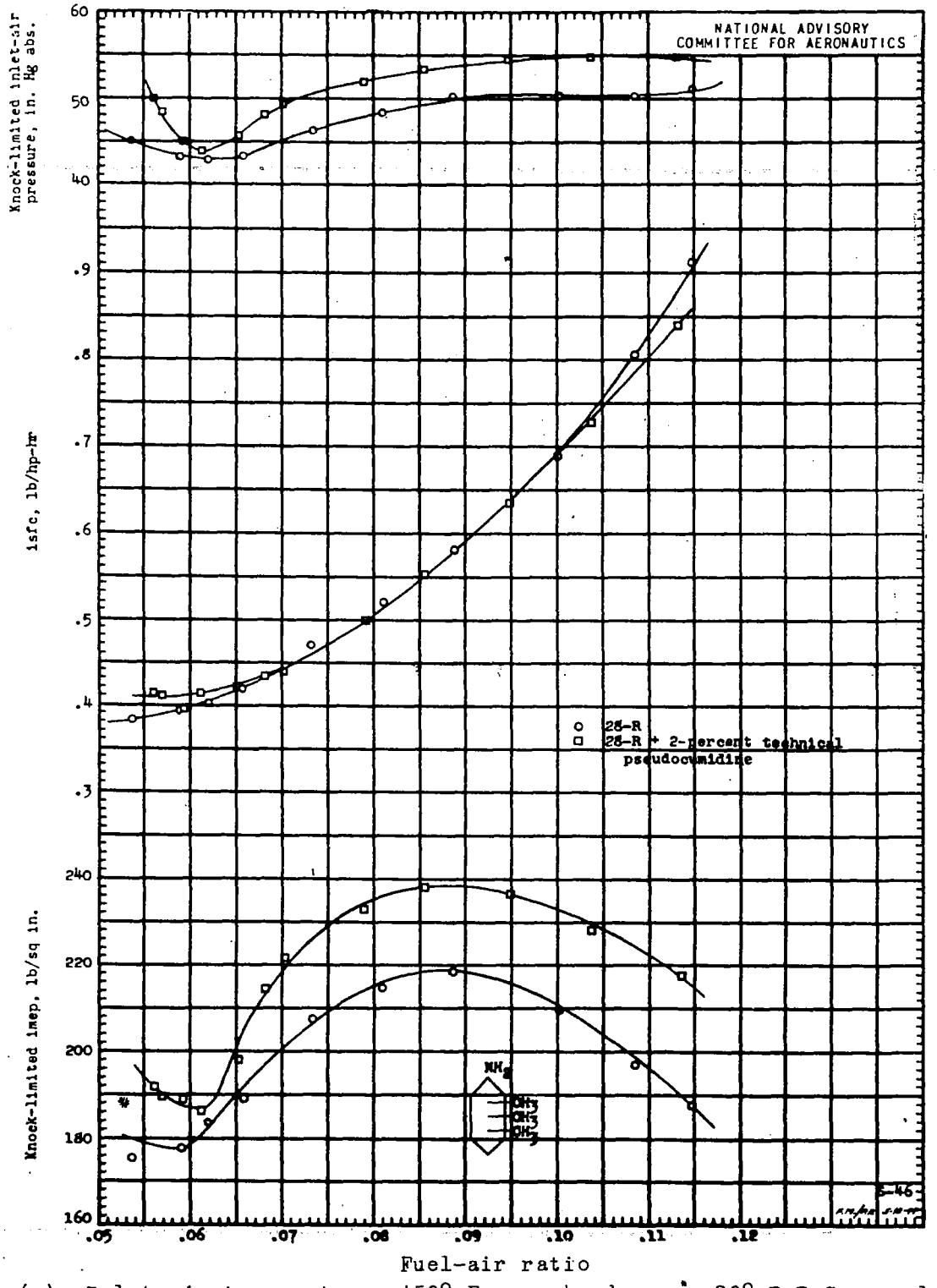
(a) Inlet-air temperature, 225° F; spark advance, 45° B.T.C.; coolant temperature, 375° F.

Figure 3. - Effect of addition of 2-percent technical pseudocumidine to 28-R fuel on knock-limited performance of a CFR engine. Engine speed, 1800 rpm; compression ratio, 7.0; oil temperature, 165° F.



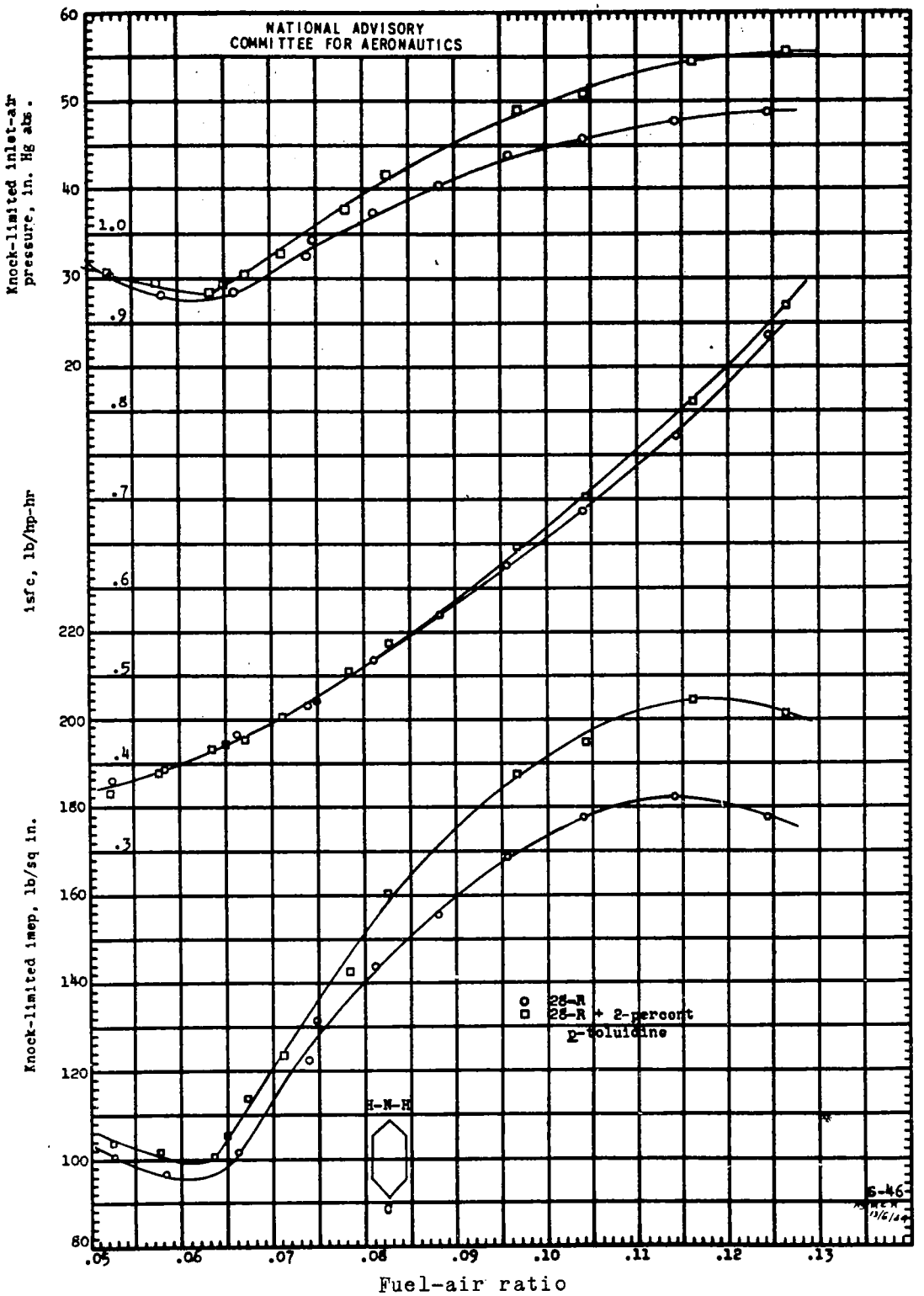
(b) Inlet-air temperature, 250° F; spark advance, 30° B.T.C.; coolant temperature, 250° F.

Figure 3. - Continued. Effect of addition of 2-percent technical pseudocumidine to 28-R fuel on knock-limited performance of a CFR engine. Engine speed, 1800 rpm; compression ratio, 7.0; oil temperature, 165° F.



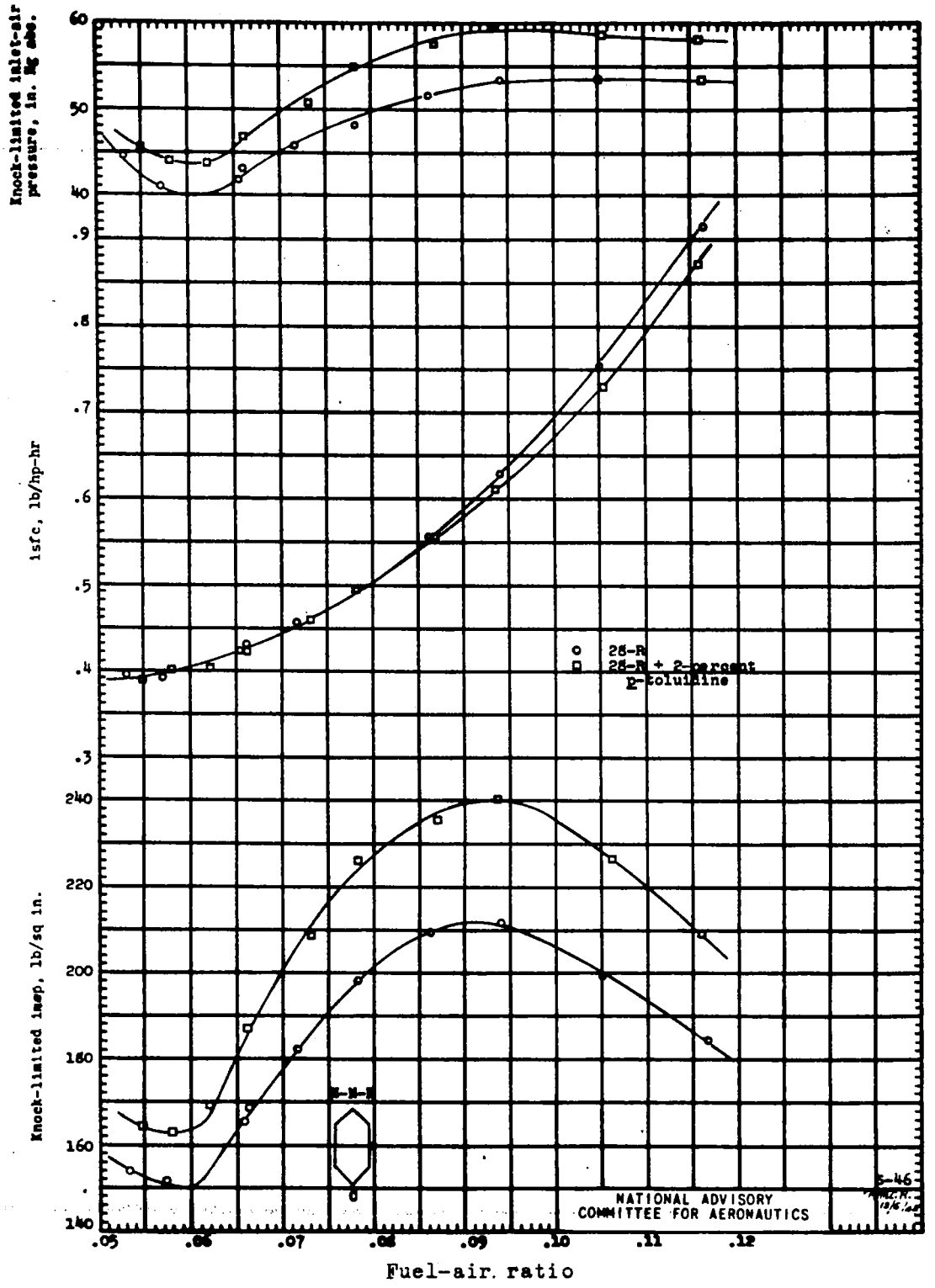
(c) Inlet-air temperature, 150° F; spark advance, 30° B.T.C.; coolant temperature, 250° F.

