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

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NACA

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NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

MEMORANDUM REPORT

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

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 of nine aromatic amines synthesized, or purchased and purified, at the NACA Cleveland laboratory. The amines are 2,4-xylidine, N-ethylaniline, 2,4-diethylaniline, diphenylamine, N,N-diethyl-p-phenylenediamine, N-isopropyl-p-isopropylaniline, N,N'-dimethyl-p-phenylenediamine, N,N-dimethyl-p-phenylenediamine, and cumidines (from refinery cumene). The knock-limited performance of 28-R fuel with and without 2-percent additions of each of these aromatic amines was determined in a CFR engine under three sets of operating conditions including F-4 conditions. Limited F-3 tests were also run. A brief analysis is also presented of the antiknock effectiveness of the aromatic amines based upon the data given in parts I and II as well as in the present report.

The results based upon the antiknock effectiveness of the 27 aromatic amines obtained to date from this program are summarized as follows:

1. The following aromatic amines tested could be of use as aviation-fuel additives:

(a) Diphenylamine gave the most consistent power improvement, roughly 10 percent, at all fuel-air ratios and engine conditions.

(b) N-Methyl-p-toluidine, N,N-diethyl-p-phenylenediamine, N,N'-dimethyl-p-phenylenediamine, and N,N-dimethyl-p-phenylenediamine were very good antiknock agents under modified conditions but their knock-limited performance was sensitive to inlet-air temperature and fuel-air ratio.

(c) Other aromatic amines that showed promise as antiknock agents are aniline, p-isopropylaniline, 2,6-xylidine, commercial xylidines, 2,4-xylidine, p-toluidine, N-methylaniline, and p-tert-butylaniline.

2. The following characteristics of the molecular structure were found in this investigation:

(a) An increase in the length of an N-alkyl radical beyond one carbon atom depreciated the power improvement in both the lean- and the rich-mixture region at the engine conditions tested.

(b) The order of decreasing temperature sensitivity and increasing performance among the toluidines was ortho, meta, and para. Under modified conditions, however, the difference between the meta position and the para position was less definite because the meta position gave better performance at some fuel-air ratios.

(c) Diphenylamine did not have the sensitivity to fuel-air ratio and engine conditions common to all of the other single-ring structures tested. The desirability of further tests on double-ring compounds is indicated.

(d) Less sensitivity to engine conditions at lean mixtures was experienced with 2,6-xylidine than with 2,4-xylidine.

3. No significance was attributed to any slight changes in indicated specific fuel consumption that occurred with the various aromatic amines during the course of the project.

INTRODUCTION

A general program is being conducted by the NACA at the request of the Army Air Forces, Materiel Command, to determine the effectiveness of aromatic amines as antiknock additives in aviation gasoline. The data presented in this report were obtained during May 1944 at the Aircraft Engine Research Laboratory, Cleveland, Ohio.

This report is part III of a series of five reports presenting knock data on a total of 48 aromatic amines. (See references 1 and 2.) Reported herein are the experimentally determined knock-limited performance data for 2-percent blends of nine aromatic amines in AN-F-28 (28-R) fuel.

The performance data for all the aromatic amines tested to date at this laboratory are summarized in this report. This summary correlates the knock-limited performance at different degrees of engine severity and at different fuel-air ratios with the molecular structure of the amines. It also permits an evaluation of the relative effectiveness of the amines as additives in aviation gasoline although it must be emphasized that knock in a CFR engine is the only criterion used in this report. Reports dealing with the preparation and the physical and chemical properties of the amines and their gasoline blends have been published by this laboratory as references 3 and 4.

APPARATUS AND TEST PROCEDURE

The preparation of the aromatic amines tested in this part of the program was carried on under the direction of Dr. W. T. Olson of the laboratory staff. The amines, with the exception of the cumidines, were distilled through a fractionating column and a narrow fraction (approximately 1° C) in the middle of the boiling range was selected. The cumidines tested for this report (tables I and II) were prepared from refinery cumene; the cumidines previously tested (reference 2) were prepared from synthetic cumene.

The data were obtained by using the same F-4 knock-testing engine, base stock, operating conditions, and operator as used in part II of this program. (See reference 2.)

The three sets of operating conditions were 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 these sets of conditions, 28-R fuel and a 2-percent blend of an aromatic amine in this gasoline were tested on the same day. In addition F-3 tests were made on the amine blends when quantity permitted. Because of solubility and quantity limitations, 1.76-percent N,N'-dimethyl-p-phenylenediamine was tested only under modification A condition. Quantity limitations also permitted tests of N,N-dimethyl-p-phenylenediamine only under F-4 and modification A conditions.

DISCUSSION OF RESULTS

Figures 1 to 9 present the knock-limited performance data for nine aromatic amines tested under the three sets of conditions. Each figure compares the effects of the transition from severe to mild test conditions for 28-R fuel and a 2-percent addition of an aromatic amine in this gasoline.

Table I is a summary of the relative power obtained by using 2 percent aromatic-amine additives at fuel-air ratios of 0.062, 0.070, 0.090, and 0.110. Table II presents the F-3 rating of the fuel blends. Of the nine amines tested, diphenylamine was outstanding because it was apparently insensitive to fuel-air ratio and engine conditions and gave a consistent power improvement of about 10 percent. An F-3 rating of 120 performance number (see table II) given to diphenylamine is an added indication of the lean-mixture response at severe engine conditions.

The symmetrical addition of two amine groups to the aromatic ring resulted in greatly increased power at moderate conditions. At severe conditions the rich-mixture response was good but the relative power improvement was considerably depreciated at lean fuel-air ratios. The greatest power improvement of all the amines tested was given by N,N'-dimethyl-p-phenylenediamine at modification A condition but the tests were limited because of lack of material. The results of the N,N-dimethyl-p-phenylenediamine and N,N-diethyl-p-phenylenediamine indicate that the double-amino compounds are sensitive to engine conditions.

The addition of 2-percent 2,4-xylidine to 28-R fuel gave about the same result as previously experienced with other xylidine isomers. It acted very well as an additive at moderate engine conditions but with increasing severity of engine conditions the power improvement became increasingly dependent on fuel-air ratio. Sensitivity to engine conditions has come to be expected with the xylidines.

The three other aromatic amines tested in this part of the program, N-ethylaniline, 2,4-diethylaniline, and N-isopropyl-p-isopropylaniline, showed poor antiknock properties as aviation-fuel additives. None of them had very good rich-mixture response and each one either acted as a proknock agent or gave little power improvement in the lean region.

No significance was attributed to any slight changes in indicated specific fuel consumption that occurred between the various test fuels during the course of the project.

Figures 10 to 14 summarize the data on the 27 aromatic amines tested to date in this program. These figures have been prepared from references 1 and 2 and from table I in this report. The effect of the toluidines and aniline on the knock-limited performance of AN-F-28 fuel is summarized in figure 10.

For lean-mixture improvement under severe conditions, the methyl radical in the para position gave the most satisfactory results. At modified conditions, however, the meta position gave better results. Of the p-toluidines, N-methyl-p-toluidine permitted the best average knock-limited performance. When the N-alkyl side chain was extended beyond one methyl group, the power improvement was depreciated.

The same trends of knock-limited performance with respect to structure and engine conditions are indicated by both figures 10(a) and 10(b). At modified conditions the difference in power improvement between the ortho, meta, and para positions are not so evident as under F-4 condition. Again, the addition of more than one carbon atom to the amino group on the p-toluidine depreciates the rich-mixture response. Figure 10(b) clearly shows that N-methyl-p-toluidine has a better rich-mixture response than any other toluidine tested.

The knock-limited lean- and rich-mixture performance of N-alkylaniline is presented in figure 11. At modified conditions (fig. 11(a)), N-methylaniline and aniline gave a better lean-mixture knock-limited performance than did the other amine additives presented. The limit of profitable addition to the nitrogen atom seems to be one methyl group, beyond which the improvement in knock-limited power decreases very rapidly.

The trend for the rich-mixture response (fig. 11(b)) is the same as that for the lean-mixture response. Again, N-methylaniline and aniline gave a better performance than the other amines and further extension of the N-aliphatic side chain beyond one methyl group decreased the knock-limited power improvement. A slightly better average rich-mixture response was obtained with N-methylaniline than with aniline. A noticeable depreciation of the knock-limited power was experienced in going from N-methylaniline to N,N-dimethylaniline and from N-ethylaniline to N,N-diethylaniline. A greater knock-limited power was permitted with N,N-diethylaniline than with N,N-dimethylaniline although N-methylaniline gave a greater knock-limited power than N-ethylaniline.

The effect of alkyl substitutions to the aromatic ring on the rich- and the lean-mixture knock-limited performance is shown in

figure 12. A comparison of p-isopropylaniline with aniline indicates that the addition of the isopropyl radical increased the lean-mixture response at modified conditions but had no apparent effect at F-4 condition. The addition of a methyl radical to the isopropyl radical (p-tert-butylaniline) resulted in a more consistent performance under severe and mild operation. When this methyl radical was added to the 2 position of the aromatic ring instead of to the isopropyl (4-isopropyl-2-methylaniline), the lean-mixture response became better at modified conditions and was worse at severe conditions.

When ethyl groups were placed on the 2 and 4 positions (2,4-diethylaniline), a lower knock-limited performance resulted than with 2,4-xylidine in all tests presented. In a comparison of the xylidine isomers, moving one of the methyl groups from the 4 to the 6 position apparently decreased the sensitivity to engine conditions.

On the basis of the rich-mixture data shown in figure 12(b) not much choice can be made among aniline, p-isopropylaniline, p-tert-butylaniline, and 4-isopropyl-2 methylaniline. In the F-4 tests, 2,6-xylidine, 2,4-xylidine, and 2,4-diethylaniline gave progressively less favorable performance in the order given. A comparison of the amines presented in figure 12 shows that p-tert-butylaniline was less sensitive to engine conditions than the other compounds presented.

In figures 13 and 14 the indicated mean effective pressure ratio is plotted against the number of carbon atoms in each molecular structure. For convenience, the aromatic ring structure rather than the chemical name of the compound designates its position (located by a point) on the graph. Figure 13 presents a summary of the data obtained under F-4 condition at fuel-air ratios of 0.062 and 0.110. A similar study at fuel-air ratios of 0.062 and 0.090 for data taken under modification A condition is presented in figure 14.

The existence of several trends can be noted from a study of these charts and two of the more obvious ones are indicated by the connecting lines. The effect of varying the N-alkyl radicals on aniline and on the p-toluidines is indicated by solid and dashed lines, respectively, connecting similar structures. For radicals with more than one N-methyl group, the relative knock-limited power, in general, decreases.

Two nitrogen atoms attached to the aromatic ring produced a very good performance at modified conditions and a good rich-mixture

response at severe conditions but the knock-limited power of these amines was sensitive to engine operating conditions at low fuel-air ratios. Diphenylamine was of interest because its effectiveness was almost independent of engine variables. Cumidines made from refinery cumene and cumidines made from synthetic cumene gave about the same performance under modified conditions but, as the severity increased, the cumidines made from refinery cumene appeared to give a better performance than those made from synthetic cumene.

Other trends in knock-limited performance at given engine conditions and fuel-air ratio can be easily correlated with chemical structure. (See figs. 13 and 14.)

SUMMARY OF RESULTS

The following results were obtained from the entire investigation of the antiknock effectiveness of 2-percent additions of 27 aromatic amines to AN-F-28 (28-R) fuel in a CFR engine:

1. The following aromatic amines tested could be of use as aviation-fuel additives:

(a) Diphenylamine gave the most consistent power improvement, roughly 10 percent, at all fuel-air ratios and engine conditions.

(b) N-methyl-p-toluidine, N,N-diethyl-p-phenylenediamine, N,N'-dimethyl-p-phenylenediamine, and N,N-dimethyl-p-phenylenediamine were very good antiknock agents under modified conditions but their knock-limited performance was sensitive to inlet-air temperature and fuel-air ratio.

(c) Other aromatic amines that showed promise as antiknock agents are aniline, p-isopropylaniline, 2,6-xylidine, commercial xylidines, 2,4-xylidine, p-toluidine, N-methylaniline, and p-tert-butylaniline.

2. The following characteristics of the molecular structure were found in this investigation:

(a) An increase in the length of an N-alkyl radical beyond one carbon atom depreciated the power improvement in both the lean- and the rich-mixture region at the engine conditions tested.

(b) The order of decreasing temperature sensitivity and increasing performance among the toluidines was ortho, meta, and

para. Under modified conditions the difference between the meta and the para position was questionable, however, because the meta position gave better performance at some fuel-air ratios.

(c) Diphenylamine did not have the sensitivity to fuel-air ratio and engine conditions common to all of the other single-ring structures tested. The desirability of further tests on double-ring compounds is indicated.

(d) Less sensitivity to engine conditions at lean mixtures was experienced with 2,6-xylidine than with 2,4-xylidine.

3. No significance was attributed to any slight changes in indicated specific fuel consumption that occurred with the various aromatic amines during the course of the project.

Aircraft Engine Research Laboratory,
National Advisory Committee for Aeronautics,
Cleveland, Ohio, August 23, 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. Alquist, Henry E., and Tower, Leonard K.: Knock-Limited Performance of Blends of AN-F-28 Fuel Containing 2 Percent Aromatic Amines - II. NACA Memo. rep., June 26, 1944.

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

4. Olson, Walter T., Tischler, Adelbert O., and Goodman, Irving A.: Gasoline-Water Distribution Coefficients of 27 Aromatic Amines. NACA Memo. rep., Aug. 3, 1944.

TABLE I

SUMMARY OF ANTIKNOCK EFFECTIVENESS OF 2-PERCENT 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)											
	F/A = 0.062			F/A = 0.070			F/A = 0.090			F/A = 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	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
2,4-Xylidine	.93	1.04	1.13	.92	1.03	1.14	.99	1.12	1.13	1.05	1.12	1.12
N-Ethylaniline	.91	.99	1.04	.97	1.04	1.04	1.04	1.05	1.05	1.01	1.04	1.04
2,4-Diethylaniline	.37	.98	1.04	.92	.92	1.04	.93	1.03	1.03	.98	1.06	1.03
Diphenylamine	1.10	1.11	1.10	1.07	1.08	1.08	1.09	1.10	1.11	1.11	1.15	1.10
N,N-Diethyl-p-phenylenediamine	.98	1.11	1.10	.89	1.11	1.19	1.10	1.17	1.19	1.16	1.17	1.14
N-Isopropyl-p-isopropylaniline	1.00	1.00	1.00	.99	1.02	1.03	1.00	1.01	1.02	1.00	1.03	1.03
N,N'-Dimethyl-p-phenylenediamine[a,b]	-----	1.15	-----	------	1.13	-----	------	1.22	-----	------	-----	-----
N,N-Dimethyl-p-phenylenediamine[b]	.97	1.12	-----	.89	1.13	-----	.99	1.18	-----	1.16	1.16	-----
Cumidines (from refinery cumene)	1.01	1.05	1.06	1.02	1.10	1.09	1.04	1.07	1.04	1.05	1.07	1.11

[a]1.76 percent amine added.
[b]Data limited because of insufficient fuel.

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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
2,4-Xylidine	.06	102
N-Ethylaniline	.06	102
2,4-Diethylaniline	[a]99.7	99.5
Diphenylamine	.72	120
N,N-Diethyl-p-phenylenediamine	[a]99.2	99
N-Isopropyl-p-isopropylaniline	.10	104
Cumidines (from refinery cumene)	.13	105

[a]Octane number.

