F-33

NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

WARTIME REPORT

ORIGINALLY ISSUED

May 1944 as
Advance Restricted Report E4E25

KNOCK-LIMITED PERFORMANCE OF PURE HYDROCARBONS BLENDED WITH A BASE FUEL IN A FULL-SCALE AIRCRAFT-ENGINE CYLINDER

I - EIGHT PARAFFINS, TWO OLEFINS

By Anthony W. Jones and Arthur W. Bull

Aircraft Engine Research Laboratory
Cleveland, Ohio

NACA

WASHINGTON

NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

ADVANCE RESTRICTED REPORT

KNOCK-LIMITED PERFORMANCE OF PURE HYDROCARBONS BLENDED WITH A BASE FUEL IN A FULL-SCALE AIRCRAFT-ENGINE CYLINDER

I - EIGHT PARAFFINS, TWO OLEFINS

By Anthony W. Jones and Arthur W. Bull

SUMMARY

Object. - To determine the knock-limited performance in a full-scale aircraft-engine cylinder of leaded blends of 10 pure hydrocarbons and a base fuel.

Scope. - Tests that are part of a program to determine the anti-knock effectiveness of additions of pure hydrocarbons to aircraft-engine fuels were conducted on a Wright R-1820 G200 cylinder at two operating conditions: cruise rating at 2000 rpm and an inlet-air temperature of 210° F and take-off rating at 2500 rpm and an inlet-air temperature of 250° F (CRC conditions). The following fuels were tested:

2,2-dimethylbutane (neohexane)
2,3-dimethylbutane (diisopropyl)
2-methylbutane (isopentane)
2,2,3-trimethylbutane (triptane)
2,2,4,4-tetramethylpentane
2,3,3-trimethylpentane
2,2,3-trimethylpentane
2,3,4-trimethylpentane
2,4,4-trimethyl-1-pentene
2,4,4-trimethyl-2-pentene
PPF-821
AN-F-29 (140-P) aviation gasoline
NACA base fuel (85 percent S-3 and
15 percent M-3 plus 4 ml TEL/gal)

Reference-fuel curves were obtained to bracket the test-fuel curves. Wright cylinder ratings are compared with F-3 and F-4 ratings.

Summary of results. - The results obtained from the tests of the 10 pure hydrocarbons and the NACA base fuel at two fuel-air ratios are summarized in the following table:

RATINGS OBTAINED IN A WRIGHT R-1820 G200 CYLINDER

[For each compound there are three rows of values. The first row is imep, lb/sq in.; the second is tetraethyl lead in S reference fuel, ml/gal; and the third is performance number.]

Compound	Concentration in base fuel (percent)	Engine speed, 2000 rpm; inlet-air temperature, 210° F		Engine speed, 2500 rpm; inlet-air temperature, 250° F	
		Fuel-air ratio		Fuel-air ratio	
		0.07	0.10	0.07	0.10
2,2-dimethylbutane (neohexane)	25	176 0.58 118	225 0.59 118	170 0.48 115	226 0.44 114
2,3-dimethylbutane (diisopropyl)	25	197 1.25 130	237 0.95 125	192 1.15 128	238 0.75 121
2-methylbutane (isopentane)	25	174 0.55 117	233 0.80 122	162 0.37 112	234 0.62 119
2,2,3-trimethylbutane (triptane)	25	204 1.58 134	272 2.69 144	202 1.76 136	272 2.33 142
2,2,4,4-tetramethylpentane	25	160 0.35 112	209 0.29 110	163 0.38 113	209 0.23 108
2,3,3-trimethylpentane	25	188 0.87 124	257 1.87 137	187 0.89 124	257 1.66 135
2,2,3-trimethylpentane	25	196 1.21 129	268 2.45 143	188 0.95 125	266 2.09 139
2,3,4-trimethylpentane	23.5	179 0.65 119	245 1.30 130	163 0.38 113	245 1.02 126
2,4,4-trimethyl-1-pentene	25	192 1.05 127	283 3.36 149	155 0.27 110	279 2.58 144
2,4,4-trimethyl-2-pentene	25	188 0.89 124	236 0.89 124	156 0.29 110	238 0.74 121
NACA base fuel (85 percent S-3 + 15 percent M-3 + 4 ml TEL/gal)		156 0.30 111	210 0.32 111	154 0.26 109	212 0.27 110

INTRODUCTION

Under the sponsorship of the NACA the Bureau of Standards is synthesizing to a high degree of purity various hydrocarbons for knock-testing in a full-scale aircraft-engine cylinder. Samples of these hydrocarbons are also submitted to the Ethyl Corporation for tests in the 17.6 engine and, where the quantity of supply permits, to the General Motors Corporation Research Laboratories for tests in the General Motors engine. In each of these two cases, the engine conditions are those used in research sponsored by the American Petroleum Institute Hydrocarbon Research Project on the knocking characteristics of pure hydrocarbons. The results obtained by both of these laboratories are available in the reports of the American Petroleum Institute.

Sufficient supplies of 10 of the hydrocarbons prepared by the Bureau of Standards have recently been submitted to the NACA for tests (in which the hydrocarbons are blended in a base fuel) in an R-1820 G200 cylinder operating under test conditions tentatively standardized by the Coordinating Research Council.

It is the purpose of this report to present the results of these tests. The tests were conducted at the Aircraft Engine Research Laboratory of the National Advisory Committee for Aeronautics during November and December 1943.

FUELS

The National Bureau of Standards prepared and furnished samples of the following pure hydrocarbons leaded with 1-T mix aviation ethyl fluid to a concentration of 4 ml TEL per gallon and inhibited with 72.576 milligrams of U.O.P. No. 4 inhibitor per gallon (0.8 lb/5000 gal):

2,2-dimethylbutane (neohexane)
2,3-dimethylbutane (diisopropyl)
2-methylbutane (isopentane)
2,2,3-trimethylbutane (triptane)
2,2,4,4-tetramethylpentane
2,3,3-trimethylpentane
2,2,3-trimethylpentane
2,3,4-trimethylpentane
2,4,4-trimethyl-1-pentene
2,4,4-trimethyl-2-pentene

The available amounts of the pure hydrocarbons varied from 5 to 8 gallons. All the hydrocarbons have been tested pure in the General Motors research laboratory under the American Petroleum Institute procedure.

Preliminary investigations were made by the staff of the Fuel Synthesis Section, Fuels and Lubricants Division, of AERL to determine the peroxide number of the samples; U.O.P. Method No. H-33-40 was followed. Tests of two samples of 2,4,4-trimethyl-2-pentene showed them to have peroxide numbers of 6.7 and 3.9. The peroxide number of the 2,4,4-trimethyl-2-pentene was reduced to 0.1 by passing it twice through a florite drying column. Because this process removed some of the tetraethyl lead and the inhibitor, the compound was then leaded and inhibited to correspond to the original samples as received from the National Bureau of Standards.

Two aviation gasolines containing appreciable amounts of aromatics were included in the tests: PPF-821, obtained from the Socony-Vacuum Oil Company, and AN-F-29 (140P) fuel.

The NACA base fuel was a blend of 85 percent S-3 and 15 percent M-3 reference fuels leaded to a concentration of 4 ml TEL per gallon and inhibited with 0.09 pound U.O.P. No. 4 inhibitor per 500 gallons of fuel.

The leaded pure hydrocarbons with the exception of 2,3,4-trimethylpentane were mixed with the NACA base fuel to form blends consisting of 25 percent pure hydrocarbon and 75 percent base fuel by volume. The blend containing 2,3,4-trimethylpentane consisted of only 23.5 percent pure hydrocarbon instead of the desired 25 percent owing to an error in measurement made during the blending of the fuels.

The reference fuels used to bracket the test fuels were:

Blend of 90 percent S-3 plus 10 percent M-3
S-3
S-3 plus 0.5 ml TEL per gallon
S-3 plus 1.25 ml TEL per gallon
S-3 plus 2.0 ml TEL per gallon
S-3 plus 3.0 ml TEL per gallon

The Universal Oil Products Laboratory determined F-4 ratings on the previously listed hydrocarbons in 10, 25, and 50 percent blends in the same base fuel used in the NACA tests.

The F-3 ratings for the 25 percent blends were determined by the Small-Scale Section, Fuels and Lubricants Division of AERL.

APPARATUS

Tests were conducted in a Wright R-1820 G200 cylinder mounted on a CUE crankcase. Standard baffles were fitted to the cylinder and cooling air was directed toward the cylinder to simulate cooling conditions in flight. The arrangement of the cooling-air deflectors in front of the cylinder is shown in figure 1. Cooling air came from the laboratory supply system and was regulated by a damper valve in the pipe. No means of controlling the temperature of the cooling air was available for these tests.

Combustion air was controlled by a pilot-operated pressure-regulating valve. The air quantity was measured by a square-edge thin-plate orifice of 1.500-inch diameter that was installed in a pipe of 4.03-inch inside diameter in the manner prescribed by the A.S.M.E. Flange taps provided the manometer connections. The combustion-air surge tank had a volume of approximately 18 cubic feet and was separated from the engine by an inlet pipe of 14-inch length and $2\frac{5}{8}$-inch inside diameter.

Fuel flow was measured with a calibrated rotameter. The calibration showed a maximum error of 3 percent in the range from 80 to 90 pounds per hour. The fuel-injection nozzle was located in the center of the intake pipe 10 inches from the intake port of the cylinder and directed fuel toward the cylinder. The fuel system at the engine is shown in figure 2.

All temperatures were measured by iron-constantan thermocouples and were read directly from a self-balancing potentiometer. The thermocouple at the rear spark-plug bushing was located in the bushing about 1/8 inch from the outer surface of the bushing.

Two magnetos were used in the ignition system, one for each spark plug. Champion C34S spark plugs were used in all the tests. Engine torque was absorbed by an electric-hydraulic dynamometer unit.

METHODS

<u>Test conditions.</u> - The fixed engine conditions were:

Compression ratio	7.3
Spark advance, degrees B.T.C.	20/20
Oil flow to piston jets, pounds per minute	8
Oil pressure to piston jets, pounds per square inch	50
Oil pressure to crankpin, pounds per square inch	64 to 67
Oil-in temperature, °F	180 to 190
Gasoline temperature at entrance to injection pump, °F. .	60 to 80

Valve timing:

Intake opens, degrees B.T.C.	15
Intake closes, degrees A.B.C.	44
Exhaust opens, degrees B.B.C.	74
Exhaust closes, degrees A.T.C.	25

The cooling-air flow was determined for each test by running the engine at a brake mean effective pressure of 140 pounds per square inch and a fuel-air ratio of 0.10 and by adjusting the damper valve in the cooling-air line until a rear spark-plug-bushing temperature of 365° F was reached. The cooling-air flow thus determined was maintained constant for each test. The cooling-air temperature remained almost constant for each test but over the period in which the tests were conducted varied from 60° F to 95° F.

The oil flow to the piston was carefully calibrated and the pressure was determined to give a flow of 8 pounds per minute through the four 0.0465-inch-diameter jets used.

Knock was detected with a magnetostriction pickup unit, which was inserted in the combustion chamber and used in conjunction with a cathode-ray oscillograph.

Test procedure. - Cylinder temperatures are normally allowed to stabilize before the data for a point on a knock curve are taken. The practice at AERL is to allow 10 to 15 minutes per test point for the temperatures to stabilize. Because the supply of pure hydrocarbon fuel blends was limited, however, special procedures were adopted to obtain complete curves at both cruise and take-off conditions. The mixture-response curves were run as rapidly as possible; for each point on a curve conditions were held constant only long enough to take the most essential observations. The average time taken per test curves was approximately 20 minutes.

Because sufficient time could not be allowed for cylinder temperatures to stabilize, a series of tests was made on AN-F-28 aviation gasoline to determine the accuracy of rapidly obtained knock curves. The inlet-air pressure, the indicated mean effective pressure, and the indicated specific fuel consumption agreed very closely with the values obtained in the conventional manner except in the fuel-air-ratio range from 0.065 to 0.075. In this region the inlet-air pressure and the indicated mean effective pressure tended to be higher than normal and the cylinder temperatures tended to be lower. Additional time for obtaining points in this region was allotted to overcome this effect, and the results are presented in figure 3. The agreement of the curves under these conditions was very close with respect to the inlet-air pressure, the indicated mean effective pressure, and the indicated specific fuel consumption. The data for the three curves presented in figure 3 were obtained by three operators in order to insure the precision of detecting knock. The cylinder temperatures varied somewhat but the variation was small and cannot be considered a serious source of error.

Whenever possible, knock data at take-off and cruise conditions were taken on the same day for each of the fuel blends tested. A run of three or four knock points was made with the base fuel before each test-fuel run to check engine conditions.

Complete mixture-response curves for the reference fuels were determined at take-off and cruise conditions to bracket the test fuels. Friction runs were made after each test by motoring the engine at test speed with the fuel flow and cooling air shut off.

RESULTS AND DISCUSSION

Precision of tests. - The variation of the knock-limited indicated mean effective pressure of the base fuel with the number of test runs is shown in figure 4. The points are plotted in order of decreasing indicated mean effective pressure and are not in the order the tests were run; points representing first and last runs are identified in the figure. The standard error was calculated for the check points and is presented in the following table.

