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RESEARCH MEMORANDUM

PERFORMANCE OF PURE FUELS IN A SINGLE J33 COMBUSTOR

I - FIVE LIQUID HYDROCARBON FUELS

By Jerrold D. Wear and Ralph T. Dittrich

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SUMMARY

Investigations of several pure hydrocarbon fuels were conducted in a single tubular-type combustor in order to determine possible relations between combustor performance and fuel properties. The combustor temperature rise, combustion efficiency, and blow-out limits were determined with five liquid hydrocarbon fuels of high purity over a range of heat input and air-flow rates and at two inlet-air-temperature conditions. The fuels were isooctane, cyclohexane, methylcyclohexane, n-heptane, and benzene. Performance parameters were selected to compare with the physical and fundamental combustion properties of the fuel.

The general performance order among the fuels was: benzene highest; isooctane lowest; cyclohexane, methylcyclohexane, and n-heptane intermediate. Of the several fuel properties considered, maximum burning velocity best correlated with fuel performance, indicating an approximately linear increase in the performance of the fuels with an increase in burning velocity. For the various test conditions investigated, the maximum combustor temperature rise and the combustion efficiencies increased by 230° to 400° F and 2 to 17 percent for an increase in maximum burning velocity from 34.6 to 40.7 centimeters per second.

INTRODUCTION

Research is being conducted at the NACA Lewis laboratory to determine possible design parameters for improving the performance of turbojet engines. One phase of the over-all program is concerned with improving combustion efficiency and the altitude combustion blow-out limits of the combustor. Investigations of this phase of the research included systematic changes in combustor design and performance evaluations of various types of fuels. Results of some of these investigations are summarized in reference 1. These studies were concerned primarily with over-all effects on performance; that is, they did not attempt to describe combustion inefficiency and blow-out in terms of basic processes which take place within the combustor. Knowledge of the importance of each of the several basic processes in establishing over-all combustor performance would assist materially in a rational approach to design improvements and fuel selection.

One study of the role of individual processes such as fuel atomization, evaporation, mixing, and combustion was conducted in reference 2. Oxygen concentration of the inlet oxygen-nitrogen mixture was varied to alter the combustion reaction without appreciably affecting other processes. The data indicated reasonable correlations with a reaction-mechanism factor. The data also correlated with fundamental combustion properties such as maximum burning velocity and minimum ignition energy. 2688

Another approach to the problem of determining the role of fundamental combustion properties in establishing combustor performance is the use of fuel variables. Thus, the fundamental combustion characteristics that may influence combustion can be varied by varying fuel type. Use of pure fuels for which the various fundamental combustion properties are known would be desirable for any investigation that was concerned with the combustion mechanism. A number of investigations have been conducted with pure fuels for which fundamental combustion data are available. Data obtained by the Ethyl Corporaton show a relation between effective flame speed and laminar flame speed for several liquid and gaseous fuels in a small-scale combustor. The effective flame speed was considered as the maximum velocity of primary air required to cause lean blow-out at any fuel-air ratio. Rogers (reference 3) shows data with a reasonable correlation between combustion efficiency at rich blow-out and relative flame speed. Data reported in reference 4 show a relation between maximum stable temperature rise, octane number, and refractive index.

Investigations are being conducted at the NACA Lewis laboratory to study in more detail possible relations between physical and fundamental combustion properties of relatively pure fuels and full-scale single-combustor performance. The combustor performance data reported herein were obtained with five fuels, each representative of a particular class of hydrocarbons. The fuels were relatively pure, were available in sufficient quantities, and had self-consistent sets of fundamental combustion data available. In order to minimize effects of variations in fuel evaporation rates on the combustion process, fuels having similar boiling temperatures were selected. In addition, to minimize effects of variations in fuel atomization and mixing on the combustion process, a variable-area fuel nozzle was used. This type of nozzle permitted large changes in fuel-flow rates with small changes in fuel-nozzle pressure. The combustor test conditions included one inlet-air pressure, two inlet-air temperatures, and four rates of inlet-air mass flow. The inlet-air pressure condition was sufficiently low to be considered severe from the standpoint of combustion. The two inlet-air temperatures differed by 160° F. The air-flow rate was varied by more than 100 percent, which enabled the investigations to be conducted at inlet conditions which covered a considerable range of severity.

The fundamental combustion properties considered were maximum burning velocity, minimum ignition energy, spontaneous ignition temperature, and flammability range. The combustor performance parameters used to compare the fuels were maximum combustor temperature rise, combustion efficiency at a heat-input value of 325 Btu per pound of air, and combustion efficiency at a combustor-temperature-rise value of 830° F. Relations between the fundamental combustion properties and the combustor performance parameters are described.

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FUELS

Laboratory inspection data of the fuels used in the investigation are presented in table I. It was desired that these fuels have purities in excess of 95 mole percent. Comparisons of the laboratory inspection data with physical data for pure fuels (values taken from the literature and included in table I) indicate that the purities of all the test fuels except cyclohexane were above 95 mole percent. The purity of cyclohexane was about 92 mole percent.

Self-consistent sets of some fundamental combustion data of these fuels are also included in the table. The flammability-range data were obtained with samples of the same fuels used for the data reported herein.

APPARATUS AND INSTRUMENTATION

A diagram of the general arrangement of the J33 single combustor and the auxiliary equipment is shown in figure 1. Air flow to the combustor was measured by a square-edged orifice plate installed according to A.S.M.E. specifications and located upstream of all regulating valves. The combustor-inlet-air temperature was regulated by use of electric heaters. The combustor-inlet-air quantities and pressures were regulated by remote-controlled valves in the laboratory air-supply and exhaust systems. The combustion air supplied to the combustor had a dew point of either -20° or -70° F.

A diagrammatic cross-section showing the combustor and its auxiliary ducting, the position of instrumentation planes, and the location of temperature- and pressure-measuring instruments in the instrumentation planes is presented in figure 2. Thermocouples and total-pressure tubes in each instrumentation plane were located at centers of equal areas. Construction details of the temperature- and pressure-measuring instruments are shown in figure 3.

Fuel-flow rates to the combustor were measured by rotameters calibrated for each fuel. Pressure and temperature data were obtained by means of manometers and automatic-balancing potentiometers, respectively.

The test conditions used for the investigations reported herein required large variations in fuel-flow rates. Under these conditions the use of a constant-area fuel nozzle would require a very wide range in fuel-nozzle pressure drop (fig. 4). Large changes in spray characteristics accompany large changes in fuel-nozzle pressure drop. For this reason, a variable-area fuel nozzle with a pressure-flow curve similar to that presented in figure 4 was used in this investigation to minimize the pressure changes with change in fuel-flow rate.

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A diagrammatic cross-section of the fuel nozzle is shown in figure 5. Fuel enters the nozzle body and into channels that feed individual tangential slots in the swirl plate. The fuel flows through these slots into a constant-size swirl chamber and is then ejected through the orifice. For very low rates of fuel flow, the fuel travels through two small passageways feeding two tangential slots on the downstream face of the swirl plate. As more fuel is required, the piston moves and uncovers entrances to additional channels which lead to other tangential slots on the upstream face of the swirl plate. This permits large changes in fuel-flow rate with small change in pressure drop across the swirl plate. After all tangential slots are in use, the nozzle acts as a constant-area type (see high-flow region of curve, fig. 4).