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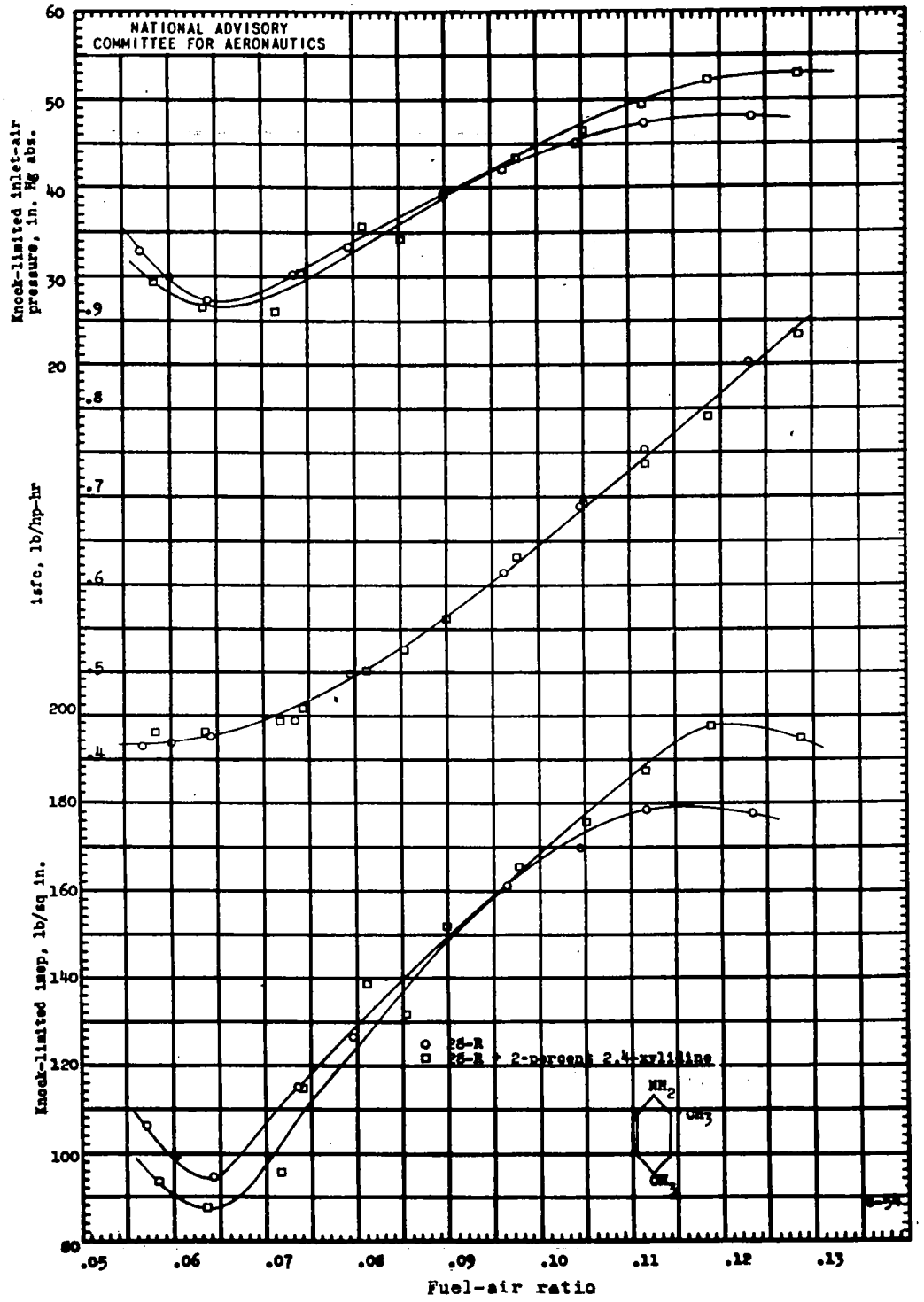
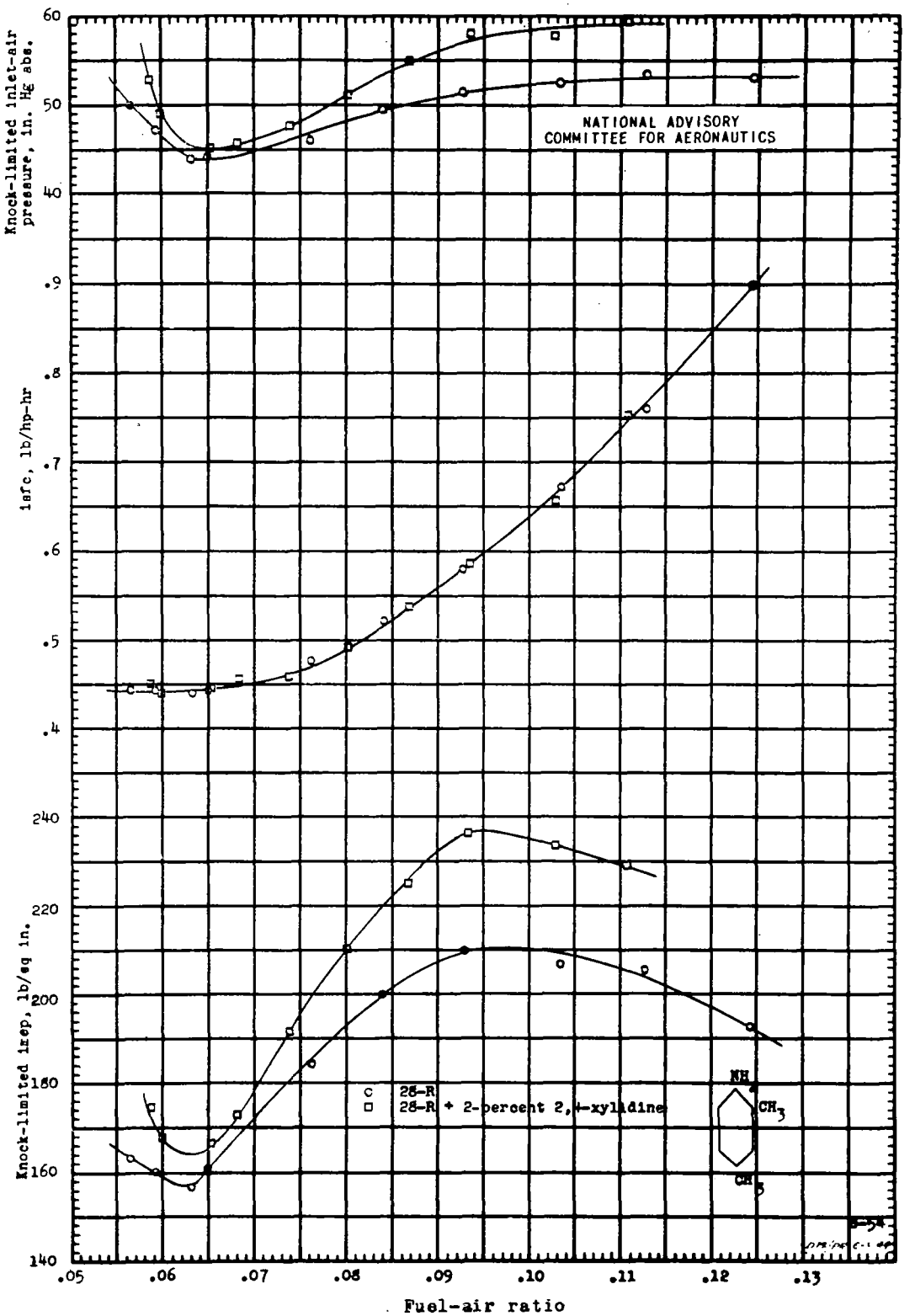


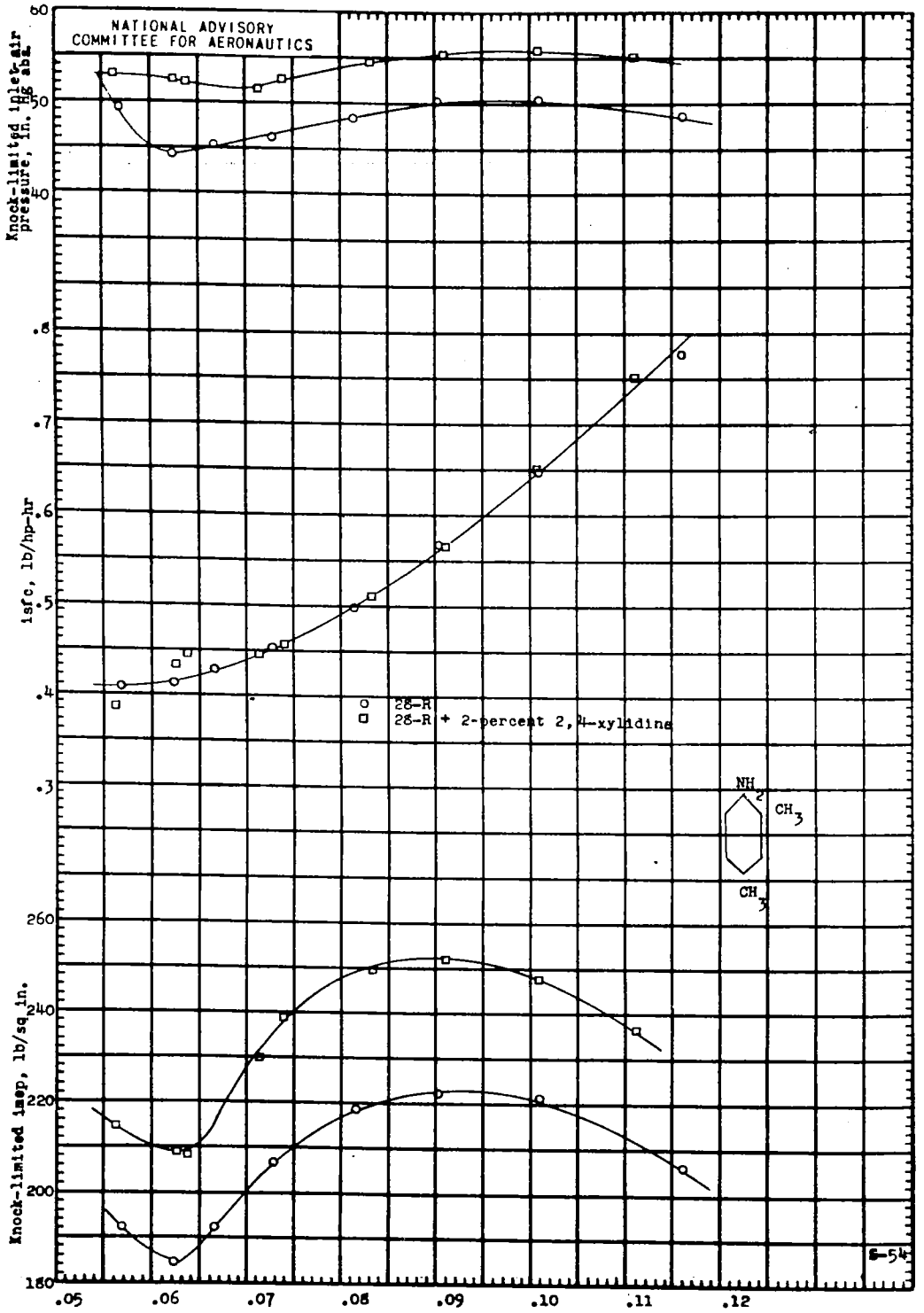
(a) Inlet-air temperature, 225° F; spark advance, 45° B.T.C.; coolant temperature, 375° F.

Figure 1. - Effect of addition of 2-percent 2,4-xylidine 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.

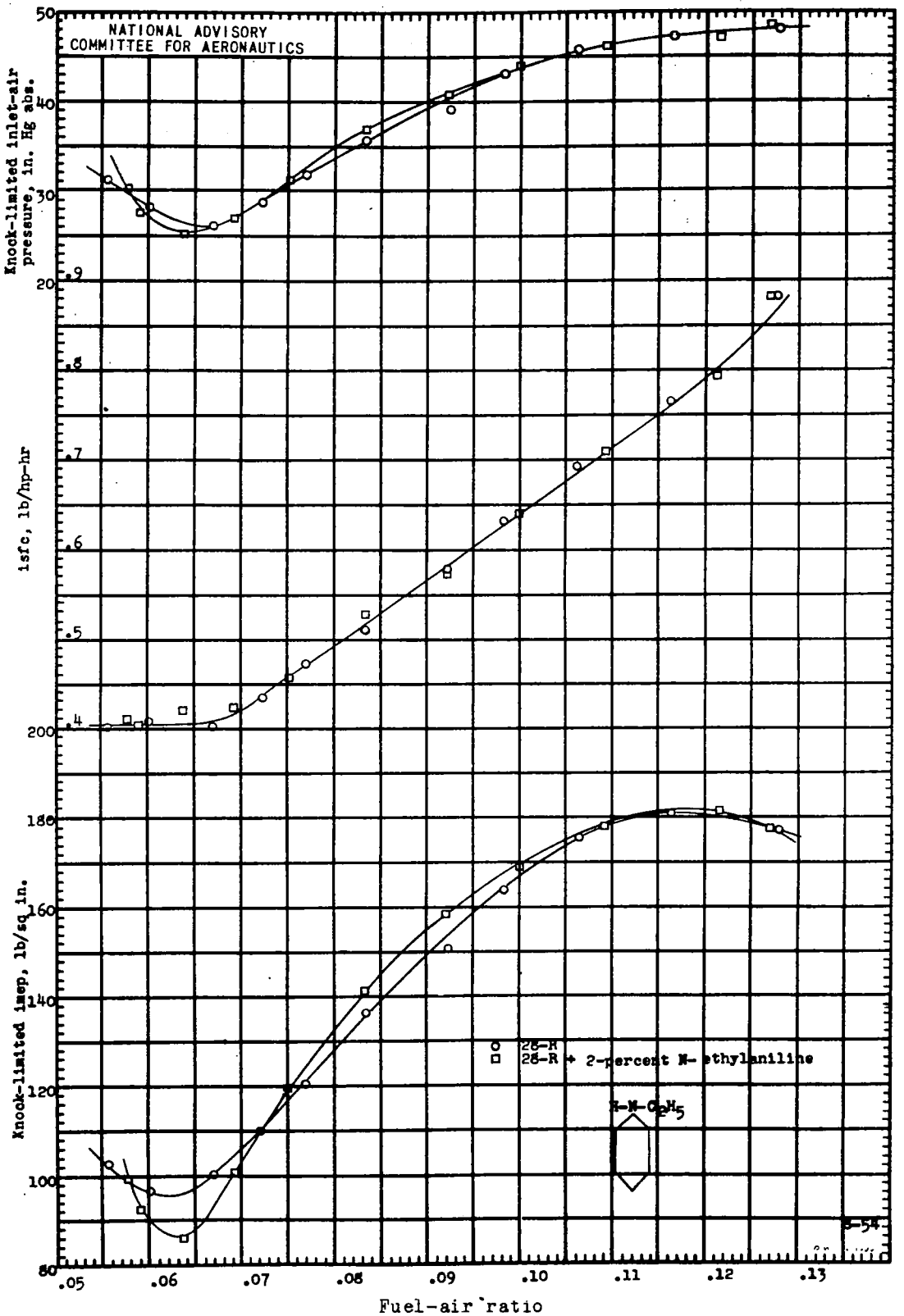
Figure 1. - Continued. Effect of addition of 2-percent 2,4-xylidine to 28-R fuel on knock-limited performance of a CFR engine. Engine speed, 1800 rpm; compression ratio, 7.0; oil temperature, 165° F.



Fuel-air ratio

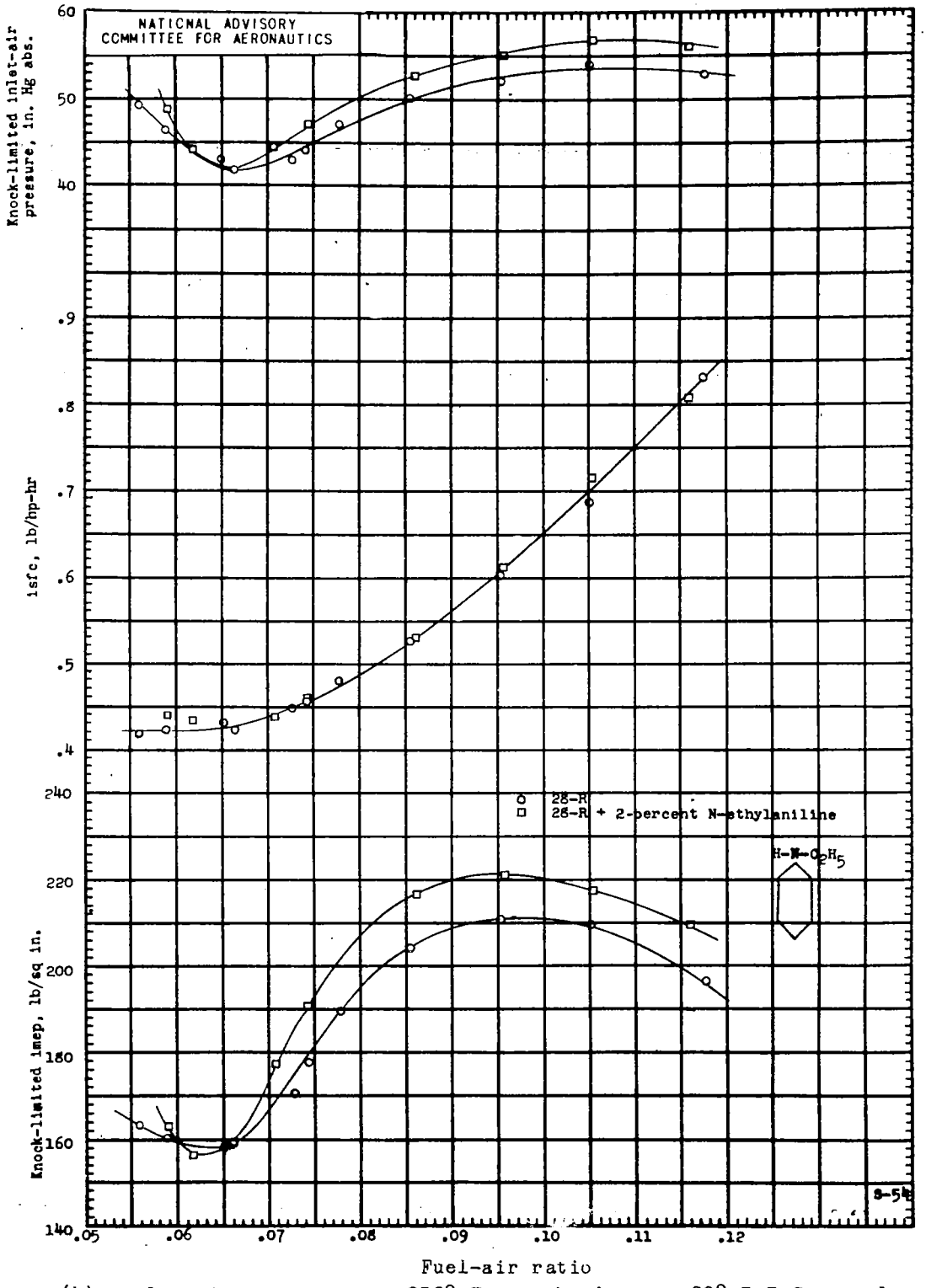
(c) Inlet-air temperature, 150° F; spark advance, 30° B.T.C.; coolant temperature, 250° F.

Figure 1. - Concluded. Effect of addition of 2-percent 2,4-xylidine to 28-R fuel on knock-limited performance of a CFR engine. Engine speed, 1800 rpm; compression ratio, 7.0; oil temperature, 165° F.



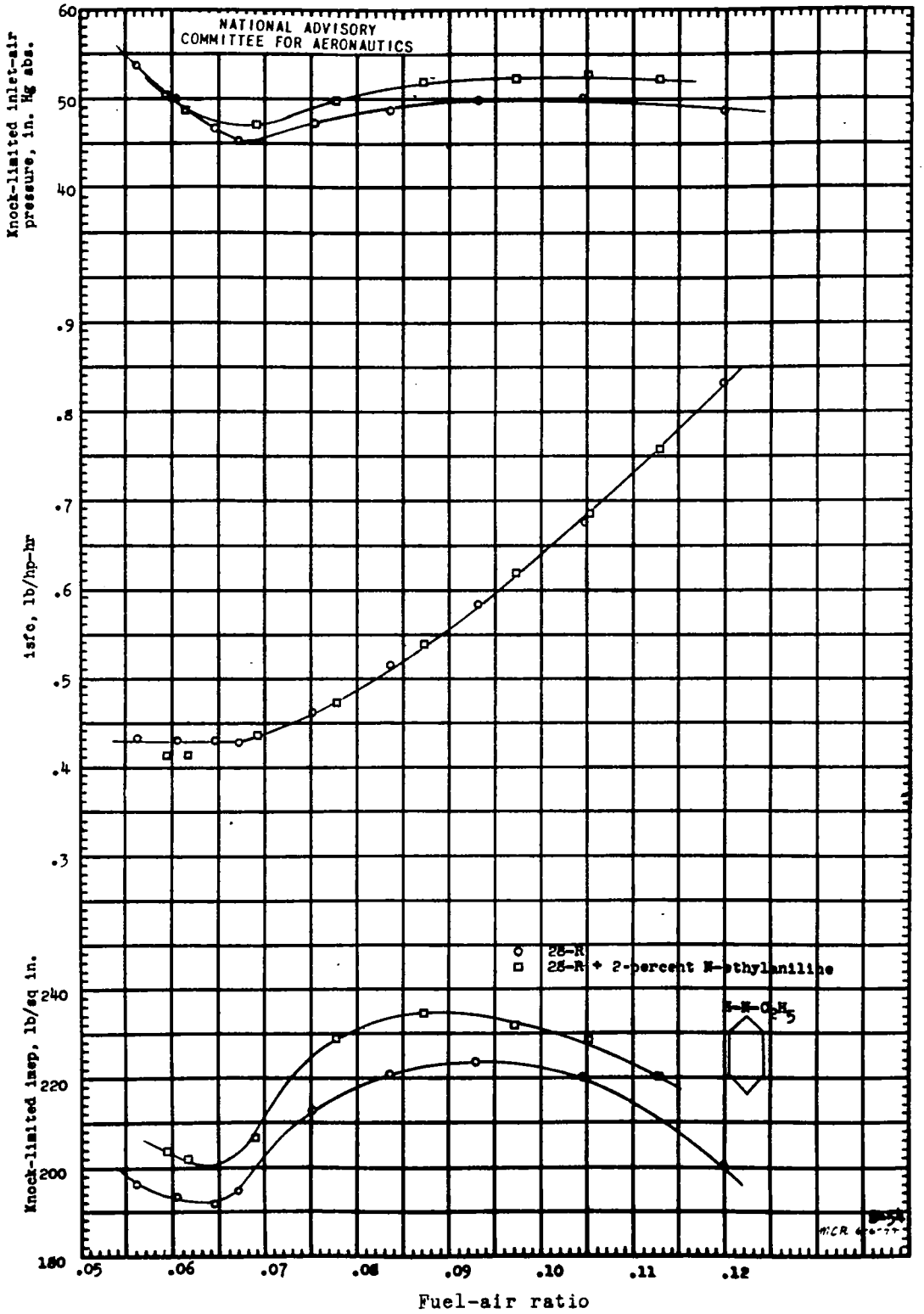
(a) Inlet-air temperature, 225° F; spark advance, 45° B.T.C.; coolant temperature, 375° F.