VALUES OF STANDARD ERROR IN INDICATED-MEAN-EFFECTIVE-PRESSURE UNITS

	Engine speed, 2000 rpm; inlet-air temperature, 210° F		Engine speed, 2500 rpm; inlet-air temperature, 250° F	
	Fuel-air ratio		Fuel-air ratio	
	0.075	0.10	0.075	0.10
NACA base fuel (85 percent S-3 + 15 percent M-3 + 4 ml TEL/gal)	2.22	1.95	1.39	2.43

Test results. - The reference-fuel framework covering these tests at both engine operating conditions is presented in figures 5 and 6. From these curves cross plots were made to facilitate conversion of the test fuels to lead ratings. (See fig. 7.) Conversion of test fuels to percentage S in M was made from the curves in figure 8, which were obtained by using equation 3(b) of reference 2.

Table 1 compares the F-3 ratings, the F-4 ratings, and the Wright R-1820 G200 ratings on the basis of performance number and equivalent reference-fuel concentration or octane number.

Figures 9 and 10 compare the performance of the two fuels containing aromatics (PPF-821 and AN-F-29) with that of the base fuel.

The knock-limited performance of the blends of the 10 pure hydrocarbons and the base fuel is presented in figures 11 and 12. The four methylbutanes and three trimethylpentanes increased the knock-limited power of the base fuel; 2,2,3-trimethylbutane caused the greatest increase of these seven hydrocarbons. The two olefins (2,4,4-trimethyl-1-pentene and 2,4,4-trimethyl-2-pentene) also increased the knock-limited power and 2,4,4-trimethyl-1-pentene gave a higher power than 2,2,3-trimethylbutane for fuel-air ratios greater than 0.098 for take-off conditions and 0.078 for cruise conditions. The tetramethylpentane gave no appreciable change in the knock limit.

The correlation of the Wright R-1820 G200 ratings with the F-4 ratings from reference 1 are presented in figures 13 and 14. The ratings at a fuel-air ratio of 0.10 compare favorably except for the pentene. At lean mixture (0.07 fuel-air ratio) the data are somewhat more scattered and the points for the two pentene ratings show considerable deviation from those of the other fuels.

In figure 15 the Wright R-1820 G200 lean ratings are compared with the F-3 ratings. The correlation at either operating condition is not good. The F-3 ratings show little improvement of 2,2,3-trimethylbutane (triptane) over 2-dimethylbutane (isopentane), whereas 2,2,3-trimethylbutane is decidedly better than 2-methylbutane in the Wright R-1820 G200 cylinder.

SUMMARY OF RESULTS

The results are summarized in table 1.

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

REFERENCES

1. Puckett, Afton D., and Brooks, Donald B.: Supercharged CFR Engine Tests of Twelve Pure Hydrocarbons. Special Rep. No. 11, Nat. Bur. Standards Hydrocarbon Fuel Res. Lab., Sept. 17, 1943.

2. Sanders, Newell D.: A Method of Estimating the Knock Rating of Hydrocarbon Fuel Blends. NACA ARR No. 3H21, 1943.

TABLE 1. - COMPARISON OF RATINGS OBTAINED IN A WRIGHT R-1820 G200 CYLINDER WITH F-4 AND F-3 RATINGS

[For each compound there are three rows of values. The first row is imep, lb/sq in.; the second is tetraethyl lead in S reference fuel, ml/gal, except as noted; and the third is performance number]

Compound	Concentration in base fuel (percent)	F-3 ratings	F-4 ratings (a)			Wright R-1820 G200 ratings (compression ratio, 7.3; spark advance, 20° B.T.C.)									
						Engine speed, 2000 rpm; inlet-air temperature, 210° F					Engine speed, 2500 rpm; inlet-air temperature, 250° F				
			Fuel-air ratio			Fuel-air ratio					Fuel-air ratio				
			0.07	0.10	Rich	0.065	0.07	0.08	0.09	0.10	0.065	0.07	0.08	0.09	0.10
2,2-dimethylbutane (neohexane)	25	----------	-----	-----	--------	165	176	196	210	225	162	170	193	210	226
		0.89	0.95	0.83	0.84	0.49	0.58	0.64	0.56	0.59	0.46	0.48	0.46	0.44	0.44
		124	125	123	123	116	118	119	117	118	115	115	115	114	114
2,3-dimethylbutane (diisopropyl)	25	----------	-----	-----	--------	190	197	212	226	237	183	192	214	228	238
		0.90	0.99	1.35	1.32	1.09	1.25	1.30	1.13	0.95	0.96	1.15	1.09	0.90	0.75
		124	126	131	131	137	130	130	128	125	125	128	127	124	121
2-methylbutane (isopentane)	25	----------	-----	-----	--------	165	174	198	220	233	154	162	204	221	234
		0.86	0.80	1.01	0.79	0.50	0.55	0.68	0.87	0.80	0.35	0.37	0.70	0.65	0.62
		123	122	126	122	116	117	120	124	122	112	112	120	119	119
2,2,3-trimethylbutane (triptane)	25	----------	-----	-----	--------	202	204	221	244	272	200	202	238	259	272
		1.29	2.13	3.03	2.95	1.64	1.58	1.74	2.05	2.69	2.31	1.76	2.37	2.44	2.33
		130	140	147	146	135	134	136	139	144	141	136	142	143	142
2,2,4,4-tetramethyl-pentane	25	----------	-----	-----	--------	158	160	172	189	209	164	163	178	193	209
		0.39	0.51	0.33	0.27	0.40	0.35	0.24	0.24	0.29	0.50	0.38	0.27	0.24	0.23
		113	116	111	110	113	112	108	109	110	116	113	110	109	108
2,3,3-trimethyl-pentane	25	----------	-----	-----	--------	179	188	205	228	257	182	187	213	242	257
		0.66	1.15	1.95	1.97	0.75	0.87	0.96	1.23	1.87	0.91	0.89	1.05	1.69	1.66
		119	128	138	138	121	124	125	129	137	124	124	127	135	135
2,2,3-trimethyl-pentane	25	----------	-----	-----	--------	191	196	218	244	268	182	188	224	250	266
		0.95	1.79	2.45	2.26	1.10	1.21	1.59	2.02	2.45	0.91	0.95	1.67	2.09	2.09
		125	136	143	141	127	129	134	139	143	124	125	135	139	139
2,3,4-trimethyl-pentane	23.5	----------	-----	-----	--------	174	179	201	224	245	164	163	201	229	245
		0.55	0.45	1.58	1.42	0.65	0.65	0.80	1.01	1.30	0.50	0.38	0.63	0.95	1.02
		117	115	134	132	119	119	122	126	130	116	113	119	125	126
2,4,4-trimethyl-1-pentene	25	----------	-----	-----	--------	189	192	224	256	283	150	155	190	238	279
		[b]99.9	0.25	2.20	3.10	1.03	1.05	1.89	2.77	3.36	0.30	0.27	0.41	1.45	2.58
		100	108	140	147	127	127	137	145	149	110	110	114	132	144
2,4,4-trimethyl-2-pentene	25	----------	-----	-----	--------	187	188	206	220	236	152	156	194	207	238
		0.07	0.28	0.47	0.68	0.96	0.89	1.00	0.88	0.89	0.33	0.29	0.47	0.38	0.74
		103	109	115	120	125	124	126	124	124	111	110	115	113	121
PPF-821		----------	-----	-----	--------	102	114	187	234	246	107	114	176	221	248
		[b]94.5	[c]98.1	1.38	1.25	[c]94.8	[c]97.8	0.44	1.53	1.34	[c]94.8	[c]96.3	0.25	0.65	1.18
		92	97	132	130	92	97	114	133	131	92	94	109	119	129
AN-F-29 (140-P)		----------	-----	-----	--------	113	136	218	256	266	133	141	196	248	275
		[b]98.3	0.10	2.21	2.14	[c]99.6	0.12	1.60	2.77	2.34	0.11	0.13	0.52	2.00	2.44
		97	104	141	140	99	105	134	145	142	105	105	117	139	142
NACA base fuel (85% S-3 and 15% M-3 + 4 ml TEL/gal)		----------	-----	-----	--------	150	156	174	192	210	144	154	176	198	212
		0.41	0.49	0.41	0.36	0.31	0.30	0.26	0.28	0.32	0.23	0.26	0.25	0.28	0.27
		113	115	114	112	111	111	109	110	111	108	109	109	110	110

[a]All values are averages and are taken from reference 1.
[b]Octane number.
[c]Percentage S in M.

NATIONAL ADVISORY
COMMITTEE FOR AERONAUTICS

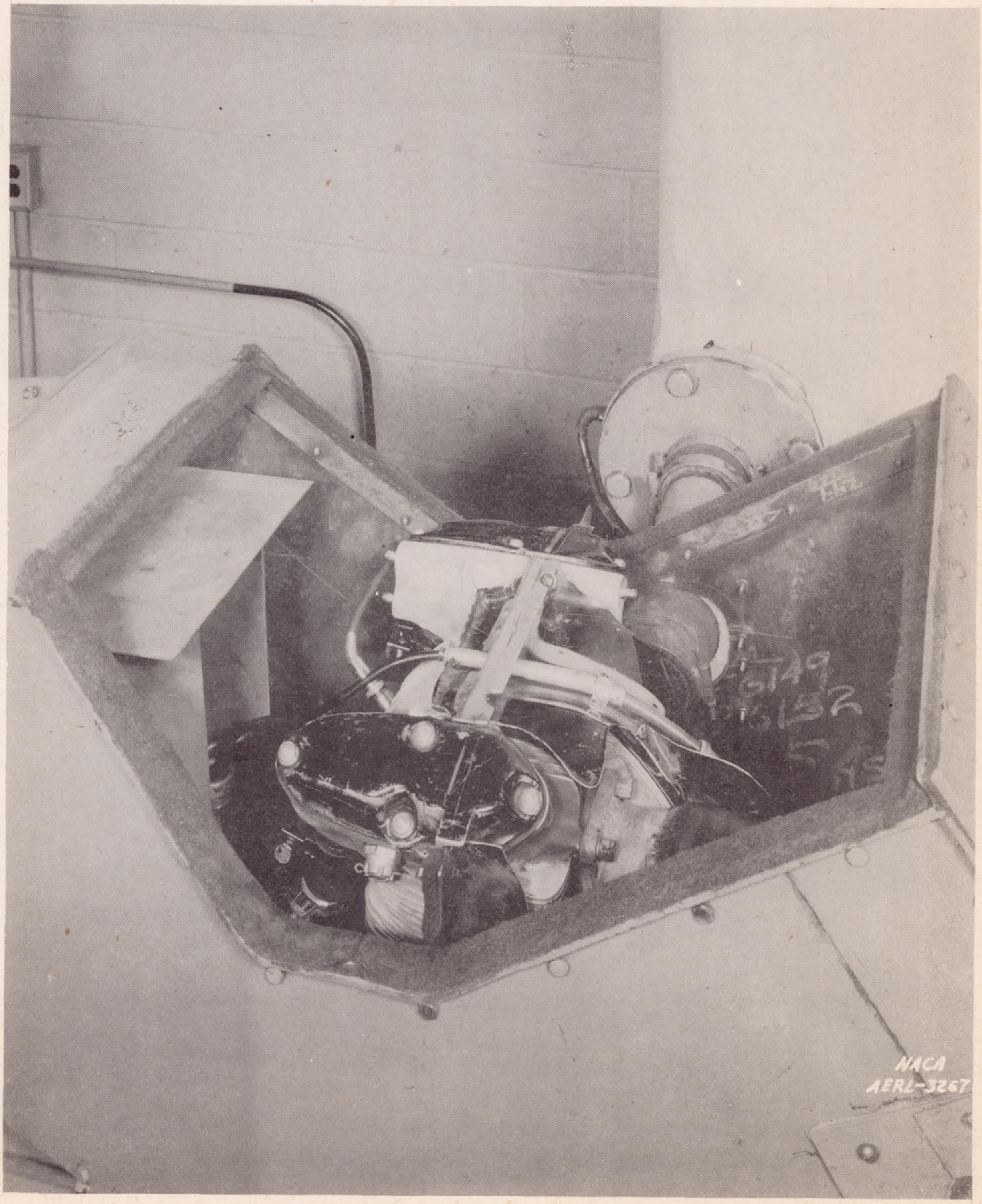


Figure 1. - Top view showing cooling-air deflector vanes in front of cylinder.