PROCEDURE

The combustion performance of the fuels was determined at the following inlet-air conditions:

Inlet-air total pressure (in. Hg abs)	Inlet-air mass flow (lb/sec)	Inlet-air velocity[a] (ft/sec)	
		Inlet-air total temperature (°F)	
		40	200
14.3	0.6	61	81
14.3	0.8	81	107
14.3	1.0	101	134
14.3	1.3	133	178

[a]Based on combustor maximum cross-sectional area of 0.267 sq ft measured $12\frac{1}{2}$ inches downstream of section B-B (fig. 2).

The desired combustor inlet-air test conditions were established at a low fuel-flow rate (about 200° F combustor-temperature rise) and data recorded when conditions were stabilized. Fuel flow was increased to obtain increments in combustor-temperature rise of about 100° F. This procedure was continued until rich blow-out occurred. After the rich blow-out was checked, the fuel-flow rate was decreased to two or three different values and the data recorded. No lean blow-out data were obtained. The ignition plug was de-energized during operation.

At some inlet conditions the performance differences between fuels were small. In order to determine if these differences were significant or within experimental error, data were obtained to establish the degree of repeatability. One fuel, isooctane, was used as a check fuel, and data were obtained with this fuel before and after investigations of each of the other fuels.

CALCULATIONS

Combustor-temperature rise. - The combustor-temperature rise was determined as the increase in gas temperature from section B-B to C-C, figure 2. The temperature at B-B was the average indication of the two iron-constantan thermocouples; the temperature at C-C was the arithmetical average indication of the 16 chromel-alumel thermocouples. The indicated thermocouple readings were accepted as true values of the total temperature.

Combustion efficiency. - Combustion efficiency was defined as:

$$\frac{\text{actual enthalpy rise across combustor}}{\text{heating value of fuel supplied}}$$

The equation used for determining combustion efficiency η_b in percent was as follows:

$$\eta_b = \frac{\left(h_a\right)_{t_1}^{t_2} + F/A \left(\frac{Am + B}{m + 1}\right)_{t_{ref}}^{t_2}}{F/A \times h_c} \times 100$$

where

$(h)_{t_1}^{t_2}$ increase in enthalpy of air from combustor-inlet temperature t_1 to combustor-outlet temperature t_2, Btu/lb

F/A actual fuel-air ratio

$\left(\frac{Am + B}{m + 1}\right)_{t_{ref}}^{t_2}$ enthalpy correction accounting for change in gas composition due to burning of oxygen, Btu/lb

h_c lower heating value of fuel, Btu/lb 2688

Charts presented in reference 5 and in figure 6 were used to determine the enthalpy rise across the combustor; heating values of the fuels are presented in table I (lower heat of combustion).

The inlet-air total-pressure values were obtained from the 12 total-pressure tubes (section A-A, fig. 2) which were connected to a single manifold.

In order to place the performance of the various fuels on a comparable basis, heat input (product of fuel-air ratio and lower heat of combustion of the fuel) was used in place of fuel-air ratio as one independent variable.

RESULTS AND DISCUSSION

Combustor temperature rise, combustion efficiency, and rich blow-out data obtained with five hydrocarbon fuels in a single J33 combustor are presented in table II. Relations among heat input, combustor temperature rise, and combustion efficiency for each of the fuels investigated at each of the various operating conditions are shown in figures 7 to 11. The curves of constant combustion efficiency were determined for each fuel.

The repeatability of the performance data is indicated in figure 7. Combustor temperature rise, combustion efficiency, and heat-input data were obtained with isooctane fuel before and after each test. These data were obtained over a period of 4 months, during which time the combustor was disassembled several times. The average percentage deviation of the combustion efficiency of individual data points from the curves faired through all data was about ±1 percent. Differences in the combustion efficiency data of more than 2 percent between fuels can thus normally be considered as real differences, while differences less than 2 percent fall within the repeatability range.

The data obtained with isooctane (fig. 7) show, in general, an increase in temperature rise and combustion efficiency with an increase in heat input. Continued increases in heat input, however, resulted in rich blow-out of the flame. Rich blow-out points as shown could be checked closely at the time they were obtained; however, after a period of intervening tests a repeat rich blow-out point might vary considerably, on the heat-input scale, from a previously determined point. At some

inlet conditions the maximum temperature rise was obtained at the rich blow-out point, and at other conditions the maximum temperature rise was obtained at a lower value of heat input than that required for rich blow-out. The combustion efficiencies at rich blow-out were considerably below their maximum values. The highest combustor temperature rise and combustion efficiency observed were about 1420° F and 88 percent, respectively, and were obtained at a low inlet-air mass flow. The maximum heat-input values at the rich blow-out points decreased, in general, with an increase in air flow and with decrease in air temperature at
2688 constant inlet velocity.

The data obtained with cyclohexane (fig. 8), methylcyclohexane (fig. 9), n-heptane (fig. 10), and benzene (fig. 11) exhibited the same general trends as were noted for isooctane. The differences in actual values of temperature rise and combustion efficiency are compared in later figures. In the case of n-heptane, an exception to the general trend was noted at the lowest air-flow conditions. The temperature rise and combustion efficiency values obtained over a part of the heat input range were lower than values obtained at higher air flows. This anomaly was not obtained with any of the other fuels. Another exception to the general trend of the fuel data was the benzene data obtained at the higher air temperature and highest-air-flow condition (fig. 11(a)). At these conditions much more scatter in the data was observed than was observed with any of the other fuels at any of the inlet-air conditions.

Combustor Performance Parameters

The objective of the investigations reported herein is to relate the combustor performance of various fuels to physical or fundamental combustion characteristics of the fuels. Three representative combustor performance parameters were chosen for making comparisons among the fuels. The first parameter chosen was maximum temperature rise, which is related to the altitude operational limits of the turbojet engine. The two other parameters were combustion efficiency at a specific heat-input value of 325 Btu per pound of air and combustion efficiency at a specific temperature-rise value of 830° F. The latter performance parameters are related to the fuel consumption of the engine. The values of 325 Btu and 830° F are approximate average values corresponding to engine cruise operation.

Maximum temperature rise. - A comparison of the maximum temperature rise obtained with each fuel over the range of combustor operating conditions is presented in figure 12. At all conditions investigated, benzene fuel provided the highest values of maximum temperature rise and isooctane the lowest values. The differences between isooctane and benzene varied from 270° to 400° F for comparable conditions. The maximum temperature-rise values obtained with the three remaining fuels (cyclohexane, methylcyclohexane, and *n*-heptane) were similar and were between those obtained with benzene and with isooctane. The fuel flow rate required to obtain the maximum combustor-temperature-rise data was beyond the variable-area characteristic of the fuel nozzle (fig. 4).