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



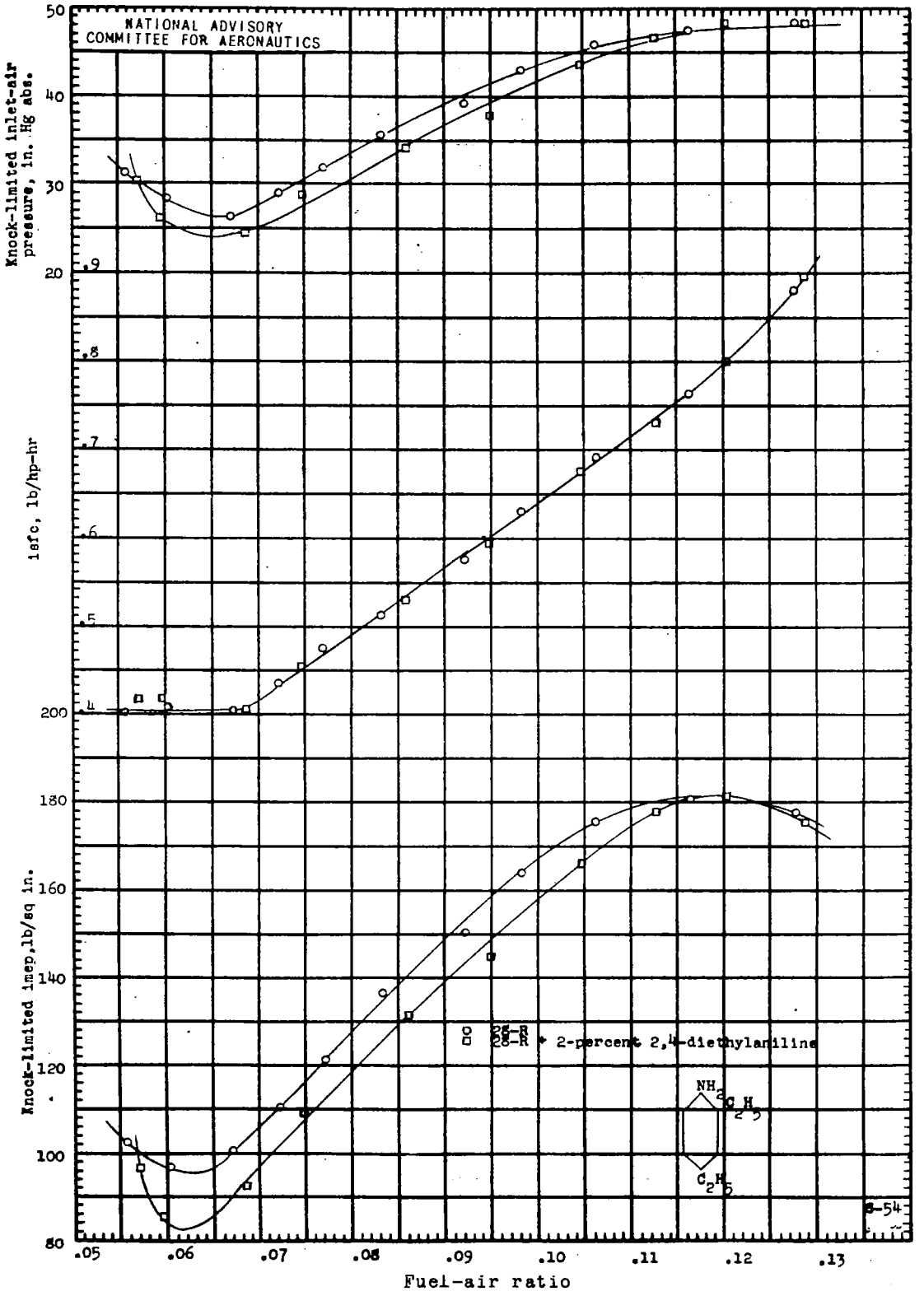
(b) Inlet-air temperature, 250° F; spark advance, 30° B.T.C.; coolant temperature, 250° F.

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



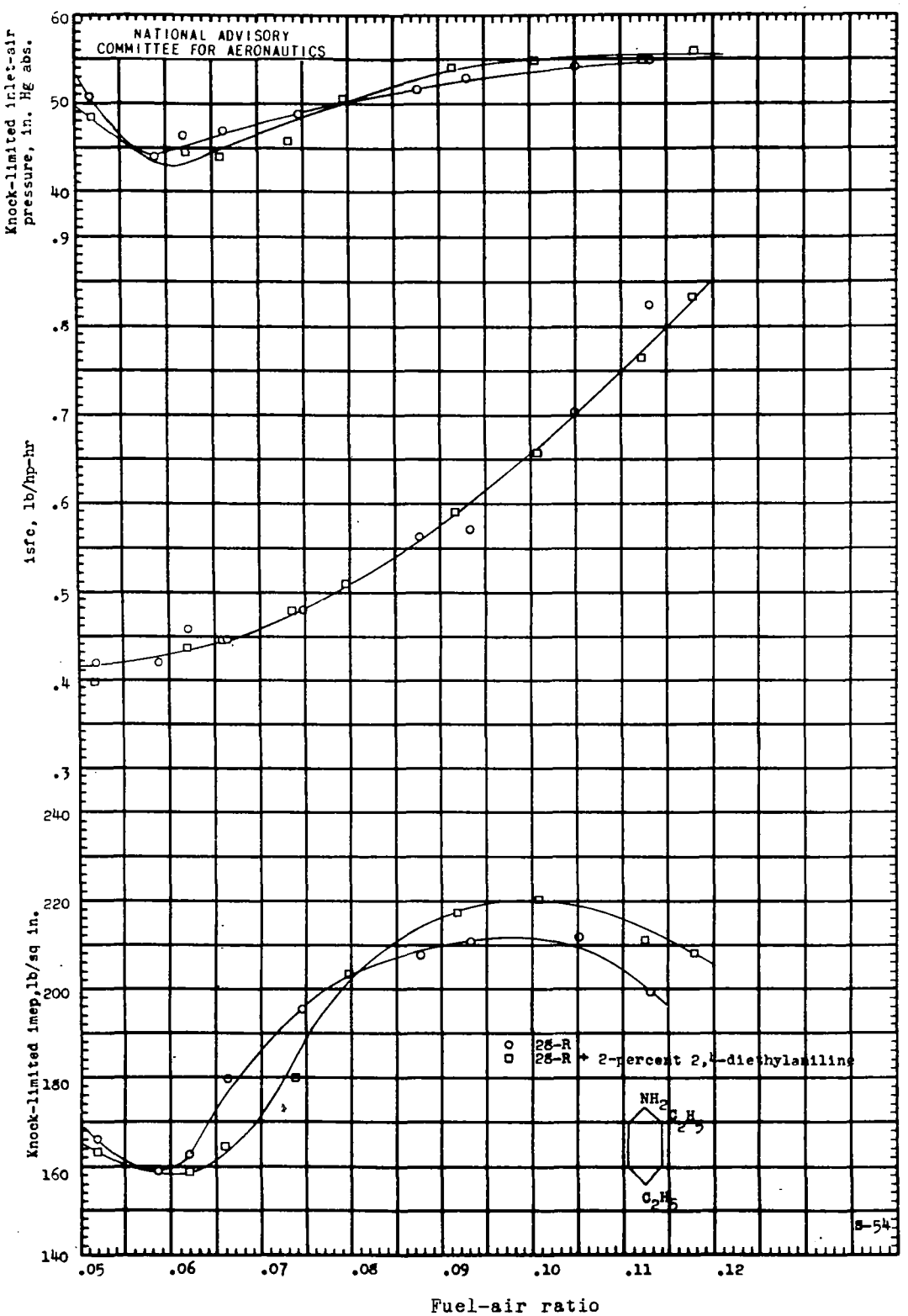
(c) Inlet-air temperature, 150° F; spark advance, 30° B.T.C.; coolant temperature, 250° F.

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



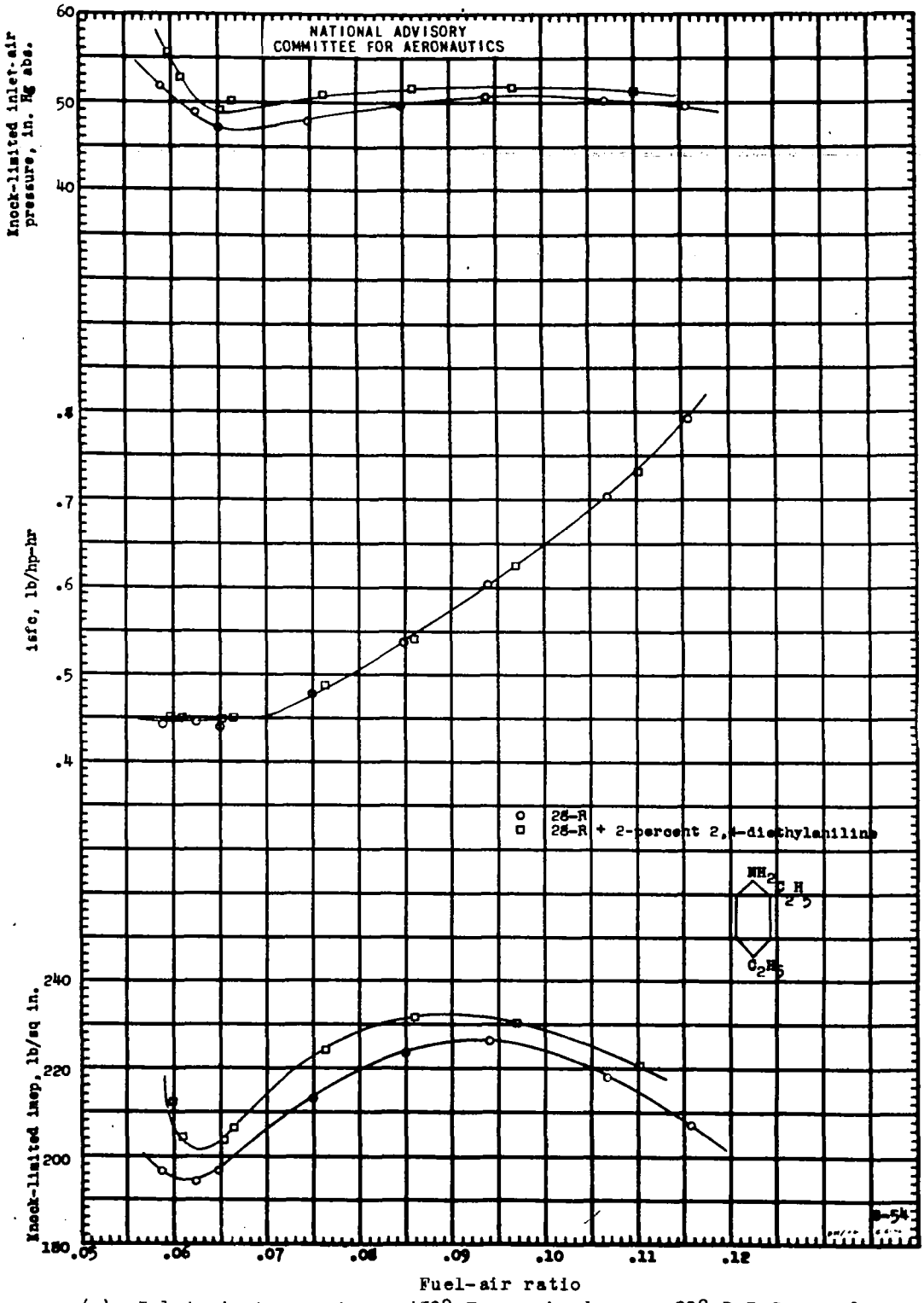
(a) Inlet-air temperature, 225° F; spark advance, 45° B.T.C.; coolant temperature, 375° F.

Figure 3. - Effect of addition of 2-percent 2,4-diethylaniline to 28-R fuel on knock-limited performance of a CFR engine. Engine speed, 1800 rpm; compression ratio, 7.0; oil temperature, 185° F.



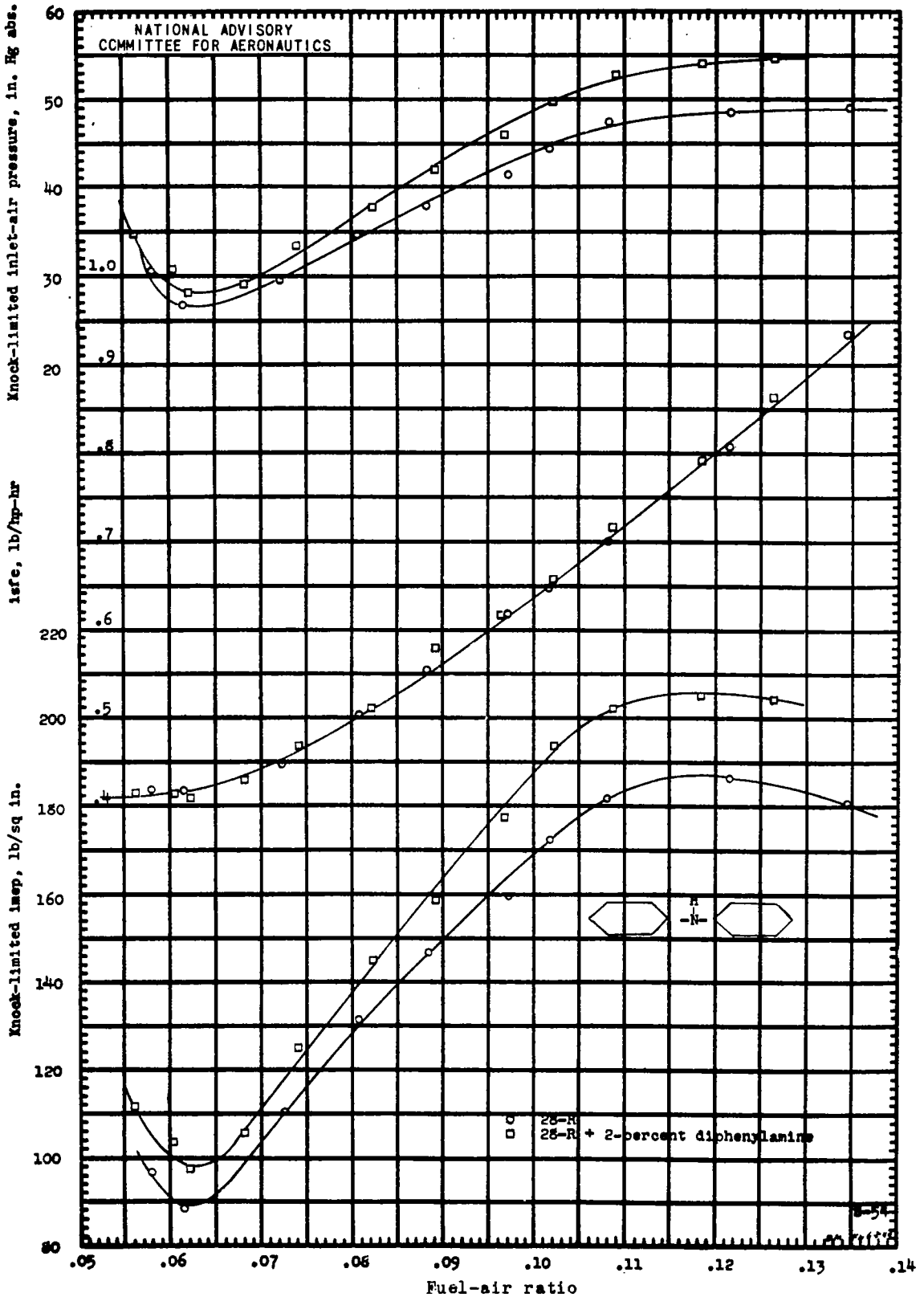
(b) Inlet-air temperature, 250° F; spark advance, 30° B.T.C.; coolant temperature, 250° F.

Figure 3. - Continued. Effect of addition of 2-percent 2,4-diethylaniline to 28-R fuel on knock-limited performance of a CFR engine. Engine speed, 1800 rpm; compression ratio, 7.0; oil temperature, 165° F.