Figure 3. - Concluded. Effect of addition of 2-percent technical pseudocumidine to 28-R fuel on knock-limited performance of a CFR engine. Engine speed, 1800 rpm; compression ratio, 7.0; oil temperature, 165° F.



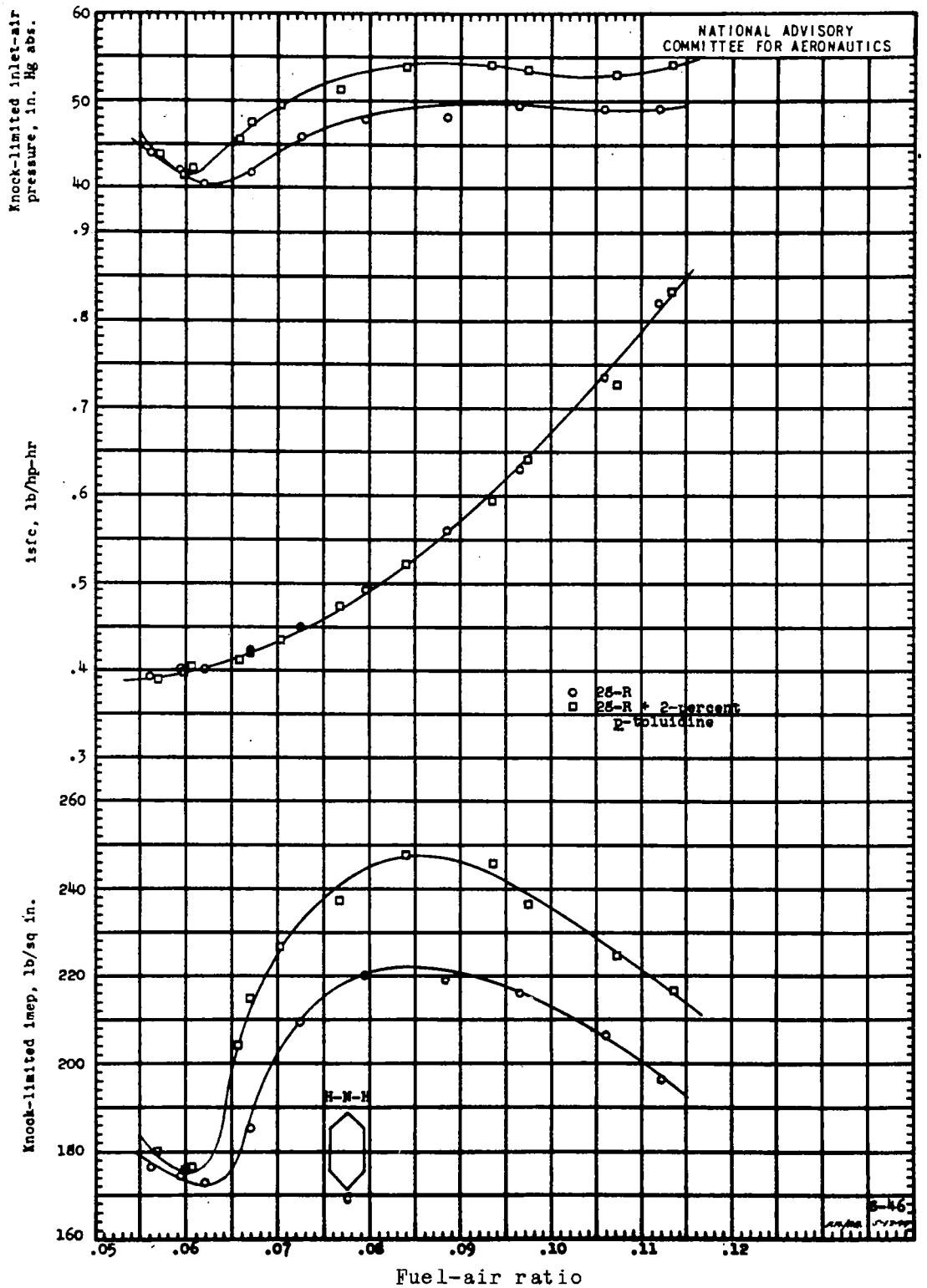
(a) Inlet-air temperature, 225° F; spark advance, 45° B.T.C.; coolant temperature, 375° F.

Figure 4. - Effect of addition of 2-percent p-toluidine to 28-R fuel on knock-limited performance of a CFR engine. Engine speed, 1800 rpm; compression ratio, 7.0; oil temperature, 165° F.



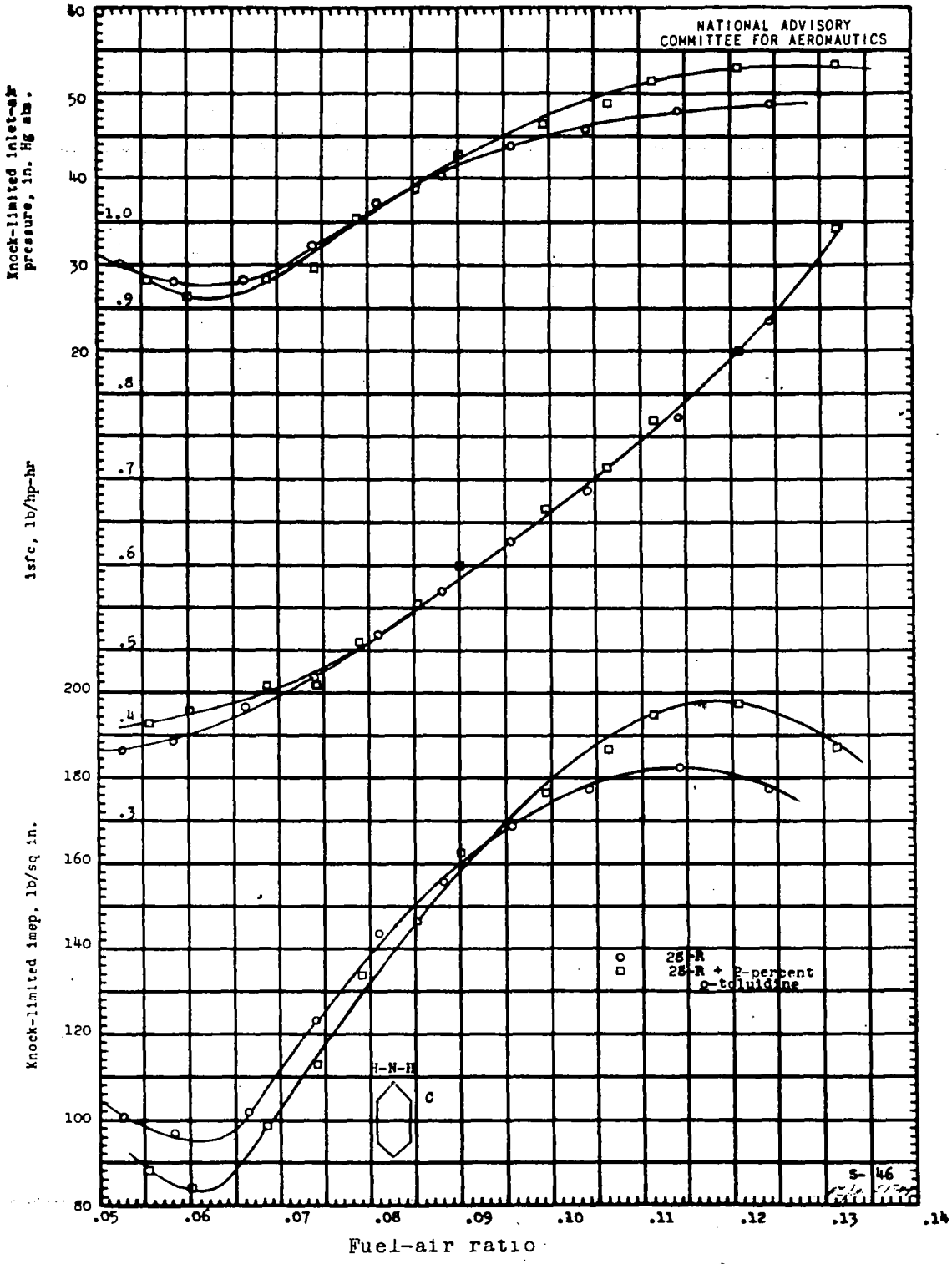
(b) Inlet-air temperature, 250° F; spark advance, 30° B.T.C.; coolant temperature, 250° F.

Figure 4. - Continued. Effect of addition of 2-percent p-toluidine to 28-R fuel on knock-limited performance of a CFR engine. Engine speed, 1800 rpm; compression ratio, 7.0; oil temperature, 165° F.



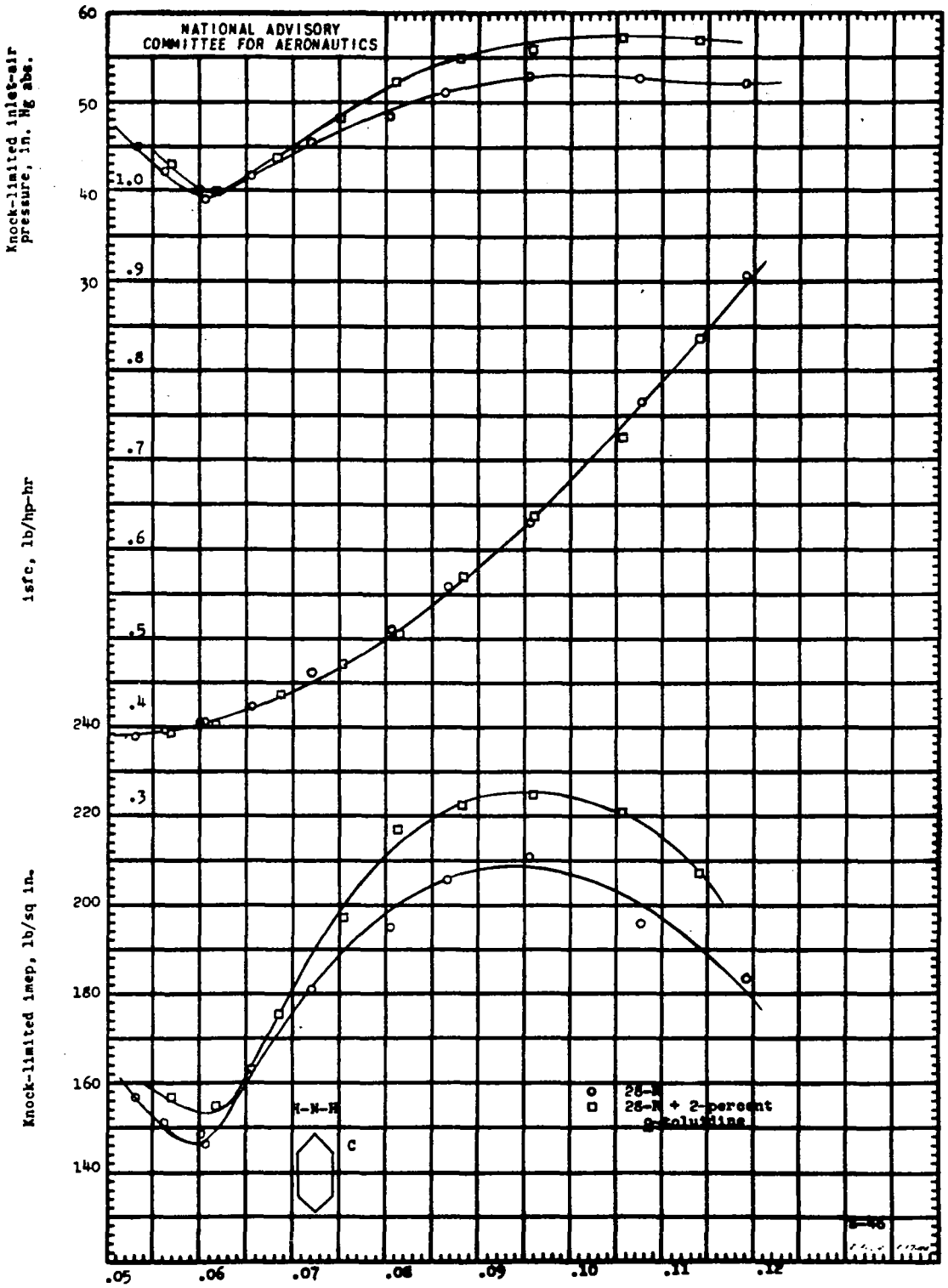
(c) Inlet-air temperature, 150° F; spark advance, 30° B.T.C.; coolant temperature, 250° F.

