[redacted]

RM No. E6J07

NACA

RESEARCH MEMORANDUM

for the

Air Materiel Command, Army Air Forces

KNOCK-LIMITED PERFORMANCE OF TRIPTANE AND XYLIDINES BLENDED WITH 28-R AVIATION FUEL AT HIGH COMPRESSION RATIOS AND MAXIMUM-ECONOMY SPARK SETTING

By Louis F. Held and Ernest I. Pritchard

Aircraft Engine Research Laboratory
Cleveland, Ohio

NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

WASHINGTON

[redacted]

NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

RESEARCH MEMORANDUM

for the

Air Materiel Command, Army Air Forces

KNOCK-LIMITED PERFORMANCE OF TRIPTANE AND XYLIDINES BLENDED WITH 28-R AVIATION FUEL AT HIGH COMPRESSION RATIOS AND MAXIMUM-ECONOMY SPARK SETTING

By Louis F. Held and Ernest I. Pritchard

SUMMARY

An investigation was conducted to evaluate the possibilities of utilizing the high-performance characteristics of triptane and xylidines blended with 28-R fuel in order to increase fuel economy by the use of high compression ratios and maximum-economy spark setting.

Full-scale single-cylinder knock tests were run with 20° B.T.C. and maximum-economy spark settings at compression ratios of 6.9, 8.0, and 10.0, and with two inlet-air temperatures. The fuels tested consisted of triptane, four triptane and one xylidines blend with 28-R, and 28-R fuel alone.

At a fuel-air ratio of 0.065, 20-percent triptane blended with 28-R fuel gave increases in knock-limited indicated power ranging from 4 to 28 percent relative to 28-R fuel; and 3-percent xylidines blended with 28-R gave increases ranging from -4 to 37 percent. The maximum observed increase was 78 percent. This increase was obtained with 100-percent triptane at a compression ratio of 10.0 and an inlet-air temperature of 150° F. This value would probably have been exceeded if 100-percent triptane had been knock-tested at a lower compression ratio.

In general, the knock-limited performance of the xylidines blend was affected more by changes in severity of engine operating conditions than the 20-percent triptane blend and relative to 28-R fuel, the knock-limited performance of both blends was less favorable as the severity of engine operating conditions was raised by increases in compression ratio, inlet-air temperature, and spark setting.

Indicated specific fuel consumption at lean mixtures was decreased approximately 17 percent at a compression ratio of 10.0 and maximum-economy spark setting, as compared to that obtained with a compression ratio of 6.9 and normal spark setting.

When compression ratio was increased from 6.9 to 10.0 at an inlet-air temperature of 150° F, normal spark setting, and a fuel-air ratio of 0.065, 55-percent triptane was required with 28-R fuel to maintain the knock-limited brake power level obtained with 28-R fuel at a compression ratio of 6.9. Brake specific fuel consumption was decreased 17.5 percent at a compression ratio of 10.0 relative to that obtained at a compression ratio of 6.9. Approximately similar results were noted at an inlet-air temperature of 250° F.

For concentrations up through at least 20 percent, triptane can be more efficiently used at normal than at maximum-economy spark setting to maintain a constant knock-limited power output over the range of compression ratios tested.

INTRODUCTION

Previous experimental investigations conducted by the American Petroleum Institute and other organizations have shown that triptane (2,2,3-trimethylbutane) is of high quality for use in aviation fuels. In the past, however, triptane has been limited in supply and considered too expensive for general use in aviation fuel. Recent developments in production methods have made triptane available in sufficient quantities for extended experimental work. At the request of the Air Materiel Command, Army Air Forces, an investigation has been conducted at the NACA Cleveland laboratory to evaluate triptane as a component of an improved grade of aviation fuel. The program consisted of knock-limited tests conducted on several engines including small-scale and full-scale single-cylinder engines and multicylinder engines on torque stands and in flight. The results of work completed on this program are reported in references 1 to 14.

Data were obtained on a full-scale R-2600-13 cylinder that show the possibilities of utilizing the high performance characteristics of triptane to allow knock-free operation at high compression ratios and maximum-economy spark setting with the accompanying lower specific fuel consumptions. High-performance fuels consisting of triptane, four triptane and one xylidines blend with 28-R, and 28-R fuel alone were tested at normal and maximum-economy spark setting, compression ratios of 6.9, 8.0, and 10.0, and two inlet-air temperatures. Operation at these conditions with lean mixtures is desirable from consideration of specific fuel consumption but may be impractical because the limit of knock-free power obtainable with current grade 100/130 fuels is often below that necessary for high-powered cruise operation. The use of fuels of higher knock rating is one way to take advantage of the gain in economy at increased compression ratio and maximum-economy spark setting and still maintain required cruise power levels.

APPARATUS AND PROCEDURE

Test setup. - The investigation was conducted on a full-scale R-2600-13 front-row cylinder mounted on a CUE crankcase. Figures 1 and 2 show the instrumentation and general setup of test-engine equipment. Fuel flow was measured by a calibrated rotameter. Standard flight baffles were used and the cylinder-head temperature was measured by an iron-constantan thermocouple in the head one-fourth inch below the rear spark-plug bushing and one-half inch from the combustion chamber. Cooling-air and oil-in temperatures were controlled by heat exchangers.

The compression ratio was varied by changing the position of the cylinder through the use of different spacers under the cylinder flange and thus controlling the clearance volume above the piston. In order to permit variations up to the highest compression ratios, a special piston with a high crown was used in all tests. Comparison of unreported tests at similar operating conditions using the special piston and the standard piston revealed that the use of the special piston had no effect on the knock limit of 28-R fuel.

Knock was detected by a magnetostriction-type pickup unit that indicated on a cathode-ray oscillograph.

Conditions and procedure. - Engine conditions maintained constant were:

Engine speed, rpm.	2100±10
Cylinder-head temperature, °F.	450±5
Cooling-air temperature, °F.	90±15
Oil-in temperature, °F	185±5
Exhaust pressure, in. Hg absolute.	10.0±0.2

Values of engine conditions varied were:

Compression ratio	6.9, 8.0, 10.0
Spark setting (both plugs).	20° B.T.C., maximum economy
Inlet-air temperature, $^{\circ}F$	150, 250
Fuel-air ratio.	0.050-0.120

Operation at engine speeds above 2100 rpm was included in the original program but was omitted when a study of the valve action at varying engine speeds revealed buckling and bouncing in the intake- and exhaust-valve actuating systems to the extent that data at the higher speeds were unreliable.

Operation at reduced exhaust pressure was necessary to avoid the critical knock range in which the inlet pressure is near or equal to the exhaust pressure (reference 14); therefore, an exhaust pressure of 10 inches of mercury absolute (approximately standard pressure at an altitude of 27,500 ft) was used. The inlet-air pressure entered the critical knock range when the engine was operating at a compression ratio of 10.0 and at maximum-economy spark setting.

Normal spark setting for the R-2600-13 engine is 20° B.T.C. for both plugs. Maximum-economy spark setting was obtained by adjusting the spark advance at each datum point so that the maximum rate of pressure rise in the combustion chamber, as indicated by the magnetostriction-type pickup unit, was timed at a crank angle of 3° A.T.C. (See reference 15.)

Fuels. - The fuel blends used and the operating conditions at which they were tested are presented in the following table. Performance numbers listed are F-3 and F-4 ratings obtained from reference 2; ratings above a performance number of 161 are extrapolated values.

Fuel (1)	Performance number F-3/F-4	Spark setting	Compression ratio 6.9	8.0	10.0
			Inlet-air temperature (°F)		
28-R	100/130	20° B.T.C.	150 250	150 250	150 250
		Maximum economy	150 250	150 250	150 250
20-percent triptane 80-percent 28-R 4.6 ml TEL/gal	109/147	20° B.T.C.	150 250	150 250	150 250
		Maximum economy	150 250	150 250	150 250
3-percent xylidines 97-percent 28-R 6.0 ml TEL/gal	100/150	20° B.T.C.	150 250	150 250	150 250
		Maximum economy	150 250	150 250	150 250
40-percent triptane 60-percent 28-R 4.6 ml TEL/gal	116/179	20° B.T.C.	------- 250	150 250	150 250
60-percent triptane 40-percent 28-R 4.6 ml TEL/gal	133/220	20° B.T.C.	------- -------	------- 250	150 250
80-percent triptane 20-percent 28-R 4.6 ml TEL/gal	145/300	20° B.T.C.	------- -------	------- -------	------- 250
Triptane 4.6 ml TEL/gal	--------	20° B.T.C.	------- -------	------- -------	150 250

[1]All fuel blends were made on a percentage volume basis.

RESULTS AND DISCUSSION

Indicated Performance

Knock-limited indicated mean effective pressure. - The knock-limited performance data at compression ratios of 6.9, 8.0, and 10.0 are presented in figures 3 to 5. Each figure is comprised of the data obtained at inlet-air temperatures of 150° and 250° F with spark settings of 20° B.T.C. and maximum economy.

It was noted that mixture-temperature variation was a function of fuel-air ratio alone at a given inlet-air temperature (fig. 6).

The average mixture temperature observed is plotted against fuel-air ratio for the two inlet-air temperatures.

The data were obtained at a relatively low engine speed and with altitude exhaust; they are therefore particularly suitable to show the characteristics of the fuels at cruise conditions. The analyses of the data at lean mixtures will be stressed because, when operating at a given knock-limited power level, it is more economical to keep the mixture lean than to raise the compression ratio and have to enrich the mixture for knock-free operation. This condition exists because the necessary mixture enrichment increases the specific fuel consumption more than it is lowered by raising the compression ratio. The knock-limited indicated mean effective pressure of each of the fuels at a fuel-air ratio of 0.065 and the percentage increase of knock-limited performance relative to that obtainable with 28-R fuel at the same operating conditions are listed in table I. At a fuel-air ratio of 0.065, the 20-percent triptane blend responded with increases in knock-limited indicated power ranging from 4 to 28 percent over that obtainable with 28-R and the 3-percent xylidines blend gave increases of -4 to 37 percent. In general, the knock-limited performance of the xylidines blend was affected more by changes in severity of engine-operating conditions than the 20-percent triptane blend; and relative to 28-R fuel, the knock-limited performance of both blends became less favorable as the severity of engine operating conditions was raised by increases in compression ratio, inlet-air temperature, and spark setting. The 40-, 60-, 80-, and 100-percent triptane blends were tested only at normal spark setting but the same trend was observed for these blends. Exceptions to the general trends did occur, especially when the compression ratio was raised from 6.9 to 8.0.

The maximum increase of knock-limited performance at a fuel-air ratio of 0.065 relative to that obtainable with 28-R fuel was 78 percent, which was obtained with 100-percent triptane at a compression ratio of 10.0 and an inlet-air temperature of 150° F. This value would probably have been exceeded if 100-percent triptane had been knock-tested at a lower compression ratio. Limited laboratory cooling-air supply and high cylinder pressures made knock-limited tests at compression ratios of 6.9 and 8.0 impossible with the fuel blends containing high percentages of triptane.