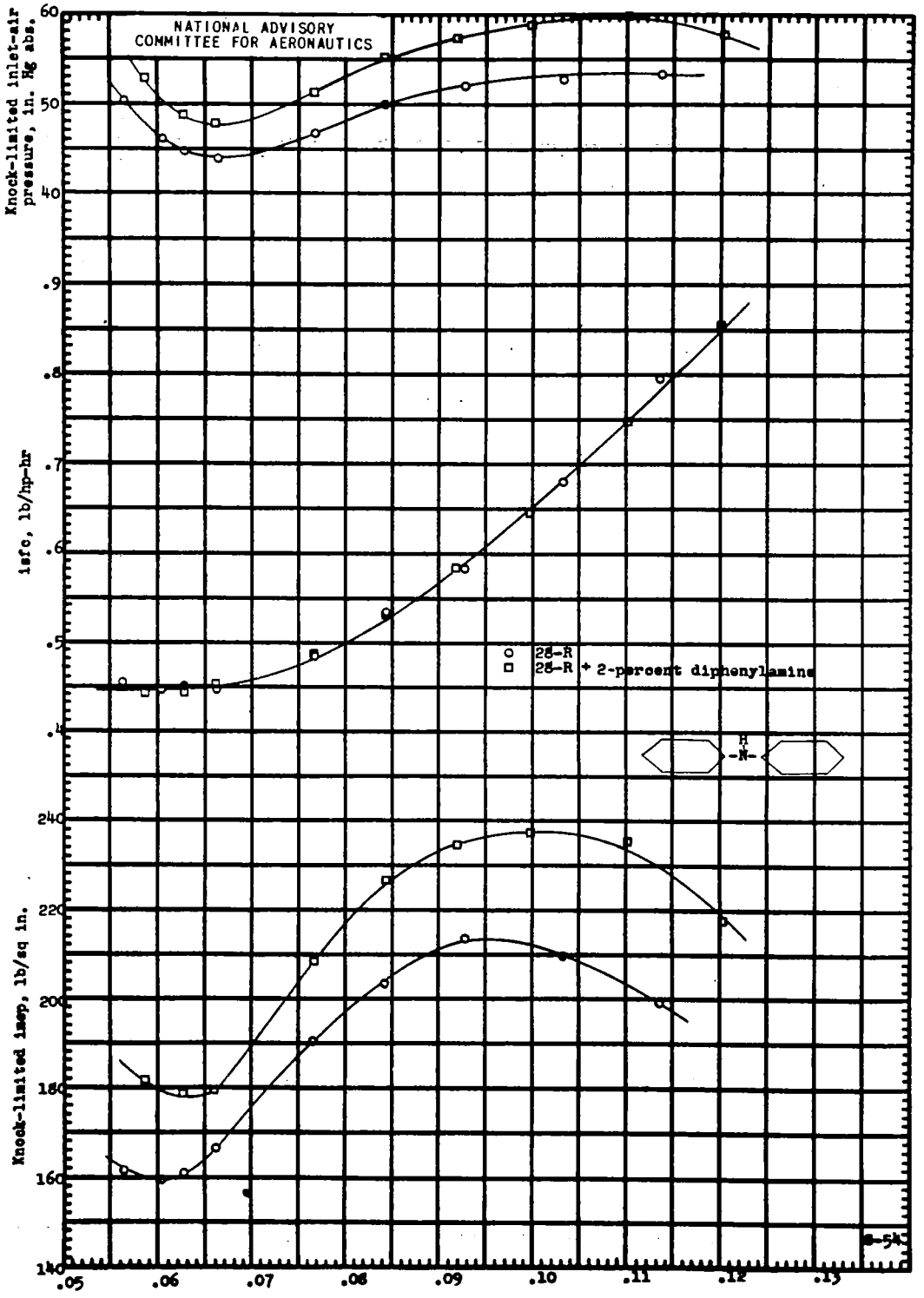
(c) Inlet-air temperature, 150° F; spark advance, 30° B.T.C.; coolant temperature, 250° F.

Figure 3. - Concluded. Effect of addition of 2-percent 2,4-diethylaniline to 28-R fuel on knock-limited performance of a CFR engine. Engine speed, 1800 rpm; compression ratio, 7.0; oil temperature, 165° F.



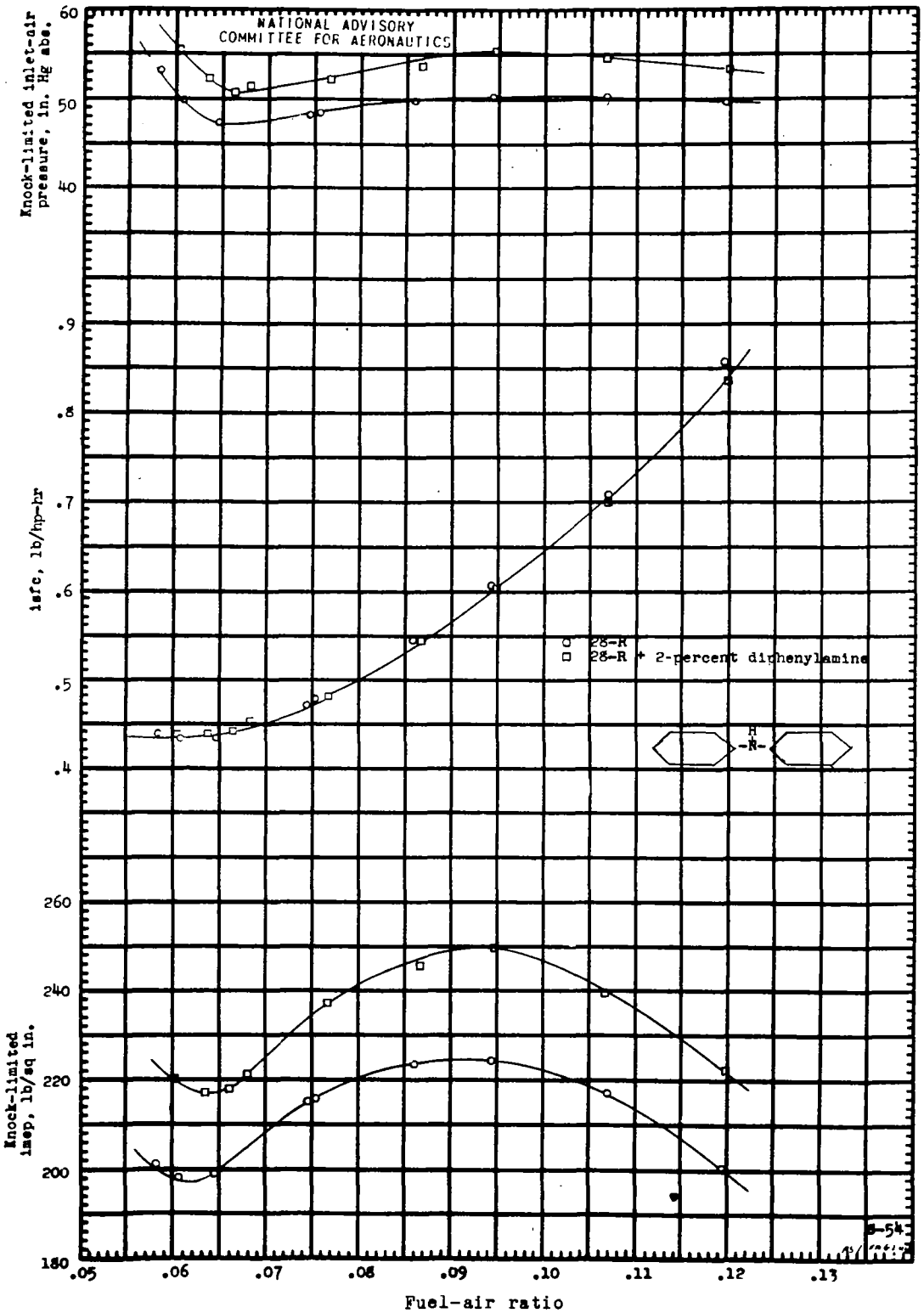
(a) Inlet-air temperature, 225° F; spark advance, 45° B.T.C.; coolant temperature, 375° F.

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



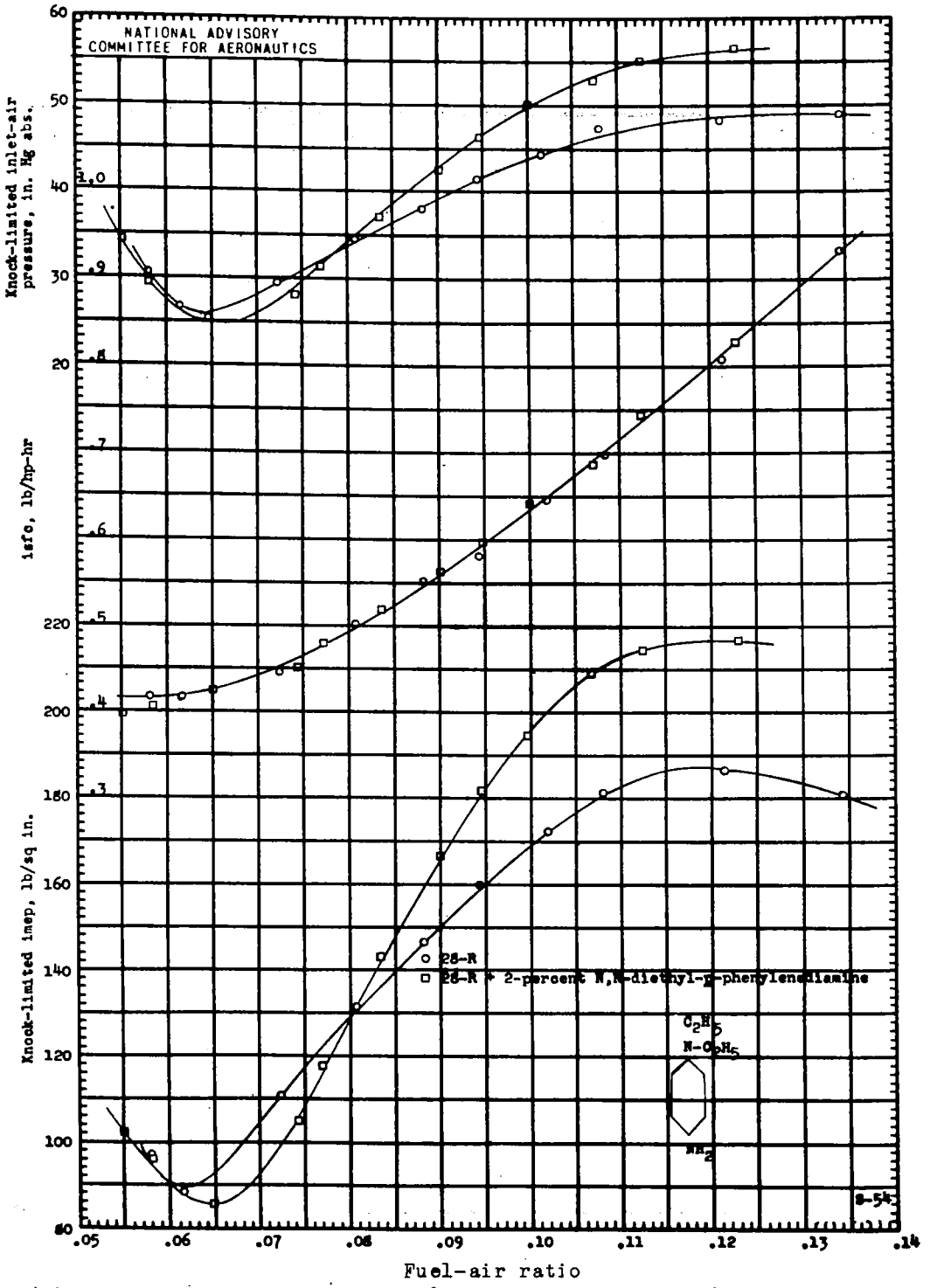
(b) Inlet-air temperature, 250° F; spark advance, 30° B.T.C.; coolant temperature, 250° F.

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



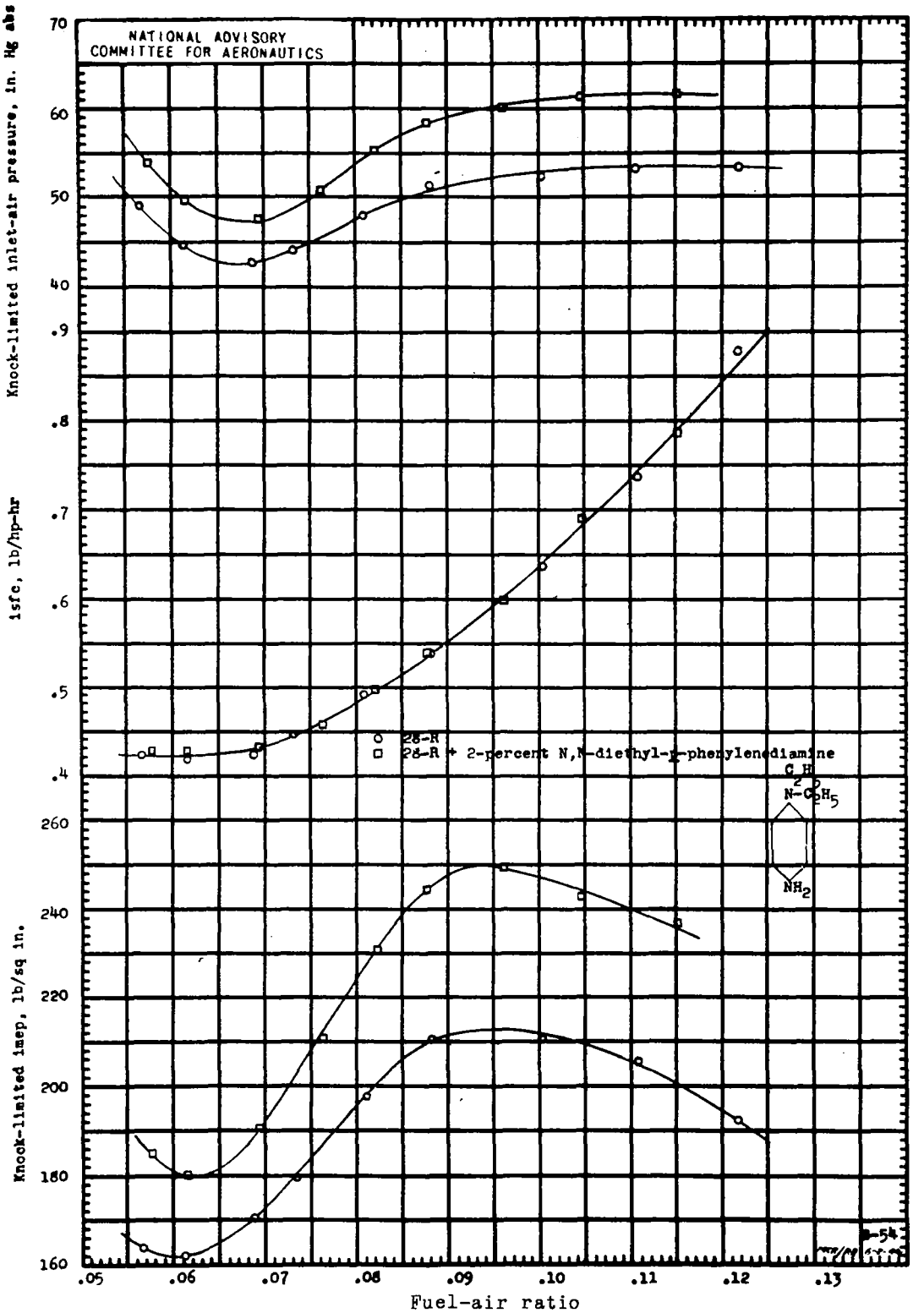
(c) Inlet-air temperature, 150° F; spark advance, 30° B.T.C.; coolant temperature, 250° F.

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



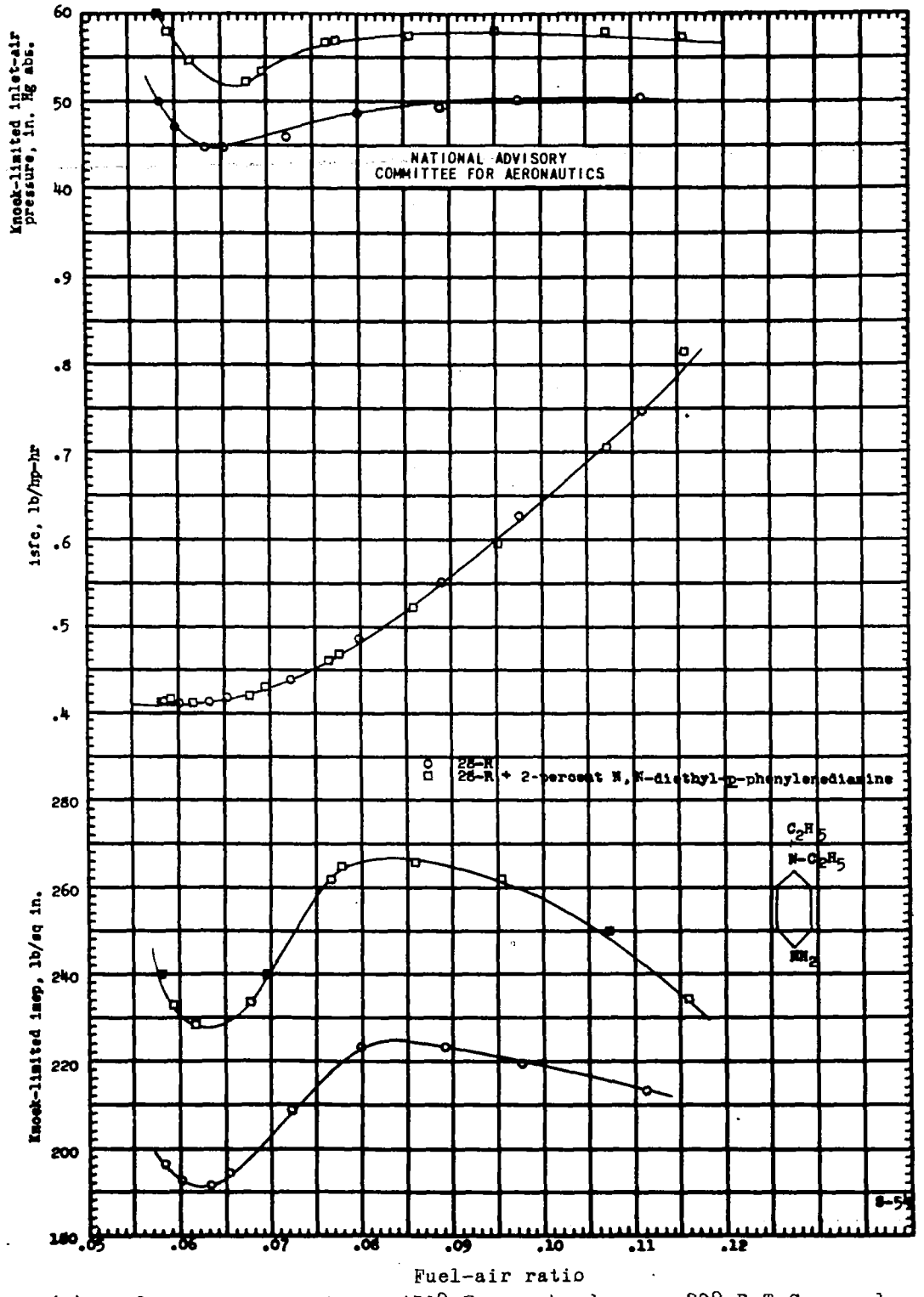
(a) Inlet-air temperature, 225° F; spark advance, 45° B.T.C.; coolant temperature, 375° F.