Figure 4. - Concluded. Effect of addition of 2-percent p-toluidine to 28-R fuel on knock-limited performance of a CFR engine. Engine speed, 1800 rpm; compression ratio, 7.0; oil temperature, 165° F.



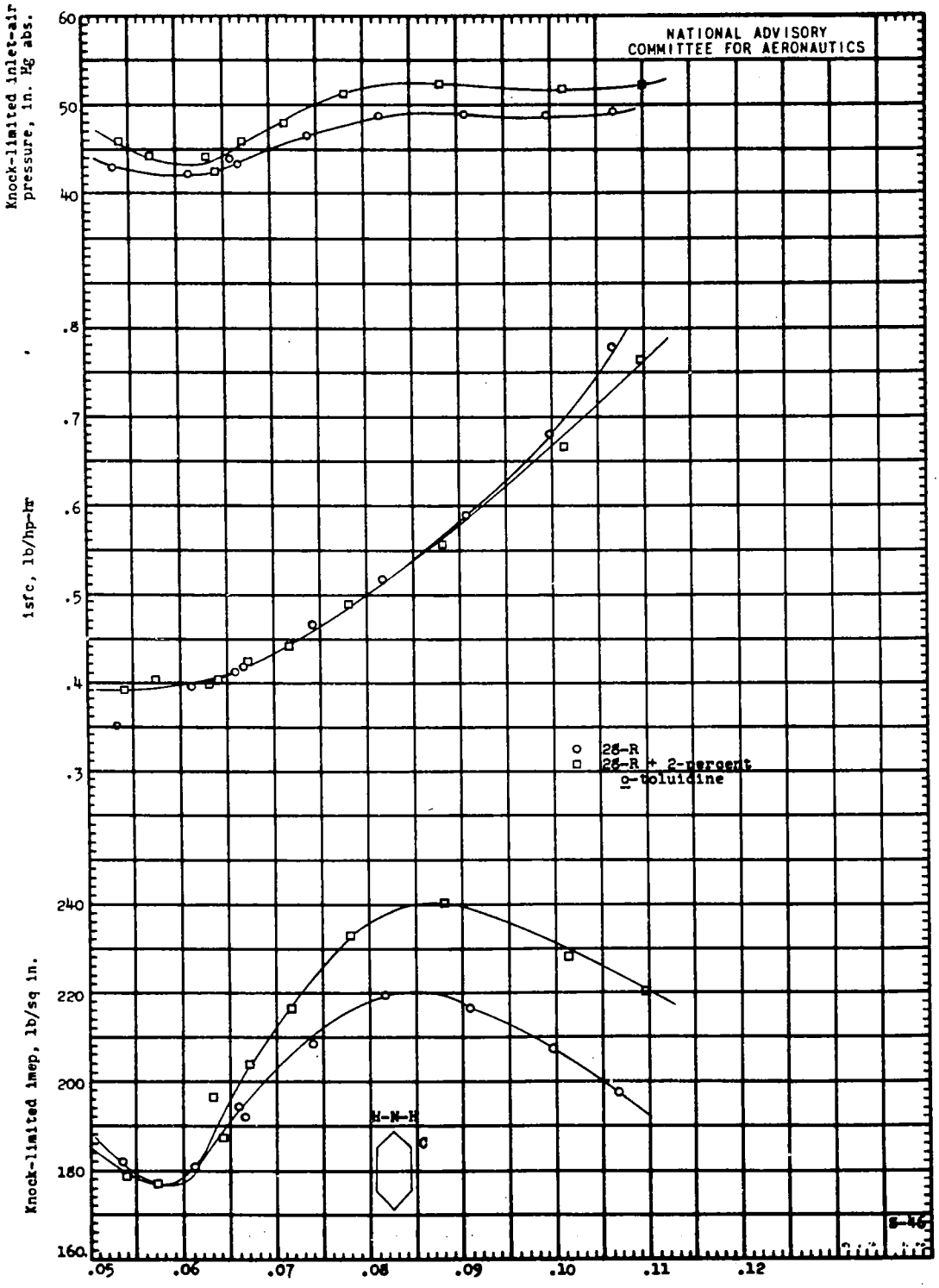
(a) Inlet-air temperature, 225° F; spark advance, 45° B.T.C.; coolant temperature, 375° F.

Figure 5. - Effect of addition of 2-percent o-toluidine to 28-R fuel on knock-limited performance of a CFR engine. Engine speed, 1800 rpm; compression ratio, 7.0; oil temperature, 165° F.



(b) Inlet-air temperature, 250° F; spark advance, 30° B.T.C.; coolant temperature, 250° F.

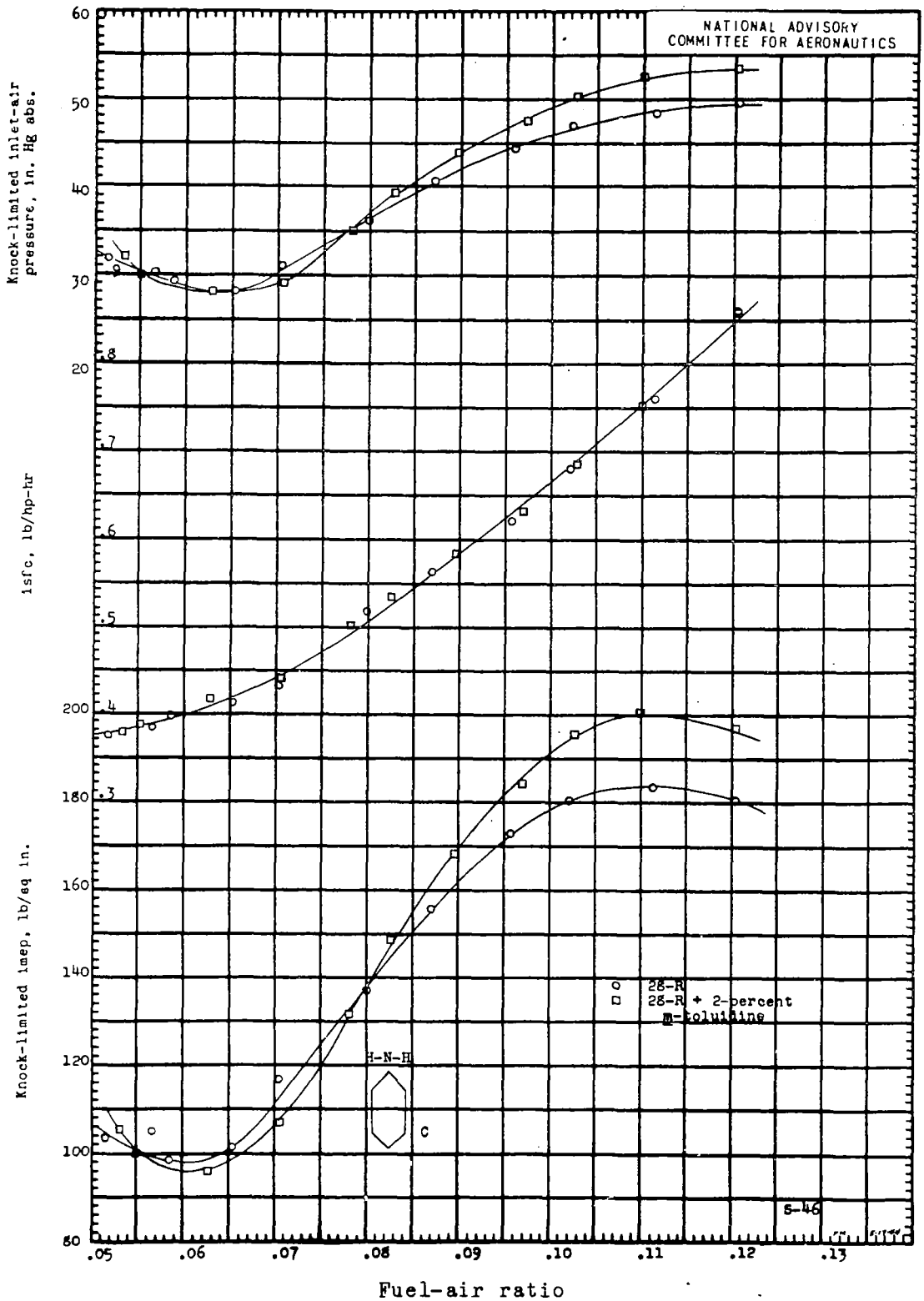
Figure 5. - Continued. Effect of addition of 2-percent o-toluidine to 28-R fuel on knock-limited performance of a CFR engine. Engine speed, 1800 rpm; compression ratio, 7.0; oil temperature, 165° F.