Indicated specific fuel consumption. - Data showing indicated specific fuel consumption at an inlet-air temperature of 150° F in figures 3 to 5 have been plotted to a larger scale in figure 7. This figure shows that fuel consumption is reduced as compression ratio is increased and as maximum-economy spark setting is used. Table II presents the percentage decrease of indicated specific fuel consumption at increased compression ratios and maximum-economy spark setting for three lean fuel-air ratios relative to that of a compression ratio of 6.9 and normal spark setting. These values show that indicated specific fuel consumption decreased approximately 17 percent at a compression ratio of 10.0 and maximum-economy spark setting, as compared to specific fuel consumption at a compression ratio of 6.9 and normal spark setting. Operation at lower fuel-air ratios shows an advantage over a fuel-air ratio of 0.065 because the reference curve rises slightly at the leaner fuel-air mixtures whereas the other curves remain approximately flat or continue to drop.

The fuel consumption in the lean region was slightly lower at an inlet-air temperature of 150° F than at an inlet-air temperature of 250° F (figs. 3, 4, and 5). The percentage change of fuel consumption with changes of compression ratio and spark setting compared to that of a compression ratio of 6.9 and normal spark setting was essentially the same for the two inlet-air temperatures as shown in table II.

In order to determine whether the experimental fuel-consumption data corresponded to the theoretical trends expected with variation in compression ratio, the experimental fuel-consumption data at a fuel-air ratio of 0.060 were converted to indicated thermal efficiency, cross-plotted against compression ratio, and compared to two theoretical-efficiency curves (fig. 7). The theoretical-efficiency curves used were those calculated from the expression for the air-cycle thermal efficiency of the Otto cycle and that obtained by using the Hottel combustion charts at a fuel-air ratio of 0.0605 (reference 16). The thermal-efficiency values of the experimental data are lower than those of the theoretical-efficiency curves but the slopes of the curves are similar.

Use of Triptane with 28-R Fuel to Improve Fuel Economy

Tables I and II present indicated performance results but a more practical picture of the value of triptane can be obtained from its effect on the brake performance. Supercharger power requirements are taken into account when the data are analyzed on a brake basis. The method of converting the data to a brake basis is shown in the appendix.

A practical evaluation of the use of triptane can be presented by showing the manner in which it can be used to offset the reduction in knock-limited power that occurs when the compression ratio is increased or the spark setting is advanced beyond that normally used. In figure 8 the percentage of triptane required with 28-R fuel in order to maintain the knock-limited power output of 28-R at a fuel-air ratio of 0.065 and a compression ratio of 6.9 is plotted against compression ratio. The curves are for the normal spark setting at inlet-air temperatures of 150° and 250° F. In order to show the effect of the reduced supercharger requirements caused by lowered specific air consumption at increased compression ratios, indicated and brake performance curves are shown.

At an inlet-air temperature of 150° F, normal spark advance, and a fuel-air ratio of 0.065, 55-percent triptane blended with 28-R fuel was required at a compression ratio of 10.0 to maintain the knock-limited power obtained with 28-R fuel at a compression ratio of 6.9 on the brake basis; the accompanying decrease in brake specific fuel consumption at this high compression ratio was 17.5 percent (fig. 8). Comparison on the basis of knock-limited indicated power shows that 65-percent triptane was required with an accompanying 12.5 percent decrease of indicated specific fuel consumption. Approximately similar results were noted at an inlet-air temperature of 250° F.

The increasing slopes of the triptane-requirement curves of figure 8 and the greater triptane requirement at the higher inlet-air temperature indicates that triptane blended with 28-R becomes less effective as the severity of engine operating conditions increases.

In order to show a more complete picture of the test results, figure 9 shows cross-plotted triptane-requirement and specific-fuel-consumption curves similar to those of figure 8 except that several power levels are included as parameters. Maximum-economy spark data at a fuel-air ratio of 0.060 are also presented. Curves of brake specific fuel consumption are presented for only two representative power levels at each inlet-air temperature.

It was concluded that for concentrations up through at least 20 percent, triptane can be more efficiently used to maintain constant knock-limited power at normal rather than at maximum-economy spark setting over the range of the compression ratios tested (fig. 10). Cross-plotted from figure 9, figure 10 shows the brake specific fuel consumption obtained at the two spark settings and two knock-limited power levels for each inlet-air temperature with variable compression ratio plotted against percentage triptane required for operation at the knock limit. Because the curves for normal spark setting are below those for maximum-economy spark setting, the foregoing conclusion was made.

SUMMARY OF RESULTS

From an investigation of the triptane, triptane and xylidines blends with 28-R fuel, and 28-R fuel alone at various compression ratios, spark settings, and inlet-air temperatures the following results were obtained:

1. At a fuel-air ratio of 0.065, 20-percent triptane blended with 28-R fuel gave increases in knock-limited indicated power ranging from 4 to 28 percent relative to 28-R fuel; and 3-percent xylidines blended with 28-R fuel gave increases of indicated performance ranging from -4 to 37 percent.

2. The maximum observed increase of knock-limited indicated power relative to 28-R fuel at a fuel-air ratio of 0.065 was 78 percent. This increase was obtained with 100-percent triptane at a compression ratio of 10.0 and an inlet-air temperature of 150° F. This value would probably have been exceeded if 100-percent triptane had been knock-tested at a lower compression ratio.

3. In general, the knock-limited performance of the xylidines blend was affected more by changes in severity of engine operating conditions than the 20-percent triptane blend and relative to 28-R fuel, the knock-limited performance of both blends was less favorable as the severity of engine operating conditions was raised by increases in compression ratio, inlet-air temperature, and spark setting.

4. Indicated specific fuel consumption at lean mixtures was decreased approximately 17 percent at a compression ratio of 10.0 and maximum-economy spark setting, as compared to that obtained with a compression ratio of 6.9 and normal spark setting.

5. When compression ratio was increased from 6.9 to 10.0, at an inlet-air temperature of 150° F, normal spark setting, and a fuel-air ratio of 0.065, 55-percent triptane was required with 28-R fuel to maintain the knock-limited brake power level obtained with 28-R fuel at a compression ratio of 6.9. Brake specific fuel consumption was decreased 17.5 percent at a compression ratio of 10.0 relative to that obtained at a compression ratio of 6.9. Approximately similar results were noted at an inlet-air temperature of 250° F.

6. For concentrations up through at least 20 percent, triptane

can be more efficiently used at normal than at maximum-economy spark setting to maintain a constant knock-limited power output over the range of compression ratios tested.

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

Louis F. Held

Louis F. Held,
Mechanical Engineer.

Ernest I. Pritchard,
Mechanical Engineer.

Approved:

Arnold E. Biermann,
Mechanical Engineer.

John H. Collins, Jr.,
Mechanical Engineer.

va

APPENDIX - CALCULATION OF BRAKE MEAN EFFECTIVE PRESSURE

In order to improve the utility of the data presented, the brake mean effective pressure and brake specific fuel consumption were calculated for all data. Estimations of cooling air and intercooler drag are too dependent upon the design of the systems to be useful and were not included. Operation of an R-2600 engine at an altitude of 27,500 feet were assumed because it corresponds to the test conditions.

The basic equation for relating the brake and indicated powers of an engine is:

$$\text{imep} = \text{bmep} + \text{fmep} + \text{pmep} + \text{smep}$$

or

$$\text{bmep} = \text{imep} - \text{fmep} - \text{pmep} - \text{smep} \qquad (1)$$

where

bmep brake mean effective pressure, lb/sq in.

imep indicated mean effective pressure, lb/sq in.

fmep friction mean effective pressure, lb/sq in.

pmep pumping mean effective pressure, lb/sq in.

smep supercharger mean effective pressure, lb/sq in.

The value of friction mean effective pressure was obtained by plotting combustion-air flow against brake mean effective pressure for an R-2600 full-scale engine at a speed of 2100 rpm (reference 17) and extrapolating the data to zero air flow. The intercept at zero air flow was used as the friction mean effective pressure.

$$\text{fmep} = 20 \text{ lb/sq in.}$$

The following equation was used to determine pumping mean effective pressure

$$\text{pmep} = -0.1\ (P_i - P_e) \qquad (2)$$

where

P_i inlet-manifold pressure, in. Hg absolute

P_e exhaust-manifold pressure, in. Hg absolute

This empirical equation for pumping mean effective pressure was determined by plotting the motoring mean effective pressure obtained while running the engine with the dynamometer against P_i. If pumping power is assumed to be zero at the point where $P_i = P_e$, the slope of the curve equals the variation of pumping mean effective pressure with $(P_i - P_e)$ because P_e is a constant. The slope showed that an increase of inlet-manifold pressure of 1 inch of mercury absolute was equal to a change of -0.1 pound per square inch of mean effective pressure; therefore, pmep = $-0.1\ (P_i - P_e)$.

In calculations of the supercharger mean effective pressure, a variable-speed supercharger with constant adiabatic efficiency is assumed. Inlet pressure to the supercharger is assumed equal to the exhaust pressure used in the test. The equation used to calculate the supercharger work (reference 18) is

$$W = J\,\frac{C_pT}{\eta}\left[\left(\frac{P_i}{P_e}\right)^{\frac{\gamma-1}{\gamma}} - 1\right] \tag{3}$$

where

W compression work per unit weight of air, ft lbs/lb of air

J mechanical equivalent of heat, 778 ft-lb/Btu

C_p specific heat at constant pressure, 0.24 Btu/lb $^{\circ}$F

T temperature of air entering compressor, 420° R (ambient-air temperature at 27,500 ft altitude)

η adiabatic compressor efficiency, assumed 70 percent

γ ratio of the specific heats $\frac{C_p}{C_v}$, 1.40

For air flow this equation then becomes

$$\text{shp} = \frac{MJC_pT}{33{,}000\ \eta}\left[\left(\frac{P_i}{P_e}\right)^{\frac{\gamma-1}{\gamma}} - 1\right] \tag{4}$$

where

shp supercharger horsepower

M air flow, lb/min

Because

$$\text{mep} = \text{Chp} \tag{5}$$

where

C constant for any one engine at one speed, 2.03 for the R-2600-13 engine at 2100 rpm

then

$$\text{smep} = C \frac{MJC_pT}{33,000\ \eta} \left[\left(\frac{P_i}{P_e}\right)^{\frac{\gamma-1}{\gamma}} - 1\right] \tag{6}$$

By substitution of equations (2) and (6) and the value of friction mean effective pressure in equation (1), it becomes

$$\text{bmep} = \text{imep} - C \frac{MJC_pT}{33,000\ \eta} \left[\left(\frac{P_i}{P_e}\right)^{\frac{\gamma-1}{\gamma}} - 1\right] - 20 + 0.1\ (P_i - P_e) \tag{7}$$

Indicated specific fuel consumption was multiplied by the ratio of indicated mean effective pressure to brake mean effective pressure to obtain brake specific fuel consumption.

REFERENCES

1. Barnett, Henry C.: An Evaluation of the Knock-Limited Performance of Triptane. NACA MR No. E6B20, Army Air Forces, 1946.