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



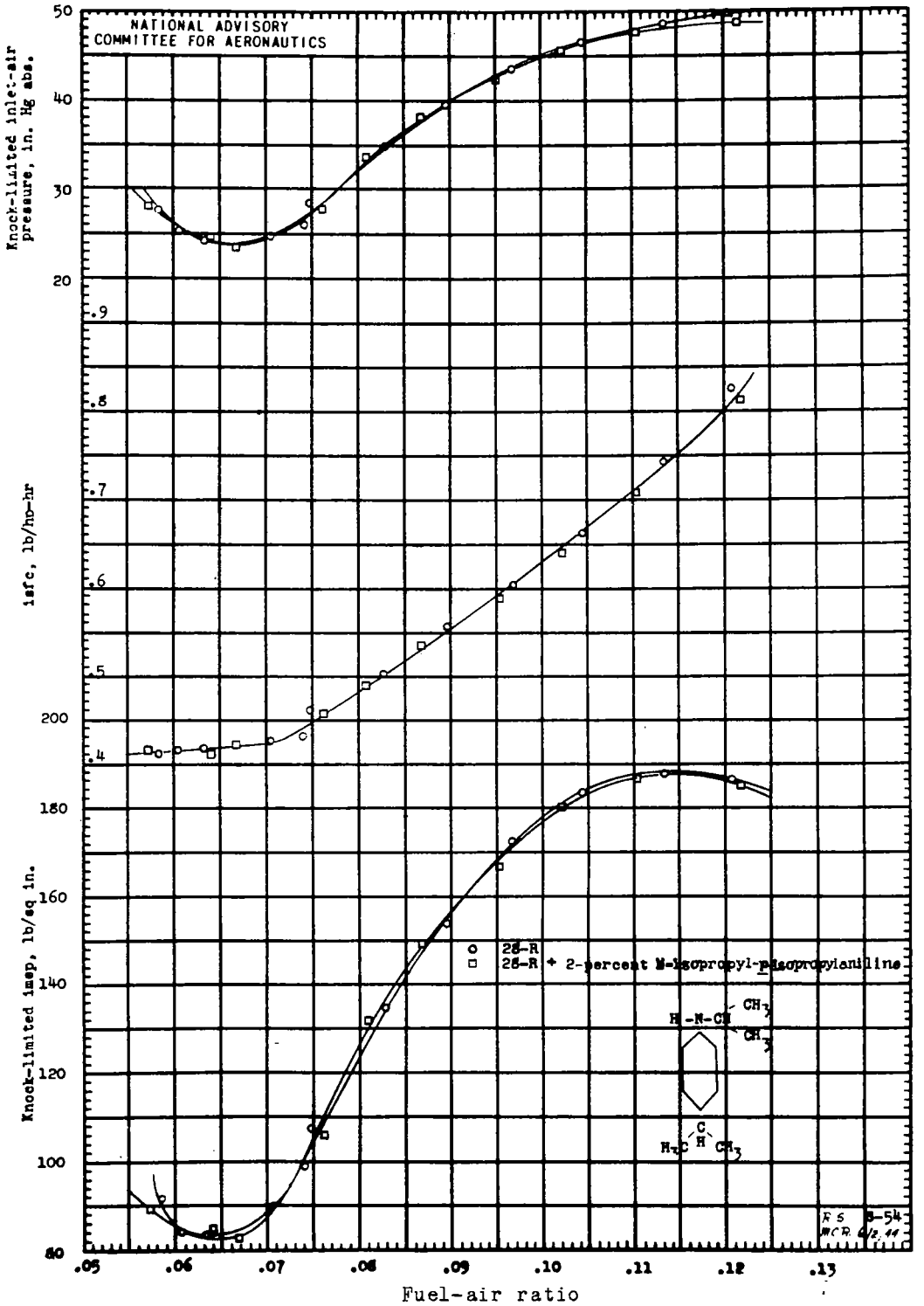
(b) Inlet-air temperature, 250° F; spark advance, 30° B.T.C.; coolant temperature, 250° F.

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



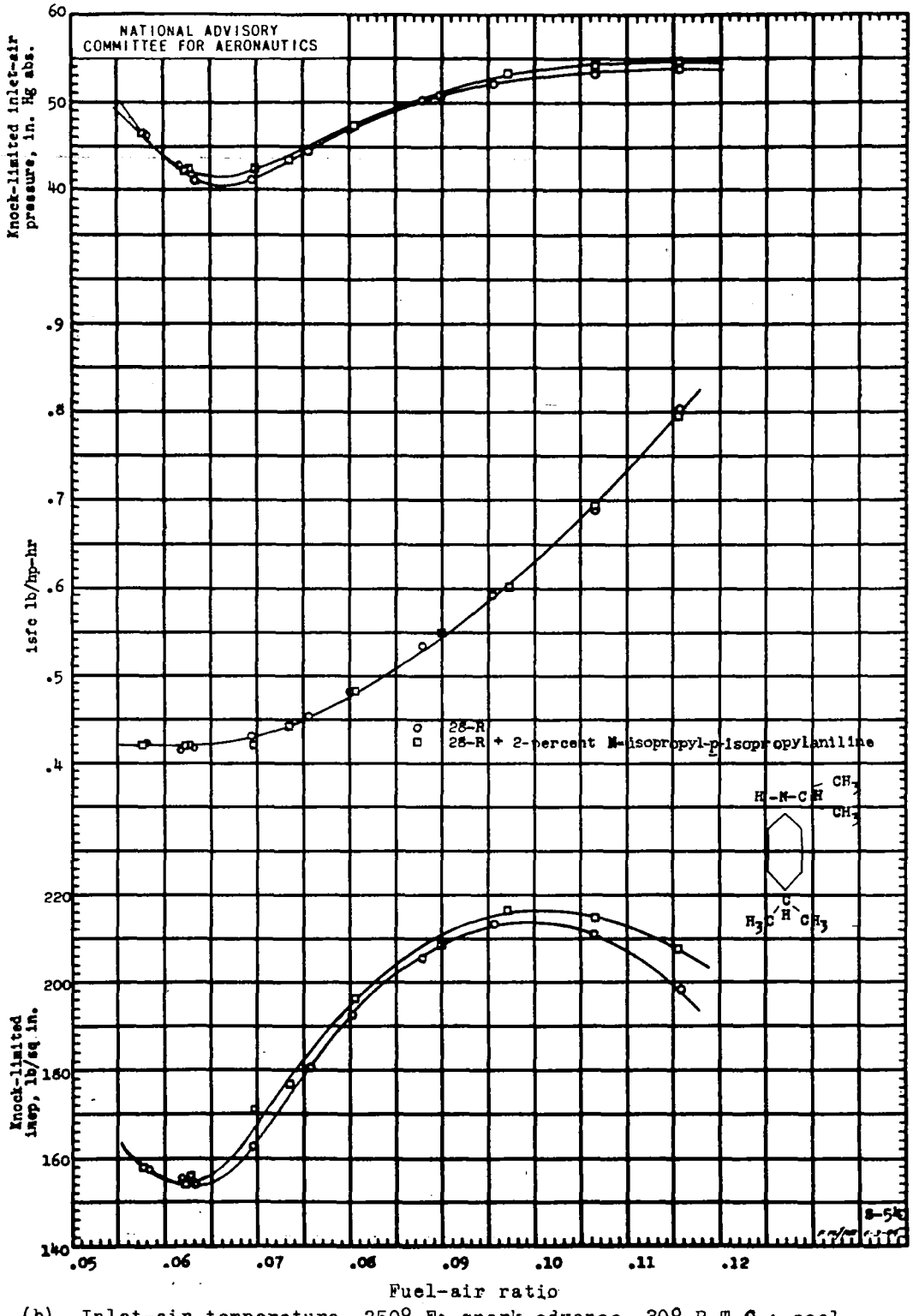
(c) Inlet-air temperature, 150° F; spark advance, 30° B.T.C.; coolant temperature, 250° F.

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



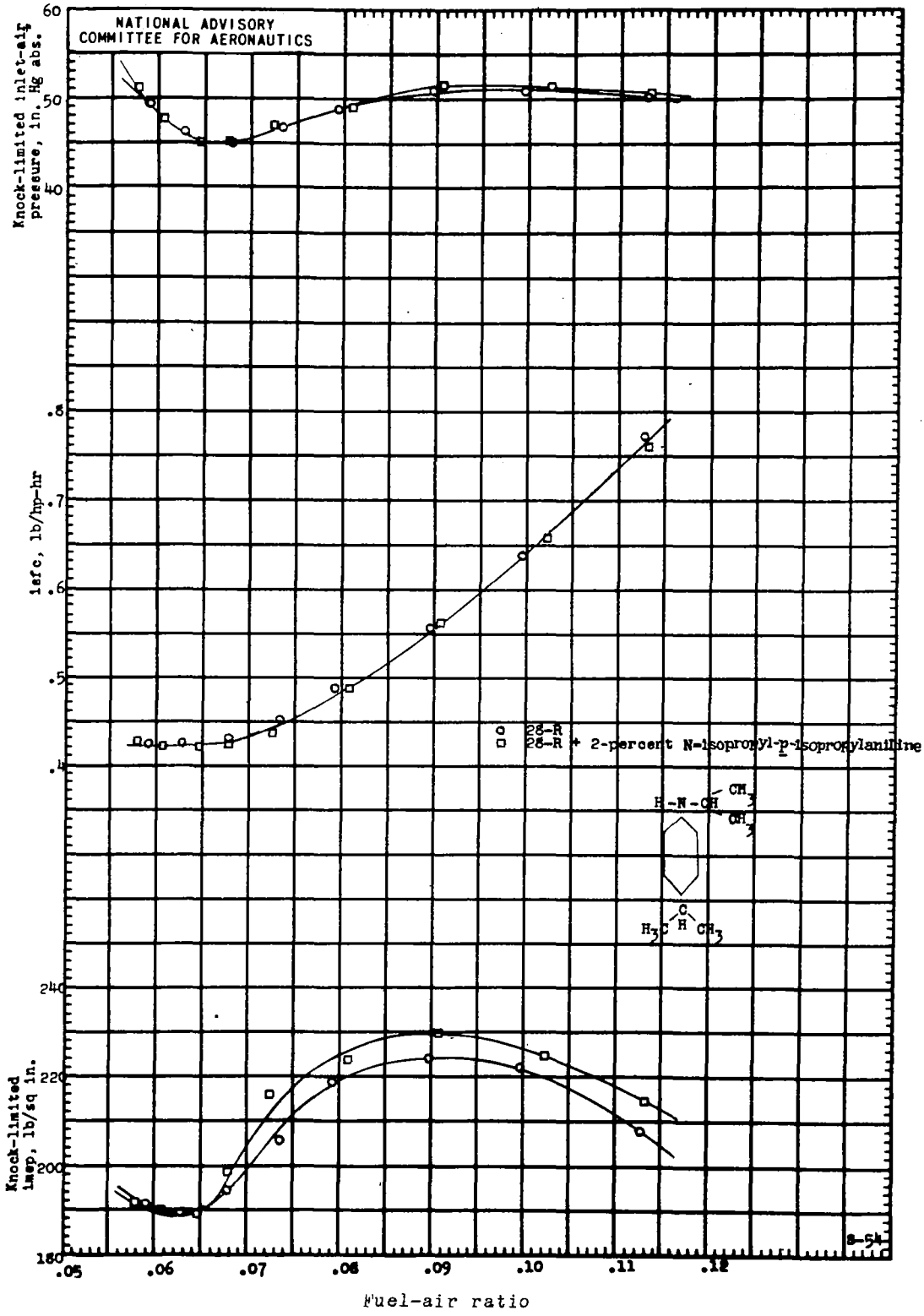
(a) Inlet-air temperature, 225° F; spark advance, 45° B.T.C.; coolant temperature, 375° F.

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

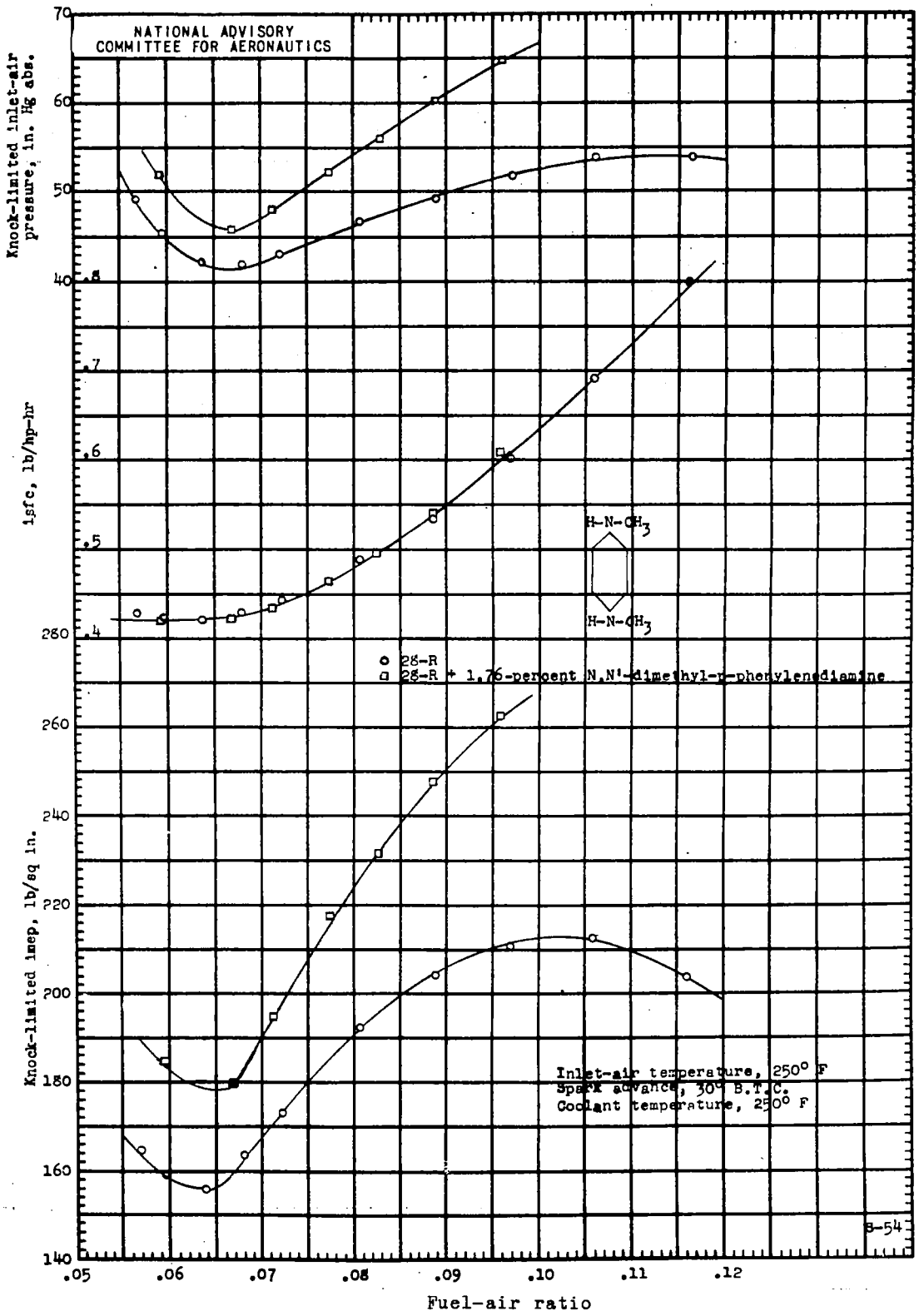
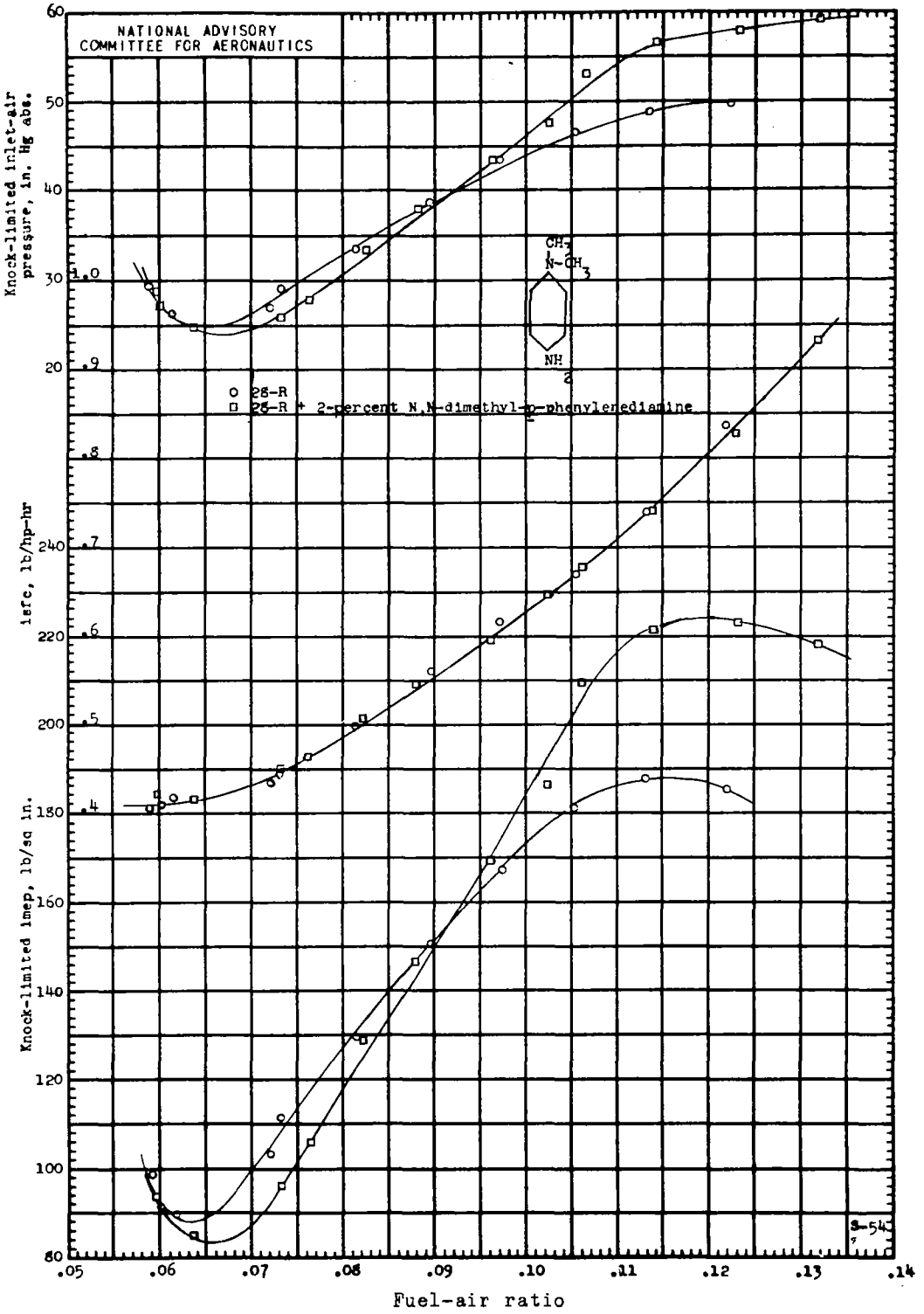
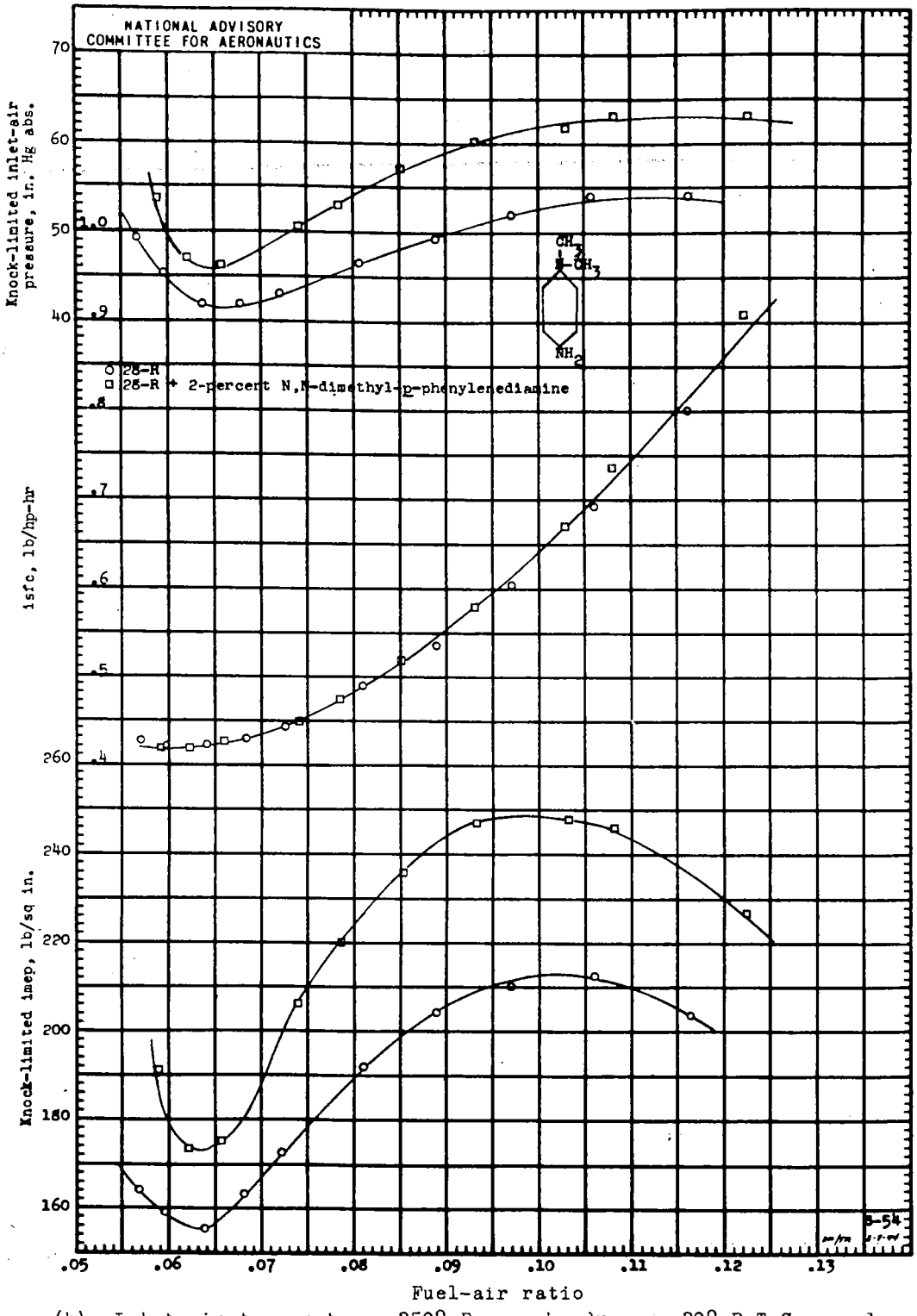