Fuel-air ratio

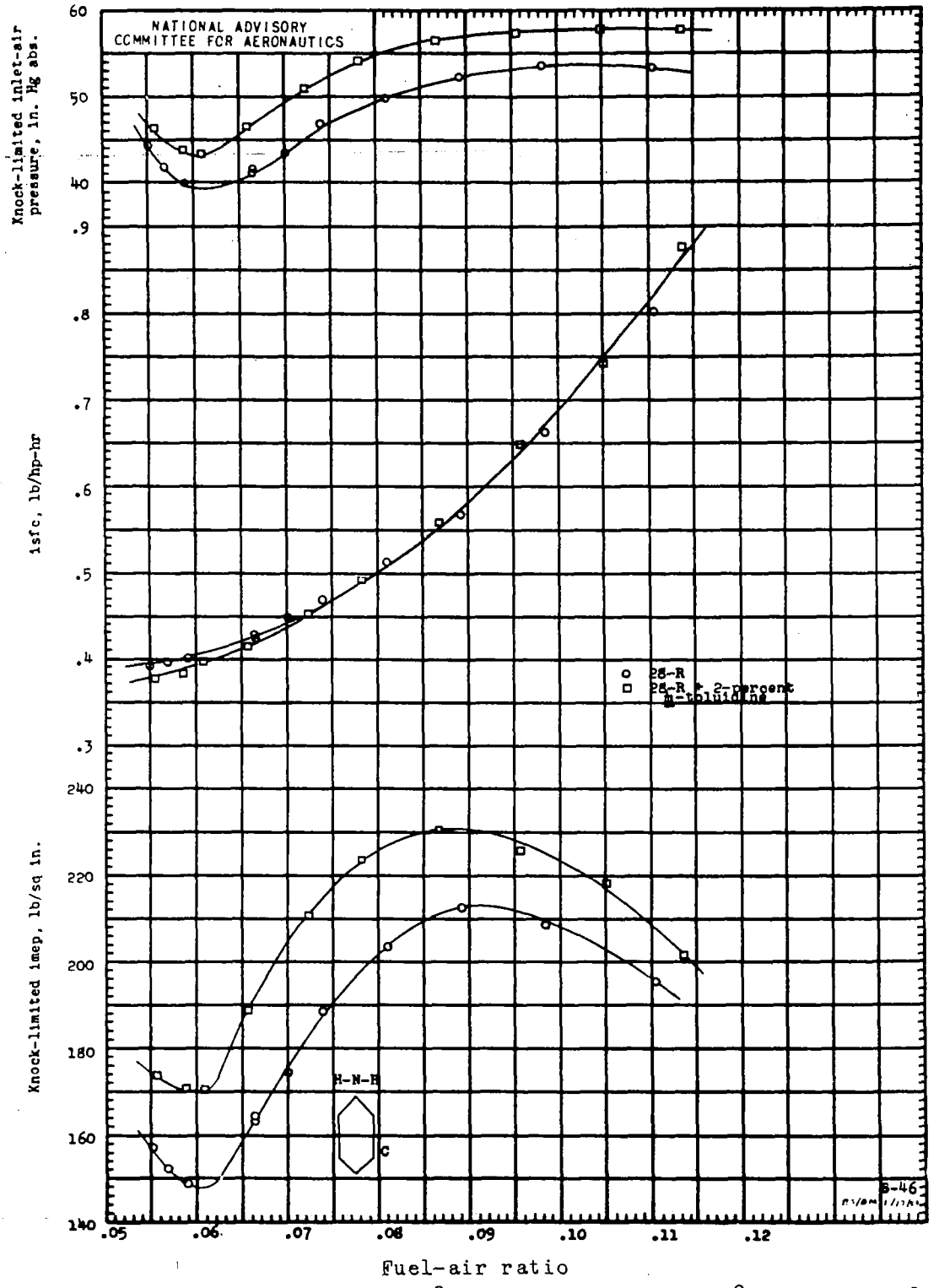
(c) Inlet-air temperature, 150° F; spark advance, 30° B.T.C.; coolant temperature, 250° F.

Figure 5. - Concluded. Effect of addition of 2-percent o-toluidine to 28-R fuel on knock-limited performance of a CFR engine. Engine speed, 1800 rpm; compression ratio, 7.0; oil temperature, 165° F.



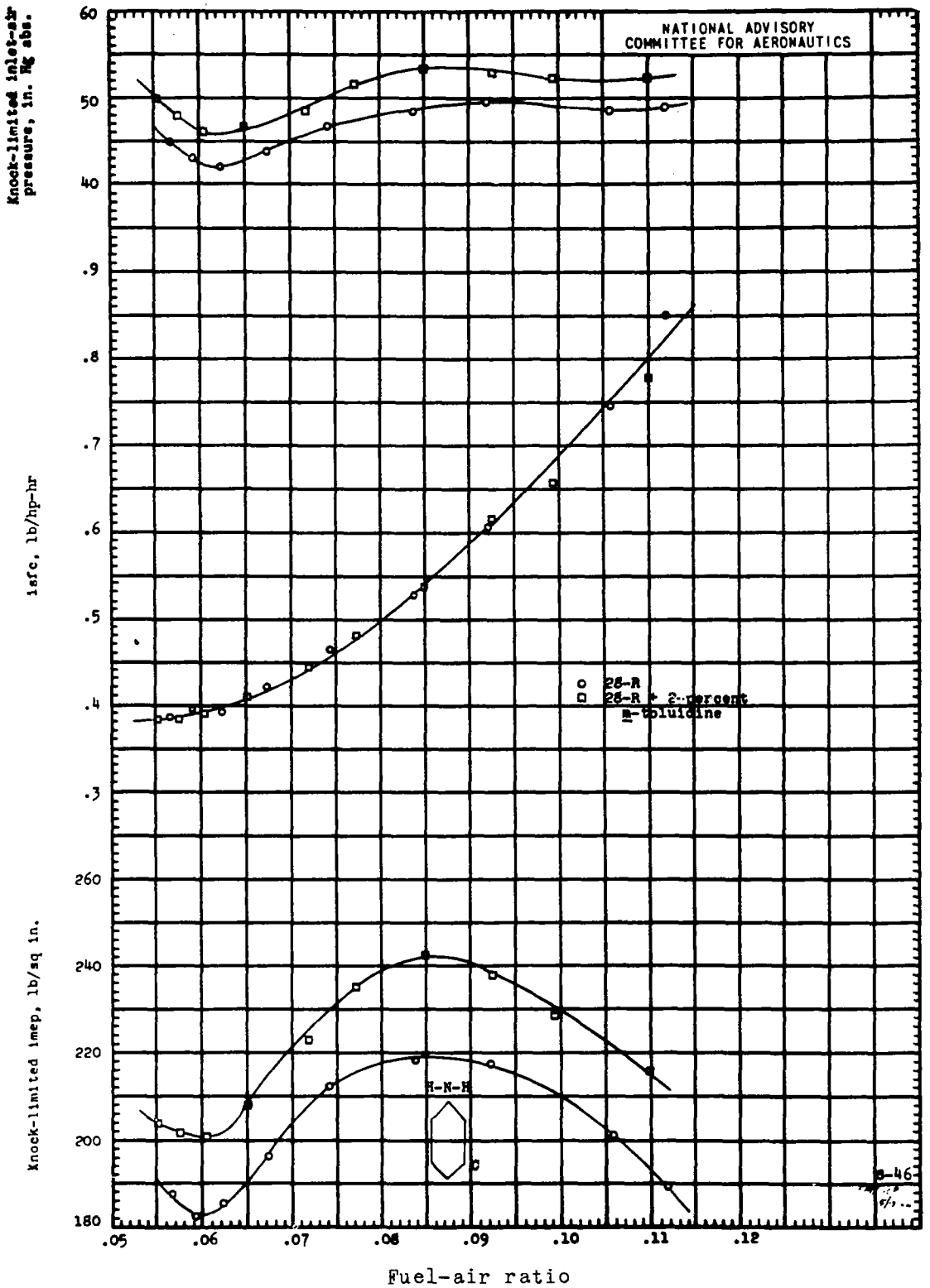
(a) Inlet-air temperature, 225° F; spark advance, 45° B.T.C.; coolant temperature, 375° F.

Figure 6. - Effect of addition of 2-percent m-toluidine to 28-R fuel on knock-limited performance of a CFR engine. Engine speed, 1800 rpm; compression ratio, 7.0; oil temperature, 165° F.



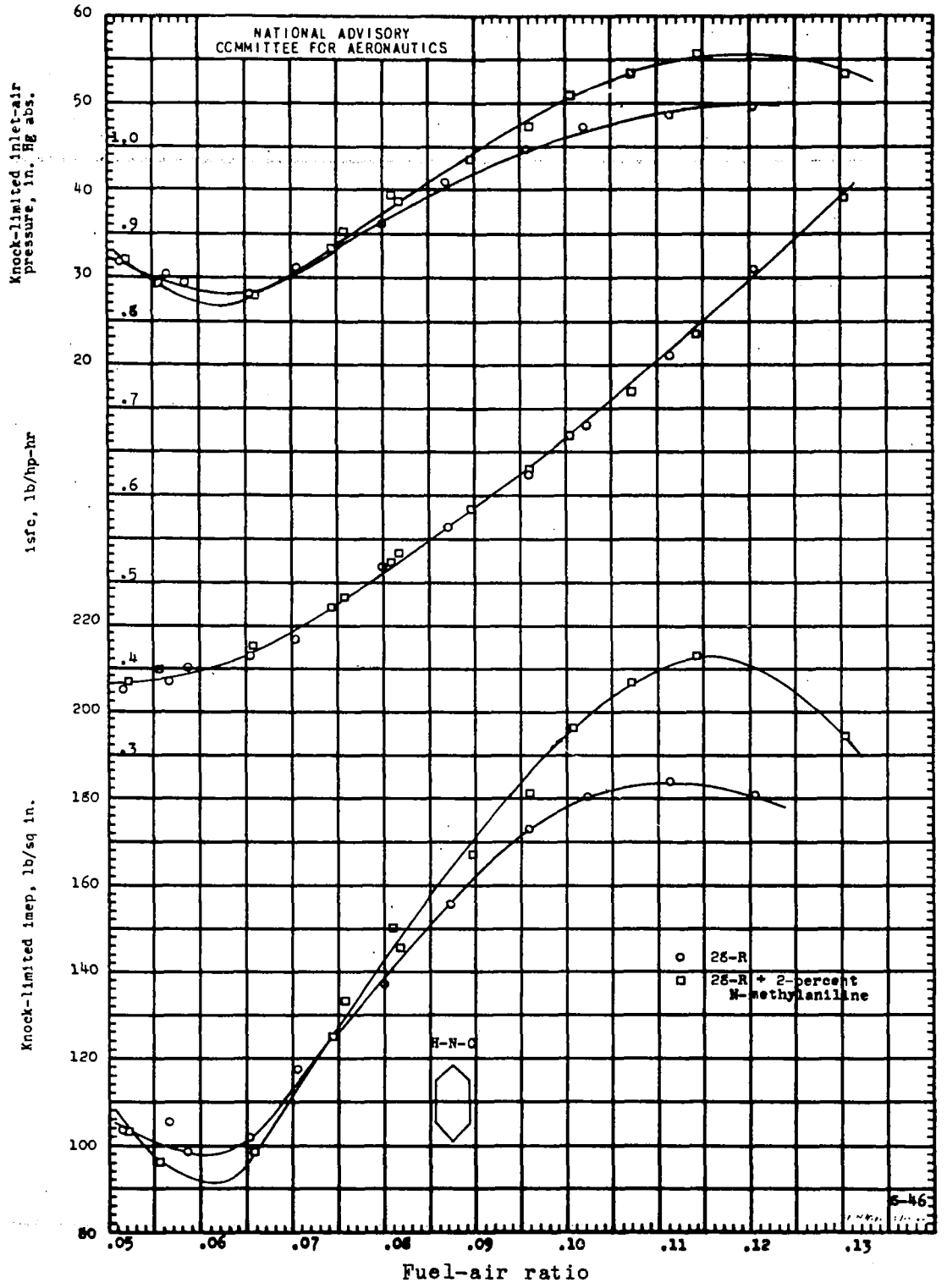
(b) Inlet-air temperature, 250° F; spark advance, 30° B.T.C.; coolant temperature, 250° F.

Figure 6. - Continued. Effect of addition of 2-percent m-toluidine to 28-R fuel on knock-limited performance of a CFR engine. Engine speed, 1800 rpm; compression ratio, 7.0; oil temperature, 165° F.