2. Evvard, John C., Imming, Harry S., and Genco, Russel S.: The Knock-Limited Blending Characteristics of Blends of Triptane and 28-R Aviation Gasoline. NACA Memo. rep., Army Air Forces, April 18, 1944.

3. Branstetter, J. Robert: Comparison of the Knock-Limited Performance of Triptane with 23 Other Purified Hydrocarbons. NACA MR No. E5E15, Army Air Forces, 1945.

4. Barnett, Henry C.: Estimation of F-3 and F-4 Knock-Limited Performance Ratings for Ternary and Quaternary Blends Containing Triptane or Other High-Antiknock Aviation-Fuel Blending Agents. NACA MR No. E5A29, Army Air Forces, 1945.

5. Barnett, Henry C., Imming, Harry S., and Clarke, Thomas C.: F-3 and F-4 Engine Tests of Triptane and Other High-Antiknock Components of Aviation Gasoline - Part I. NACA Memo. rep., Army Air Forces, Aug. 1, 1944.

6. Imming, Harry S., Barnett, Henry C., and Genco, Russel S.: F-3 and F-4 Engine Tests of Triptane and Other High-Antiknock Components of Aviation Gasoline - Part II. NACA MR No. E4K27, Army Air Forces, 1944.

7. Alquist, Henry E., and Tower, Leonard K.: The Effect of Compression Ratio on Knock Limits of High-Performance Fuels in a CFR Engine. I - Blends of Triptane and 28-R Fuel. NACA MR No. E4J10, Army Air Forces, 1944.

8. Sanders, Newell D., Wear, Jerrold D., and Stricker, Edward G.: Knock-Limited Blending Characteristics of Fuel Components in a Pratt & Whitney R-2800 Cylinder. I - Triptane, Hot-Acid Octanes, Isopentane, Diisopropyl, Neohexane, and Xylidines. NACA MR No. E4J01, Army Air Forces, 1944.

9. Breitwieser, Roland, and Hensley, Reece V.: Knock-Limited Blending Characteristics of Fuel Components in a Pratt & Whitney R-2800 Cylinder. III - Tests at Advanced Spark Setting with Triptane, Hot-Acid Octanes, Isopentane, Diisopropyl, Alkylate, Neohexane, and 2,2,3-Trimethylpentane. NACA MR No. E5C14, Army Air Forces, 1945.

10. Brown, Kenneth D., Richard, Paul H., and Wilson, Robert W.: Correlation of the Characteristics of Single-Cylinder and Flight Engines in Tests of High-Performance Fuels in a Pratt & Whitney R-1830-94 Engine. II - Knock-Limited Charge-Air Flow and Cylinder Temperatures. NACA MR No. E5J12, Army Air Forces, 1945.

11. White, H. Jack, Blackman, Calvin C., and Werner, Milton: Flight and Test-Stand Investigation of High-Performance Fuels in Pratt & Whitney R-1830-90C Engines. II - Flight Knock Data and Comparison of Fuel Knock Limits with Engine Cooling Limits in Flight. NACA MR No. E4L30, Army Air Forces, 1944.

12. White, H. Jack, Pragliola, Philip C., and Blackman, Calvin C.: Flight and Test-Stand Investigation of High-Performance Fuels in Pratt & Whitney R-1830-94 Engines. II - Flight Knock Data and Comparison of Fuel Knock Limits with Engine Cooling Limits in Flight. NACA MR No. E5H04, Army Air Forces, 1945.

13. Blackman, Calvin C., and White, H. Jack: Flight and Test-Stand Investigation of High-Performance Fuels in Pratt & Whitney R-1830-94 Engines. III - Knock-Limited Performance of 33-R as Compared with a Triptane Blend and 28-R in Flight. NACA MR No. E5H08, Army Air Forces, 1945.

14. Cook, Harvey A., Held, Louis F., and Pritchard, Ernest I.: The Influence of Exhaust Pressure on Knock-Limited Performance. NACA MR No. E5A05, Army Air Forces, 1945.

15. Cook, Harvey A., and Brightwell, Virginia L.: Relation between Fuel Economy and Crank Angle for the Maximum Rate of Pressure Rise. NACA MR No. E5E21, Army Air Forces, 1945.

16. Hershey, R. L., Eberhardt, J. E., and Hottel, H. C.: Thermodynamic Properties of the Working Fluid in Internal-Combustion Engines. SAE Trans., vol. 39, no. 4, Oct. 1936, pp. 409-424.

17. Strong, W. B., and Robbins, L.: Calibration of Wright Aeronautical Corporation XR-2600-20 Engine. Ser. No. AEL-822, Aero. Eng. Lab., Naval Air Exp. Sta., Naval Air Material Center (Philadelphia), Bur. Aero., Navy Dept., Feb. 28, 1945.

18. Pye, D. R.: The Internal Combustion Engine. Vol. II. The Aero-Engine. Clarendon Press (Oxford), 1934, p. 269. (Reprinted Oxford Univ. Press (London), 1943.)

TABLE I

KNOCK-LIMITED PERFORMANCE OF TRIPTANE AND XYLIDINES

BLENDS WITH 28-R FUEL AT A FUEL-AIR RATIO OF 0.065

[Upper numbers, knock-limited imep; lower numbers, percentage increase relative to 28-R fuel]

Fuel	Spark setting	Compression ratio					
		6.9		8.0		10.0	
		Inlet-air temperature, °F					
		150	250	150	250	150	250
28-R	20° B.T.C.	266	210	220	181	172	114
	Maximum economy	260	176	186	137	146	61
20-percent triptane 80-percent 28-R 4.6 ml TEL/gal	20° B.T.C.	317 19	249 19	273 24	208 15	213 24	121 6
	Maximum economy	298 15	201 14	238 28	152 11	152 4	69 13
3-percent xylidines 97-percent 28-R 6.0 ml TEL/gal	20° B.T.C.	364 37	225 7	296 35	210 16	188 9	112 -2
	Maximum economy	321 24	173 -2	253 36	131 -4	144 -1	63 3
40-percent triptane 60-percent 28-R 4.6 ml TEL/gal	20° B.T.C.	---- ----	312 49	326 48	240 33	231 34	141 24
60-percent triptane 40-percent 28-R 4.6 ml TEL/gal	20° B.T.C.	---- ----	--- ---	--- ---	291 61	259 51	158 39
80-percent triptane 20-percent 28-R 4.6 ml TEL/gal	20° B.T.C.	---- ----	--- ---	--- ---	--- ---	(a)	166 46
Triptane 4.6 ml TEL/gal	20° B.T.C.	---- ----	--- ---	--- ---	--- ---	306 78	194 70

[a] The 80-percent blend was not run at this condition, because its performance could be approximated from the data of the 60-percent and 100-percent blends.

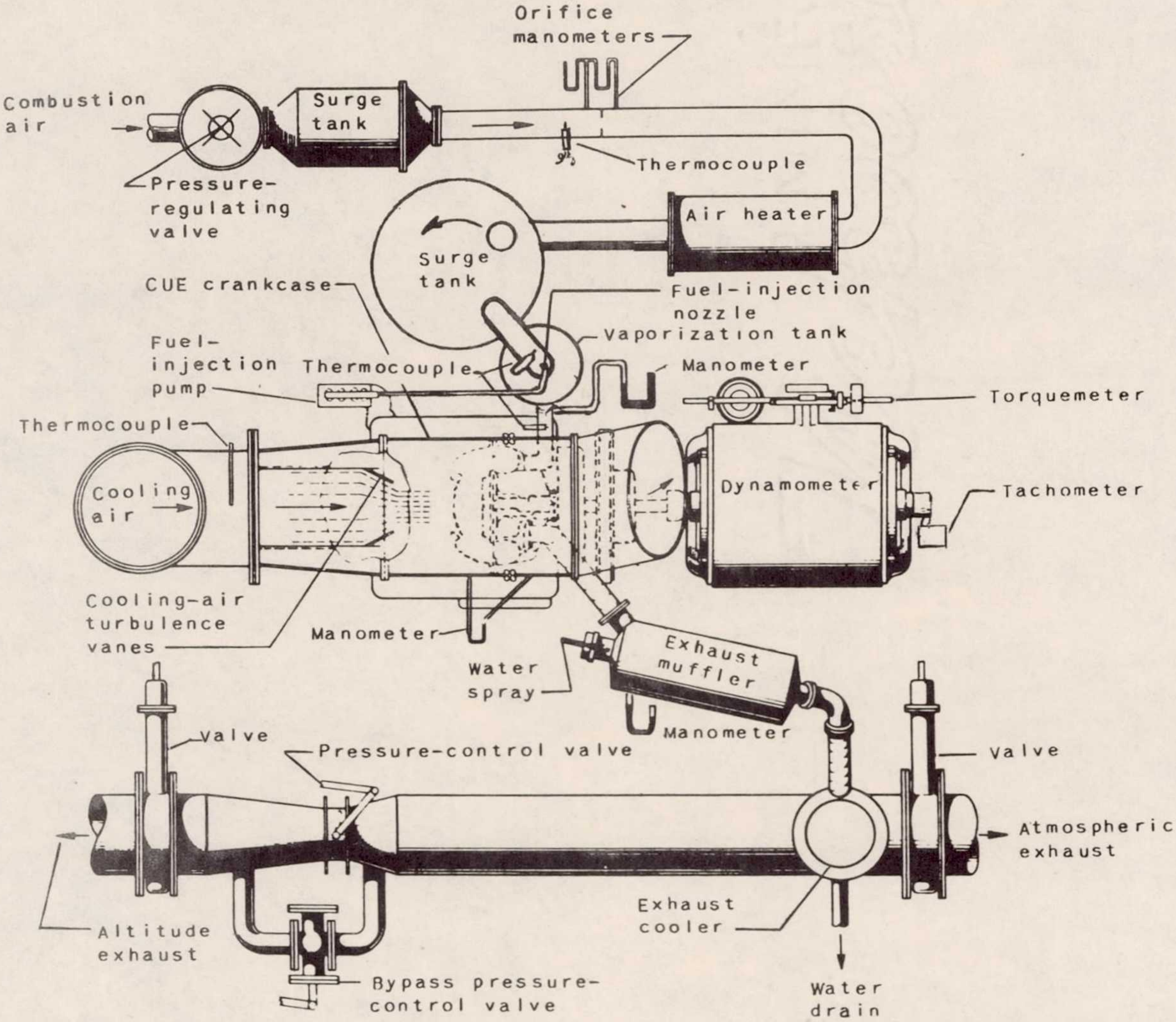
NATIONAL ADVISORY COMMITTEE
FOR AERONAUTICS

TABLE II

PERCENTAGE DECREASE OF INDICATED SPECIFIC FUEL CONSUMPTION AT VARIOUS COMPRESSION RATIOS AND SPARK SETTINGS RELATIVE TO SPECIFIC FUEL CONSUMPTION AT A COMPRESSION RATIO OF 6.9 AND NORMAL SPARK SETTING

Compression ratio	Spark setting	Fuel-air ratio		
		0.055	0.060	0.065
Inlet-air temperature, 150° F				
6.9	Maximum economy	6.8	4.6	2.5
8.0	20° B.T.C.	6.3	5.9	5.3
	Maximum economy	11.4	9.2	7.4
10.0	20° B.T.C.	13.9	13.3	12.7
	Maximum economy	16.9	15.8	14.5
Inlet-air temperature, 250° F				
6.9	Maximum economy	5.3	2.6	1.0
8.0	20° B.T.C.	4.8	4.5	4.1
	Maximum economy	9.9	7.9	5.3
10.0	20° B.T.C.	12.4	11.8	11.4
	Maximum economy	16.5	15.9	15.0

NATIONAL ADVISORY COMMITTEE
FOR AERONAUTICS



NATIONAL ADVISORY
COMMITTEE FOR AERONAUTICS

Figure 1. - Arrangement of apparatus for the R-2600-13 full-scale single-cylinder test setup.