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Combustion efficiency at heat-input value of 325 Btu per pound of air. - A comparison of the combustion efficiency at a constant heat-input value of 325 Btu per pound of air obtained with each fuel over the range of combustor operating conditions is presented in figure 13. At the high inlet-air temperature the trends observed among the fuels were similar to those noted in figure 12; that is, the highest efficiency was obtained with benzene and the lowest, in general, with isooctane. As a result of the irregular trends noted in figure 10 for *n*-heptane, this fuel exhibited reduced efficiency at the lowest air flow rate investigated. This result is further amplified at the lower inlet-air-temperature condition where *n*-heptane has the lowest efficiency of the fuels at low air flow rate, and the highest efficiency at high air flow rate. The differences in efficiency among the fuels varied from about 2 to 18 percent at the different conditions. The difference between benzene and isooctane was more nearly constant with air flow in figure 12 (maximum-temperature-rise parameter) than shown in figure 13, where the difference increased, in general, with air mass flow.

Combustion efficiency at a temperature rise of 830° F. - Comparison of the combustion efficiency at a temperature-rise value of 830° F obtained with each fuel over the range of combustor operating conditions is presented in figure 14. Benzene was the only fuel that gave temperature-rise values as high as 830° F at the high-air-flow condition. At the high inlet-air temperature, benzene provided the highest values of combustion efficiency. The same general trends for *n*-heptane were obtained as were shown in figure 13; that is, the *n*-heptane values were the lowest of all the fuels at low air flow rates, and tended to become the highest at the higher air flow rates. With the exception of *n*-heptane the values obtained with isooctane were the lowest at all conditions. The differences in efficiency among the fuels varied from about 3 to 9 percent at the various conditions.

General observations. - Considering all performance parameters, the highest performance was obtained with benzene and the lowest with isooctane. The performance values obtained with cyclohexane, methylcyclohexane, and *n*-heptane were intermediate and were very similar, in general. Exceptions to these trends were obtained with the two different efficiency parameters at the 40° F inlet-air temperature. At these conditions the combustion efficiency of *n*-heptane followed a unique trend; at low air mass flow its efficiency was lowest among the fuels, and at high air mass flow it was the highest.

Comparisons of Combustor Performance Parameters with Physical and Fundamental Combustion Fuel Properties

Physical fuel properties. - Some physical properties of a fuel which may be considered to have possible effects on the combustion process are (1) boiling point, (2) latent heat of vaporization, and (3) heat content at the spontaneous ignition temperature. Thus, an increase in any one of these particular properties may be expected to decrease the rate of fuel evaporation and may retard the over-all combustion process. Comparisons of these properties (table I) with the general performance levels of the fuels described in the preceding section, however, indicate that none would predict the relative performance trends obtained. In the case of the latent heat of vaporization, a possible trend was indicated; however, it was opposite of that expected. Since the fuels were chosen at least in part to minimize variations in evaporation rate, the variations in these properties are intentionally small.

Fundamental combustion fuel properties. - Some fundamental combustion properties of fuels which may be considered to have possible effects on the combustion process are (1) maximum burning velocity or maximum fundamental flame speed, (2) minimum ignition energy, (3) spontaneous ignition temperature, and (4) flammability range. Thus, any increase in burning velocity or widening of flammability range, or a decrease in minimum ignition energy or spontaneous ignition temperature may be expected to effect increases in the rate of the combustion process. Considering the most consistent "highest" and "lowest" performance fuels, which were benzene and isooctane, respectively, it is noted that values of maximum burning velocity and minimum ignition energy (table I) qualitatively follow the performance trends of these two fuels. Both fundamental flame speed and minimum ignition energy have been used to correlate combustion performance of fuels in previous investigations (data by Ethyl Corporation and reference 6). The values of spontaneous ignition temperature and flammability range for the fuels do not follow the same order as the combustor performance of the fuels; benzene has the highest spontaneous ignition temperature and the lowest flammability range of the fuels investigated and would therefore be expected to give the lowest performance.

A further comparison indicates that the combustor performance of cyclohexane, methylcyclohexane, and n-heptane were, in general, similar. While the maximum burning velocities for these fuels are similar, the minimum ignition energy values for cyclohexane and n-heptane vary considerably, although no minimum ignition energy data for methylcyclohexane were available. From the preceding discussion it appears that, of the fuel properties considered, burning velocity will best correlate with combustor performance.

The relations between maximum burning velocity and the selected fuel performance parameters of figures 12, 13, and 14 are presented in figures 15, 16, and 17, respectively. Figure 15 shows the relation between maximum combustor temperature rise and maximum burning velocity for the various inlet-air mass flows and two inlet-air temperatures. Five of the eight different inlet-air conditions show a regular increase in performance with increase in burning velocity; the remaining three inlet-air conditions show a general but less regular increase. 2688
The maximum combustor-temperature-rise values increased from 230° to 400° F for an increase in maximum burning velocity from 34.6 to 40.7 centimeters per second.

Combustion efficiency at a heat-input value of 325 Btu per pound of air is plotted in figure 16 against maximum burning velocity for the four rates of inlet-air flow and two inlet-air temperatures. The regular increase in performance with burning velocity is not so pronounced with this combustor parameter as with the maximum-temperature-rise parameter. Values of the combustor parameter obtained at three of the inlet conditions show a regular increase in performance with increase in burning velocity and at the other five conditions a somewhat general increase. The values obtained with n-heptane (burning velocity of 38.6 cm/sec) deviate most from the general trend of all the fuels. Increases in the combustion efficiency parameter varied from 2 to 17 percent for the increase in burning velocity.

The combustor performance parameter, combustion efficiency at a combustor-temperature-rise value of 830° F, is plotted in figure 17 against maximum burning velocity for various air flows and two inlet-air temperatures. The trend of the data is similar to that presented in figure 16, except that the deviations of n-heptane values from the general trend of the fuel data are greater. The consistent deviation of the data obtained with n-heptane from the "general trend" indicates that controlling factors other than or in addition to burning velocity are needed for correlation. Of the six inlet conditions, only one has values that show a regular increase in performance with increase in burning velocity. At other inlet conditions, a similar trend is evident but much less pronounced. Increases in this combustion efficiency parameter varied from 2 to 5 percent for the increase in burning velocity.

It should be pointed out that the burning-velocity data used herein were obtained with fuel-air mixtures at room temperature. The order of maximum burning velocities among the fuels may differ at the elevated temperatures encountered in the combustor.

CONCLUDING REMARKS

In order to determine possible relations between physical or fundamental combustion properties of fuels, or both, and combustor performance, investigations of several pure hydrocarbon fuels were conducted in a single tubular combustor. Combustor performance parameters which were considered to be significant in engine operation were (1) maximum combustor temperature rise, (2) combustion efficiency at a heat-input value of 325 Btu per pound of air, and (3) combustion efficiency at a combustor temperature rise of 830° F. The following general order of fuel performance was obtained from comparison of these parameters; benzene highest, isooctane lowest, with cyclohexane, methylcyclohexane and *n*-heptane intermediate. For the two combustion-efficiency parameters, the performance of *n*-heptane varied considerably from the general performance orders. For certain inlet conditions, the performance of *n*-heptane was either the highest or lowest of all the fuels.