Figure 7. - Effect of addition of 1.76-percent N,N'-dimethyl-p-phenylenediamine to 28-R fuel on knock-limited performance of a CFR engine. Inlet-air temperature, 250° F; spark advance, 30° B.T.C.; coolant temperature, 250° F; engine speed, 1800 rpm; compression ratio, 7.0; oil temperature, 165° F.



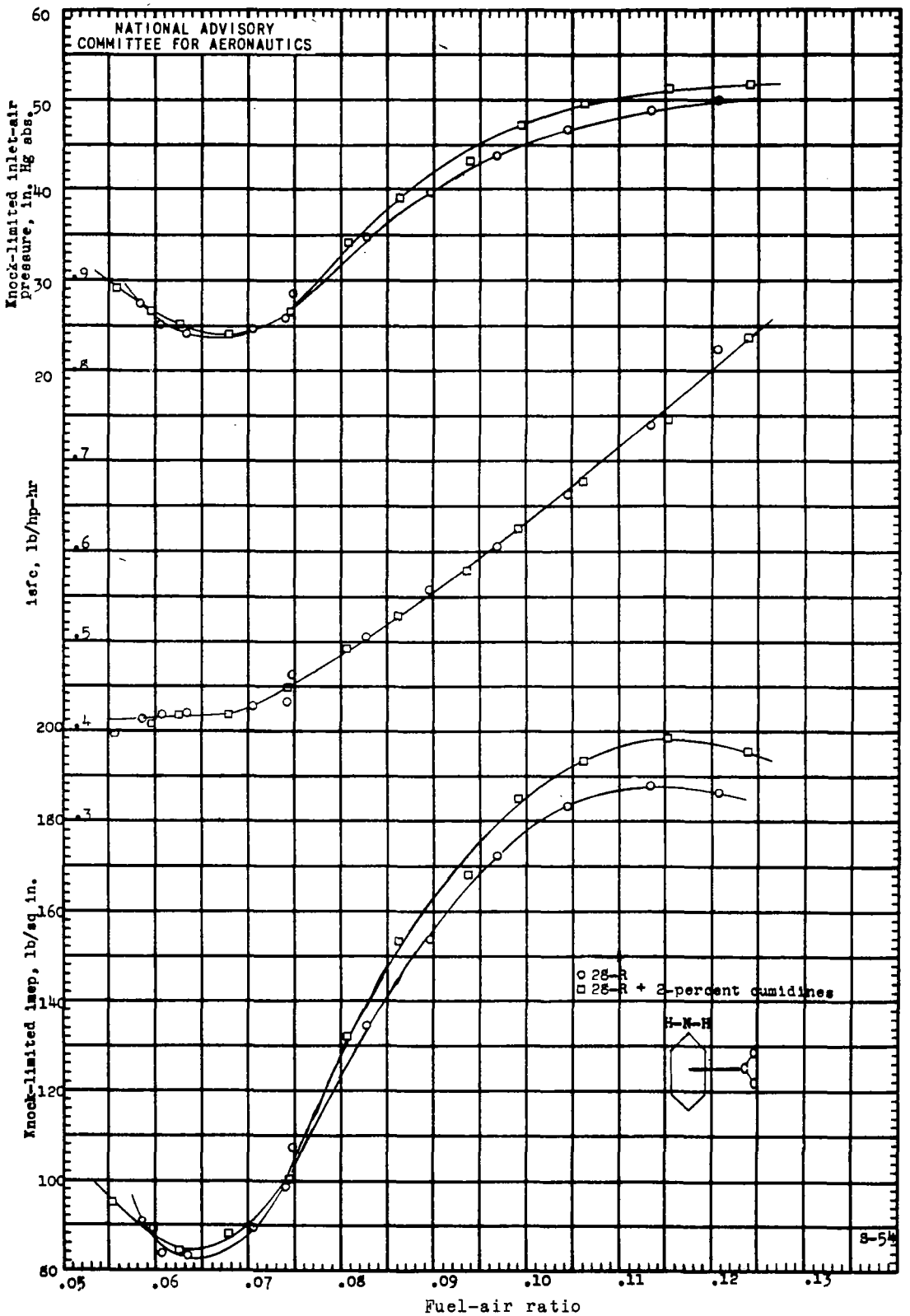
(a) Inlet-air temperature, 225° F; spark advance, 45° B.T.C.; coolant temperature, 375° F.

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



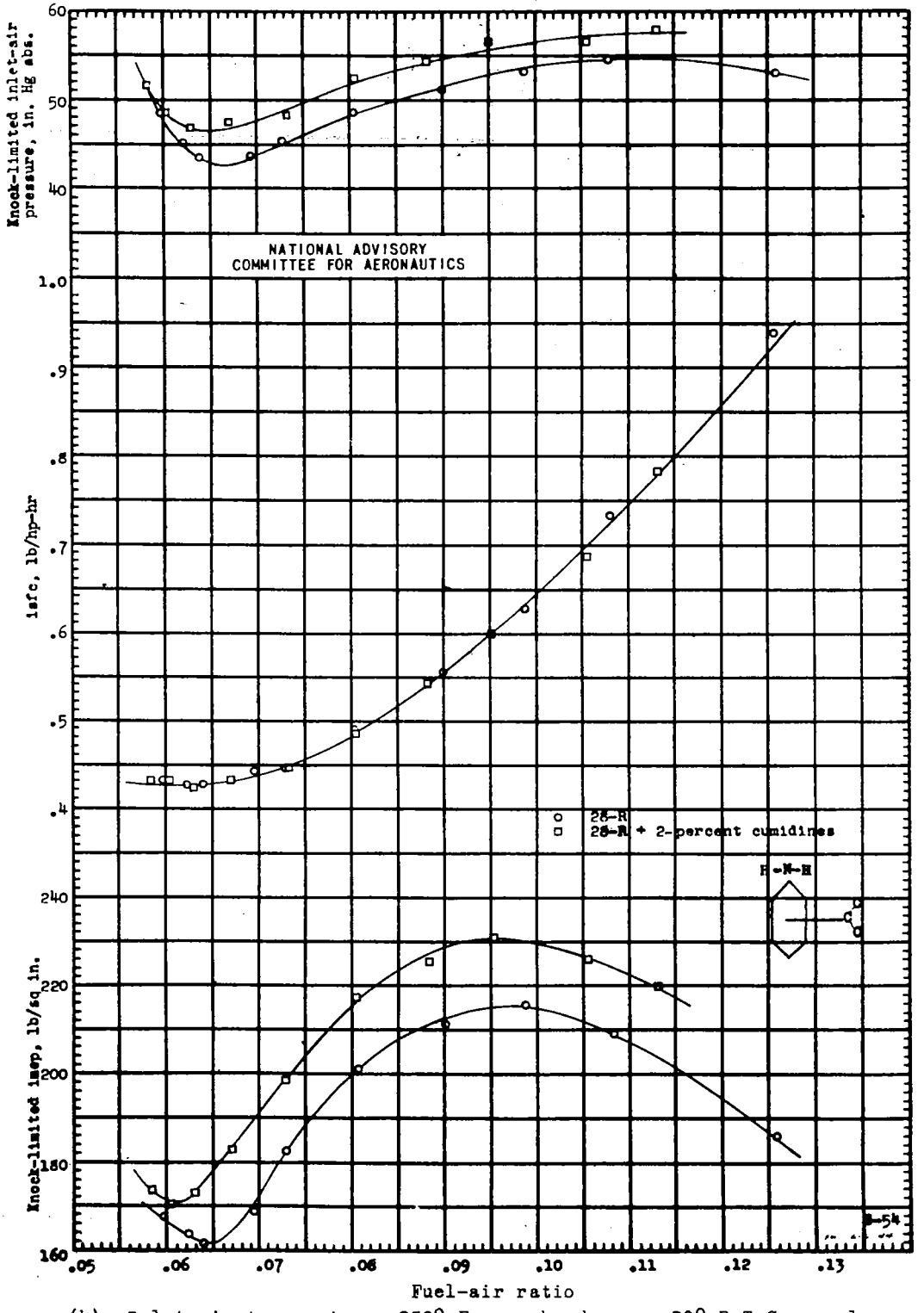
(b) Inlet-air temperature, 250° F; spark advance, 30° B.T.C.; coolant temperature, 250° F.

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



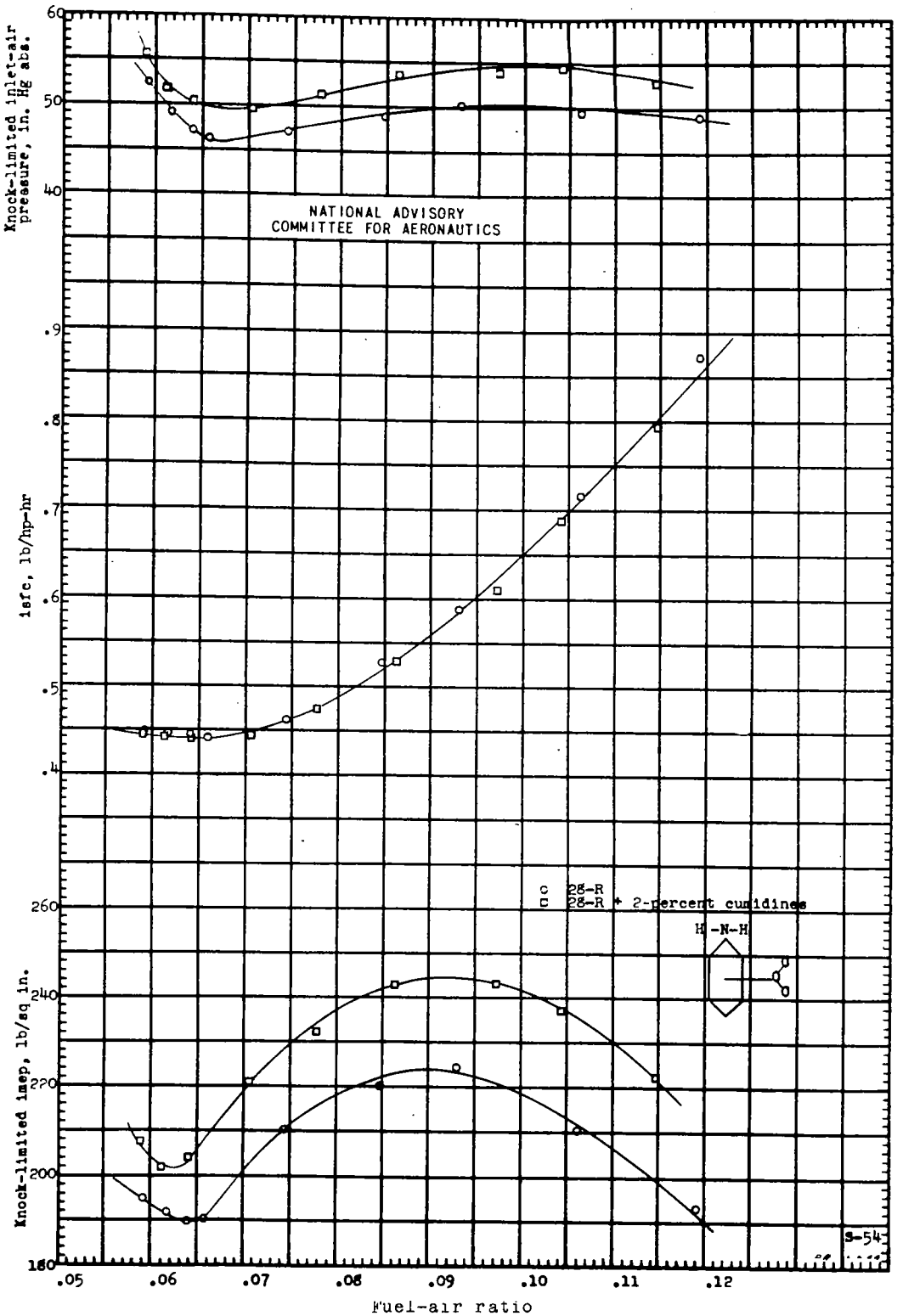
(a) Inlet-air temperature, 225° F; spark advance, 45° B.T.C.; coolant temperature, 375° F.

Figure 9. - Effect of addition of 2-percent cumidines (from refinery cumene) to 28-R fuel on knock-limited performance of a CFR engine. Engine speed, 1800 rpm; compression ratio, 7.0; oil temperature, 165° F.



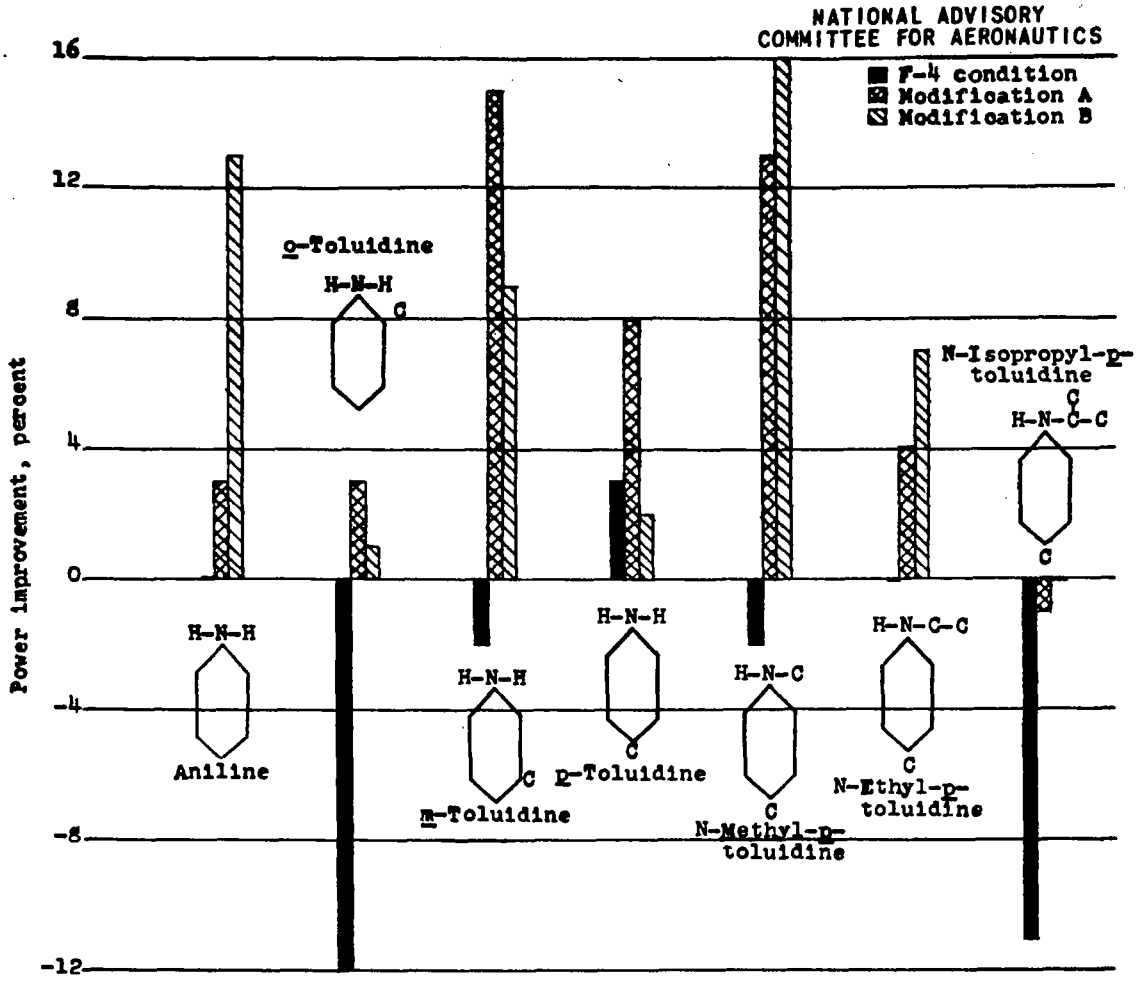
(b) Inlet-air temperature, 250° F; spark advance, 30° B.T.C.; coolant temperature, 250° F.