754

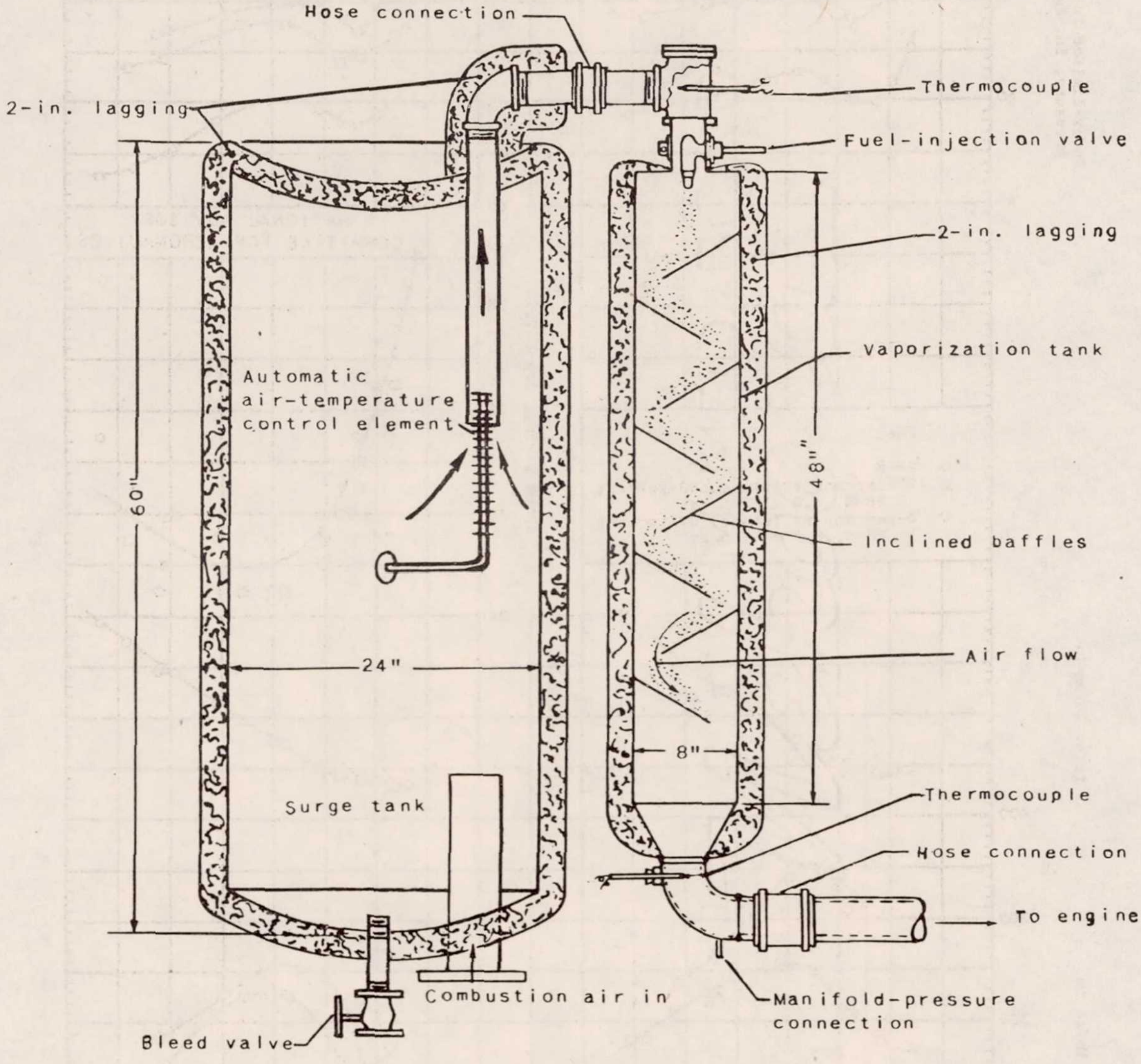
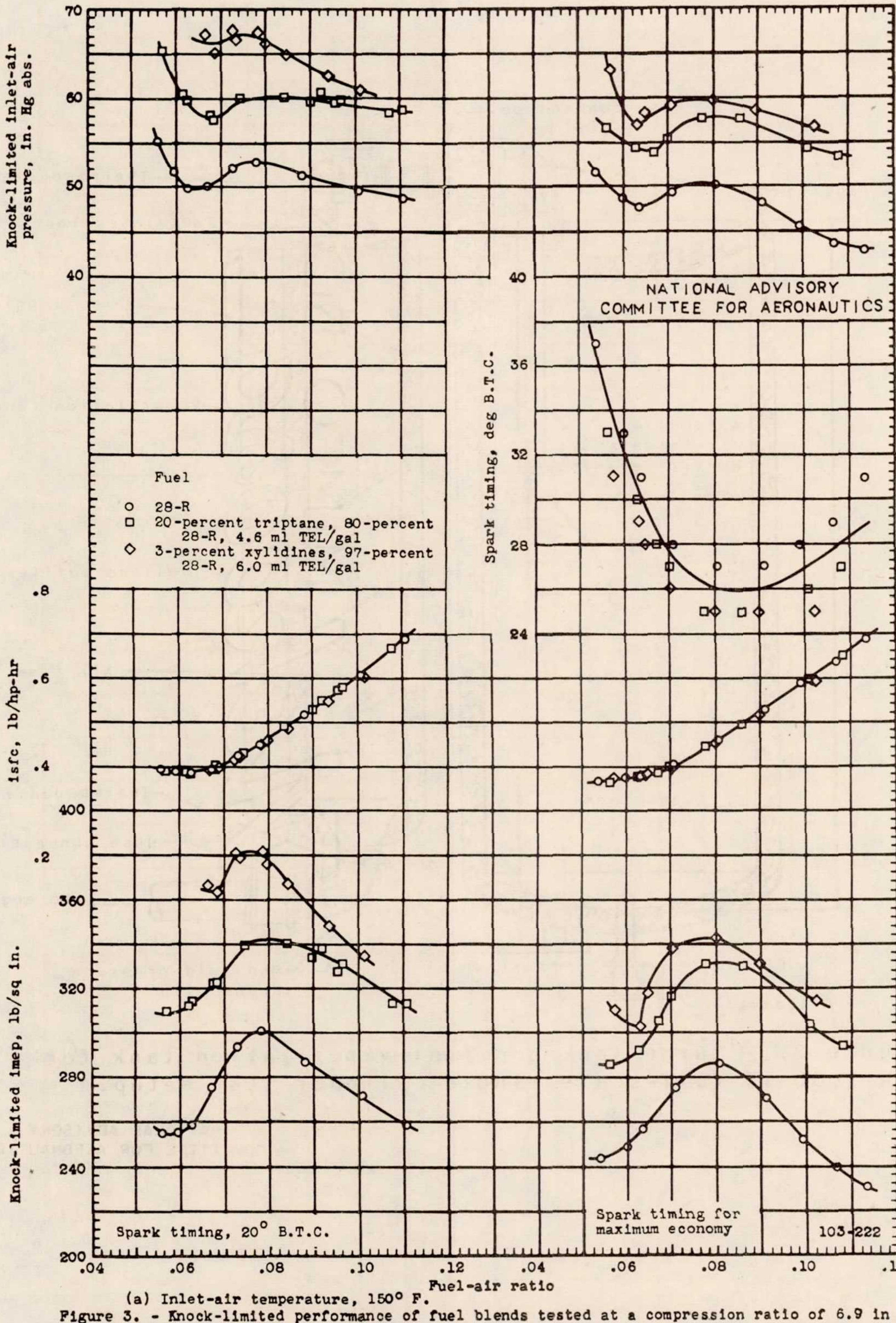


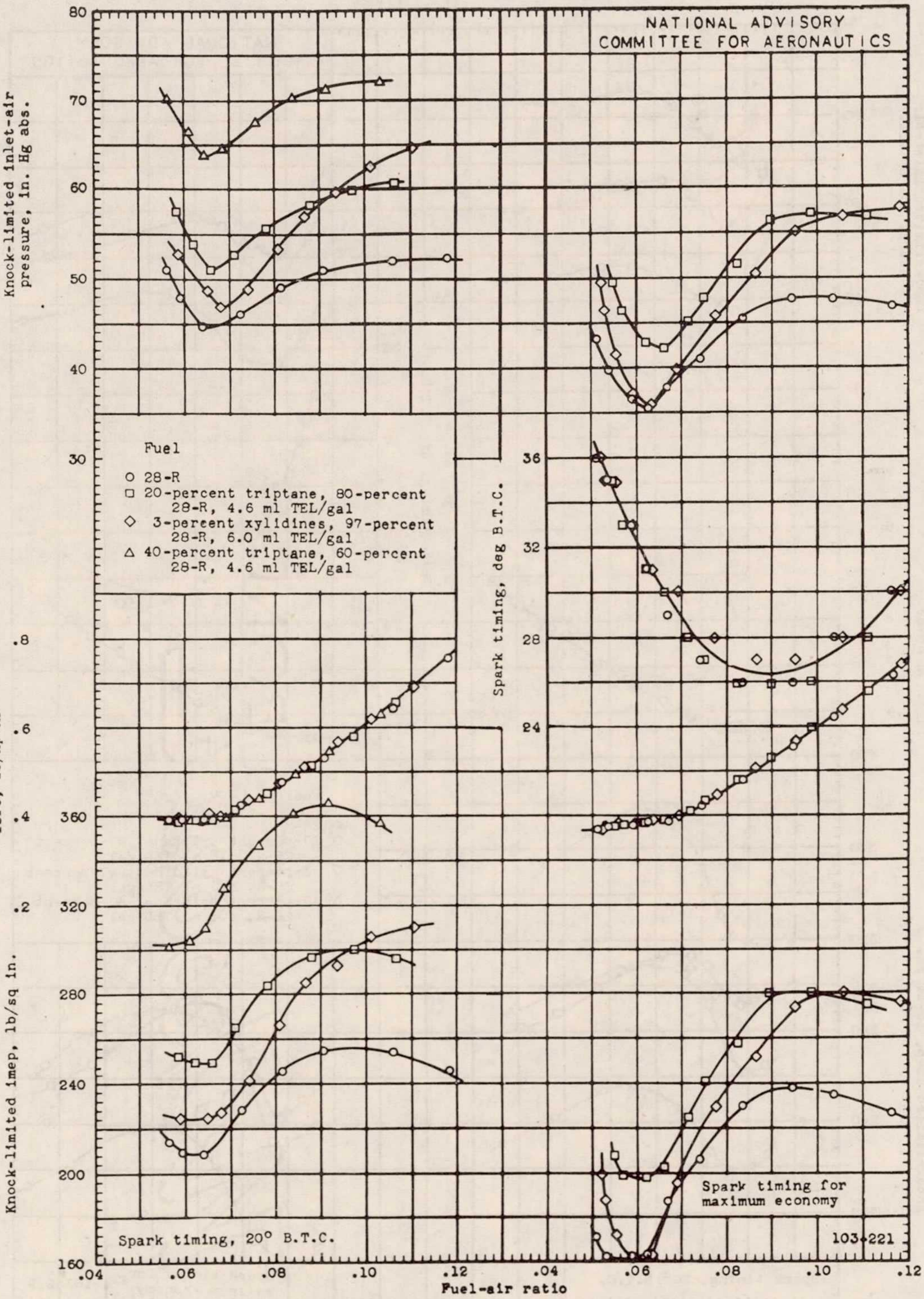
Figure 2. - Surge tank and fuel-vaporization tank for R-2600-13 full-scale single-cylinder test setup.