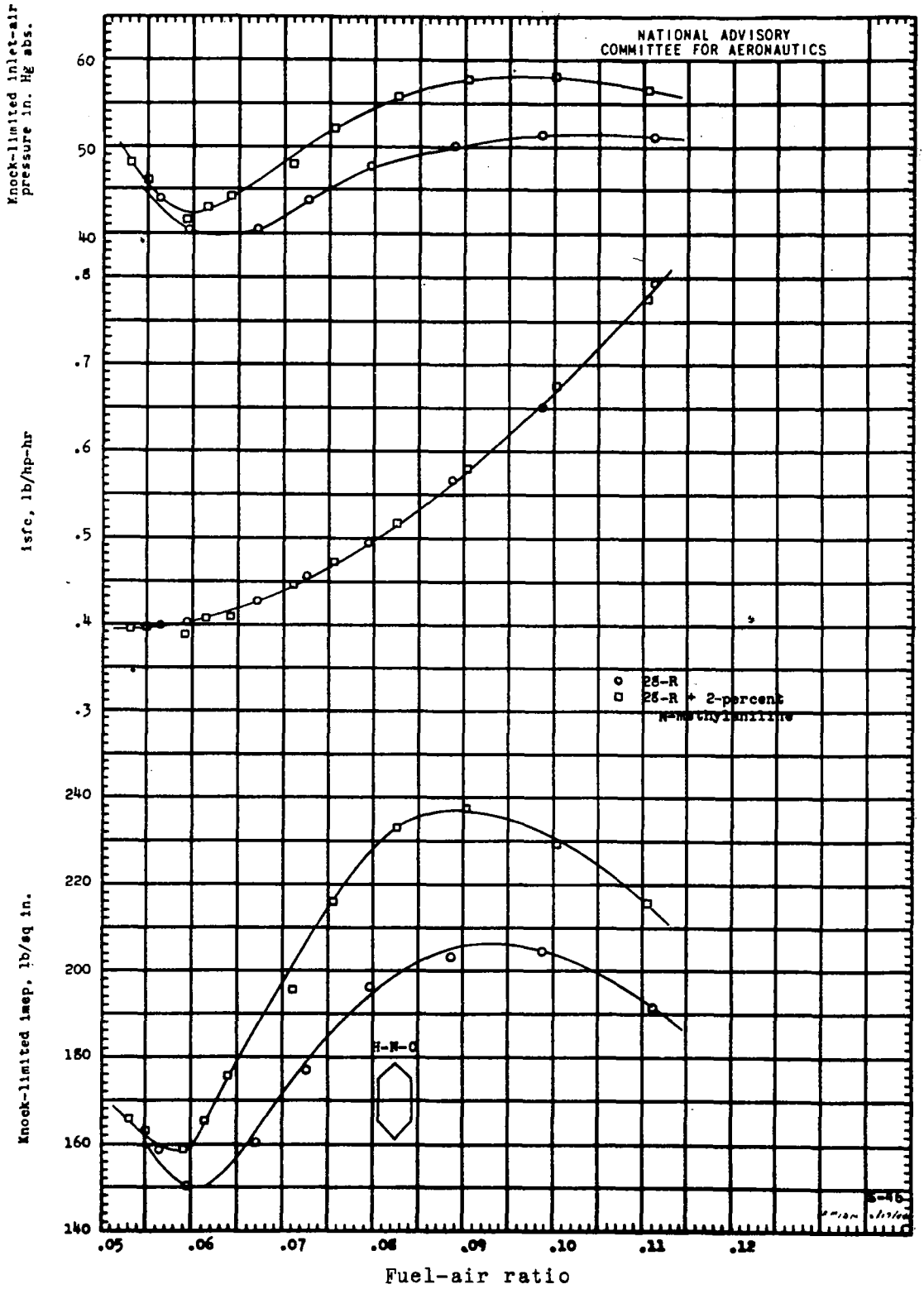
(c) Inlet-air temperature, 150° F; spark advance, 30° B.T.C.; coolant temperature, 250° F.

Figure 6. - Concluded. Effect of addition of 2-percent m-toluidine to 28-R fuel on knock-limited performance of a CFR engine. Engine speed, 1800 rpm; compression ratio, 7.0; oil temperature, 165° F.



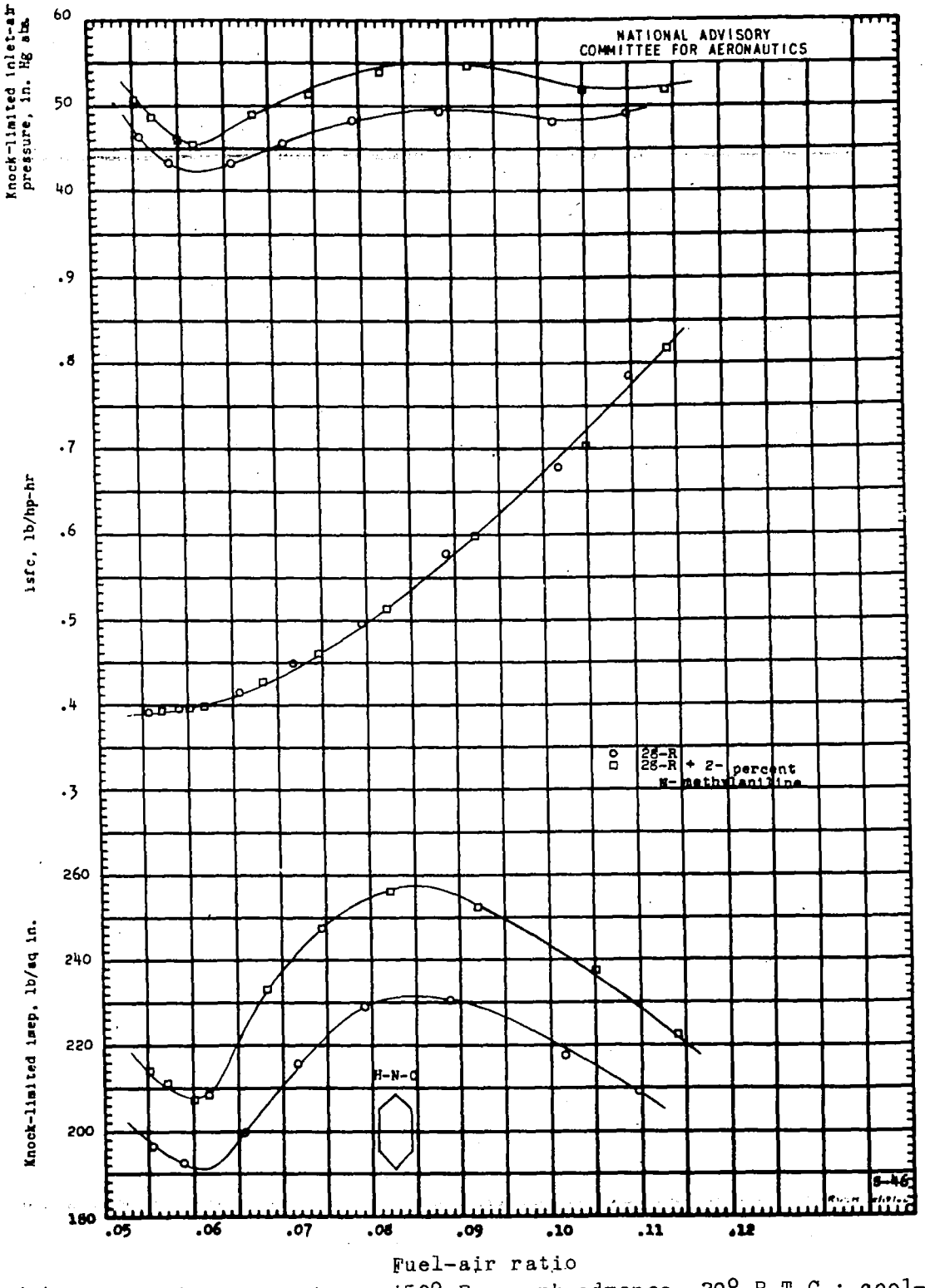
(a) Inlet-air temperature, 225° F; spark advance, 45° B.T.C.; coolant temperature, 375° F.

Figure 7. - Effect of addition of 2-percent N-methylaniline to 28-R fuel on knock-limited performance of a CFR engine. Engine speed, 1800 rpm; compression ratio, 7.0; oil temperature, 165° F.



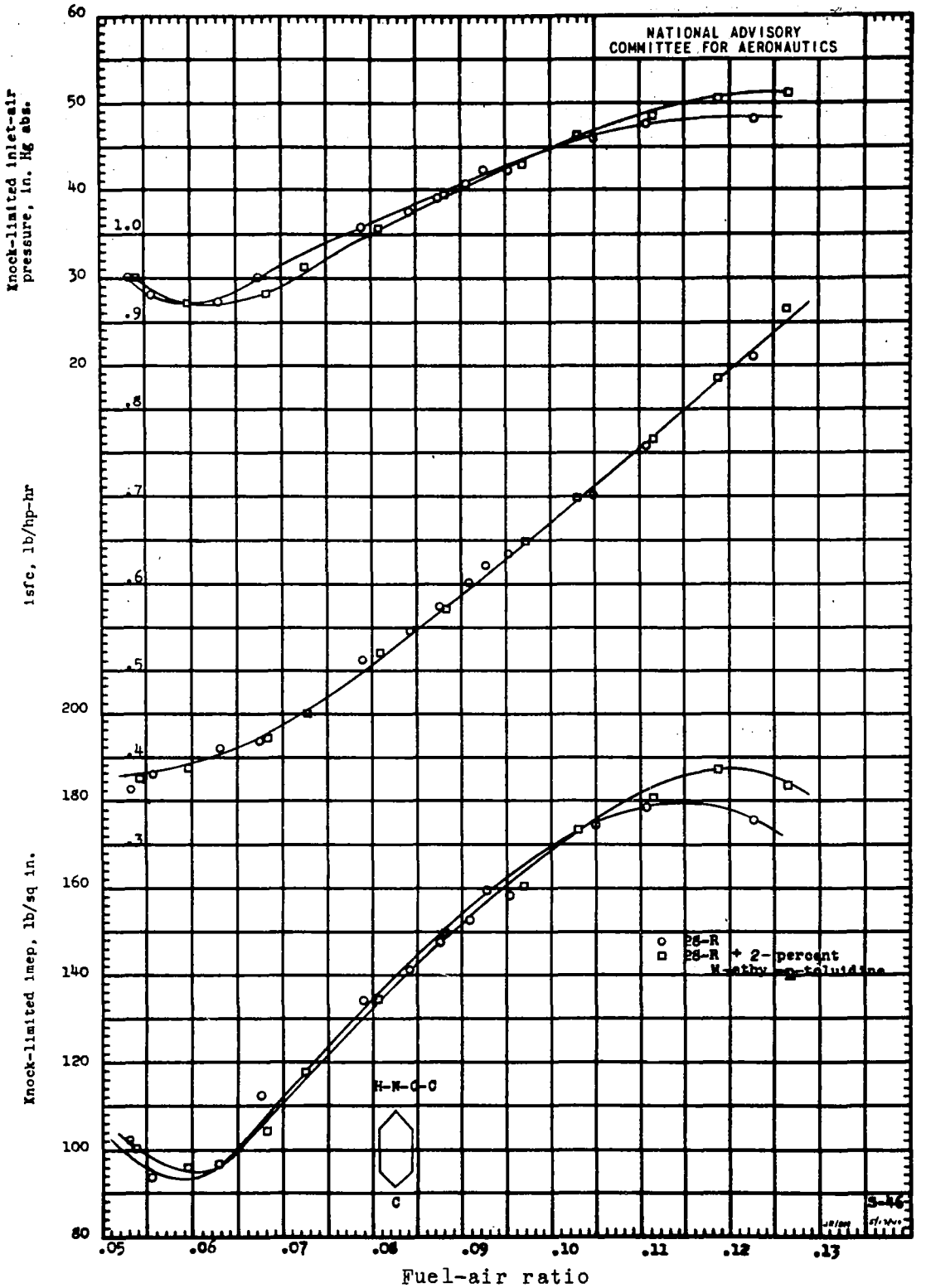
(b) Inlet-air temperature, 250° F; spark advance, 30° B.T.C.; coolant temperature, 250° F.