Of the several fuel properties considered, maximum burning velocity best correlated with the general performance of the fuels indicating an approximate linear increase in fuel performance with increase in burning velocity for the narrow range of burning velocities investigated. The combustor performance parameters of maximum temperature rise, efficiency at a heat-input value of 325 Btu per pound of air, and efficiency at a temperature-rise value of 830° F were increased by 230° to 400° F, 2 to 17 percent, and 2 to 5 percent, respectively, for the increase in maximum burning velocity of the fuels from 34.6 to 40.7 centimeters per second.

Conclusive relations between combustor performance and fuel properties were not established in this investigation; such relations will require tests with fuels having wider ranges of properties.

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TABLE I - LABORATORY INSPECTION DATA, AND PHYSICAL AND FUNDAMENTAL COMBUSTION DATA OF FUELS

Fuel	Physical data																Fundamental combustion data			
	Laboratory values						Literature values of pure fuel													
	Specific gravity $\left(\frac{60^{\circ}}{60^{\circ}\ F}\right)$	Refractive index at 68° F	Freezing point (°F)	Hydrogen-carbon ratio	Lower heat of combustion $\left(\frac{Btu}{lb}\right)$	Estimates of purity (mole percent)	Specific gravity $\left(\frac{60^{\circ}}{60^{\circ}\ F}\right)$	Refractive index at 68° F	Freezing point (°F)	Normal boiling point (°F)	Latent heat of vaporization at normal boiling point $\left(\frac{Btu}{lb}\right)$	Heat content, 77° F to normal boiling point, liquid $\left(\frac{Btu}{lb}\right)$	Heat content, 77° F through spontaneous ignition temperature $\left(\frac{Btu}{lb}\right)$	Viscosity at 68° F (centipoises)	Hydrogen carbon ratio	Lower heat of combustion $\left(\frac{Btu}{lb}\right)$	Maximum burning velocity $\left(\frac{cm}{sec}\right)$	Minimum ignition energy (joules)	Spontaneous ignition temperature (°F)	Flammability range (percent stoichiometric, rich minus lean)
							(a)	(a)	(a)	(a)	(a)	(a)	(a)	(b)	(a)	(a)	(c)	(d)	(e)	(f)
Isooctane[g]	0.695	1.3915[h]	-161.3[h]	0.169[i]	19,065[i]	99.6[h]	0.6963	1.3915	-161.3	210.6	116.7	78	601	5.025×10^{-1}	0.169	19,065	34.6	13.5×10^{-4}	837	307
Cyclohexane	.783	1.4263	40.1	.170	18,718	92+	.7834	1.4262	43.8	177.3	153.7	80	368	9.65	.168	18,676	38.7	13.8	518	348
Methyl-cyclohexane	.774	1.4231	-197.9	.169	18,655	95+	.7740	1.4231	-195.9	213.7	138.9	67	389	7.28	.168	18,642	37.5	----	509	317
n-Heptane[g]	.688	1.3878[h]	-131.2[h]	.192[i]	19,157[i]	99.5[h]	.6881	1.3876	-131.1	209.2	136.0	61	385	4.10	.192	19,157	38.6	7.0	477	403
Benzene	.884	1.5009	41.7	.084	17,262	99+	.8846	1.5011	42.0	176.2	169.3	45	551	6.52	.084	17,259	40.7	5.5	1097	290

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[a]Reference 7.
[b]Reference 8.
[c]Reference 9.
[d]Reference 10.
[e]Reference 11.
[f]Unpublished NACA data. Values obtained at a pressure of 300 mm Hg abs.
[g]A.S.T.M. certified.
[h]National Bureau of Standards results.
[i]Pure fuel values.

TABLE II - PERFORMANCE DATA FROM SINGLE COMBUSTOR OPERATING WITH SEVERAL HYDROCARBON FUELS

[Combustor-inlet total pressure, 14.3 inches mercury absolute.]

(a) Isooctane.