NATIONAL ADVISORY
COMMITTEE FOR AERONAUTICS



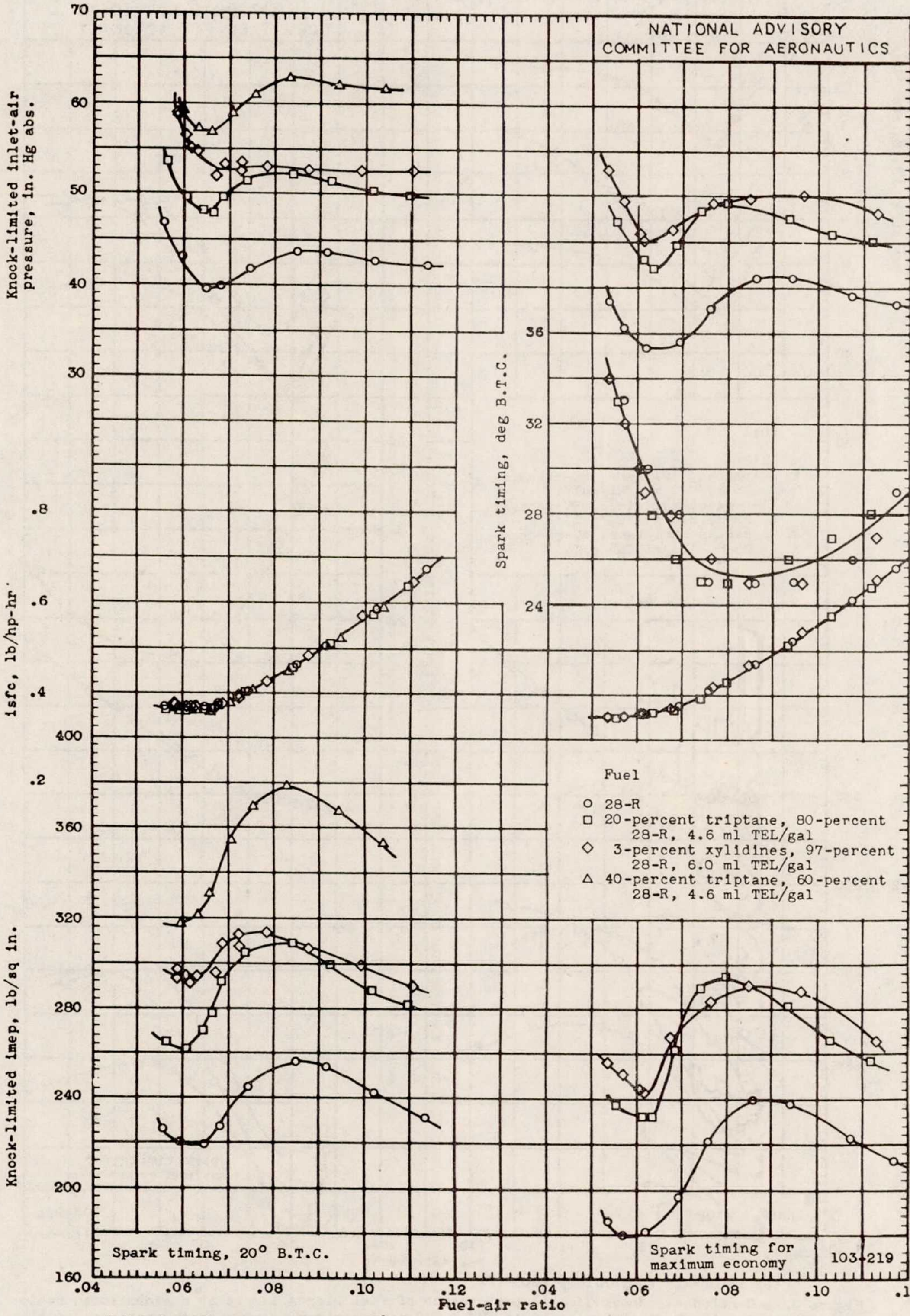
(a) Inlet-air temperature, 150° F.

Figure 3. - Knock-limited performance of fuel blends tested at a compression ratio of 6.9 in R-2600-13 single cylinder at 20° B.T.C. and maximum-economy spark settings. Engine speed, 2100 rpm; cylinder-head temperature. 450° F; exhaust pressure, 10 inches mercury absolute.



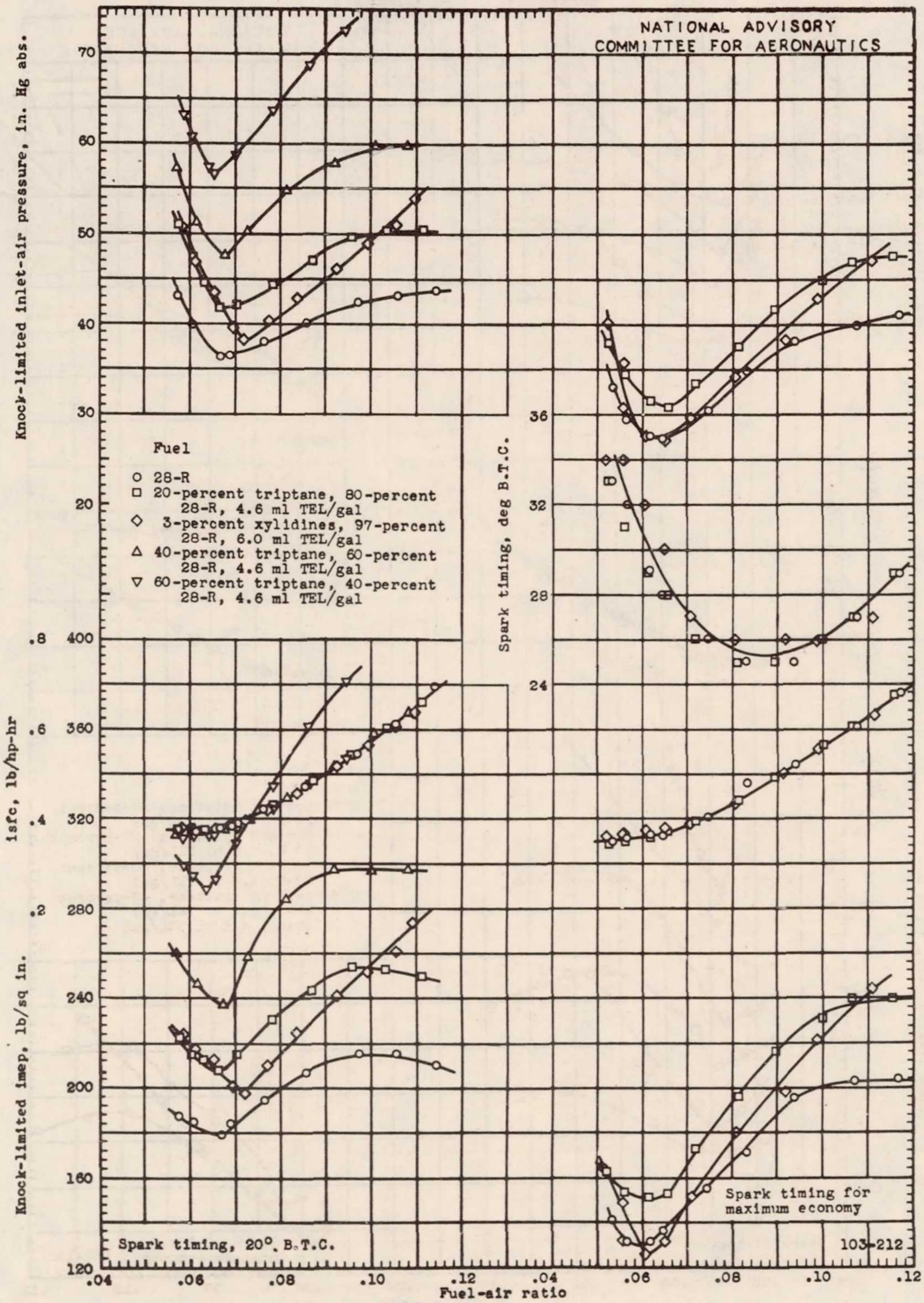
(b) Inlet-air temperature, 250° F.

Figure 3. - Concluded. Knock-limited performance of fuel blends tested at a compression ratio of 6.9 in R-2600-13 single cylinder at 20° B.T.C. and maximum-economy spark settings. Engine speed, 2100 rpm; cylinder-head temperature, 450° F; exhaust pressure, 10 inches mercury absolute.