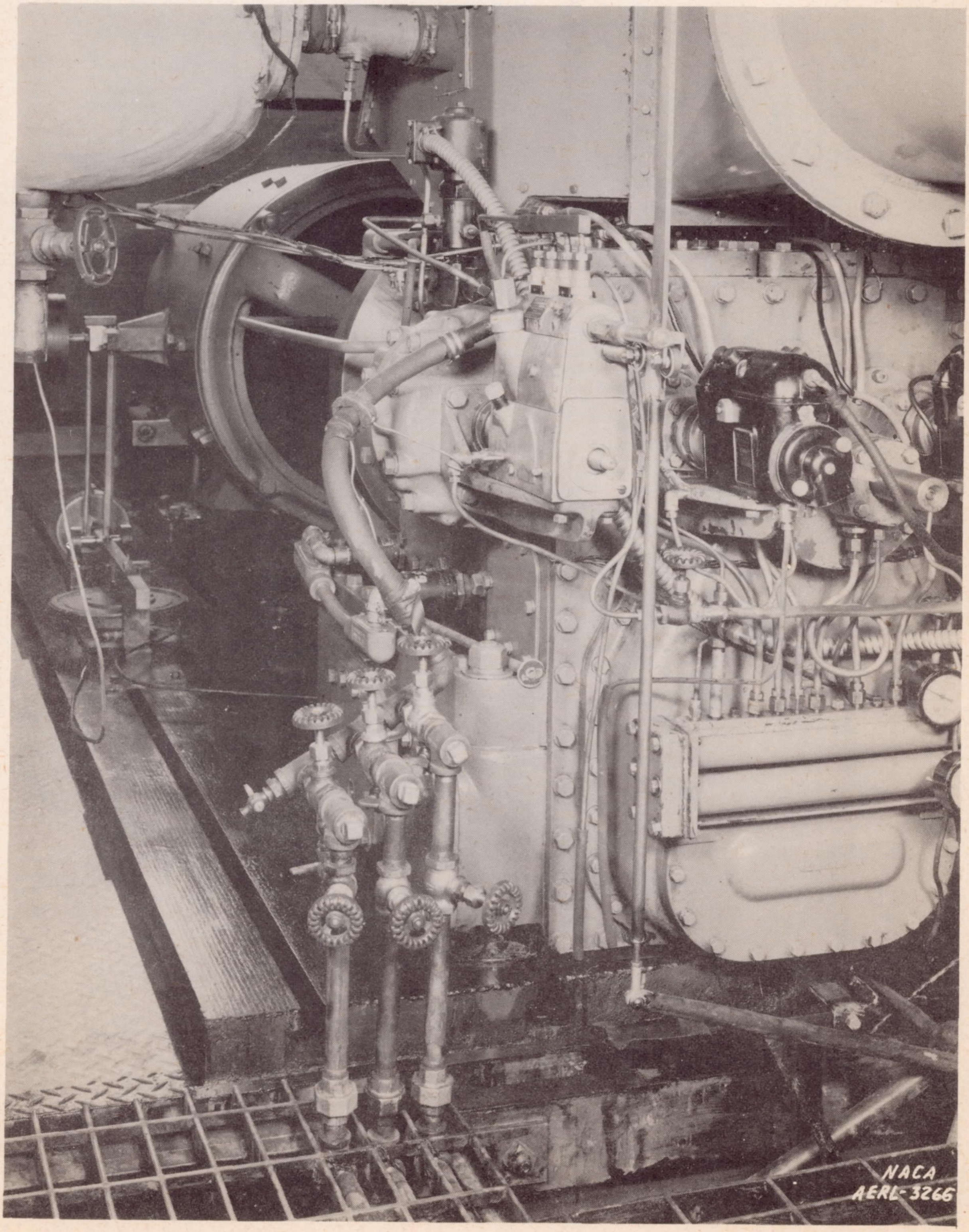


Figure 2. - Front view showing three-line fuel system, injection pump, and location of injection nozzle.

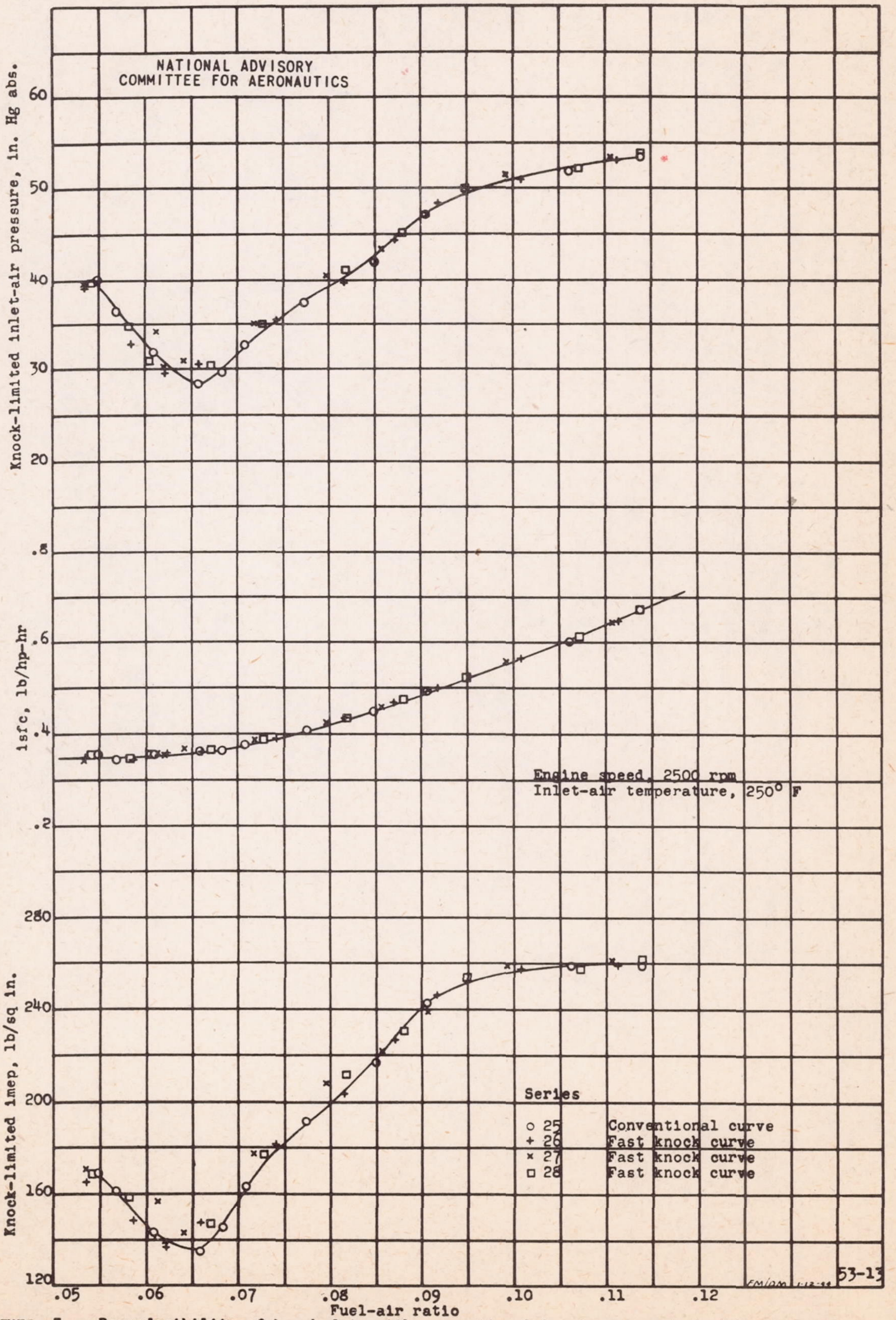
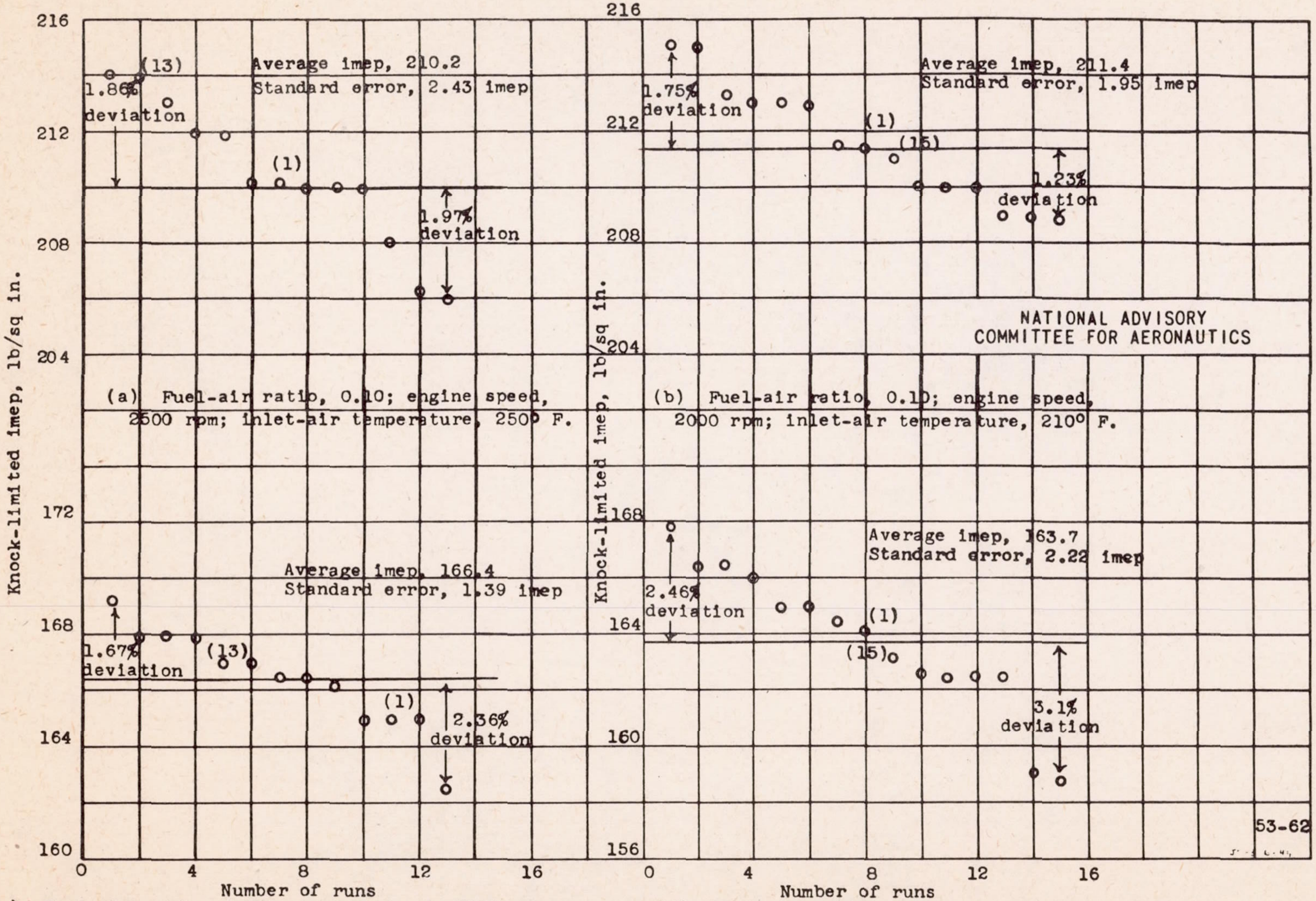


Figure 3. - Reproducibility of knock data with conventional knock curve and fast knock curve. Wright R-1820 G200 cylinder; compression ratio, 7.3; spark advance, 20° B.T.C.; fuel, AN-F-28; cooling air adjusted at 140 bmep and 0.10 fuel-air ratio to give a rear spark-plug-bushing temperature of 365° F.



(c) Fuel-air ratio, 0.075; engine speed, 2500 rpm; inlet-air temperature, 250° F.

(d) Fuel-air ratio, 0.075; engine speed, 2000 rpm; inlet-air temperature, 210° F.

Figure 4. - Deviation of knock-limited indicated mean effective pressure with number of test runs. Fuel, 85 percent S-3 and 15 percent M-3 plus 4 ml tetraethyl lead per gallon. The number of runs are not in chronological order; the first and last runs are identified.