Figure 9. - Continued. Effect of addition of 2-percent cumidines (from refinery cumene) to 28-R fuel on knock-limited performance of a CFR engine. Engine speed, 1800 rpm; compression ratio, 7.0; oil temperature, 165° F.



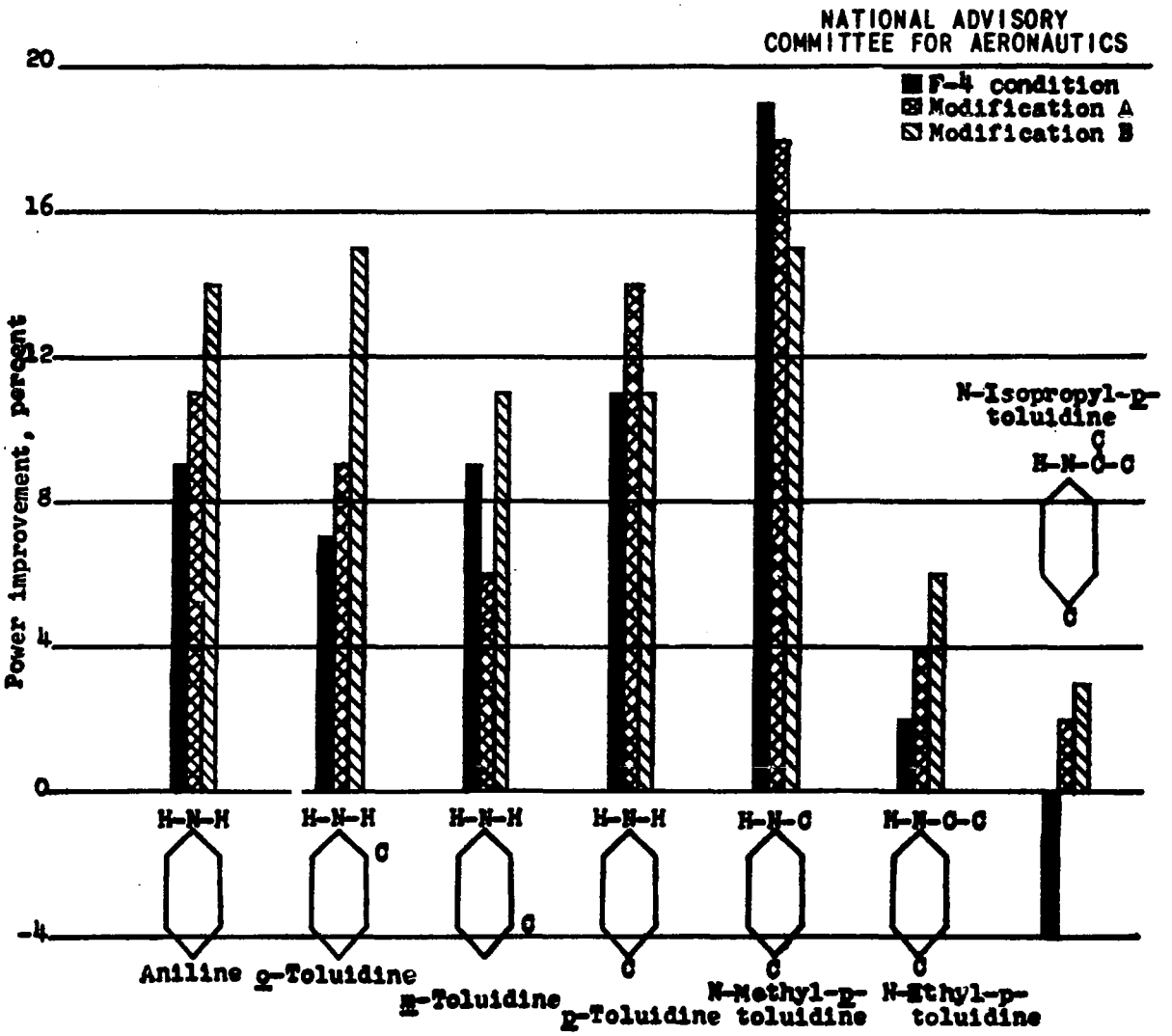
(c) Inlet-air temperature, 150° F; spark advance, 30° B.T.C.; coolant temperature, 250° F.

Figure 9. - Concluded. Effect of addition of 2-percent cumidines (from refinery cumene) to 28-R fuel on knock-limited performance of a CFR engine. Engine speed, 1800 rpm; compression ratio, 7.0; oil temperature, 165° F.



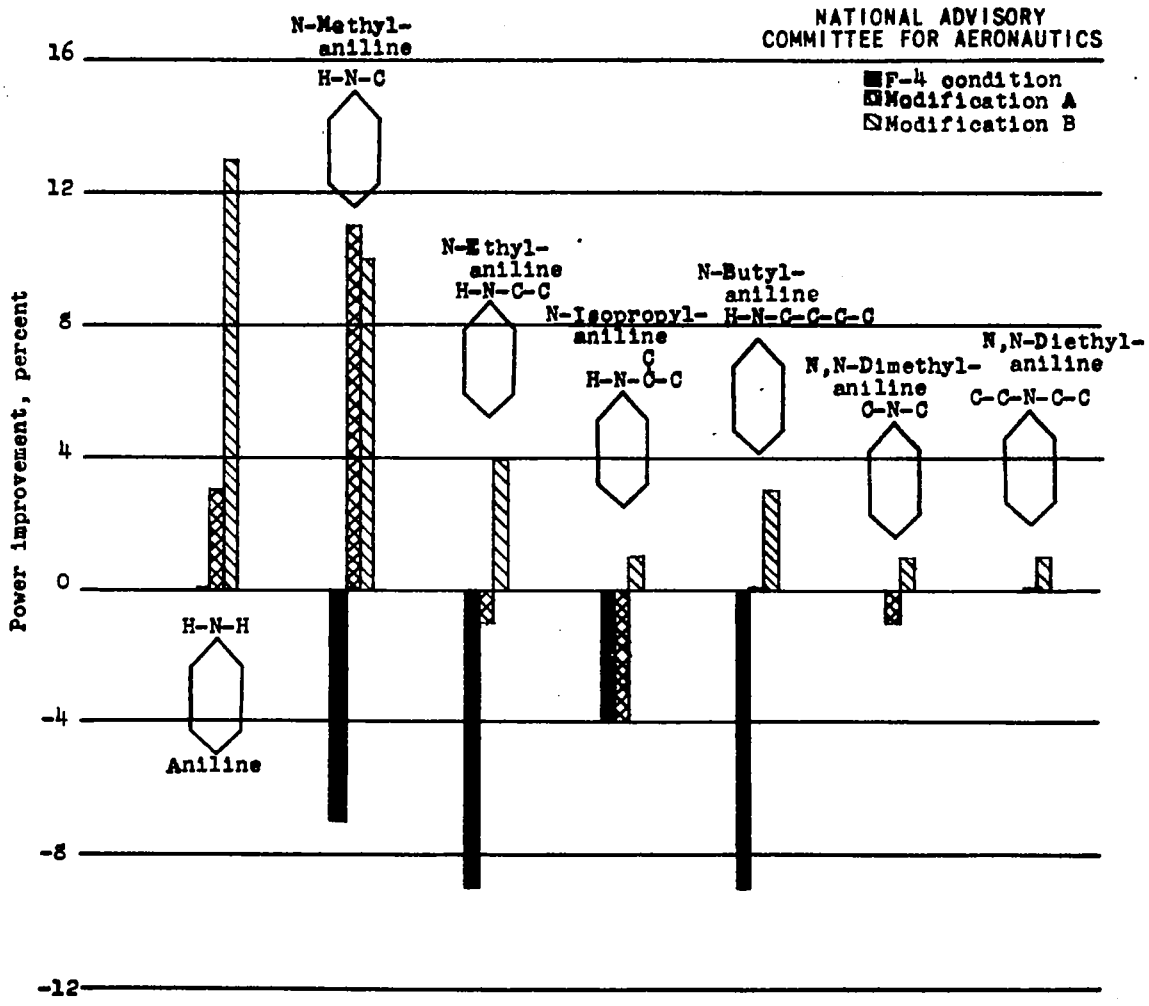
(a) Fuel-air ratio, 0.062.

Figure 10. - Effect of toluidines and aniline on knock-limited performance of AN-F-28 fuel. (Data from references 1 and 2.)



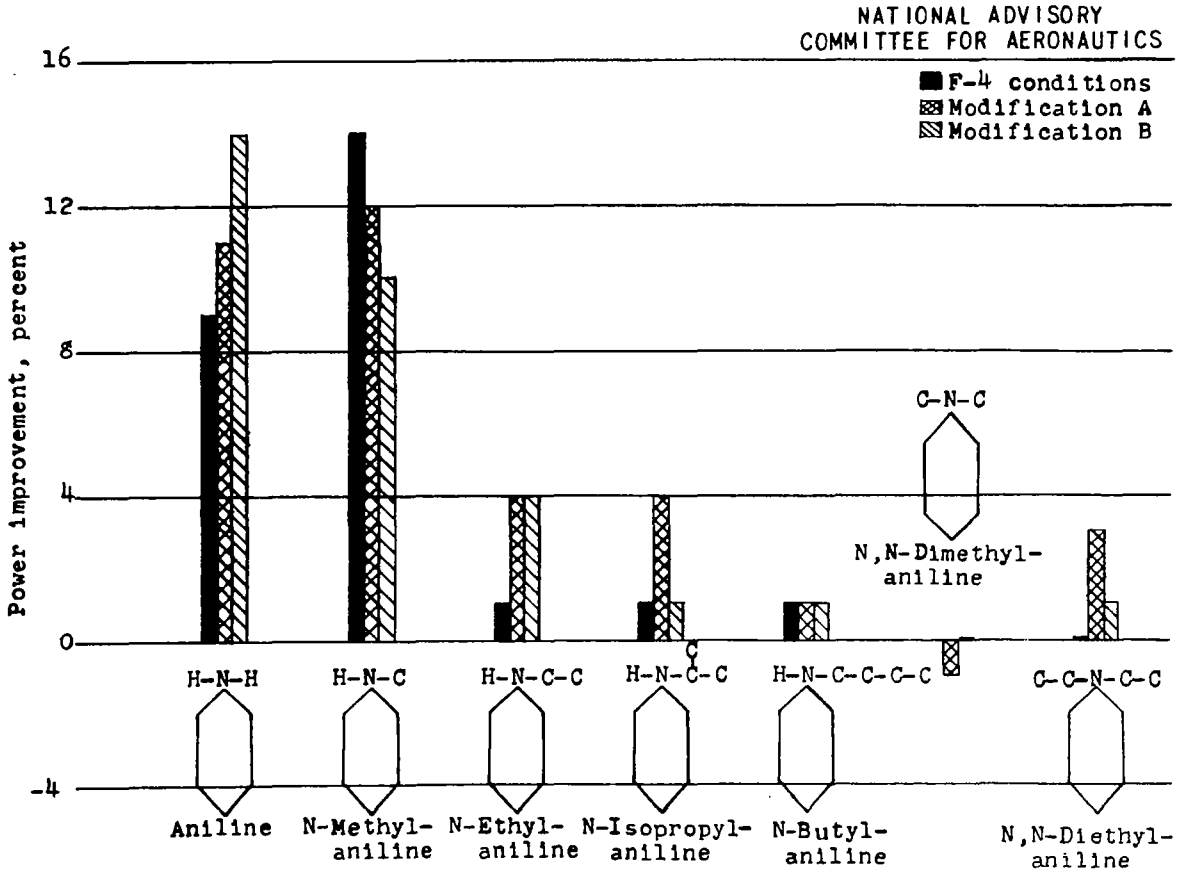
(b) Fuel-air ratio, 0.110.

Figure 10. - Concluded. Effect of toluidines and aniline on knock-limited performance of AN-F-28 fuel. (Data from references 1 and 2.)



(a) Fuel-air ratio, 0.062.

Figure 11. - Effect of N-alkyl substitutions on aniline on knock-limited performance of AN-F-28 fuel. (Data from references 1 and 2 and from table 1 of this report.)



(b) Fuel-air ratio, 0.110.

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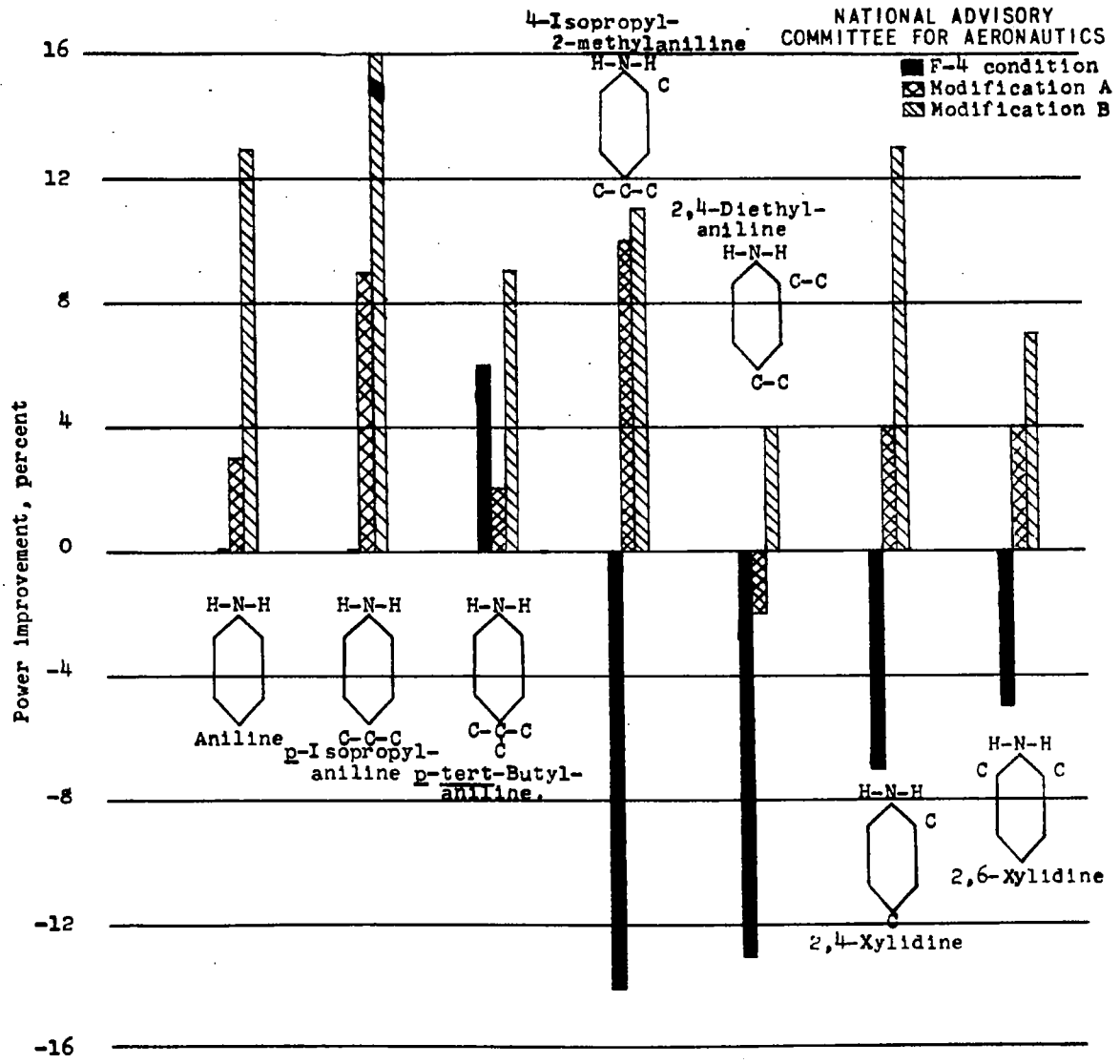
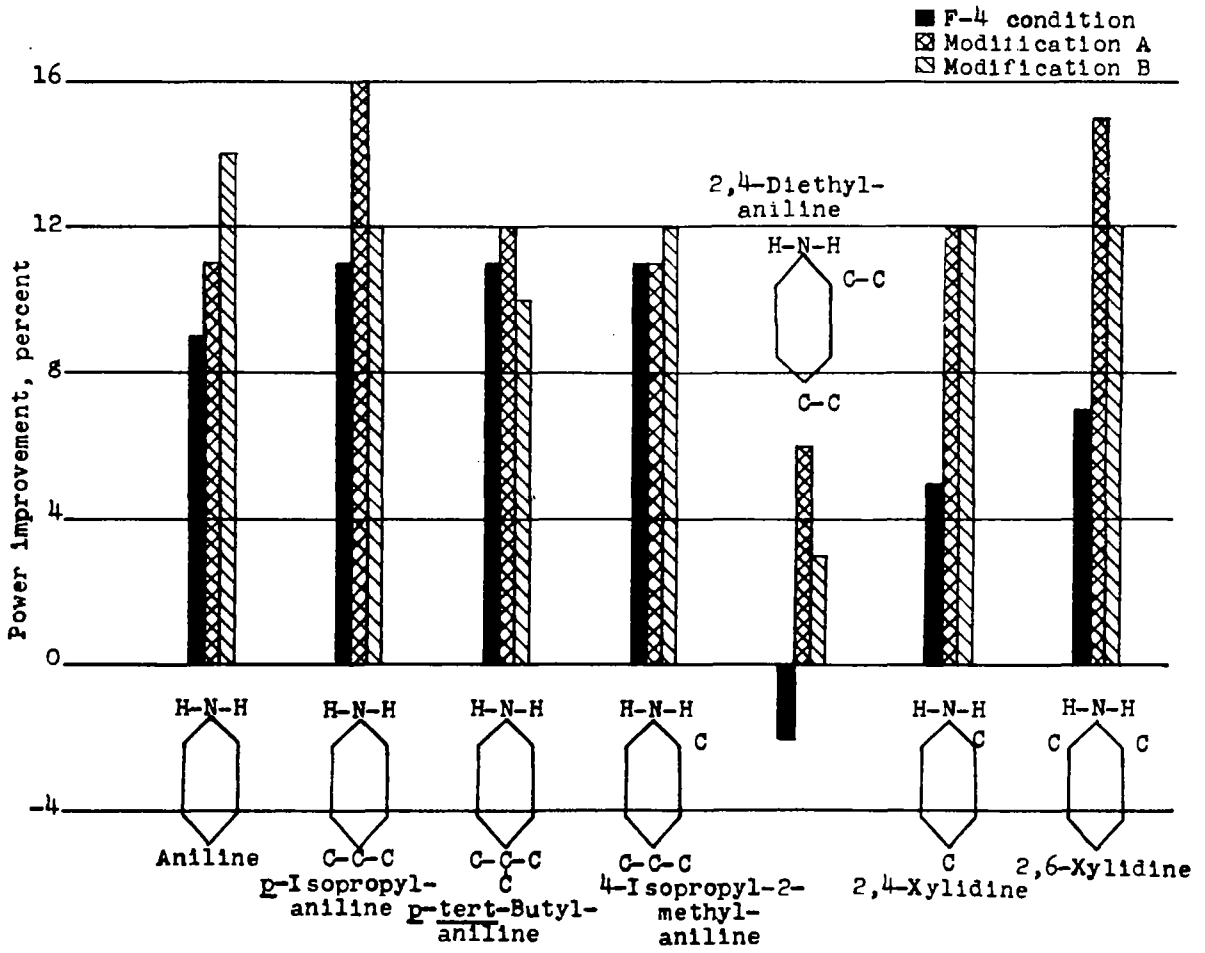


(a) Fuel-air ratio, 0.062.