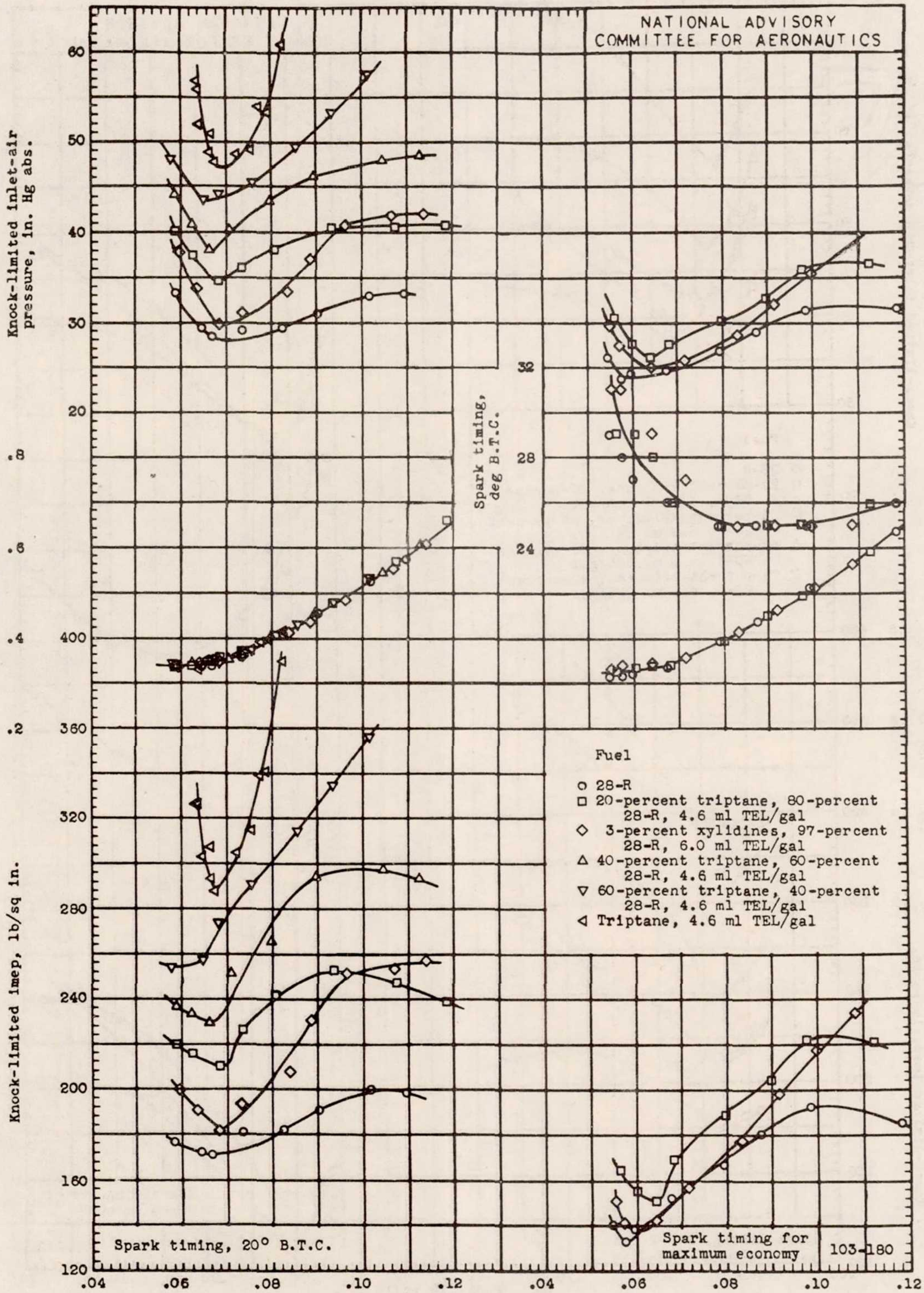
(a) Inlet-air temperature, 150° F.

Figure 4. - Knock-limited performance of fuel blends tested at a compression ratio of 8.0 in R-2600-13 single cylinder at 20° B.T.C. and maximum-economy spark settings. Engine speed, 2100 rpm; cylinder-head temperature, 450° F; exhaust pressure, 10 inches mercury absolute.



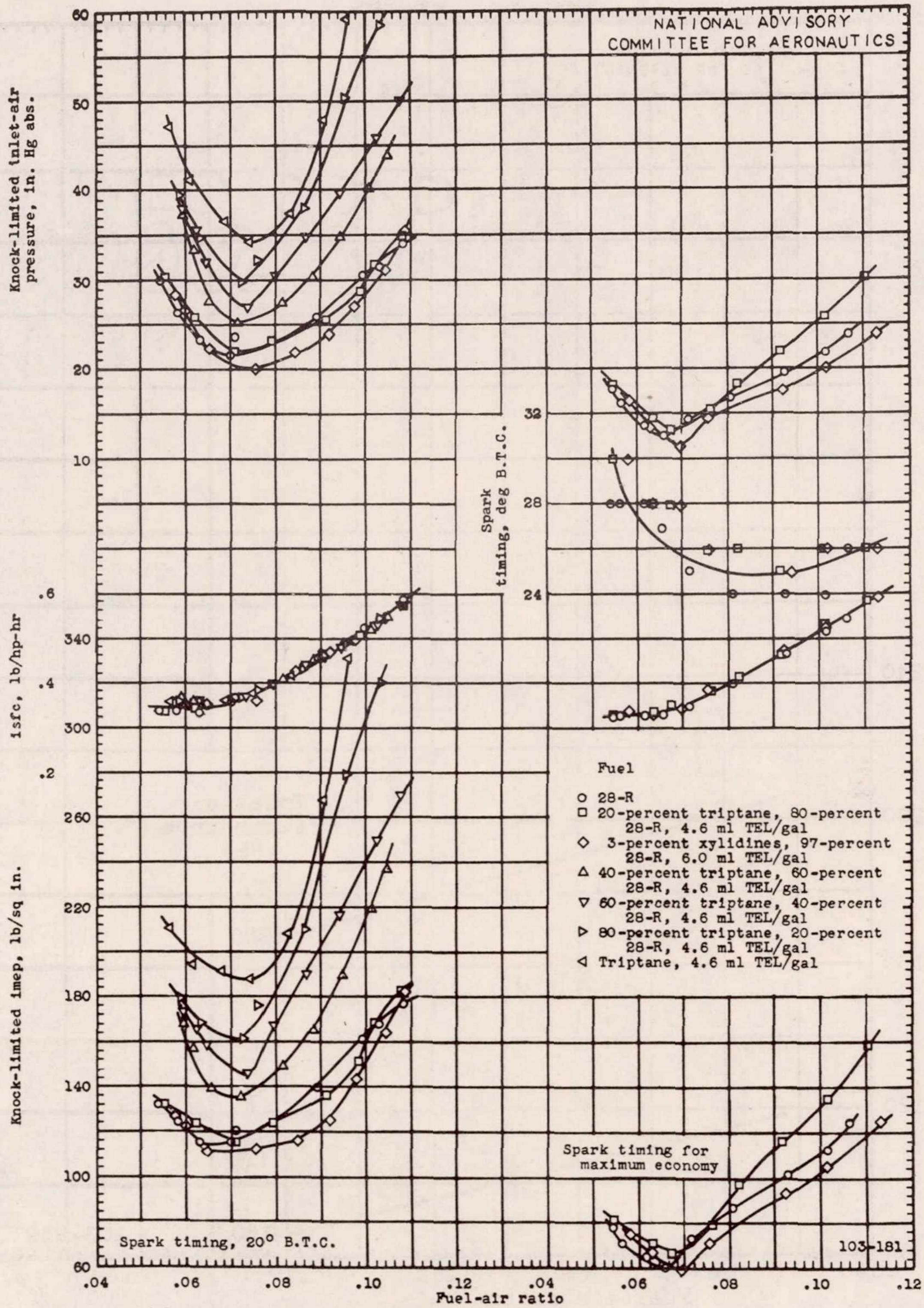
(b) Inlet-air temperature, 250° F.

Figure 4. - Concluded. Knock-limited performance of the fuel blends tested at a compression ratio of 8.0 in R-2600-13 single cylinder at 20° B.T.C. and maximum-economy spark settings. Engine speed, 2100 rpm; cylinder-head temperature, 450° F; exhaust pressure, 10 inches mercury absolute.



(a) Inlet-air temperature, 150° F.

Figure 5. - Knock-limited performance of fuel blends tested at a compression ratio of 10.0 in R-2600-13 single cylinder at 20° B.T.C. and maximum-economy spark settings. Engine speed, 2100 rpm; cylinder-head temperature, 450° F; exhaust pressure, 10 inches mercury absolute.



(b) Inlet-air temperature, 250° F.

Figure 5. - Concluded. Knock-limited performance of fuel blends tested at a compression ratio of 10.0 in R-2600-13 single cylinder at 20° B.T.C. and maximum-economy spark settings. Engine speed, 2100 rpm; cylinder-head temperature, 450° F; exhaust pressure, 10 inches mercury absolute.

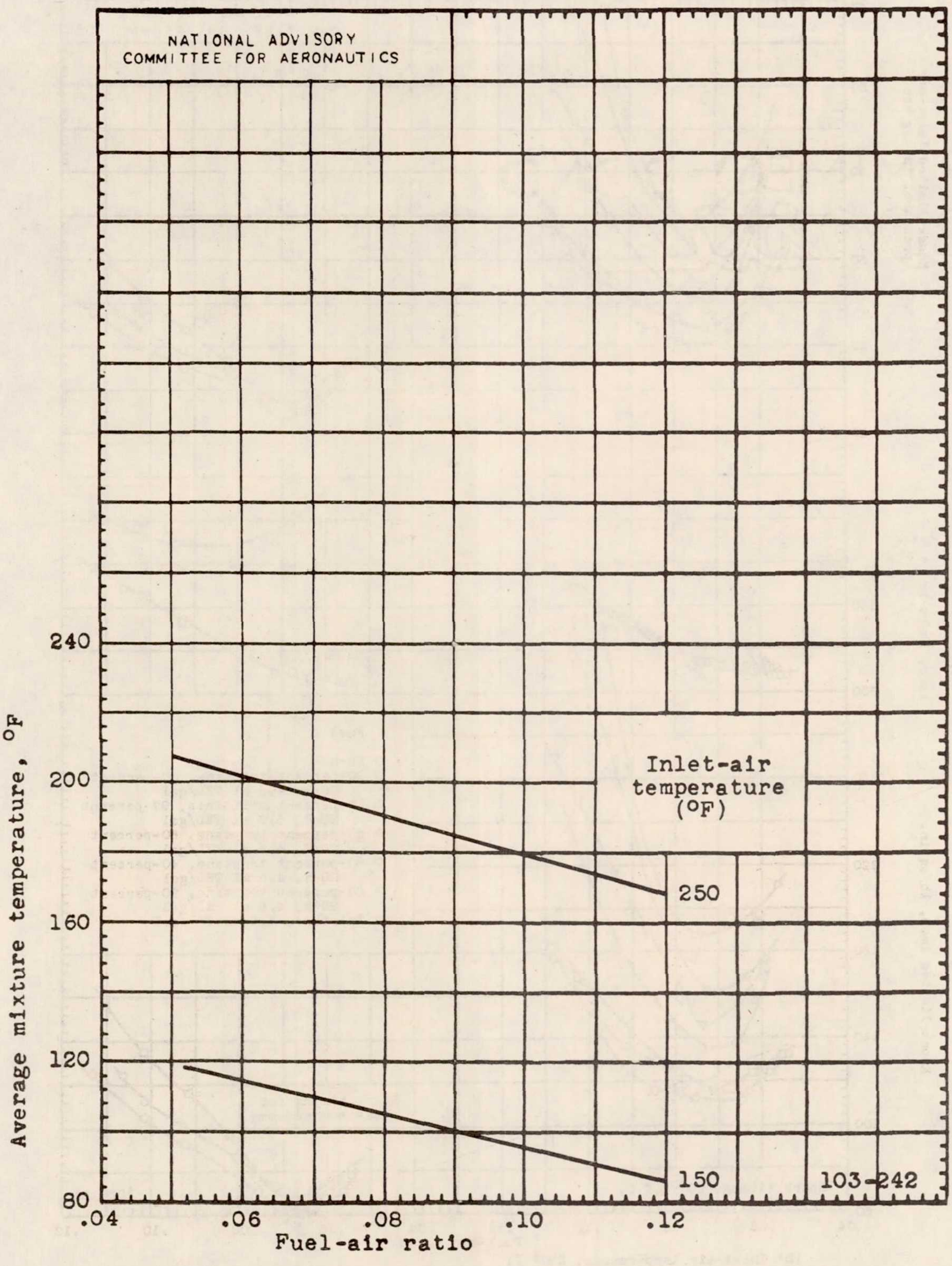


Figure 6. - Effect of fuel-air ratio on mixture temperature.