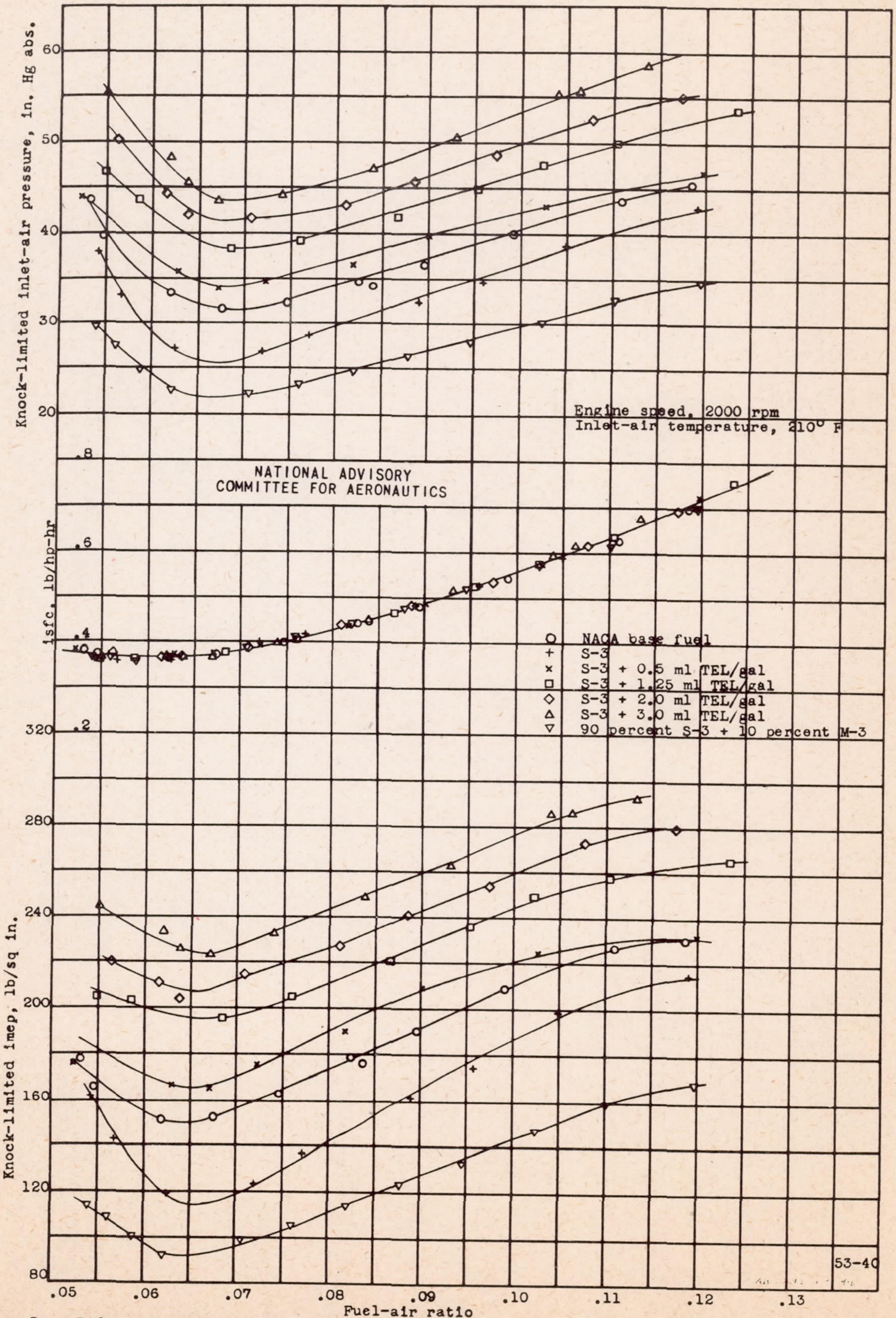


Figure 5. - Reference-fuel framework at an engine speed of 2000 rpm and an inlet-air temperature of 210° F. Wright R-1820 G200 cylinder; compression ratio, 7.3; spark advance, 20° B.T.C.; cooling air adjusted at 140 bmep and 0.10 fuel-air ratio to give a rear spark-plug-bushing temperature of 365° F.

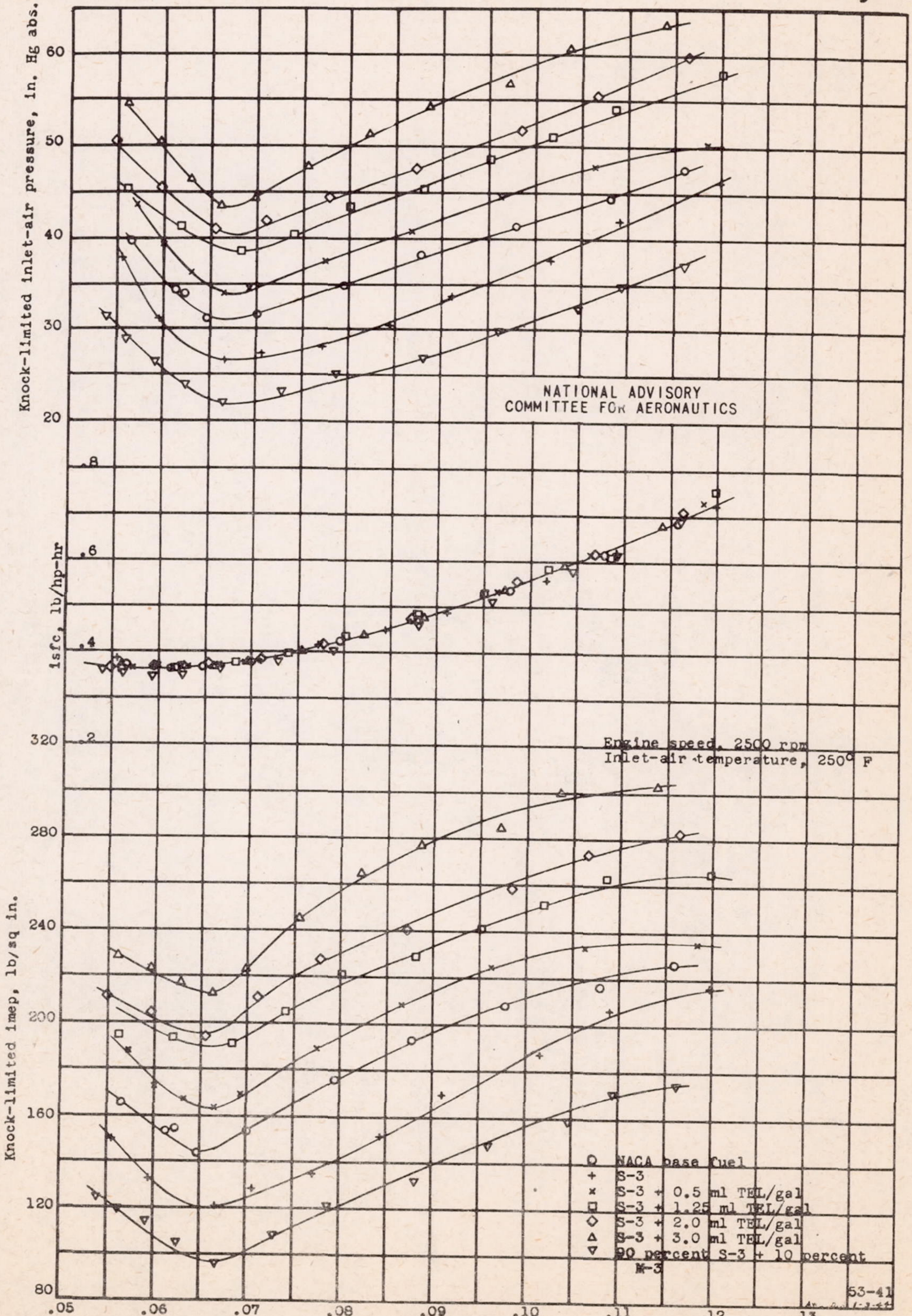


Figure 6. - Reference-fuel framework at an engine speed of 2500 rpm and an inlet-air temperature of 250° F. Wright R-1820 G200 cylinder; compression ratio, 7.3; spark advance, 20° B.T.C.; cooling air adjusted at 140 bmep and 0.10 fuel-air ratio to give a rear spark-plug-bushing temperature of 365° F.

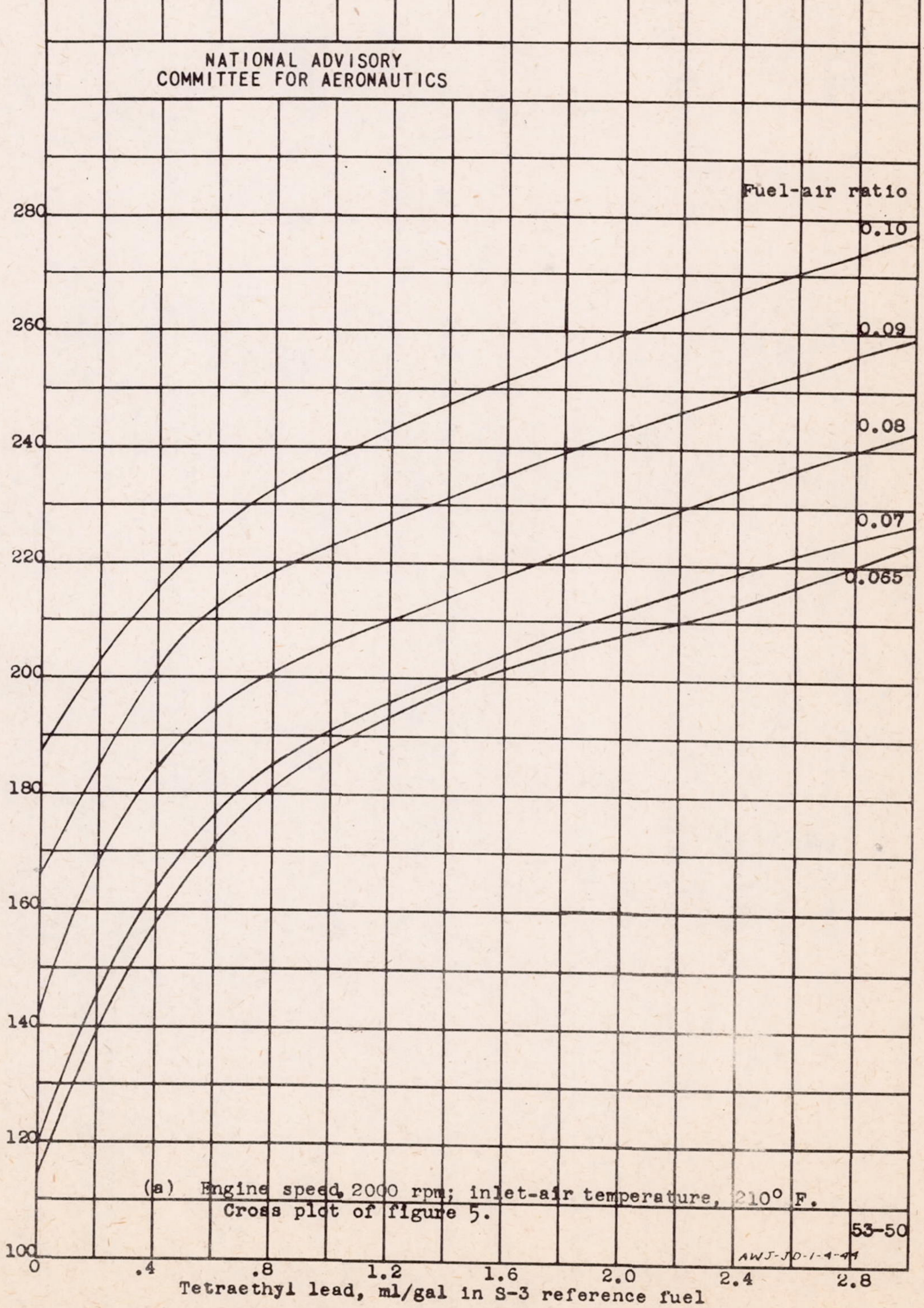


Figure 7. - Relation between knock-limited indicated mean effective pressure and lead concentration in S-3 reference fuel for different fuel-air ratios. Wright R-1820 G200 cylinder; compression ratio, 7.3; spark advance, 20° B.T.C.

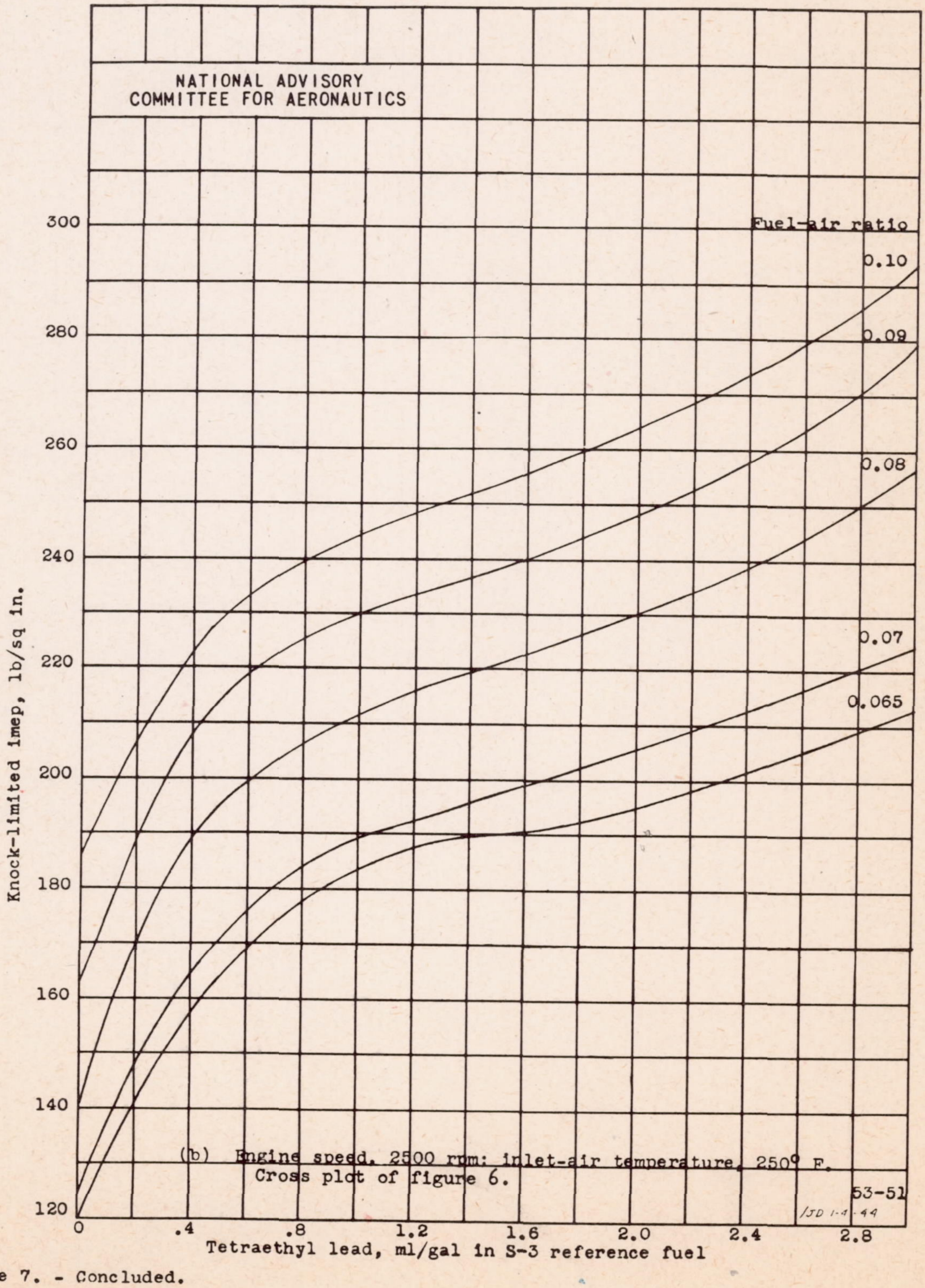


Figure 7. - Concluded.