Run	Air flow (lb/sec)	Combustor reference velocity (nominal) (ft/sec)	Fuel flow (lb/hr)	Fuel-air ratio	Fuel-nozzle pressure differential (lb/sq in.)	Fuel temperature (°F)	Heat input (Btu/lb air)	Mean combustor-outlet temperature (°R)	Mean temperature rise through combustor (°F)	Combustion efficiency (percent)	Remarks
Combustor-inlet total temperature, 500° R											
1	0.598	61	12.4	0.0058	19.4	90	110	730	230	51.0	
2	.601	61	20.1	.0093	24.9	90	177	1003	503	70.5	
3	.596	61	25.4	.0118	23.5	90	225	1193	693	77.6	
4	.595	61	28.9	.0135	24.0	90	257	1315	815	80.7	
5	.597	61	32.0	.0149	25.0	89	284	1402	902	81.6	
6	.598	61	33.8	.0157	25.7	89	299	1445	945	81.6	
7	.603	61	23.4	.0108	25.7	86	206	1120	620	75.5	
8	.600	61	18.8	.0087	22.7	86	166	932	432	64.3	
9	.600	61	16.2	.0075	21.2	85	143	830	330	56.6	
10	.600	61	13.6	.0063	19.9	85	120	742	242	49.1	
11	.600	61	26.4	.0122	22.9	86	233	1232	732	79.6	
12	.600	61	29.5	.0137	26.2	87	261	1323	823	80.4	
13	.600	61	33.5	.0155	25.9	87	296	1415	915	79.8	
14	.600	61	36.1	.0167	26.1	87	318	1483	983	80.1	Occasional resonance
15	.601	61	39.5	.0183	27.8	88	349	1552	1052	78.9	
16	.600	61	42.8	.0198	27.7	89	378	1602	1102	76.9	Resonance
17	.599	61	43.3	.0201	27.7	90	383	1612	1112	76.5	Blow-out
18	.598	61	25.8	.0120	21.9	75	229	1212	712	78.6	
19	.599	61	19.4	.0090	22.2	75	172	952	452	65.2	
20	.598	61	32.3	.0150	25.2	75	286	1387	887	79.7	
21	.598	61	39.3	.0183	27.2	75	349	1545	1045	78.3	Resonance
22	.600	61	17.2	.0080	20.7	75	153	859	359	57.8	
23	.600	61	22.7	.0105	20.1	76	200	1052	552	68.8	
24	.600	61	28.9	.0134	23.2	77	256	1292	792	78.9	
25	.601	61	33.2	.0153	23.0	78	292	1433	933	82.5	
26	.601	61	43.0	.0199	25.8	77	379	1592	1092	75.8	
27	.600	61	17.2	.0080	20.5	75	153	882	382	61.6	
28	.600	61	33.1	.0153	22.9	79	292	1425	925	81.8	
29	.600	61	40.7	.0188	25.7	79	358	1560	1060	77.5	
30	.796	81	66.4	.0232	28.8	91	442	1653	1153	69.4	
31	.800	81	49.4	.0172	27.4	74	328	1464	964	76.3	
32	.801	81	64.5	.0224	27.8	74	427	1667	1167	72.7	
33	.791	81	56.3	.0198	27.2	74	378	1602	1102	76.9	
34	.798	81	31.5	.0110	23.1	72	210	1053	553	65.8	
35	.798	81	45.0	.0157	28.5	73	289	1370	870	74.7	
36	.798	81	57.9	.0202	26.9	73	385	1605	1105	75.7	
37	.800	81	39.8	.0138	26.0	76	263	1268	768	74.3	
38	.800	81	52.2	.0181	26.7	76	345	1527	1027	77.7	
39	.800	81	61.7	.0214	26.9	76	408	1652	1152	74.9	
40	.799	81	35.8	.0124	25.9	77	236	1161	661	70.5	
41	.799	81	43.9	.0153	26.5	77	292	1357	857	75.4	
42	.801	81	55.1	.0191	26.7	77	364	1572	1072	77.3	
43	.800	81	63.1	.0219	27.4	77	418	1666	1166	74.2	
44	.800	81	24.8	.0086	22.7	71	164	857	357	53.6	
45	.800	81	32.2	.0112	23.5	72	214	1034	534	62.4	
46	.799	81	40.0	.0139	23.2	74	265	1242	742	71.1	
47	.799	81	47.4	.0165	23.9	74	315	1433	933	76.7	
48	.798	81	77.0	.0268	28.2	72	511	1595	1095	57.4	Blow-out
49	.800	81	22.8	.0079	21.6	75	151	837	337	54.9	
50	.800	81	29.1	.0101	22.7	76	193	963	463	59.7	
51	.800	81	38.2	.0133	25.9	77	254	1177	677	67.5	
52	.801	81	46.1	.0160	23.8	77	305	1374	874	73.8	
53	.804	81	57.2	.0198	26.2	75	378	1594	1094	76.3	Unsteady inlet pressure
54	.801	81	63.9	.0221	26.2	74	421	1647	1147	72.3	Unsteady inlet pressure
55	.800	81	69.1	.0240	28.5	75	458	1620	1120	65.2	Blow-out
56	1.000	101	21.5	.0060	23.2	86	114	717	217	46.4	
57	1.000	101	85.0	.0236	36.2	86	450	1423	923	53.8	
58	1.000	101	19.5	.0054	24.2	84	103	682	182	42.8	
59	1.000	101	84.0	.0233	35.2	86	445	1432	932	55.0	
60	1.000	101	87.5	.0243	38.2	86	464	1453	953	54.2	
61	.997	101	35.8	.0100	25.0	77	191	923	423	54.9	
62	.998	101	43.5	.0121	27.7	78	231	1065	565	61.3	
63	.998	101	54.2	.0151	27.2	77	288	1215	715	63.2	
64	.999	101	54.9	.0153	27.2	76	292	1225	725	63.3	
65	.999	101	60.9	.0169	27.9	75	322	1308	808	64.4	
66	.999	101	67.0	.0186	28.0	75	355	1375	875	63.9	Unsteady inlet pressure
67	.999	101	77.0	.0214	29.6	75	408	1428	928	59.4	Unsteady inlet pressure
68	1.000	101	49.4	.0137	27.7	74	261	1150	650	62.9	
69	1.000	101	57.8	.0161	27.5	74	307	1268	768	64.0	
70	1.000	101	72.0	.0200	28.4	74	381	1405	905	61.7	
71	1.000	101	44.1	.0122	27.1	77	233	1067	567	81.1	
72	1.001	101	57.0	.0158	27.3	77	301	1260	760	64.4	
73	.999	101	43.9	.0122	27.3	82	233	1075	575	62.0	
74	.999	101	33.8	.0094	24.4	82	179	900	400	55.1	
75	1.000	101	51.7	.0144	27.0	81	275	1187	687	63.5	
76	1.000	101	59.1	.0164	27.7	82	313	1290	790	64.7	
77	1.000	101	64.0	.0178	27.5	81	339	1335	835	63.4	
78	1.000	101	70.6	.0196	27.9	82	374	1386	886	61.6	
79	1.002	101	77.4	.0215	30.9	82	410	1420	920	58.6	
80	.999	101	44.1	.0123	26.4	76	235	1076	576	61.6	
81	.999	101	55.7	.0155	26.6	76	296	1245	745	64.3	
82	1.000	101	73.1	.0203	27.8	75	387	1426	926	62.4	
83	1.000	101	42.0	.0117	26.1	78	223	1026	526	58.9	
84	1.000	101	48.9	.0136	26.7	79	259	1137	637	62.0	
85	1.000	101	62.6	.0174	27.2	78	332	1298	798	61.9	

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TABLE II - PERFORMANCE DATA FROM SINGLE COMBUSTOR OPERATING WITH SEVERAL HYDROCARBON FUELS - Continued

[Combustor-inlet total pressure, 14.3 inches mercury absolute.]

NACA

(a) Isooctane - continued.