Figure 7. - Continued. Effect of addition of 2-percent N-methylaniline to 28-R fuel on knock-limited performance of a CFR engine. Engine speed, 1800 rpm; compression ratio, 7.0; oil temperature, 165° F.



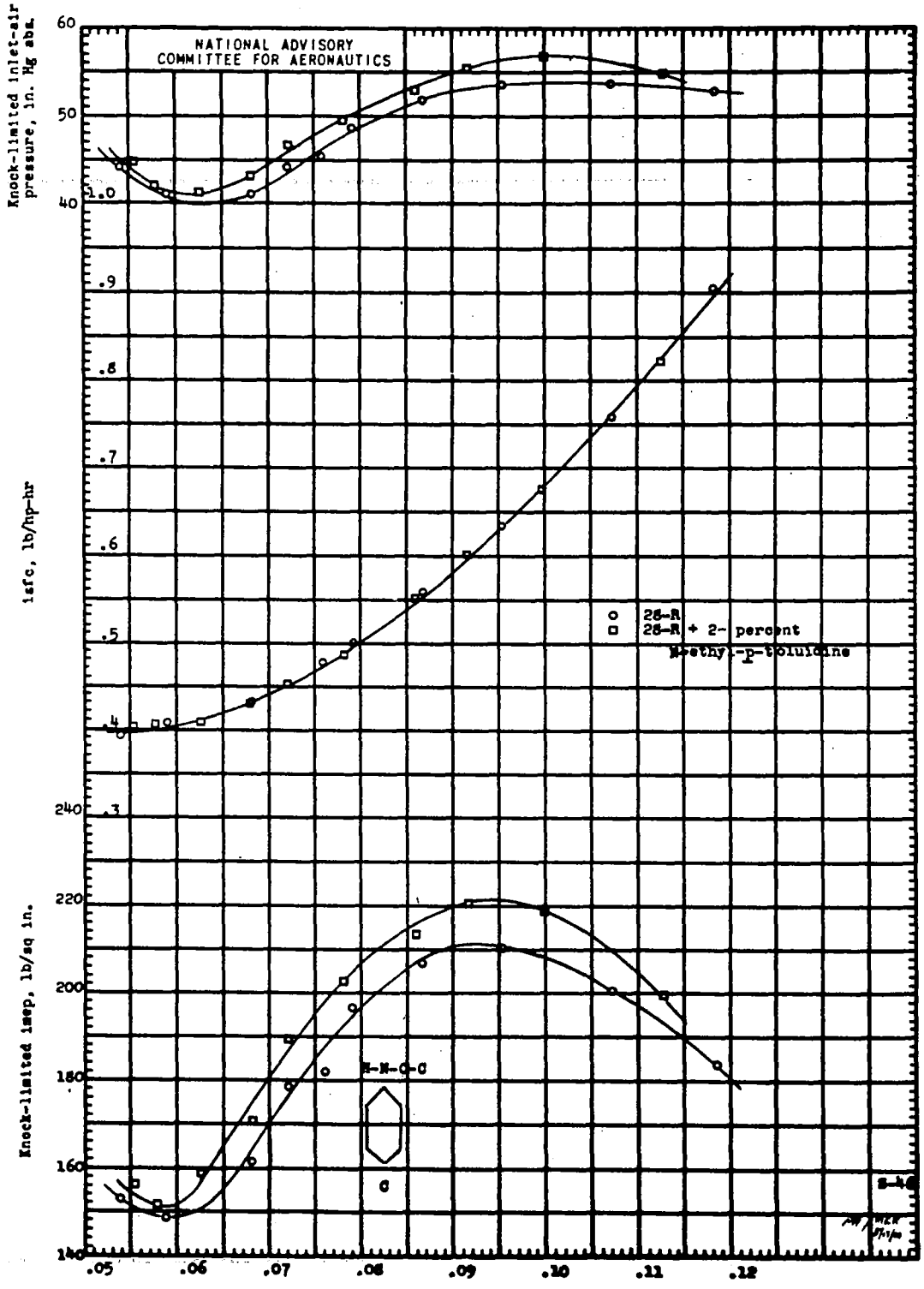
(c) Inlet-air temperature, 150° F; spark advance, 30° B.T.C.; coolant temperature, 250° F.

Figure 7. - Concluded. Effect of addition of 2-percent N-methylaniline to 28-R fuel on knock-limited performance of a CFR engine. Engine speed, 1800 rpm; compression ratio, 7.0; oil temperature, 165° F.



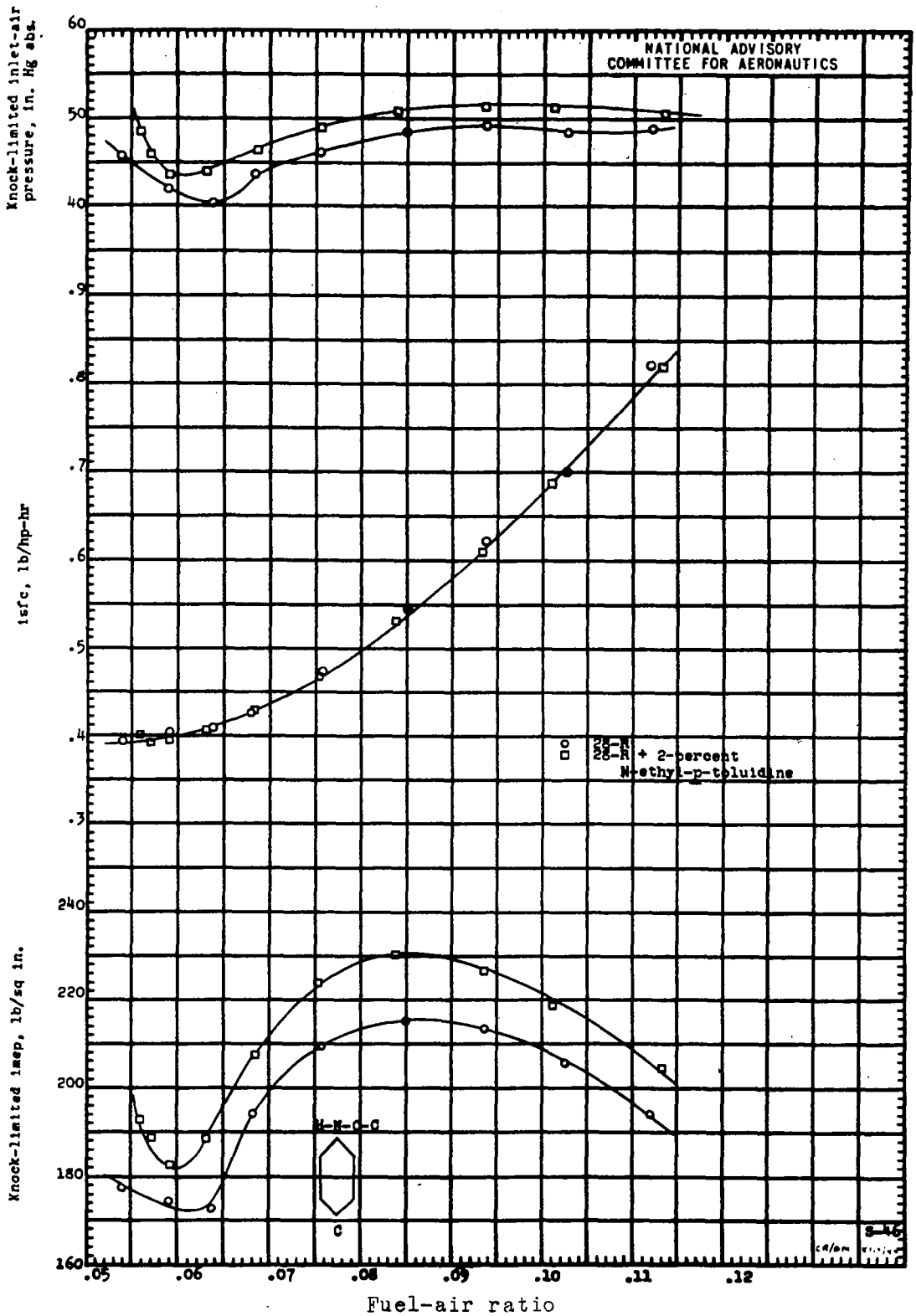
(a) Inlet-air temperature, 225° F; spark advance, 45° B.T.C.; coolant temperature, 375° F.

Figure 8. - Effect of addition of 2-percent M-ethyl-p-toluidine to 28-R fuel on knock-limited performance of a CFR engine. Engine speed, 1800 rpm; compression ratio, 7.0; oil temperature, 165° F.



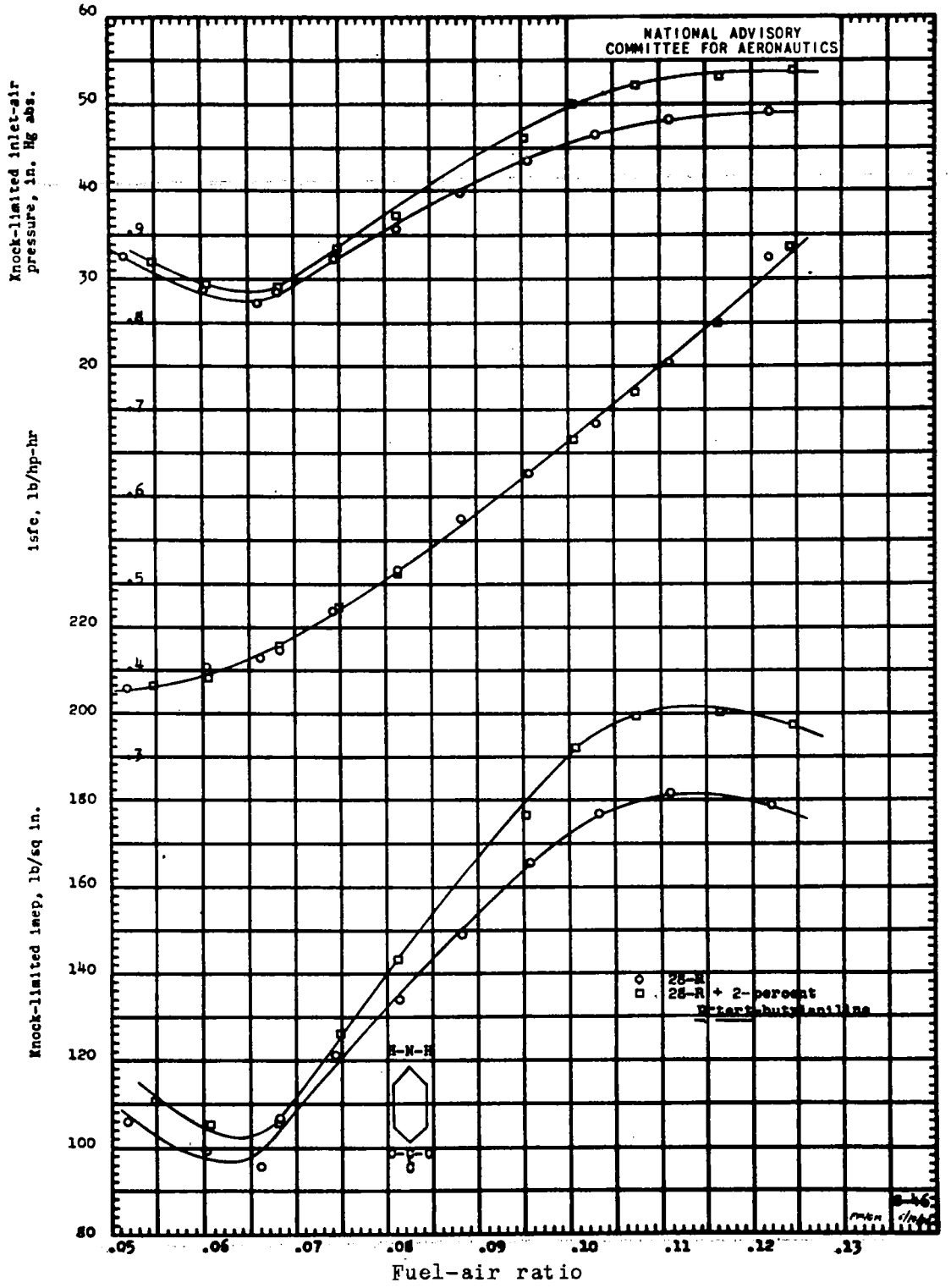
(b) Inlet-air temperature, 250° F; spark advance, 30° B.T.C.; coolant temperature, 250° F.