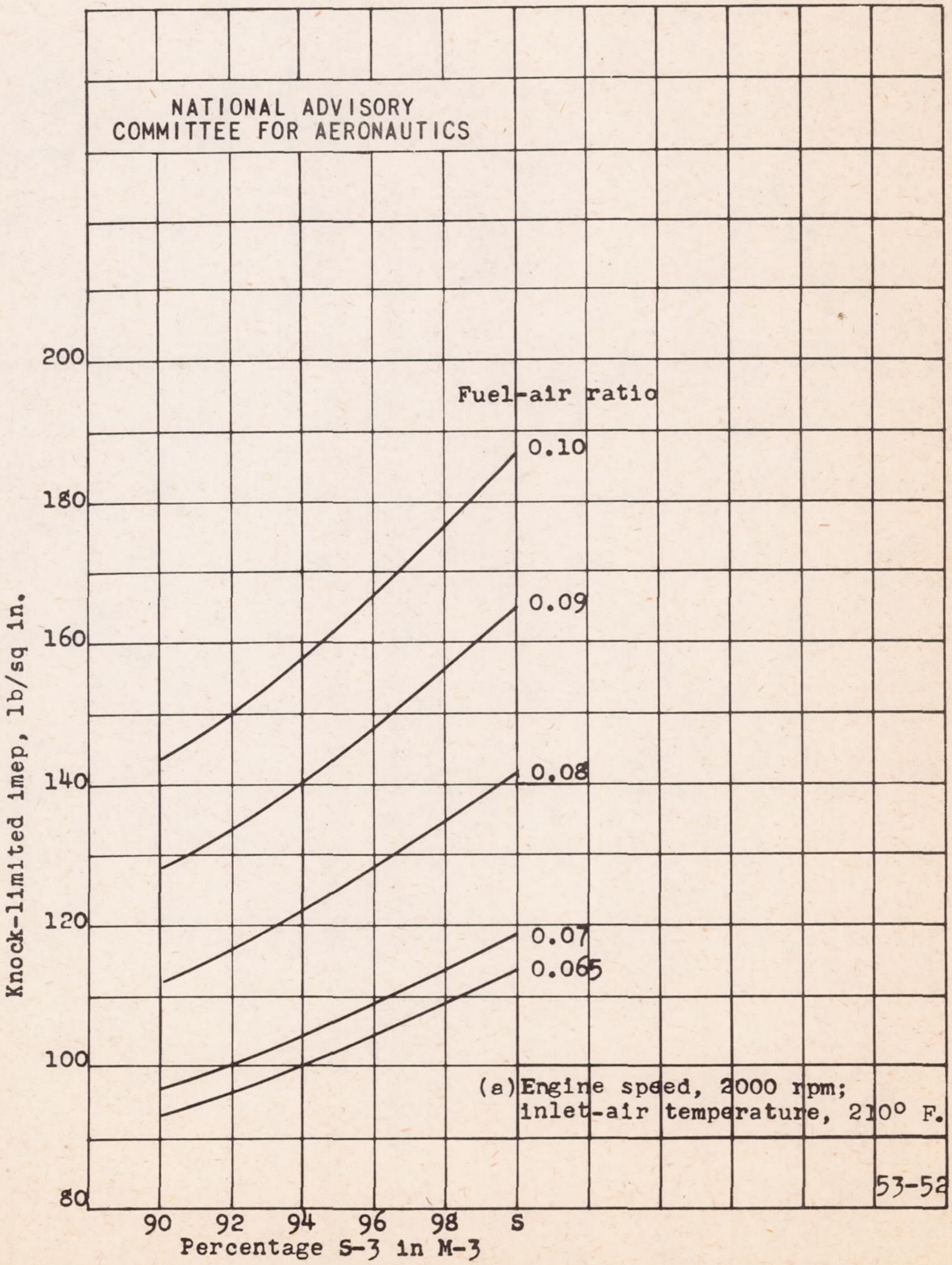


Figure 8. - Relation between knock-limited indicated mean effective pressure and percentage S-3 in M-3 for different fuel-air ratios. Wright R-1820 G200 cylinder; compression ratio, 7.3; spark advance, 20° B.T.C. Curves plotted by using equation 3(b) of reference 2.

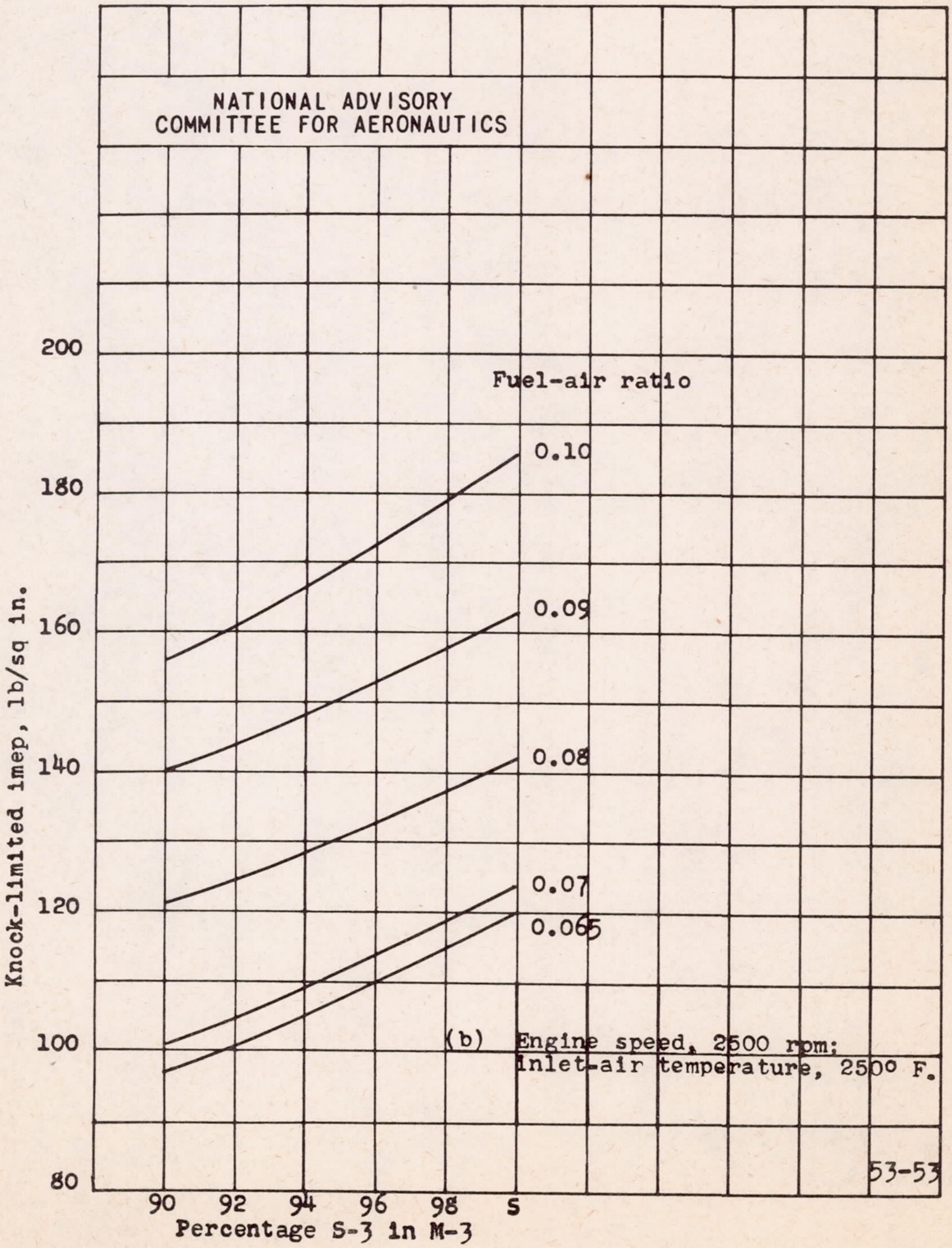


Figure 8. - Concluded.

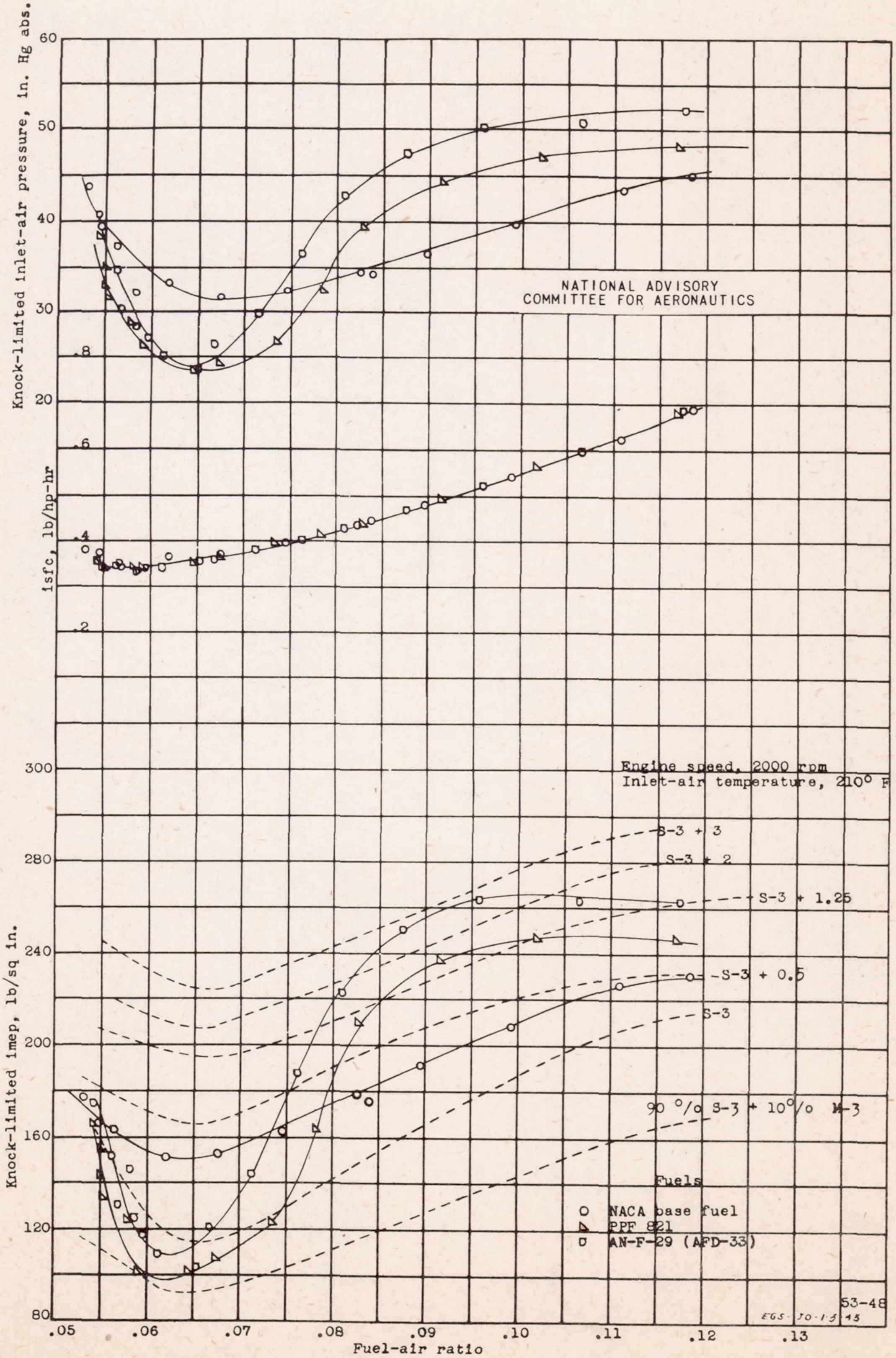


Figure 9. - Knock-limited engine performance at an engine speed of 2000 rpm and an inlet-air temperature of 210° F. Wright R-1820 G200 cylinder; compression ratio, 7.3; spark advance, 20° B.T.C.; cooling air adjusted at 140 bmep and 0.10 fuel-air ratio to give a rear spark-plug-bushing temperature of 365° F.