Run	Air flow (lb/sec)	Combustor reference velocity (nominal) (ft/sec)	Fuel flow (lb/hr)	Fuel-air ratio	Fuel-nozzle pressure differential (lb/sq in.)	Fuel temperature (°F)	Heat input (Btu/lb air)	Mean combustor-outlet temperature (°R)	Mean temperature rise through combustor (°F)	Combustion efficiency (percent)	Remarks
Combustor-inlet total temperature, 500° R											
86	0.998	101	74.6	0.0207	28.7	78	395	1398	898	59.3	Unsteady inlet pressure
87	1.001	101	29.1	.0081	22.7	72	154	783	283	44.9	
88	1.001	101	36.4	.0101	24.7	72	193	891	391	50.2	
89	1.000	101	43.7	.0121	26.2	72	231	1034	534	57.9	
90	1.000	101	50.9	.0141	24.3	71	269	1159	659	62.0	
91	1.000	101	58.0	.0161	25.4	71	307	1292	792	66.1	
92	1.000	101	89.4	.0248	39.8	68	473	1470	970	54.2	Blow-out
93	1.300	133	26.2	.0056	24.7	90	107	673	173	39.3	
94	1.300	133	32.5	.0069	24.5	90	132	711	211	38.9	
95	1.298	133	41.1	.0088	28.5	90	168	775	275	40.2	
96	1.300	133	46.3	.0099	28.1	90	187	810	310	40.5	
97	1.303	133	44.1	.0094	28.4	72	179	800	300	41.1	
98	1.301	133	52.6	.0112	27.6	72	214	857	357	41.4	
99	1.301	133	57.0	.0122	27.8	72	233	897	397	42.3	
100	1.301	133	61.8	.0132	28.0	72	252	927	427	42.3	
101	1.301	133	64.3	.0137	28.5	71	262	950	450	43.0	
102	1.301	133	67.3	.0144	28.7	70	275	972	472	43.0	
103	1.301	133	71.1	.0152	28.8	70	290	990	490	42.4	
104	1.299	133	75.3	.0161	29.5	70	307	1017	517	42.4	
105	1.300	133	81.2	.0174	32.4	70	332	1025	525	40.0	
106	1.302	133	84.9	.0181	35.9	70	345	1038	538	39.5	
107	1.296	133	90.1	.0193	40.7	70	368	1050	550	38.0	
108	1.300	133	93.0	.0199	44.7	69	379	1047	547	36.7	
109	1.302	133	97.8	.0209	49.8	68	399	1047	547	35.0	
110	1.300	133	98.9	.0211	49.2	68	402	1045	545	34.5	Blow-out
111	1.300	133	33.0	.0071	23.4	71	134	703	203	36.8	
112	1.301	133	52.5	.0112	26.5	74	214	865	365	42.3	
113	1.302	133	34.8	.0074	25.5	74	141	730	230	39.8	
114	1.303	133	64.1	.0137	27.5	74	261	938	438	41.9	
115	1.298	133	79.9	.0171	30.7	75	326	1000	500	38.7	
116	1.298	133	88.3	.0189	38.8	75	360	1032	532	37.4	
117	1.301	133	72.9	.0156	27.9	75	297	1000	500	42.3	
118	1.302	133	78.1	.0167	29.5	75	318	1012	512	40.6	
119	1.301	133	29.6	.0063	21.8	72	120	697	197	39.9	
120	1.300	133	31.6	.0068	20.8	78	130	703	203	38.2	
121	1.297	133	84.6	.0181	34.7	65	345	1050	530	38.9	
122	1.297	133	92.0	.0197	42.4	62	376	1052	552	37.4	
Combustor-inlet total temperature, 660° R											
123	0.600	81	39.3	0.0182	26.5	82	347	1734	1074	83.0	
124	.599	81	26.8	.0124	23.2	82	236	1457	797	87.6	
125	.599	81	17.5	.0081	21.3	83	154	1157	497	81.2	
126	.599	81	13.2	.0061	18.7	84	116	1027	367	78.7	
127	.599	81	22.2	.0103	23.7	83	196	1310	650	84.8	
128	.599	81	43.5	.0202	28.5	81	385	1857	1197	84.4	
129	.599	81	48.3	.0224	27.9	81	427	1972	1312	84.4	
130	.598	81	50.9	.0236	26.7	81	450	2025	1365	83.9	
131	.598	81	53.3	.0248	27.2	81	473	2055	1395	82.0	Blow-out
132	.593	81	26.3	.0133	22.9	83	254	1492	832	85.6	
133	.594	81	19.7	.0092	21.3	84	175	1255	595	86.3	
134	.599	81	42.9	.0199	27.7	82	379	1830	1170	83.5	
135	.599	81	47.6	.0221	26.5	83	421	1947	1287	83.8	
136	.600	81	47.2	.0219	26.5	78	418	1941	1281	84.1	
137	.600	81	37.8	.0175	26.0	78	334	1700	1040	83.3	
138	.601	81	27.0	.0125	21.4	79	238	1471	811	88.5	
139	.599	81	33.5	.0155	24.5	80	296	1630	970	86.9	
140	.598	81	39.3	.0183	25.2	79	349	1753	1093	84.1	
141	.598	81	45.6	.0212	24.7	79	404	1920	1260	85.2	
142	.598	81	49.2	.0229	24.9	78	437	1988	1328	83.8	
143	.598	81	53.7	.0249	26.3	77	475	2085	1425	83.6	
144	.598	81	54.9	.0255	26.4	76	486	2075	1415	81.2	Blow-out
145	.598	81	31.0	.0144	22.6	77	275	1572	912	87.4	
146	.598	81	44.0	.0204	25.2	77	389	1866	1206	84.4	
147	.598	81	51.1	.0237	24.8	77	452	2024	1364	83.6	
148	.796	107	14.3	.0050	18.8	83	85	891	231	59.9	
149	.796	107	24.5	.0085	23.9	83	162	1152	492	76.8	
150	.800	107	32.5	.0113	25.0	82	215	1328	668	79.7	
151	.800	107	38.9	.0135	27.9	82	257	1460	800	81.0	
152	.799	107	46.1	.0160	26.7	81	305	1635	975	84.7	
153	.799	107	56.9	.0198	27.9	81	378	1798	1138	81.5	
154	.799	107	60.0	.0209	27.9	81	399	1828	1168	79.6	
155	.798	107	65.5	.0228	28.2	81	435	1890	1230	77.5	
156	.798	107	69.7	.0243	28.5	81	463	1938	1278	76.1	
157	.798	107	75.1	.0261	29.1	81	498	1965	1305	72.8	
158	.799	107	38.9	.0135	26.2	78	257	1463	803	81.3	
159	.799	107	28.7	.0100	24.7	78	191	1253	593	79.3	
160	.801	107	47.6	.0165	28.5	79	315	1637	977	82.5	
161	.797	107	56.6	.0197	27.9	80	376	1773	1113	80.0	
162	.797	107	65.0	.0227	28.4	80	433	1875	1215	76.8	
163	.797	107	76.3	.0266	29.7	80	507	1955	1295	70.9	
164	.798	107	82.3	.0286	34.7	81	545	1935	1275	65.2	Blow-out
165	.802	107	38.7	.0134	27.5	82	256	1450	790	80.5	
166	.801	107	26.3	.0091	21.7	82	174	1205	545	79.7	
167	.801	107	47.6	.0165	27.6	82	315	1630	970	81.8	
168	.802	107	58.8	.0204	27.7	82	389	1807	1147	79.9	

TABLE II - PERFORMANCE DATA FROM SINGLE COMBUSTOR OPERATING WITH SEVERAL HYDROCARBON FUELS - Continued

[Combustor-inlet total pressure, 14.3 inches mercury absolute.]

(a) Isooctane - concluded.