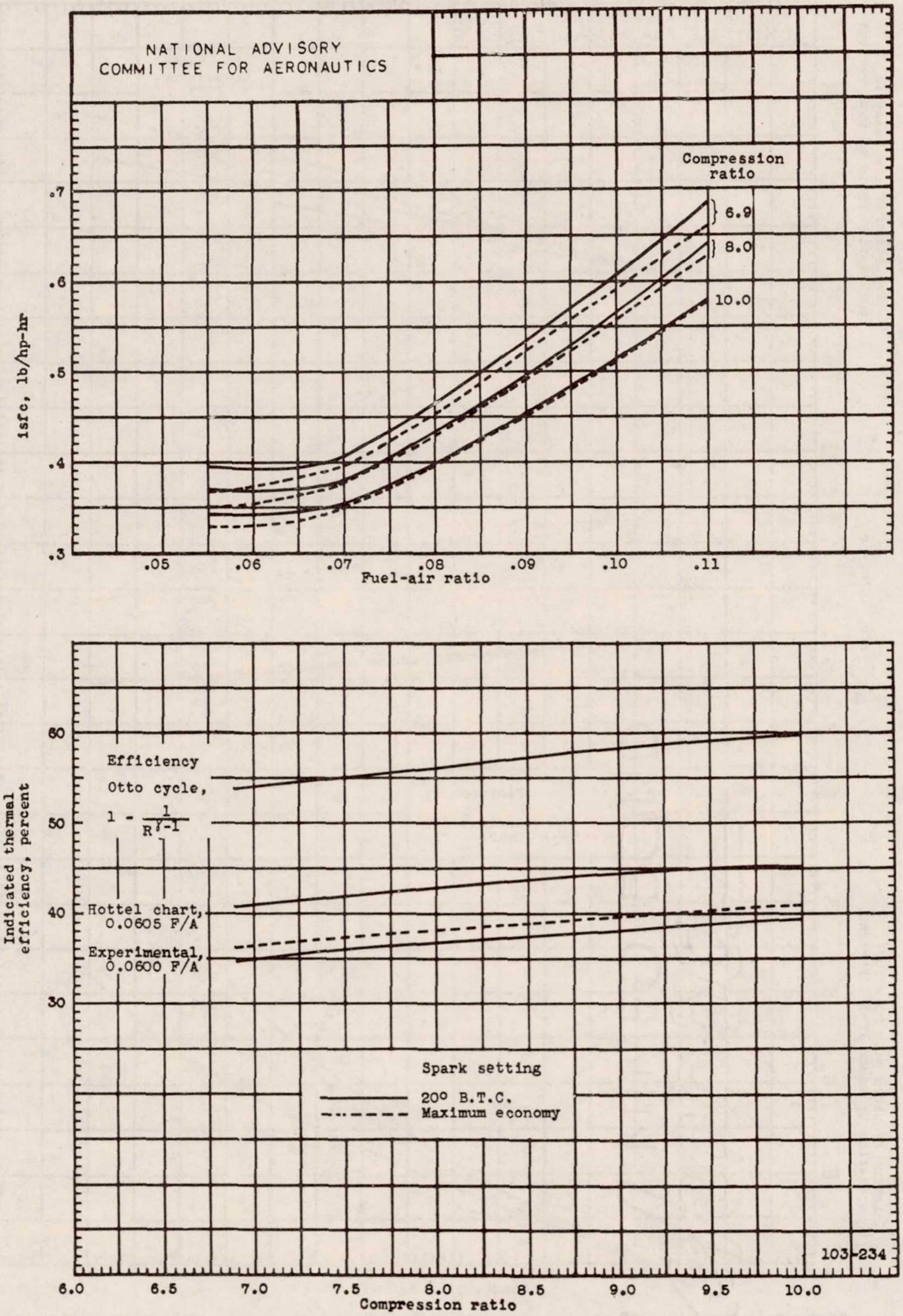


Figure 7. - Effect of engine variables on indicated fuel consumption and comparison of experimental and theoretical thermal efficiencies at an inlet-air temperature of 150° F. Engine speed, 2100 rpm; cylinder-head temperature, 450° F; exhaust pressure, 10 inches mercury absolute.

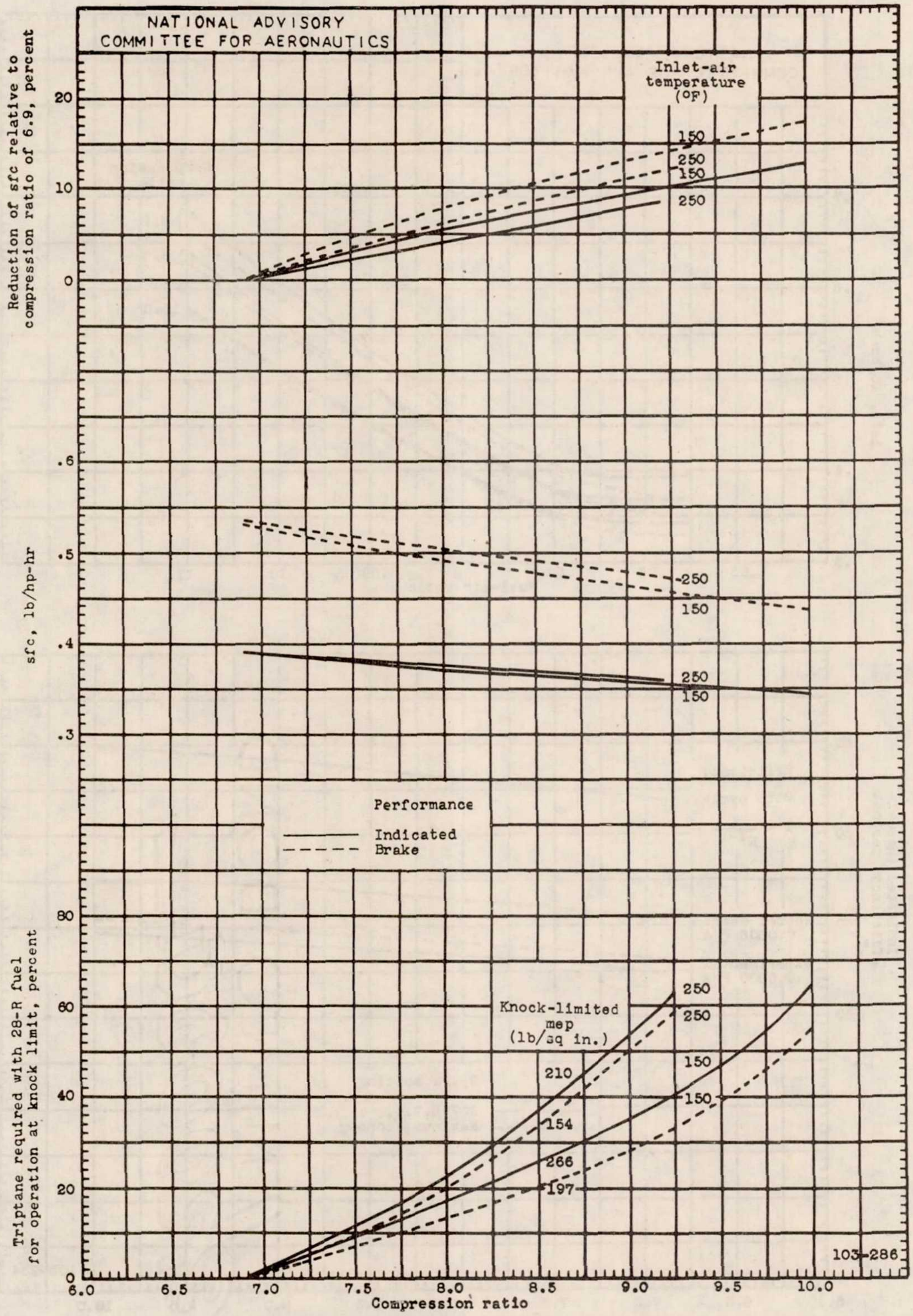
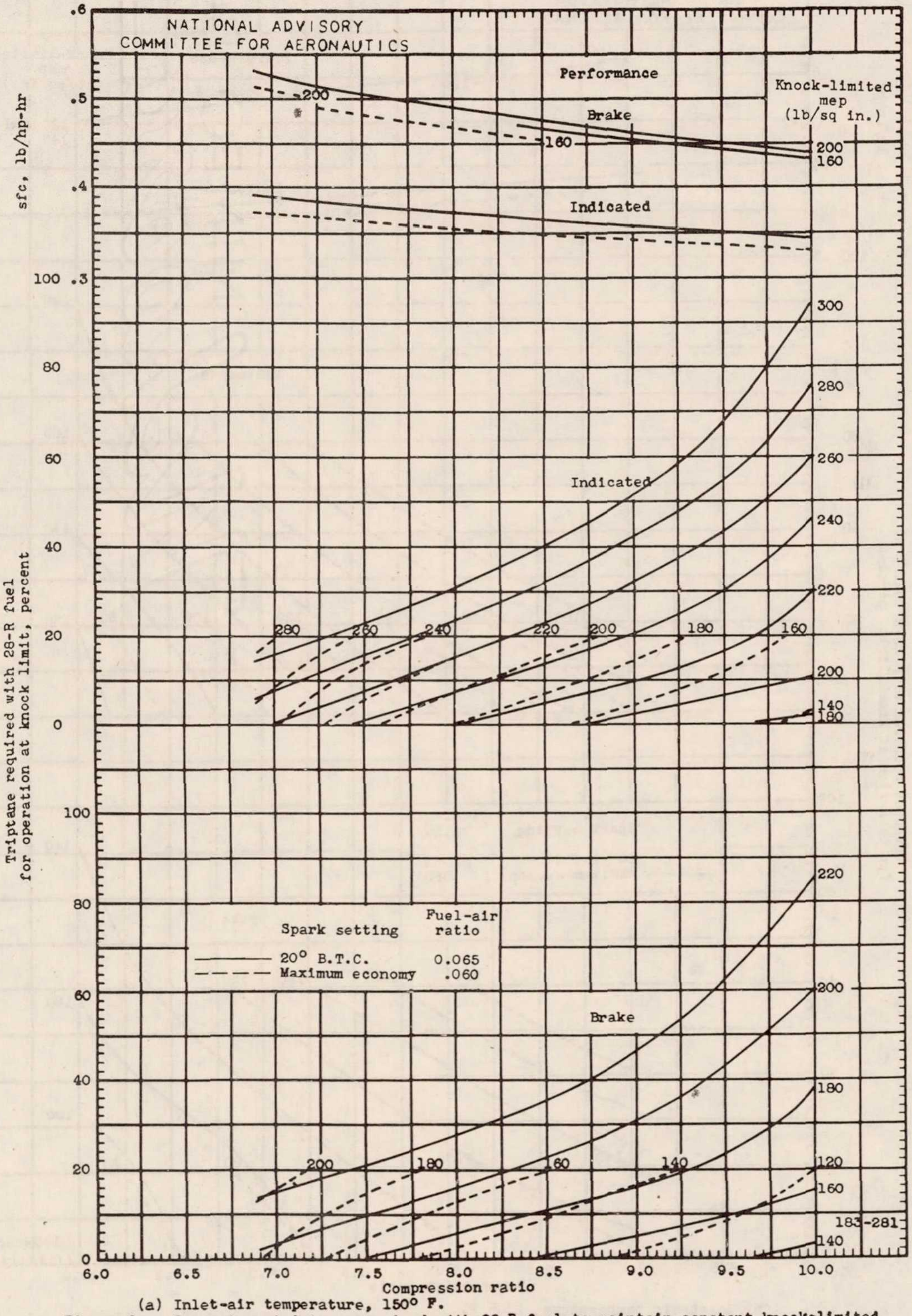
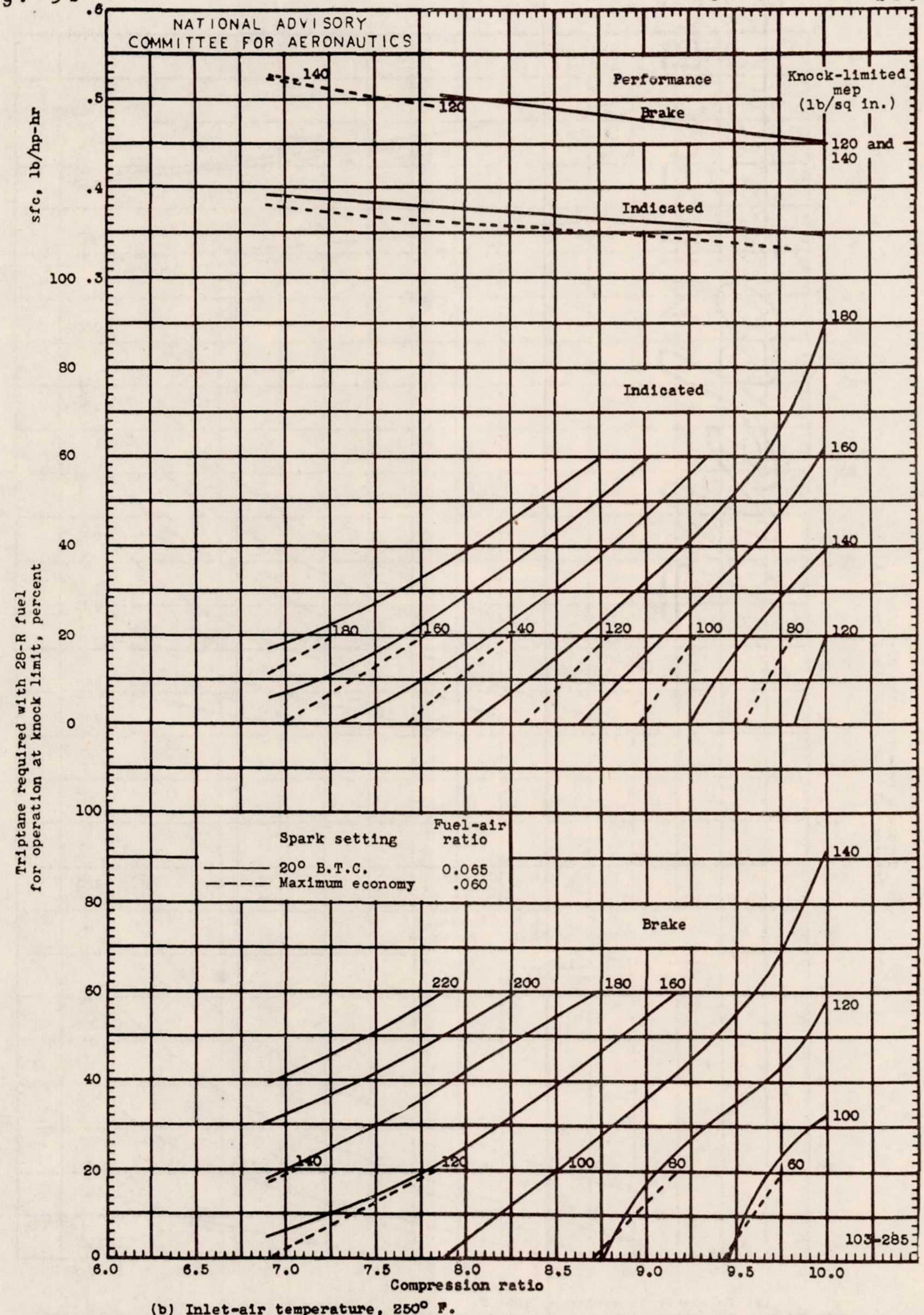