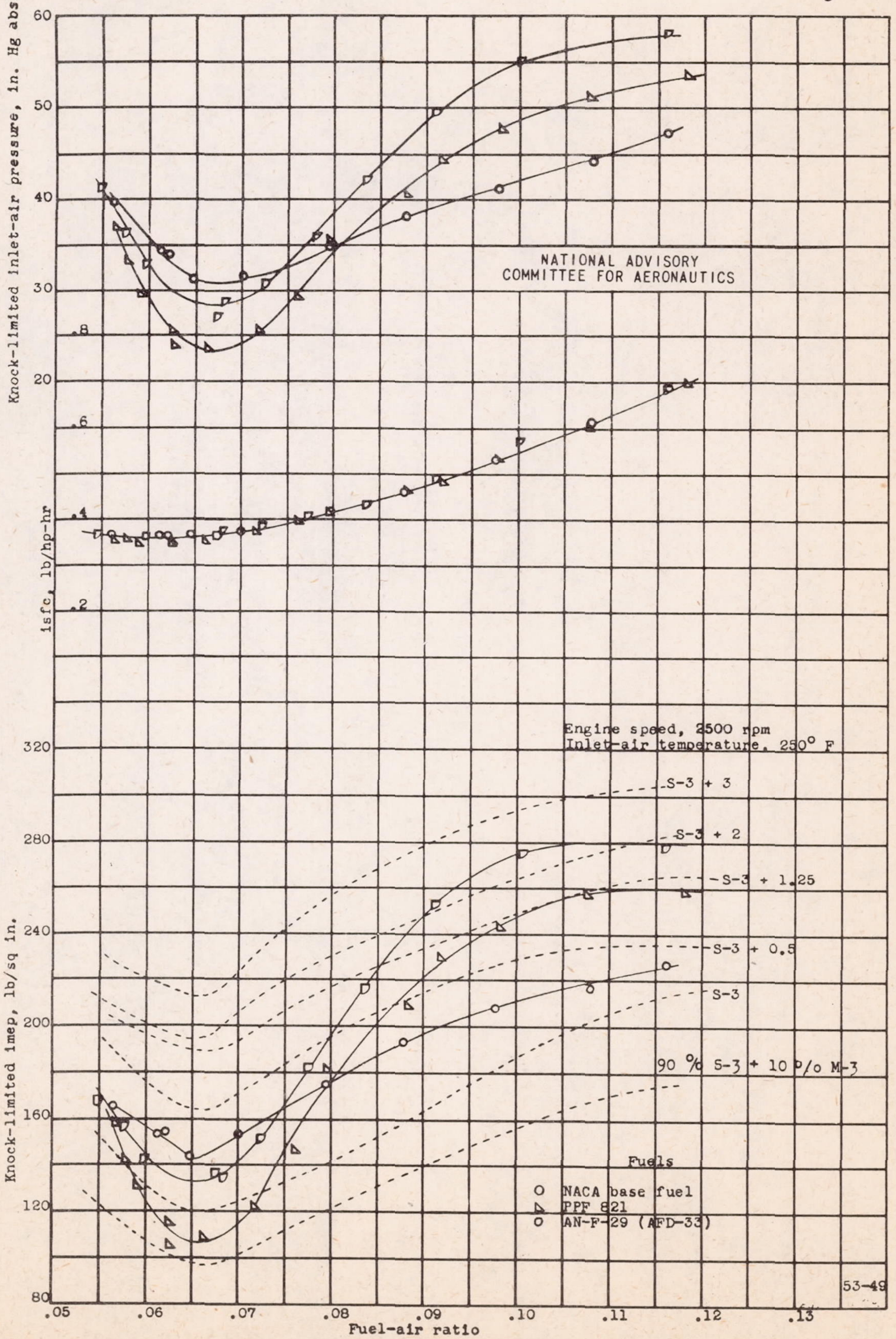


Figure 10. - Knock-limited engine performance at an engine speed of 2500 rpm and an inlet-air temperature of 250° F. Wright R-1820 G200 cylinder; compression ratio, 7.3; spark advance, 20° B.T.C.; cooling-air adjusted at 140 bmep and 0.10 fuel-air ratio to give a rear spark-plug-bushing temperature of 365° F.

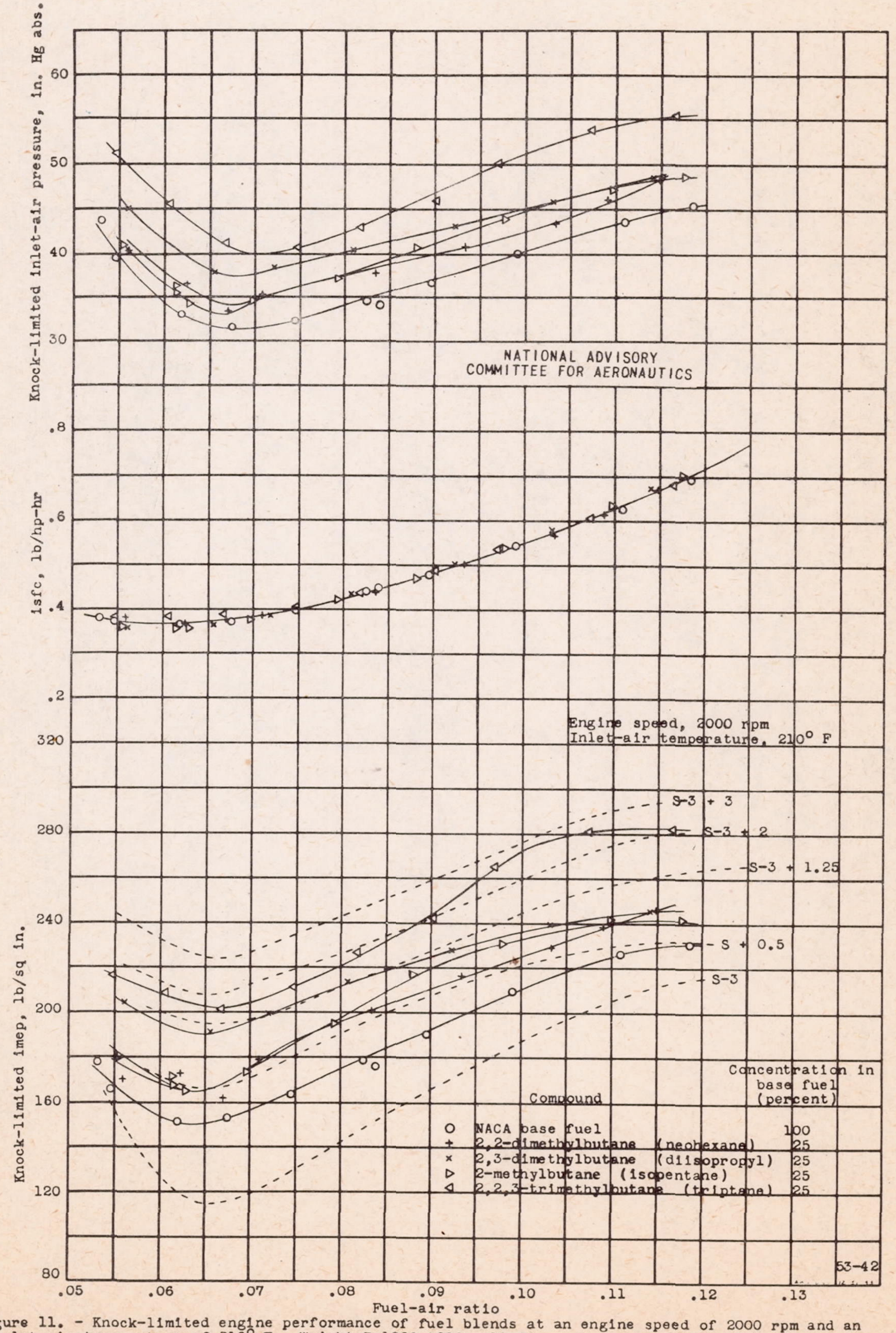


Figure 11. - Knock-limited engine performance of fuel blends at an engine speed of 2000 rpm and an inlet-air temperature of 210° F. Wright R-1820 G200 cylinder; compression ratio, 7.3; spark advance, 20° B.T.C.; cooling air adjusted at 140 bmep and 0.10 fuel-air ratio to give a rear spark-plug-bushing temperature of 365° F.

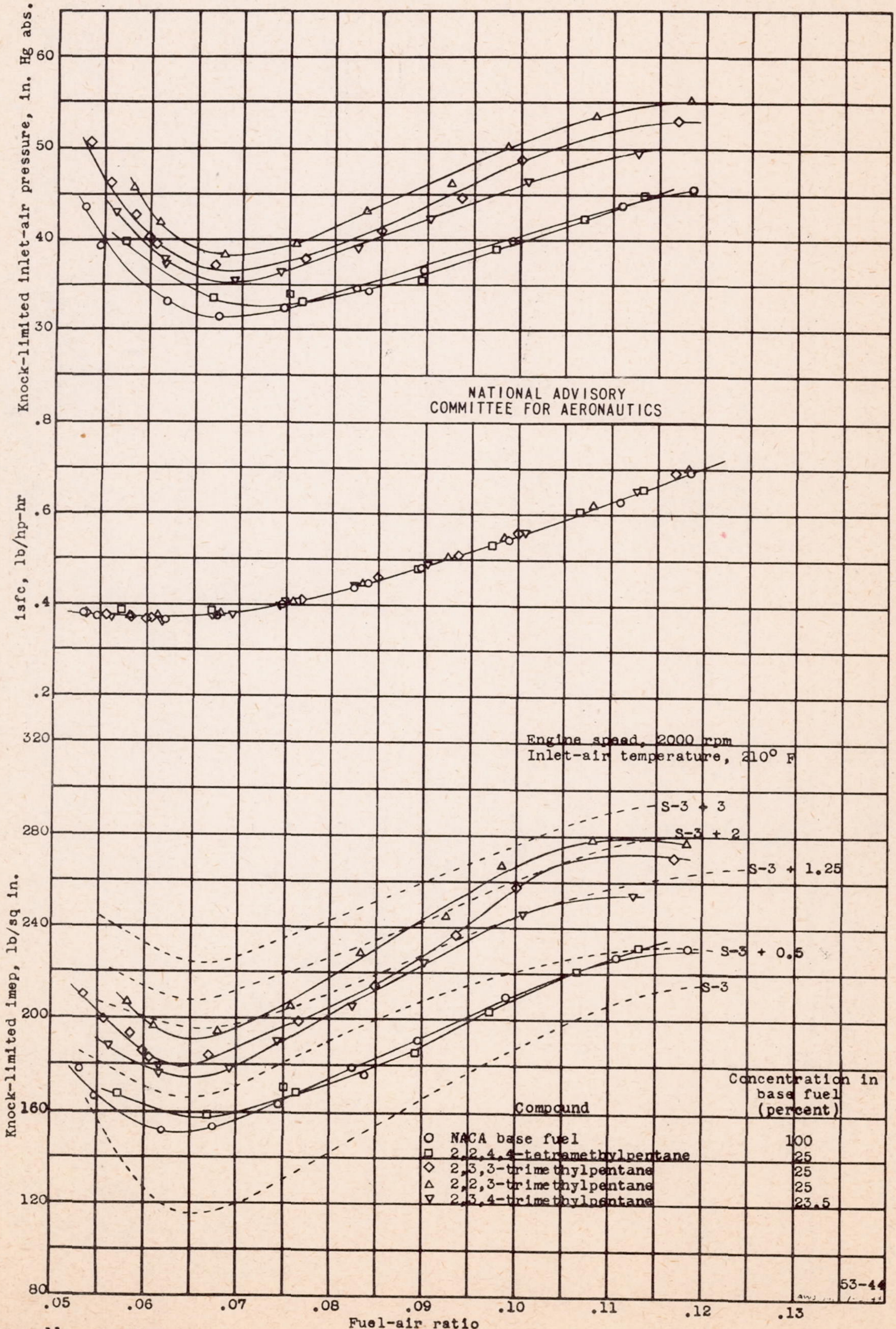


Figure 11. - Continued.