Run	Air flow (lb/sec)	Combustor reference velocity (nominal) (ft/sec)	Fuel flow (lb/hr)	Fuel-air ratio	Fuel-nozzle pressure differential (lb/sq in.)	Fuel temperature (°F)	Heat input (Btu/lb air)	Mean combustor-outlet temperature (°R)	Mean temperature rise through combustor (°F)	Combustion efficiency (percent)	Remarks
Combustor-inlet total temperature, 660° R											
169	0.802	107	71.1	0.0246	28.0	83	469	1940	1280	75.3	
170	.798	107	42.2	.0147	25.7	74	280	1555	895	84.0	
171	.798	107	54.0	.0188	26.5	74	358	1758	1098	82.4	
172	.800	107	44.1	.0153	26.6	76	292	1590	930	84.1	
173	.800	107	22.5	.0078	21.6	80	149	1100	440	74.4	
174	.801	107	31.5	.0109	23.0	80	208	1318	658	81.3	
175	.799	107	38.5	.0134	25.9	77	256	1454	794	81.0	
176	.800	107	76.5	.0266	28.2	74	507	1960	1300	71.2	
177	.801	107	79.1	.0274	30.7	75	522	1945	1285	68.4	
178	.799	107	31.3	.0109	22.8	76	208	1306	646	79.7	
179	.798	107	44.4	.0155	25.7	77	296	1594	934	83.5	
180	.998	134	44.6	.0124	27.8	74	237	1342	682	74.4	
181	.997	134	37.7	.0105	26.3	75	200	1228	568	72.4	
182	.995	134	28.6	.0080	24.6	75	152	1055	395	65.2	
183	1.000	134	19.5	.0054	21.8	76	103	870	210	50.3	
184	1.003	134	23.0	.0064	23.5	73	121	942	282	57.7	
185	1.000	134	31.2	.0087	24.2	74	165	1105	445	67.9	
186	1.000	134	39.3	.0109	27.1	74	208	1252	592	72.7	
187	1.000	134	45.7	.0127	27.9	75	242	1365	705	75.4	
188	1.002	134	78.3	.0217	29.9	75	414	1632	972	63.2	
189	.999	134	82.0	.0228	33.2	75	435	1665	1005	62.5	
190	1.003	134	42.8	.0119	26.9	80	227	1305	645	73.1	
191	1.003	134	87.5	.0242	38.7	81	461	1670	1010	58.4	
192	1.003	134	92.7	.0257	------	81	490	1660	1000	55.6	Blow-out
193	.999	134	43.0	.0120	27.2	79	229	1307	647	72.7	
194	.999	134	29.4	.0082	21.7	80	156	1076	416	66.9	
195	1.000	134	83.5	.0232	34.7	81	442	1647	987	60.3	
196	1.000	134	30.7	.0085	22.7	79	163	1097	437	68.0	
197	1.000	134	47.2	.0131	27.5	77	250	1390	730	75.8	
198	1.000	134	59.6	.0166	26.5	77	317	1540	880	73.4	
199	1.001	134	68.6	.0190	27.5	76	362	1616	956	70.4	
200	1.001	134	82.0	.0228	34.7	76	435	1655	995	61.8	
201	1.000	134	43.6	.0121	26.2	74	231	1340	680	76.0	
202	1.000	134	72.6	.0202	28.1	74	385	1630	970	67.5	
203	1.003	134	32.7	.0091	23.1	80	174	1138	478	69.7	
204	1.003	134	39.5	.0109	25.7	78	208	1256	596	73.4	
205	1.003	134	45.4	.0126	25.7	77	240	1365	705	75.9	
206	1.002	134	51.9	.0144	25.7	77	275	1465	805	76.6	
207	1.001	134	59.2	.0164	26.4	76	313	1562	902	76.2	
208	1.001	134	64.3	.0178	28.9	76	339	1592	932	73.0	
209	1.001	134	70.6	.0196	27.4	75	374	1642	982	70.4	
210	1.001	134	77.6	.0215	28.8	75	410	1650	990	65.0	
211	1.001	134	84.9	.0236	35.7	75	450	1650	990	59.6	
212	1.001	134	87.8	.0244	38.9	75	465	1630	970	56.5	Blow-out
213	1.000	134	33.1	.0092	22.6	76	175	1142	482	69.6	
214	1.000	134	45.3	.0126	24.7	76	240	1361	701	75.5	
215	1.001	134	56.2	.0156	25.4	74	297	1512	852	75.3	
216	1.001	134	65.7	.0182	26.2	74	347	1622	962	73.9	
217	1.001	134	76.0	.0211	27.7	72	402	1658	998	66.8	
218	1.300	178	32.7	.0070	23.0	73	133	917	257	48.8	
219	1.300	178	26.2	.0056	23.5	74	107	870	210	48.7	
220	1.298	178	20.2	.0043	20.9	76	82	823	163	48.8	
221	1.301	178	39.5	.0084	26.8	75	161	955	295	46.0	
222	1.300	178	44.6	.0095	27.8	74	182	985	325	45.0	
223	1.300	178	48.9	.0105	28.6	74	199	1005	345	43.7	
224	1.302	178	53.2	.0114	27.2	73	216	1030	370	43.3	
225	1.301	178	59.6	.0127	28.4	72	243	1075	415	43.6	Resonance
226	1.301	178	65.7	.0140	28.5	72	268	1124	464	44.5	Resonance
227	1.298	178	73.1	.0156	28.7	72	298	1164	504	43.6	
228	1.296	178	81.5	.0175	32.7	72	333	1187	527	41.1	
229	1.297	178	90.9	.0195	43.0	72	371	1190	530	37.3	Blow-out
230	1.300	178	23.6	.0050	22.3	81	95	860	200	51.8	
231	1.296	178	51.7	.0111	26.1	82	212	1047	387	46.3	
232	1.294	178	60.2	.0129	27.2	82	246	1108	448	46.5	
233	1.294	178	67.0	.0144	27.7	82	275	1151	491	45.9	
234	1.294	178	78.2	.0168	30.7	82	320	1186	526	42.6	
235	1.294	178	86.7	.0186	38.2	82	355	1204	544	40.0	
236	1.300	178	62.8	.0134	26.7	83	258	1112	452	45.2	
237	1.298	178	49.1	.0105	25.5	82	200	1036	376	47.5	
238	1.298	178	76.0	.0163	28.7	82	311	1165	505	42.0	
239	1.301	178	51.8	.0111	25.9	73	212	1055	395	47.3	
240	1.301	178	68.2	.0146	27.1	74	278	1155	495	45.7	
241	1.301	178	82.0	.0175	33.7	75	334	1208	548	42.7	
242	1.297	178	38.2	.0082	22.6	78	156	956	296	47.4	
243	1.295	178	44.4	.0095	25.2	78	181	986	326	45.3	
244	1.296	178	49.6	.0106	25.5	77	202	1028	368	46.1	
245	1.296	178	57.4	.0123	24.2	77	255	1078	418	45.4	
246	1.296	178	62.8	.0135	25.5	77	257	1120	460	45.8	
247	1.297	178	69.1	.0148	25.6	67	282	1152	492	44.9	
248	1.297	178	74.3	.0159	26.6	68	303	1180	520	44.2	
249	1.303	178	31.3	.0067	21.7	75	128	920	260	50.7	
250	1.303	178	43.5	.0093	23.9	74	177	977	317	45.0	
251	1.302	178	53.8	.0115	23.9	74	219	1054	394	45.6	
252	1.302	178	54.1	.0137	25.2	73	261	1123	463	45.4	
253	1.300	178	74.9	.0160	26.7	76	305	1178	516	45.7	

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TABLE II - PERFORMANCE DATA FROM SINGLE COMBUSTOR OPERATING WITH SEVERAL HYDROCARBON FUELS - Continued

[Combustor-inlet total pressure, 14.3 inches mercury absolute.]

(b) n-Heptane.