Figure 8. - Continued. Effect of addition of 2-percent M-ethyl-p-toluidine to 28-R fuel on knock-limited performance of a CFR engine. Engine speed, 1800 rpm; compression ratio, 7.0; oil temperature, 165° F.



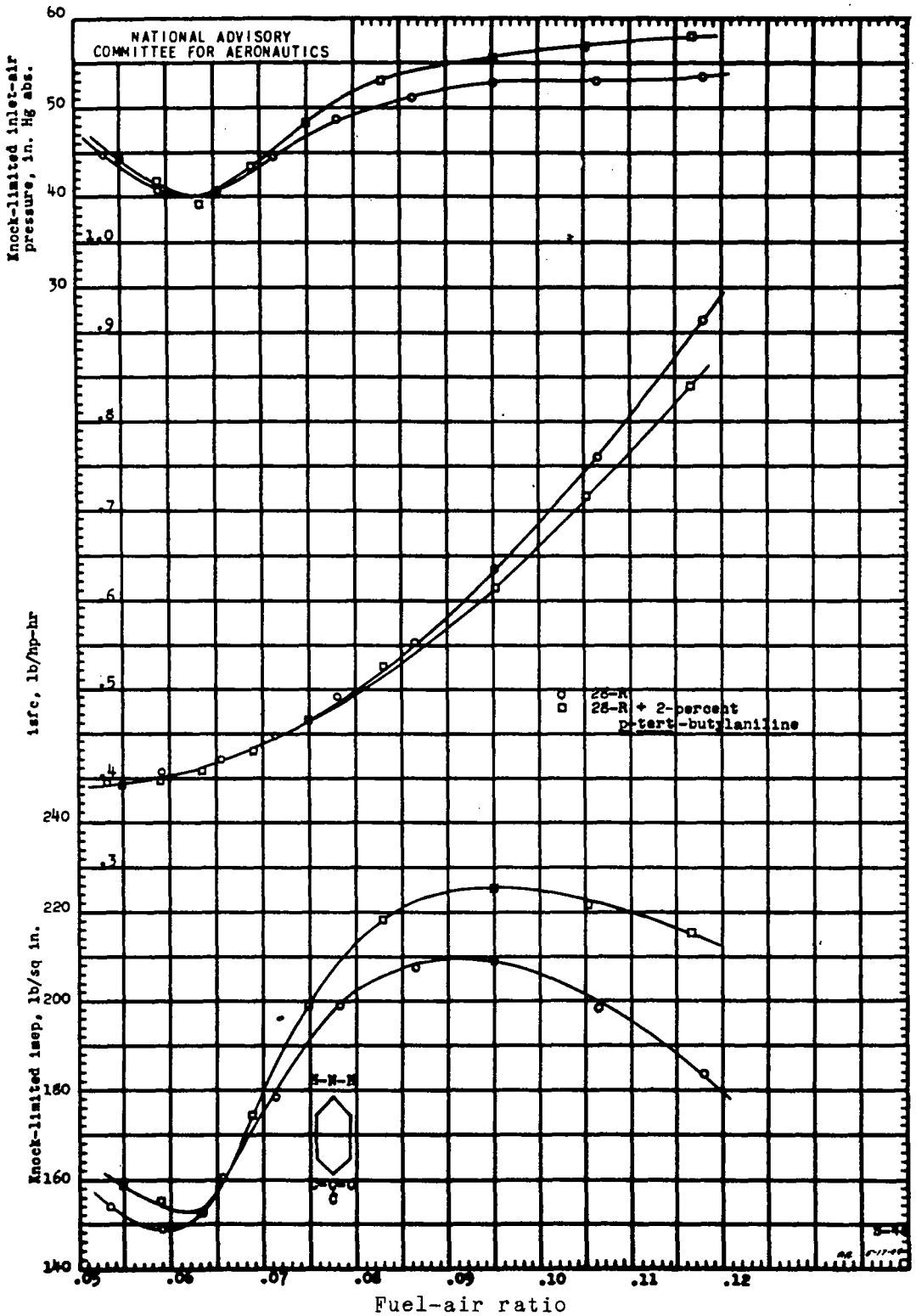
(c) Inlet-air temperature, 150° F; spark advance, 30° B.T.C.; coolant temperature, 250° F.

Figure 8. - Concluded. Effect of addition of 2-percent N-ethyl-p-toluidine to 28-R fuel on knock-limited performance of a CFR engine. Engine speed, 1800 rpm; compression ratio, 7.0; oil temperature, 165° F.



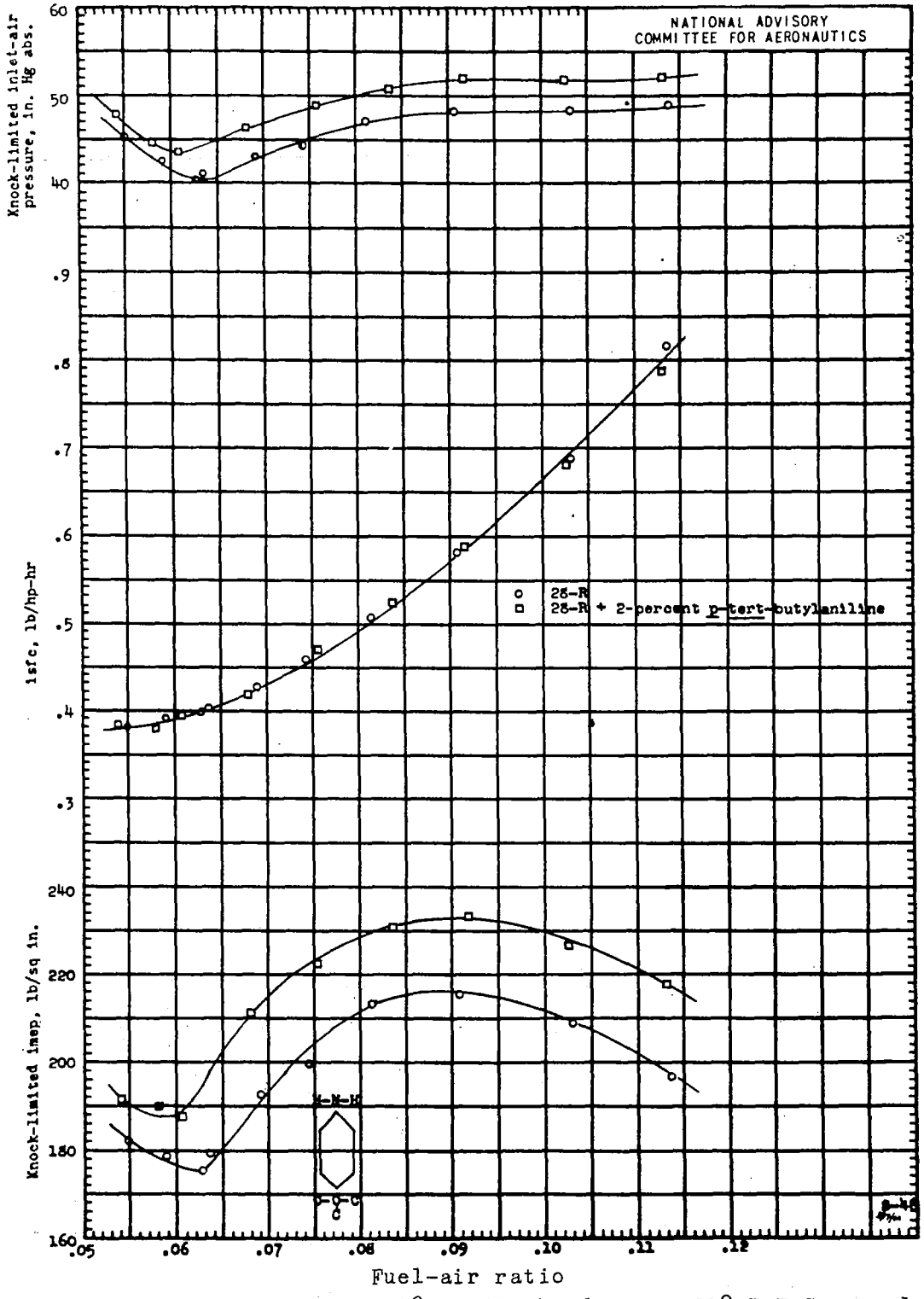
(a) Inlet-air temperature, 225° F; spark advance, 45° B.T.C.; coolant temperature, 375° F.

Figure 9. - Effect of addition of 2-percent p-tert-butylaniline to 28-R fuel on knock-limited performance of a CFR engine. Engine speed, 1800 rpm; compression ratio, 7.0; oil temperature, 165° F.



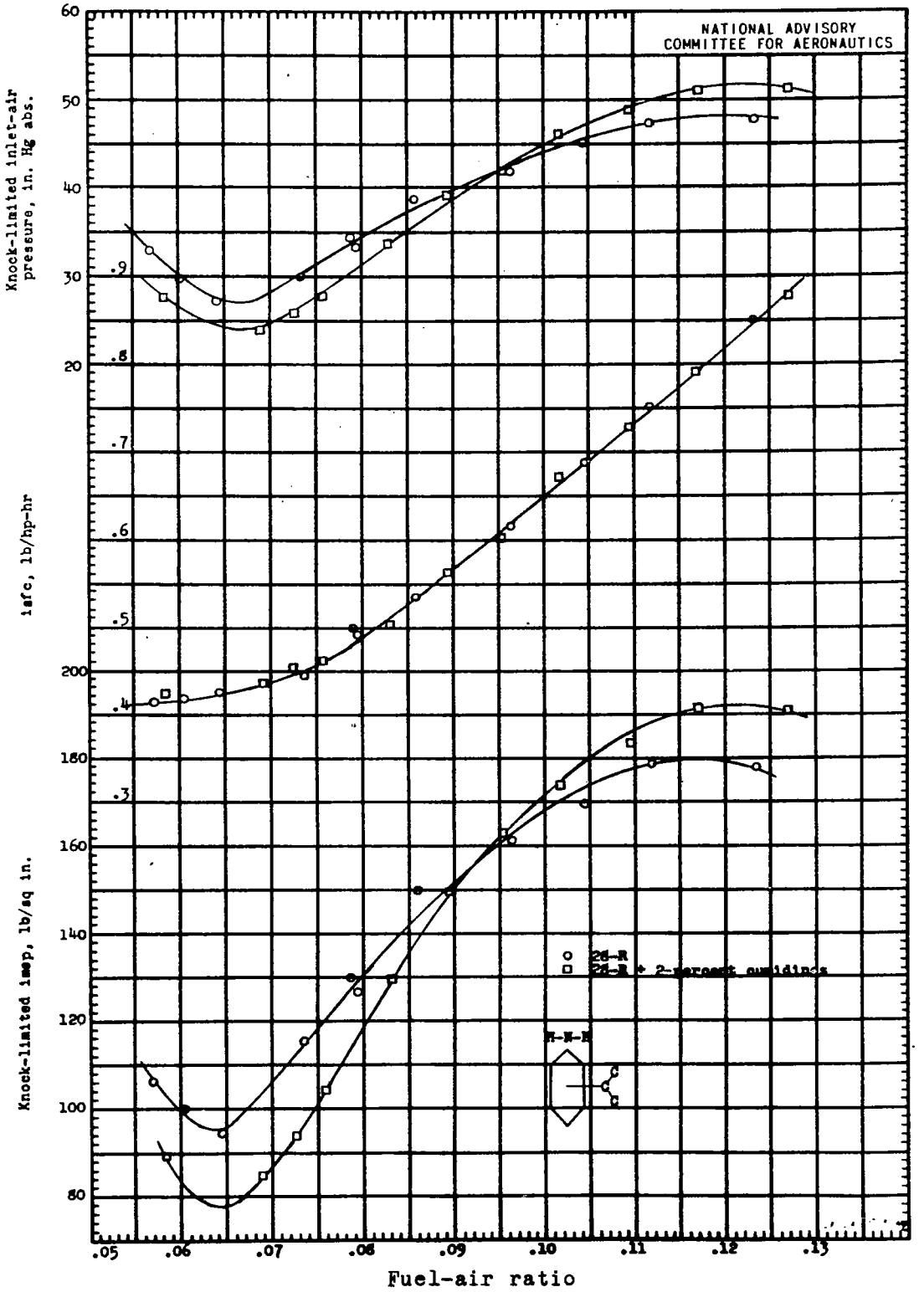
(b) Inlet-air temperature, 250° F; spark advance, 30° B.T.C.; coolant temperature, 250° F.