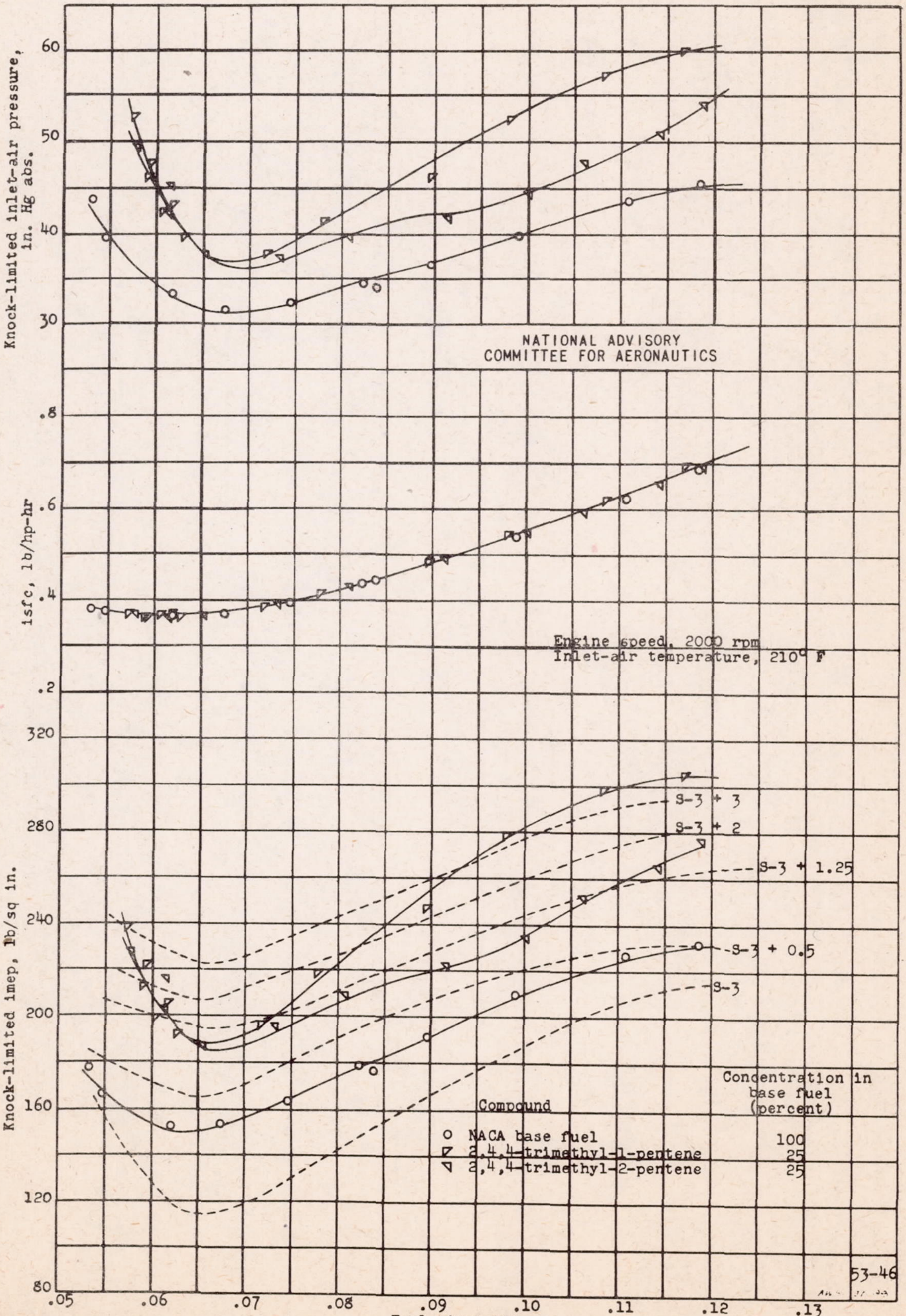


Figure 11. - Concluded.

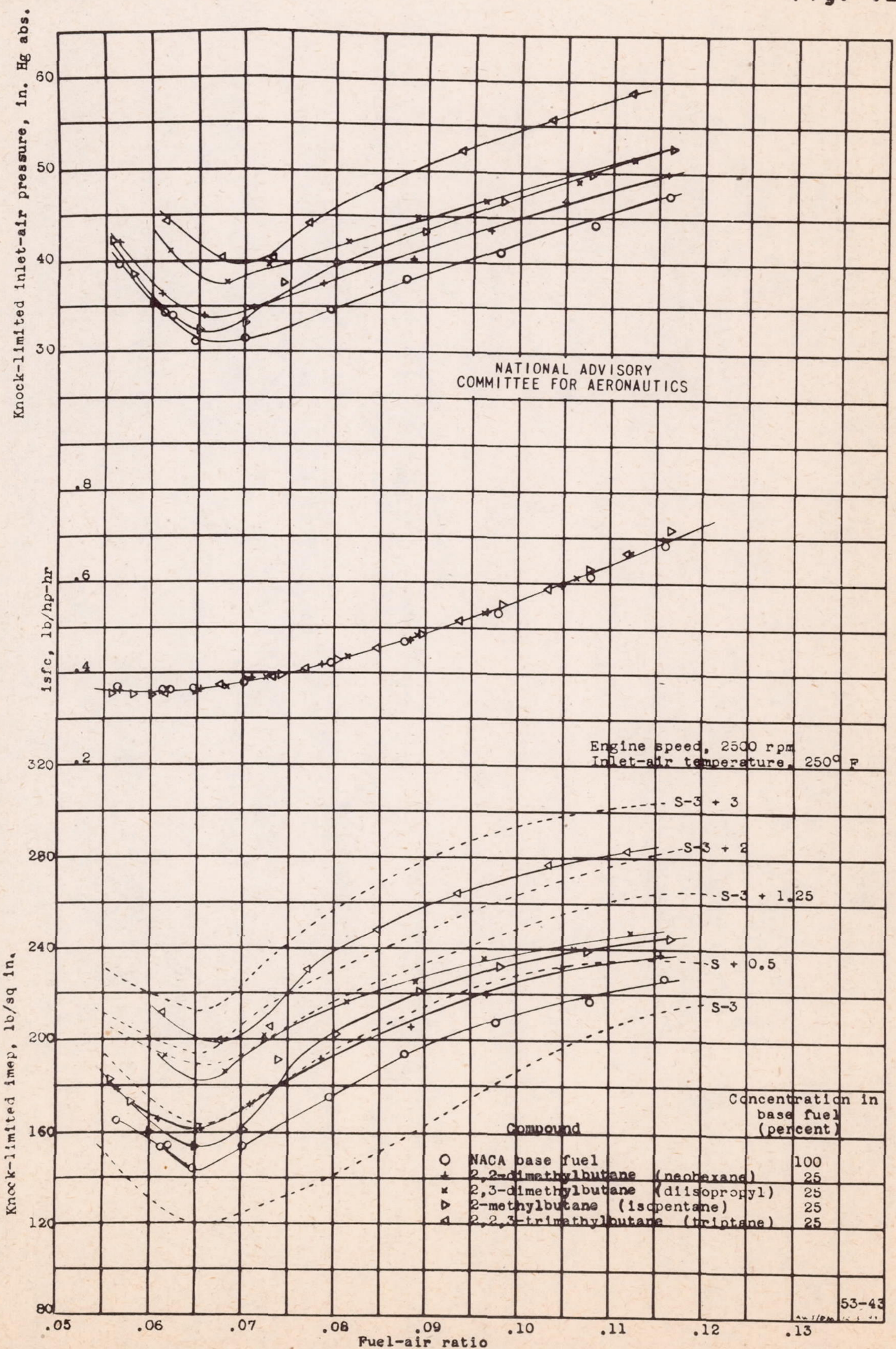


Figure 12. - Knock-limited engine performance of fuel blends at an engine speed of 2500 rpm and an inlet-air temperature of 250° F. Wright R-1820 G200 cylinder; compression ratio, 7.3; spark advance, 20° B.T.C.; cooling-air adjusted at 140 bmep and 0.10 fuel-air ratio to give a rear spark-plug-bushing temperature of 365° F.

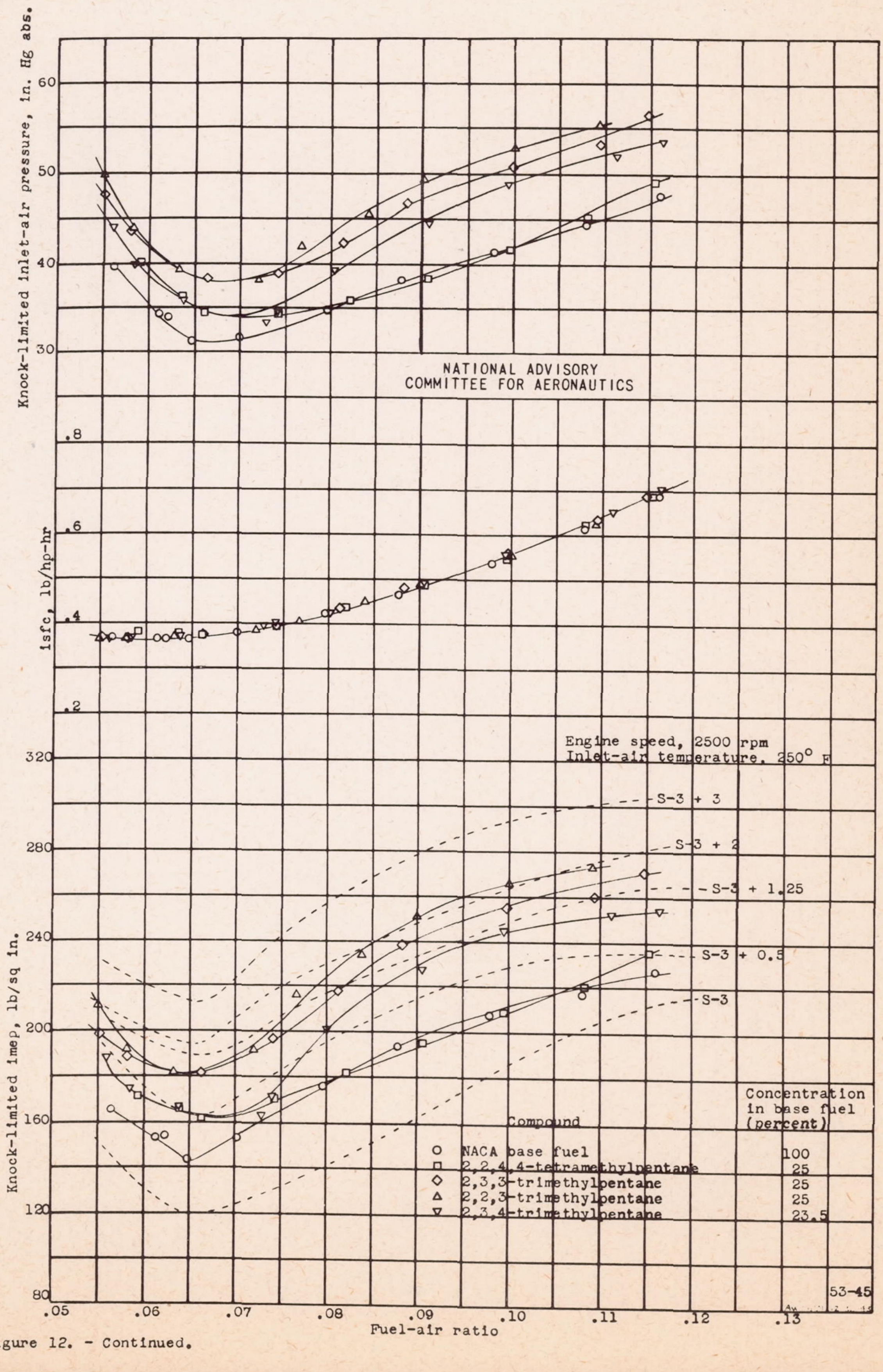


Figure 12. - Continued.

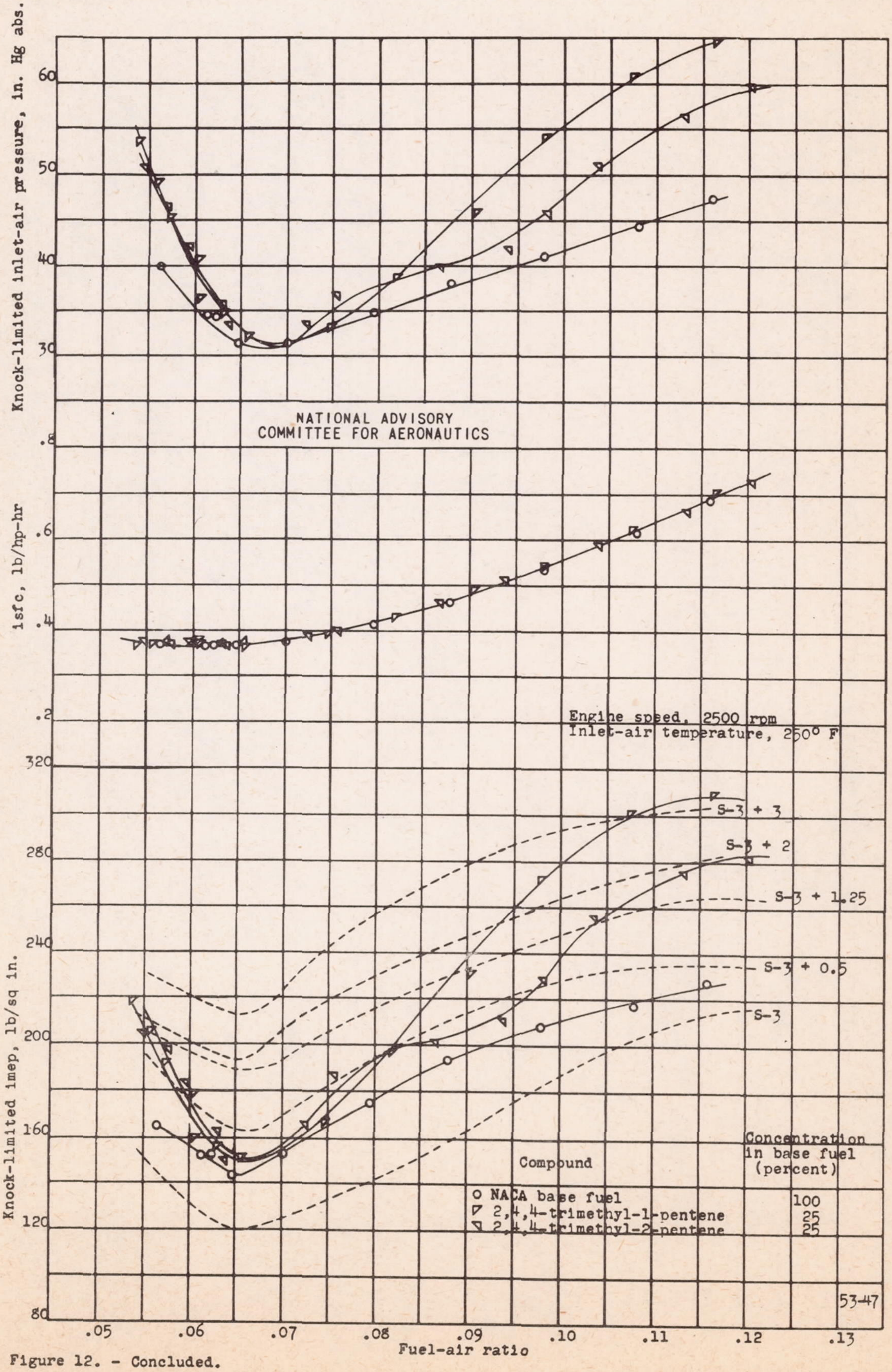


Figure 12. - Concluded.