Figure 8. - Percentage of triptane required with 28-R fuel at various compression ratios to maintain knock-limited performance of 28-R fuel at a compression ratio of 6.9. Inlet-air temperatures, 150° and 250° F; R-2600-13 single cylinder; spark setting, 20° B.T.C.; fuel-air ratio, 0.065; engine speed, 2100 rpm; cylinder-head temperature, 450° F; exhaust pressure, 10 inches mercury absolute.



(a) Inlet-air temperature, 150° F.

Figure 9. - Percentage triptane required with 28-R fuel to maintain constant knock-limited power levels with 20° B.T.C. and maximum-economy spark settings in an R-2600-13 single cylinder. Engine speed, 2100 rpm; cylinder-head temperature, 450° F; exhaust pressure, 10 inches mercury absolute.



(b) Inlet-air temperature, 250° F.

Figure 9. - Concluded. Percentage triptane required with 28-R fuel to maintain constant knock-limited power levels with 20° B.T.C. and maximum-economy spark settings in an R-2600-13 single cylinder. Engine speed, 2100 rpm; cylinder-head temperature, 450° F; exhaust pressure, 10 inches mercury absolute.

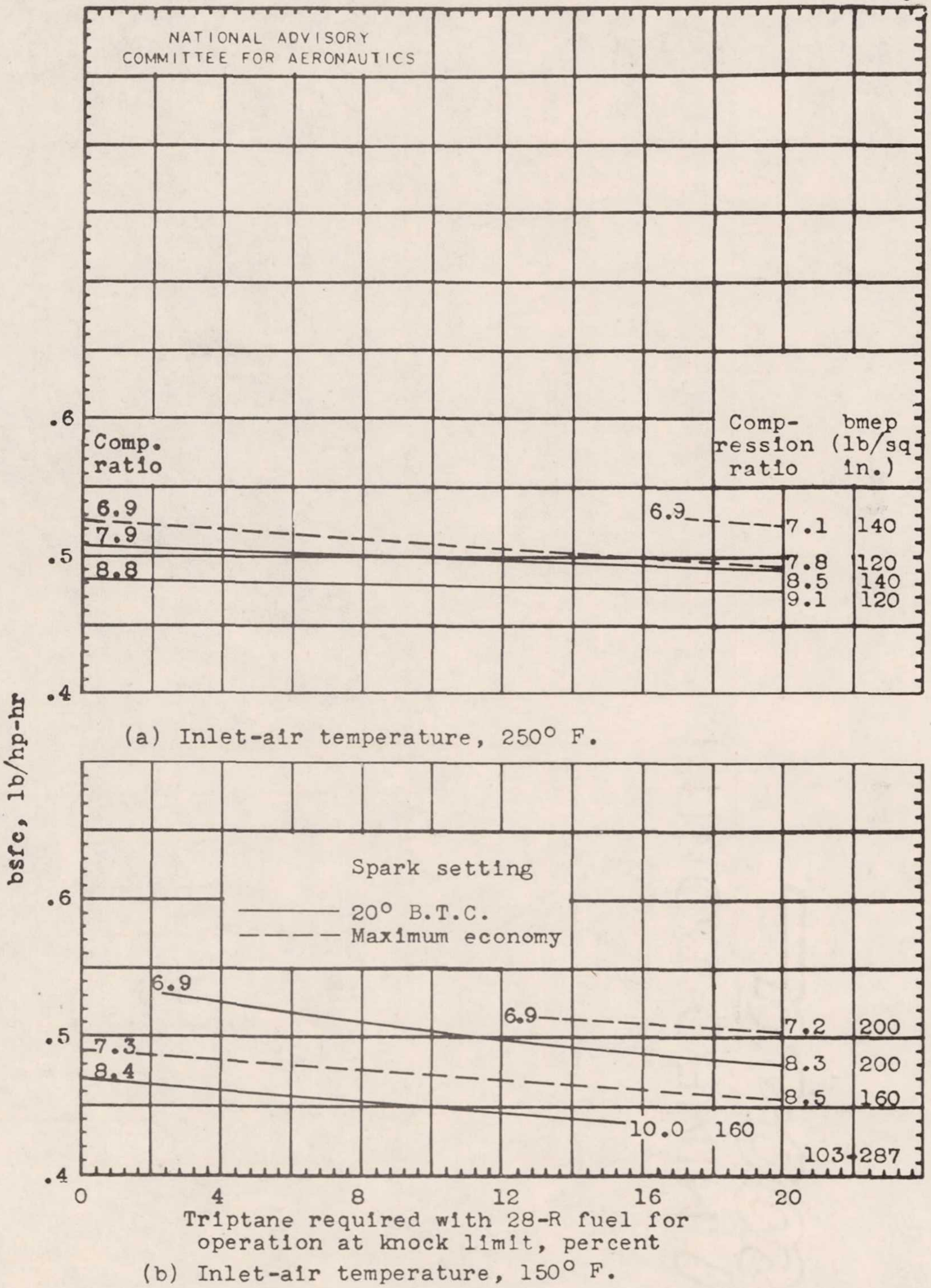


Figure 10. - Comparison of specific fuel consumption resulting from operation with 20° B.T.C. and maximum-economy spark settings at increased compression ratios when using triptane blended with 28-R fuel. Cross-plotted from figure 9 at constant power. R-2600-13 single cylinder; engine speed, 2100 rpm; cylinder-head temperature, 450° F; exhaust pressure, 10 inches mercury absolute.