Figure 12. - Effect of alkyl substitutions to the aromatic ring on knock-limited performance of AN-F-28 fuel. (Data from references 1 and 2 and from table 1 of this report.)



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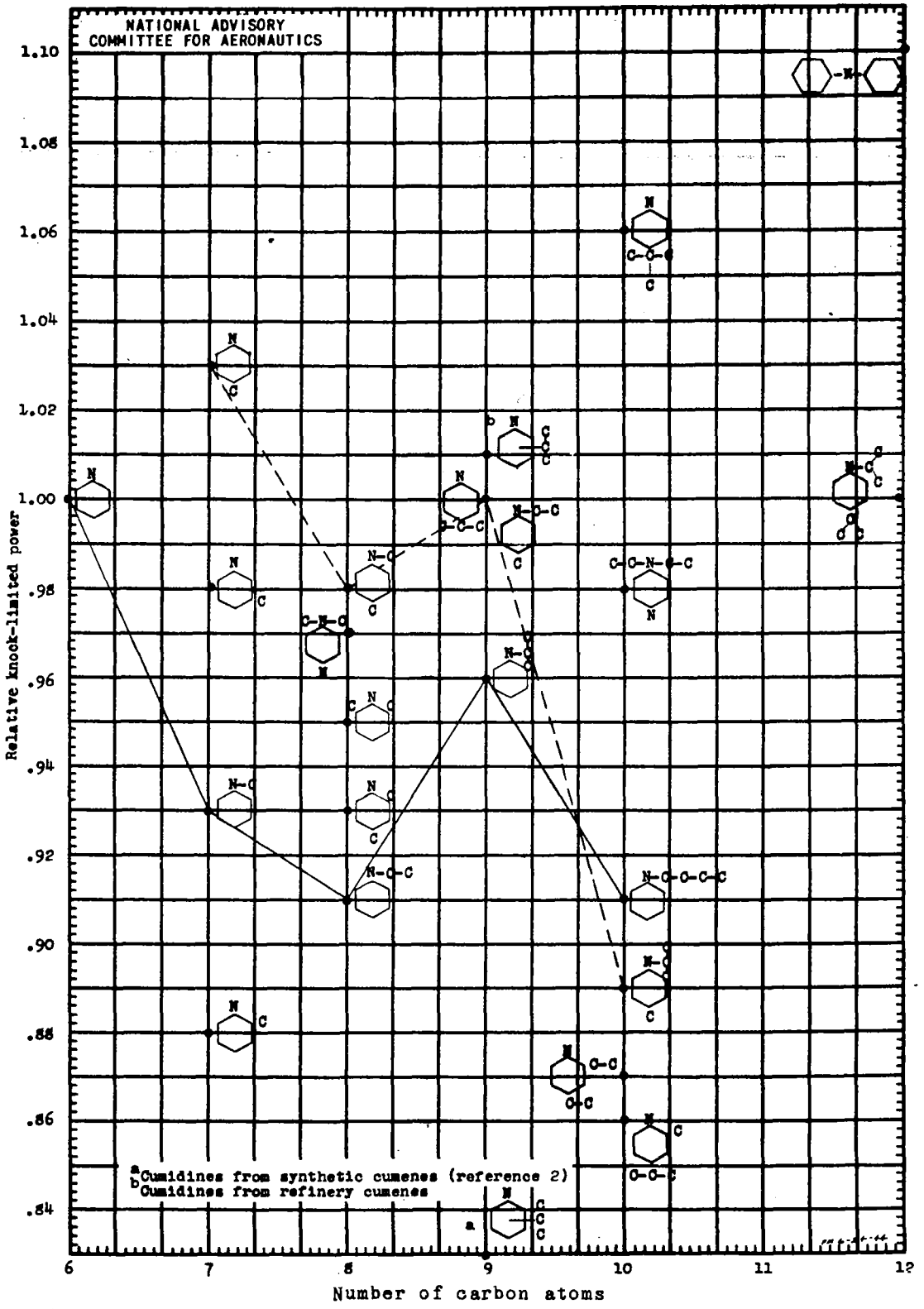
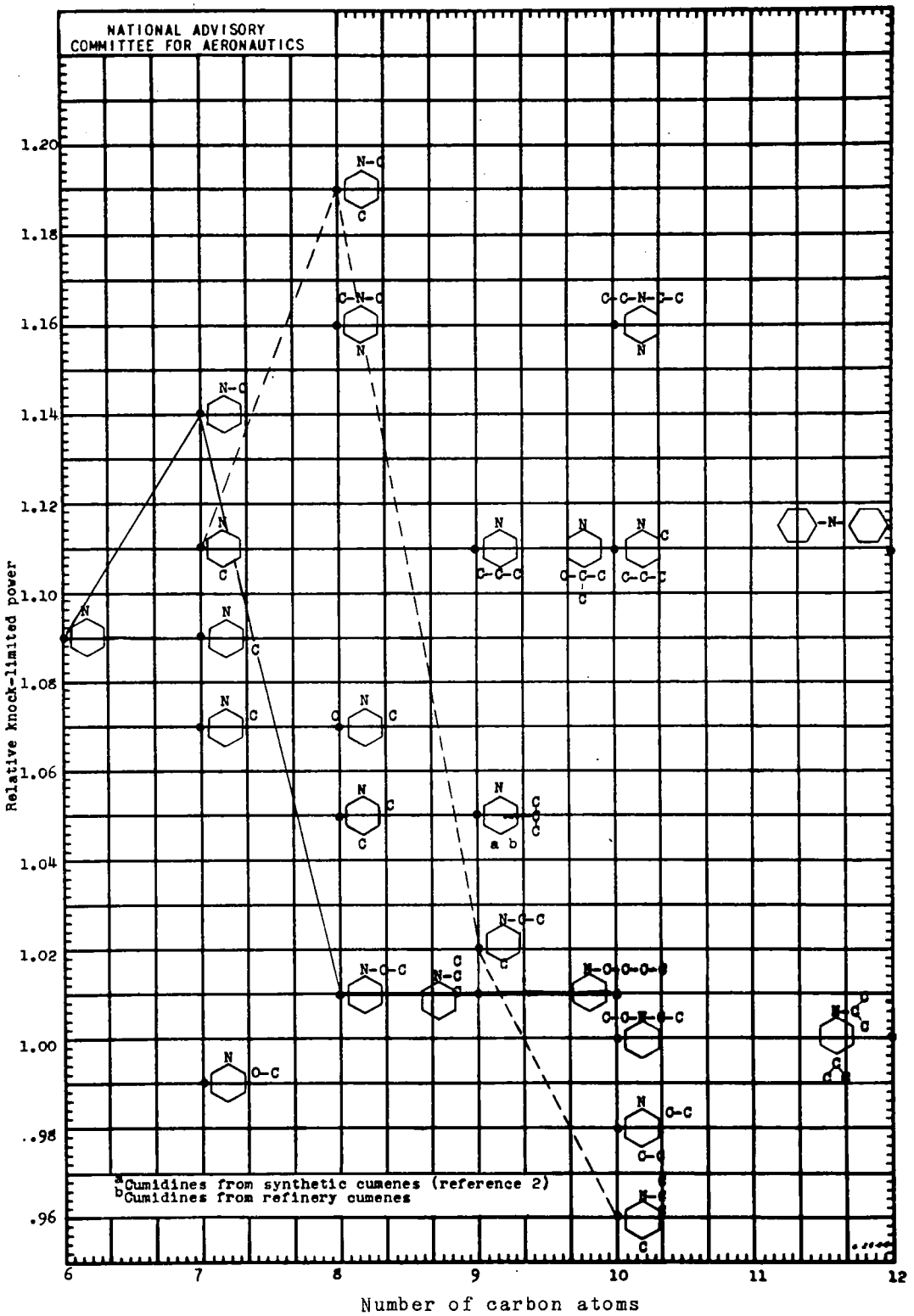
(b) Fuel-air ratio, 0.110.

Figure 12. - Concluded. Effect of alkyl substitutions to the aromatic ring on knock-limited performance of AN-F-28 fuel. (Data from references 1 and 2 and from table 1 of this report.)



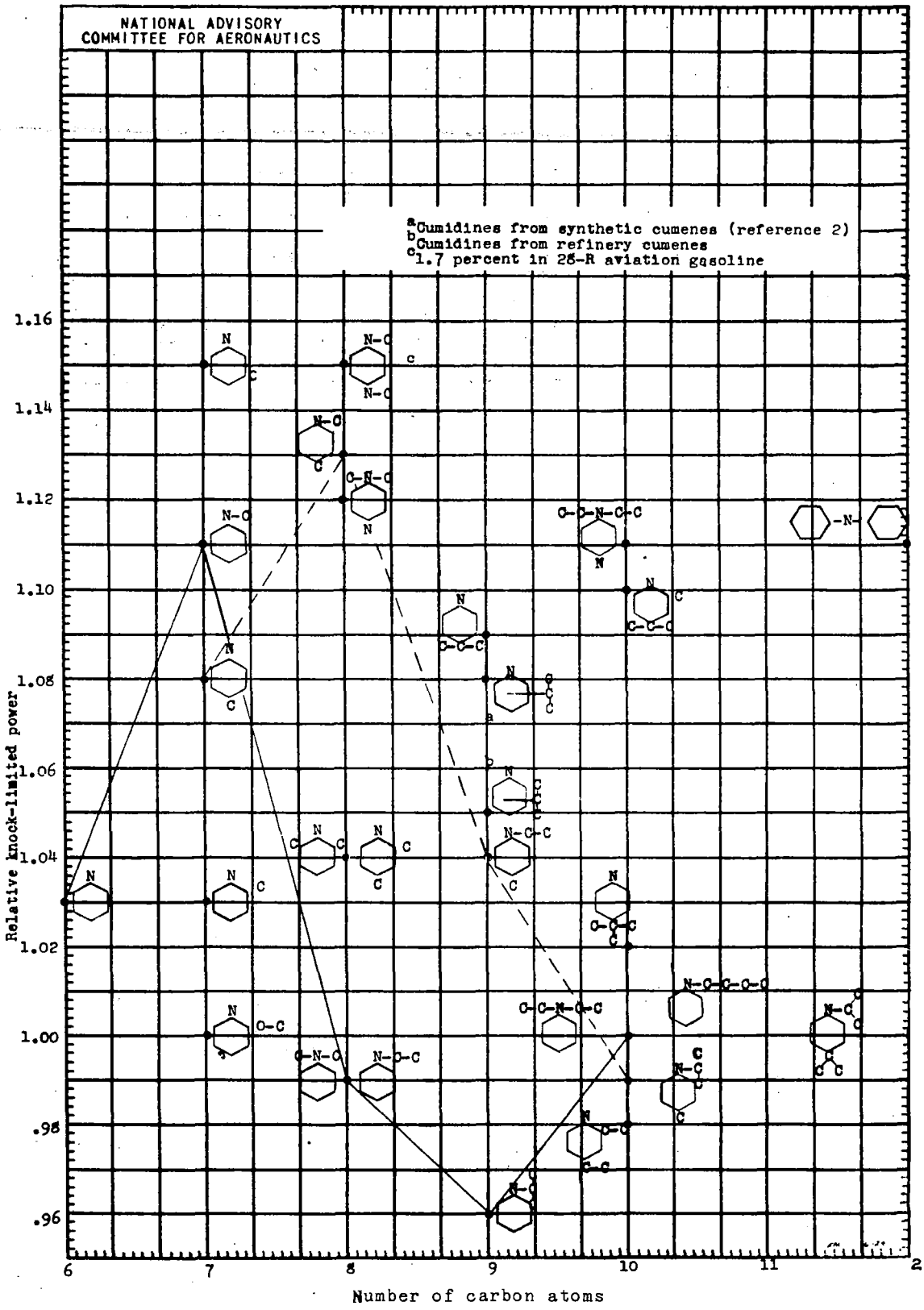
(a) Fuel-air ratio, 0.062.

Figure 13. - Effect of molecular structure on relative power of various aromatic amines in AN-F-28 fuel at F-4 conditions.



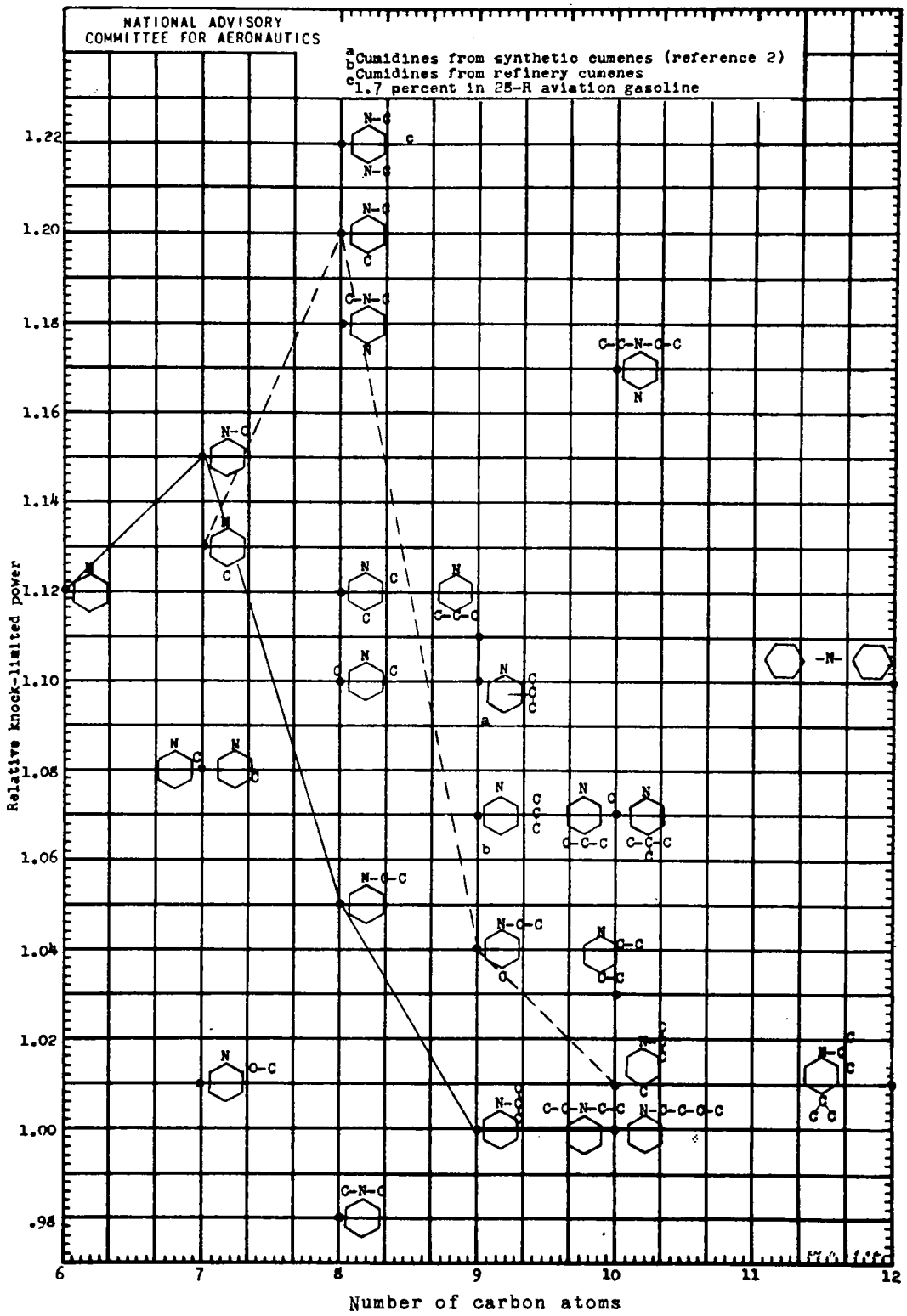
(b) Fuel-air ratio, 0.110.

Figure 13. - Concluded. Effect of molecular structure on relative power of various aromatic amines in AN-F-28 fuel at F-4 conditions.



(a) Fuel-air ratio, 0.062.

Figure 14. - Effect of molecular structure on relative power of various aromatic amines in AN-F-28 fuel at modification A.



(b) Fuel-air ratio, 0.090.

Figure 14. - Concluded. Effect of molecular structure on relative power of various aromatic amines in AN-F-28 fuel at modification A.

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Alquist, Henry
Tower, Leonard

AUTHOR(S)

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ABSTRACT

Diphenylamine gives the most consistent power improvement, about 10 percent, at all fuel/air ratios and engine conditions. N-methyl-p-toluidine, N,N-dimethyl-p-phenylenediamine, N,N'-dimethyl-p-phenylenediamine, and N,N-dimethyl-p-phenylenediamine are very good antiknock agents under modified conditions, but their performance is sensitive to inlet-air temperature and fuel/air ratio. Aniline, p-isopropylaniline, 2,6-xylidine, commercial xylidines, 2,4-xylidine, p-toluidine, N-methylaniline, and p-tert-butylaniline show promise as antiknock agents.

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

AUTHOR(S): Alquist, H. E.; Tower, L. K.
ORIGINATING AGENCY: Aircraft Engine Research Lab., Cleveland, O.

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ABSTRACT:

Knock-limited performance tests were conducted on AN-F-28 (28-R) fuel to determine the effect of 2% additions of aromatic amines. Data was obtained on 2,4-xylidine, N-ethylaniline, 2,4-diethylaniline, diphenylamine, N,N-diethyl-p-phenylenediamine, N-isopropyl-p-isopropylaniline, N,N'-dimethyl-p-phenylenediamine, N,N-dimethyl-p-phenylenediamine, and cumidines at the following operating conditions: inlet-air temperatures of 150°, 250° and 225°F, spark advance of 30° and 45° B.T.C. and coolant temperature of 250° and 375°F. Diphenylamine gave the most consistent power improvement, roughly 10% at all fuel/air ratios and engine conditions. The aromatic amines were found to be good antiknock agents under modified conditions but their knock-limited performance was sensitive to inlet-air temperature and fuel/air ratio.

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