Figure 9. - Continued. Effect of addition of 2-percent p-tert-butylaniline to 28-R fuel on knock-limited performance of a CFR engine. Engine speed, 1800 rpm; compression ratio, 7.0; oil temperature, 165° F.



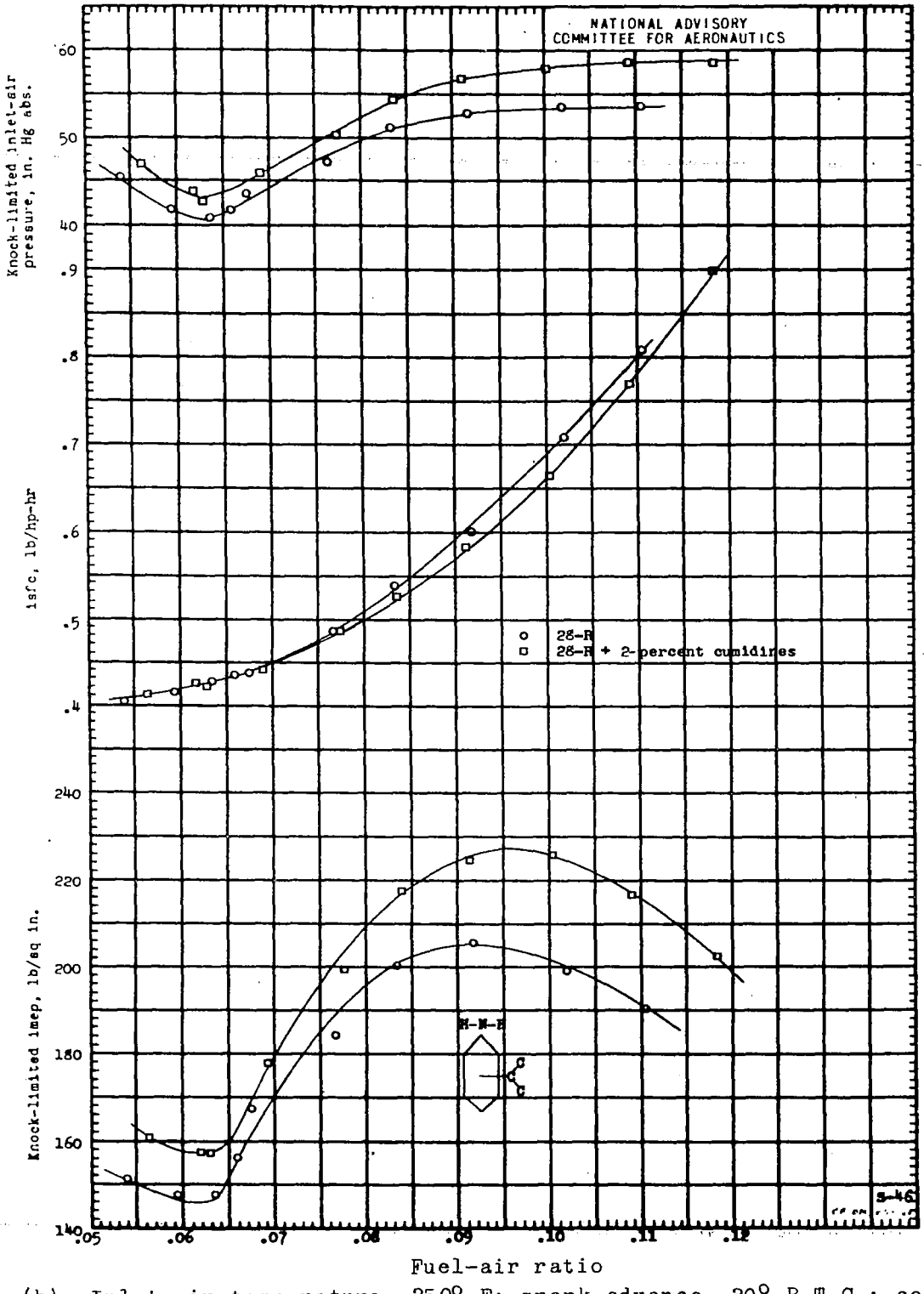
(c) Inlet-air temperature, 150° F; spark advance, 30° B.T.C.; coolant temperature, 250° F.

Figure 9. - Concluded. Effect of addition of 2-percent p-tert-butylaniline to 28-R fuel on knock-limited performance of a CFR engine. Engine speed, 1800 rpm; compression ratio, 7.0; oil temperature, 165° F.



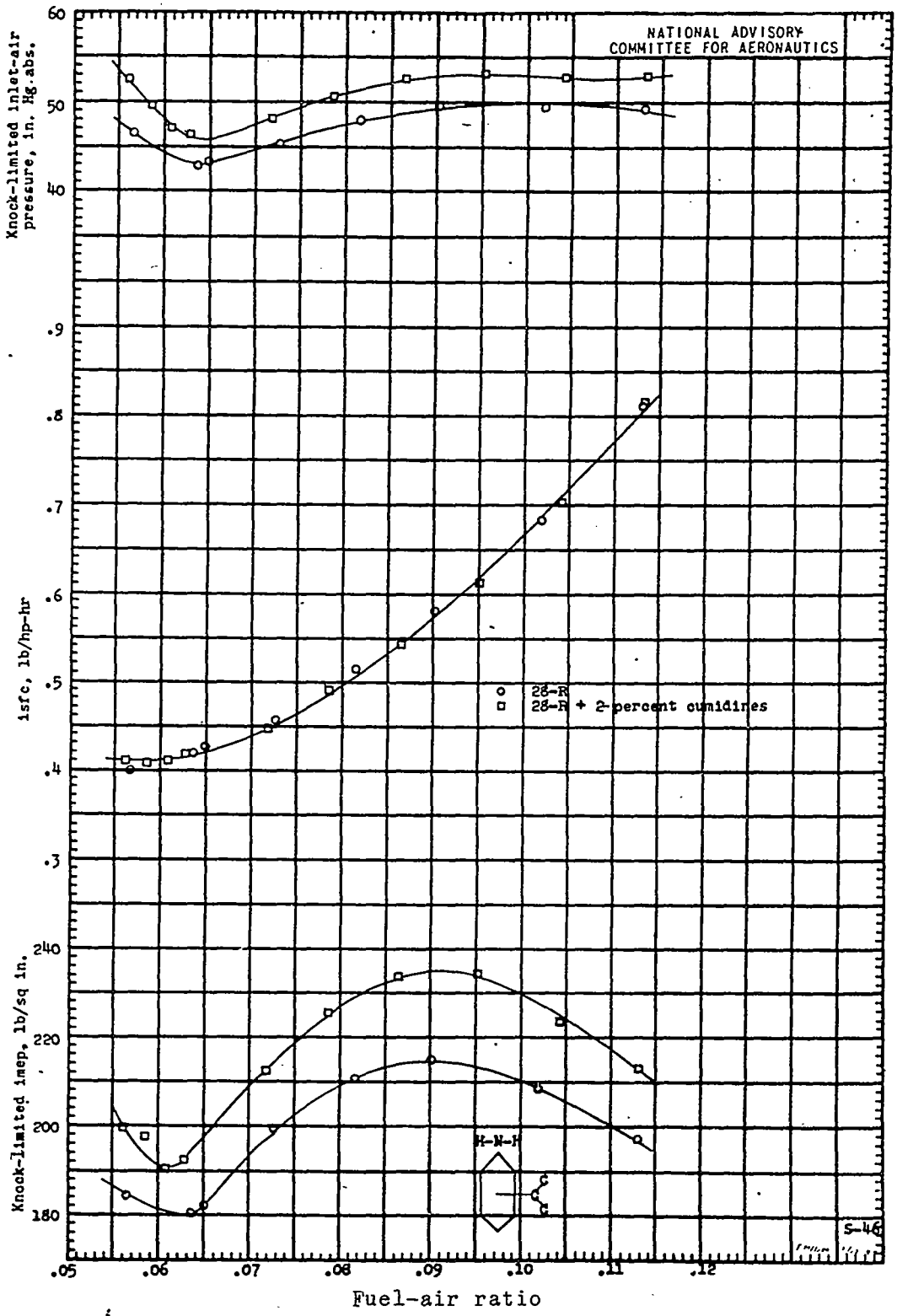
(a) Inlet-air temperature, 225° F; spark advance, 45° B.T.C.; coolant temperature, 375° F.

Figure 10. - Effect of addition of 2-percent cumidines to 28-R fuel on knock-limited performance of a CFR engine. Engine speed, 1800 rpm; compression ratio, 7.0; oil temperature, 165° F.



(b) Inlet-air temperature, 250° F; spark advance, 30° B.T.C.; coolant temperature, 250° F.

Figure 10. - Continued. Effect of addition of 2-percent cumidines to 28-R fuel on knock-limited performance of a CFR engine. Engine speed, 1800 rpm; compression ratio, 7.0; oil temperature, 165° F.



(c) Inlet-air temperature, 150° F; spark advance, 30° B.T.C.; coolant temperature, 250° F.

Figure 10. - Concluded. Effect of addition of 2-percent cumidines to 28-R fuel on knock-limited performance of a CFR engine. Engine speed, 1800 rpm; compression ratio, 7.0; oil temperature, 165° F.

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TITLE: Knock-Limited Performance of Blends of AN-F-28 Aviation Gasoline Containing 2 Percent Aromatic Amines - Part II

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ABSTRACT:

The results are given on an investigation of the effect of 2% additions of nine aromatic amines on the knock-limited performance of AN-F-28 (28-R) aviation gasoline. The amines tested were aniline, technical pseudocumidine, p-toluidine, o-toluidine, m-toluidine, N-methylaniline, N-ethyl-p-toluidine, p-tert-butylaniline, and cumidines (from synthetic cumene). The tests were performed on a CFR (F-4) engine equipped with two independent fuel systems. Results showed that p-toluidine and p-tert-butylaniline gave the best over-all improvement in the knock-limited power of 28-R aviation gasoline at the three sets of engine conditions tested. Aromatic amines that might be of interest as antiknock agents are p-toluidine, p-tert-butylaniline, technical pseudocumidine, m-toluidine, N-methylaniline, and cumidines.

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