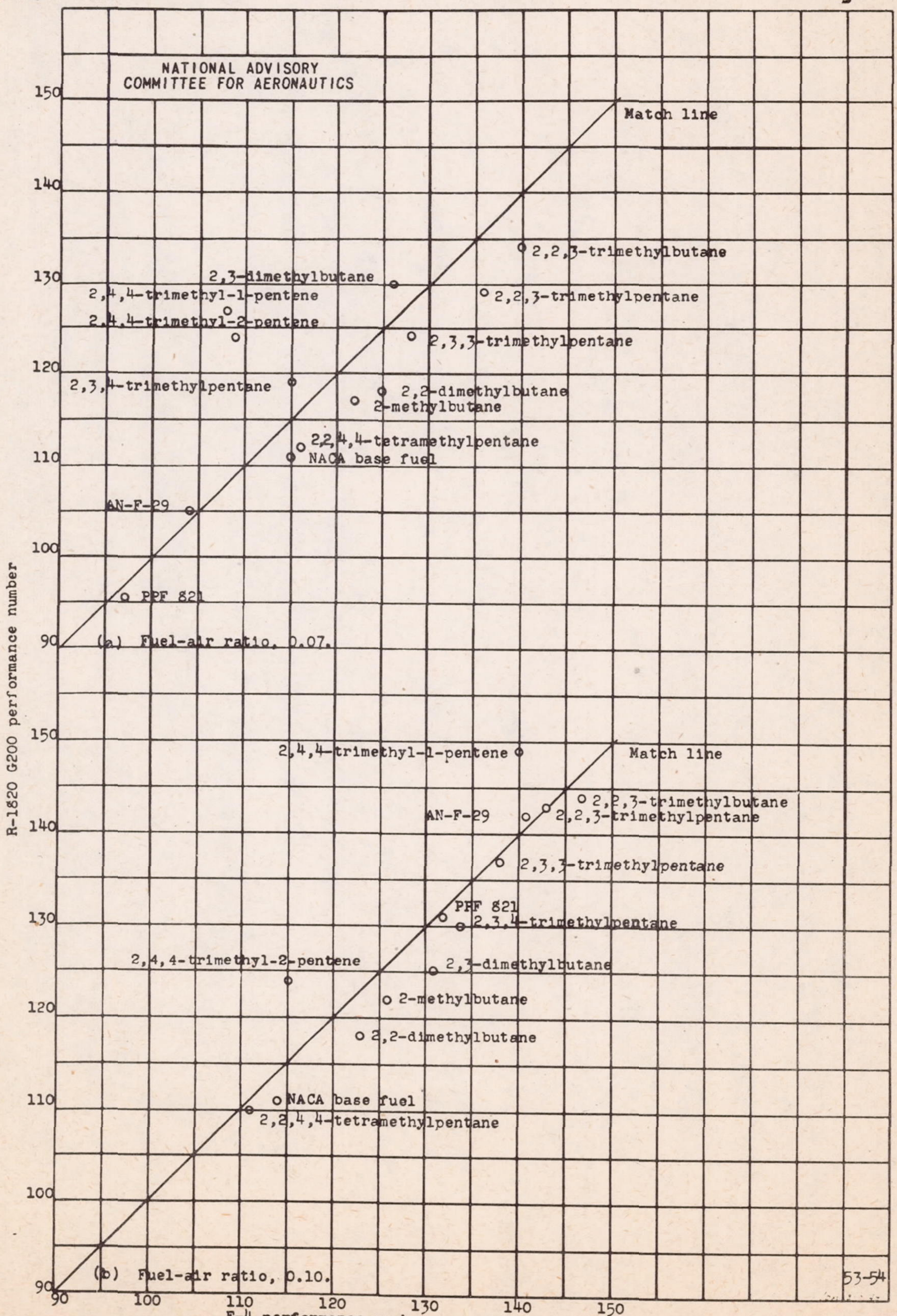


Figure 13. - Comparison of fuel blend ratings at an engine speed of 2000 rpm with F-4 ratings. Wright R-1820 G200 cylinder; compression ratio, 7.3; spark advance, 20° B.T.C.; inlet-air temperature, 210° F; cooling air adjusted at 140 bmep and 0.10 fuel-air ratio to give a rear spark-plug-bushing temperature of 365° F.

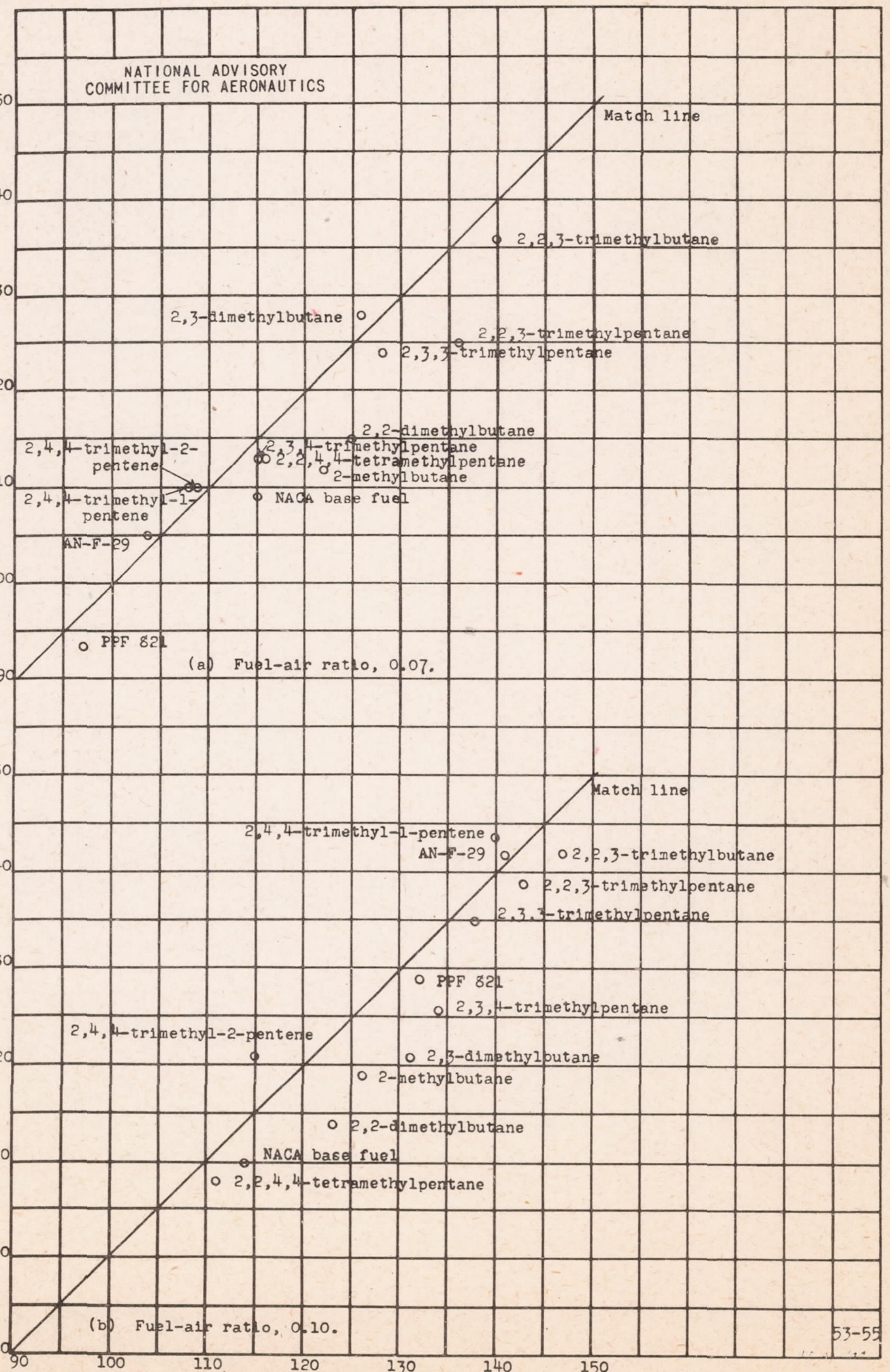


Figure 14. - Comparison of fuel blend ratings at an engine speed of 2500 rpm with F-4 ratings. Wright R-1820 G200 cylinder; compression ratio, 7.3; spark advance, 20° B.T.C.; inlet-air temperature, 250° F; cooling air adjusted at 140 bmep and 0.10 fuel-air ratio to give a rear spark-plug-bushing temperature of 365° F.

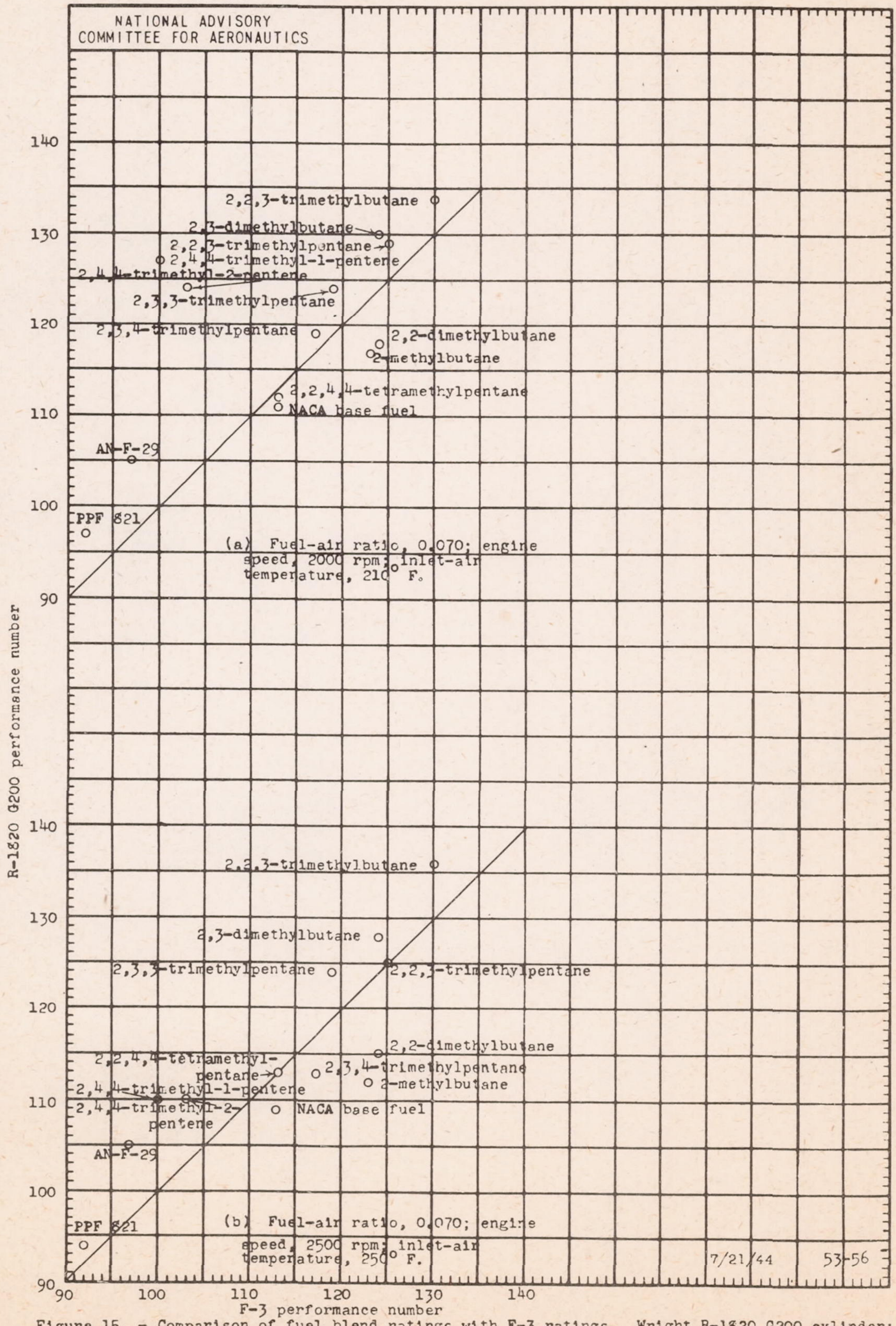


Figure 15. - Comparison of fuel blend ratings with F-3 ratings. Wright R-1820 G200 cylinder; compression ratio, 7.3; spark advance, 20° B.T.C.; cooling air adjusted at 140 bmep and 0.10 fuel-air ratio to give a rear spark-plug-bushing temperature of 365° F.