Run	Air flow (lb/sec)	Combustor reference velocity (nominal) (ft/sec)	Fuel flow (lb/hr)	Fuel-air ratio	Fuel-nozzle pressure differential (lb/sq in.)	Fuel temperature (°F)	Heat input (Btu/lb air)	Mean combustor-outlet temperature (°R)	Mean temperature rise through combustor (°F)	Combustion efficiency (percent)	Remarks
Combustor-inlet total temperature, 500° R											
254	0.598	61	37.8	0.0176	——	73	337	1440	940	72.3	
255	.597	61	32.7	.0152	23.0	74	291	1340	840	74.0	
256	.597	61	27.3	.0127	22.8	74	243	1140	640	66.3	
257	.597	61	21.4	.0100	20.2	75	192	880	380	49.0	
258	.597	61	41.5	.0193	26.6	74	370	1570	1070	76.0	Occasional resonance
259	.597	61	45.3	.0211	25.7	73	404	1718	1218	80.2	
260	.597	61	50.0	.0233	26.2	73	446	1823	1323	79.9	
261	.598	61	54.8	.0254	26.7	73	487	1918	1418	79.3	
262	.599	61	55.5	.0257	——	73	493	1930	1430	79.1	Blow-out
263	.601	61	30.0	.0139	23.7	74	266	1250	750	71.8	
264	.601	61	35.2	.0163	25.2	74	312	1363	863	71.3	
265	.602	61	40.3	.0186	27.4	74	356	1522	1022	75.0	
266	.602	61	42.8	.0197	27.0	74	378	1620	1120	78.2	Occasional resonance, blow-out
267	.799	81	50.2	.0175	26.7	68	335	1510	1010	78.5	
268	.800	81	43.0	.0149	25.6	69	285	1328	828	74.3	
269	.800	81	36.5	.0127	22.8	70	243	1093	593	61.2	
270	.800	81	30.1	.0104	22.0	71	199	920	420	52.2	
271	.800	81	25.9	.0090	21.5	71	172	790	290	41.3	
272	.800	81	54.8	.0190	26.4	70	364	1605	1105	79.9	Resonance
273	.801	81	59.3	.0206	26.7	70	395	1698	1198	80.6	Resonance
274	.801	81	63.6	.0221	27.1	70	423	1758	1258	79.5	Resonance
275	.801	81	68.0	.0236	27.2	70	452	1810	1310	78.0	Resonance
276	.802	81	72.3	.0250	28.4	70	479	1857	1357	76.8	Resonance
277	.802	81	76.8	.0266	32.2	70	510	1867	1367	73.0	Resonance
278	.802	81	78.1	.0271	33.7	71	519	1790	1290	67.4	Resonance, blow-out
279	1.000	101	35.2	.0098	23.7	76	187	890	390	51.4	
280	1.000	101	27.4	.0076	22.7	75	146	710	210	35.2	
281	1.000	101	42.8	.0119	26.1	76	228	1072	572	63.0	
282	1.000	101	50.1	.0139	26.2	74	266	1224	724	69.0	
283	.999	101	57.2	.0160	26.7	73	304	1351	851	71.8	
284	1.000	101	63.6	.0177	27.2	73	339	1468	968	74.3	
285	.999	101	70.0	.0195	27.7	73	375	1536	1036	72.8	Occasional resonance
286	.999	101	76.8	.0213	32.4	73	409	1577	1077	69.6	
287	1.000	101	82.6	.0229	40.7	73	439	1636	1136	66.8	
288	1.000	101	89.4	.0248	50.7	73	475	1650	1150	64.7	
289	.999	101	94.3	.0262	56.7	72	502	1615	1115	59.4	Blow-out
290	1.300	133	41.6	.0089	25.2	68	170	761	261	40.5	
291	1.300	133	47.6	.0102	25.7	68	195	848	348	44.1	
292	1.300	133	54.8	.0117	26.0	68	224	942	442	49.0	
293	1.300	133	61.4	.0131	26.5	68	251	1020	520	51.8	
294	1.300	133	68.0	.0145	26.9	67	278	1102	602	54.6	
295	1.300	133	74.5	.0159	29.8	67	305	1152	652	54.3	
296	1.300	133	80.7	.0172	36.8	67	330	1188	688	53.2	
297	1.300	133	89.4	.0191	46.5	67	366	1208	708	49.7	
298	1.300	133	96.2	.0206	57.7	67	394	1225	725	47.4	
299	1.300	133	102.0	.0218	67.9	67	417	1232	732	45.3	
300	1.300	133	104.3	.0223	72.8	67	427	1220	720	43.6	Blow-out
Combustor-inlet total temperature, 660° R											
301	0.600	81	20.0	0.0093	19.7	76	178	1168	508	72.3	
302	.600	81	16.8	.0078	18.7	77	149	1057	397	66.7	
303	.600	81	24.5	.0113	22.8	77	216	1312	652	77.4	
304	.600	81	30.1	.0139	23.2	77	266	1490	830	81.5	
305	.600	81	35.2	.0163	25.0	77	312	1585	925	78.4	
306	.600	81	40.3	.0187	26.8	75	358	1708	1048	78.5	
307	.600	81	45.3	.0209	26.8	74	400	1875	1215	82.7	
308	.601	81	50.0	.0231	27.0	74	443	2018	1358	84.8	
309	.601	81	54.8	.0253	27.0	74	485	2132	1472	84.9	
310	.600	81	58.5	.0271	——	73	519	2235	1575	85.7	Blow-out
311	.801	107	20.0	.0069	19.7	74	133	930	270	50.6	
312	.801	107	24.5	.0085	21.8	74	162	1067	407	63.1	
313	.801	107	30.1	.0104	23.1	76	199	1235	575	73.7	
314	.801	107	35.2	.0122	24.9	78	234	1330	670	73.9	
315	.801	107	40.3	.0140	25.7	77	268	1460	800	77.9	
316	.801	107	45.3	.0157	27.5	76	301	1592	932	81.9	
317	.801	107	50.0	.0173	26.6	75	331	1712	1052	84.9	
318	.801	107	54.8	.0190	26.9	74	364	1806	1146	85.0	
319	.801	107	59.3	.0206	27.1	72	395	1907	1247	86.2	
320	.802	107	63.6	.0220	27.5	73	421	2002	1342	87.6	
321	.801	107	68.0	.0238	27.7	73	452	2087	1427	87.6	
322	.803	107	72.2	.0250	28.5	73	479	2158	1498	87.5	
323	.803	107	77.0	.0266	32.4	73	510	2117	1457	80.2	
324	.800	107	81.0	.0281	36.7	73	538	2112	1452	75.9	Blow-out
325	1.000	134	21.4	.0059	19.1	72	114	837	177	38.6	
326	1.000	134	30.0	.0083	23.5	73	160	1042	382	60.2	
327	1.000	134	37.8	.0105	23.9	73	201	1198	538	68.2	
328	1.000	134	45.3	.0126	26.7	73	241	1362	702	75.4	
329	1.000	134	52.4	.0146	26.2	72	279	1505	845	79.4	
330	1.000	134	59.3	.0165	26.7	72	316	1625	965	81.0	
331	1.000	134	65.8	.0183	27.5	72	351	1742	1082	82.9	
332	1.000	134	72.3	.0201	28.1	72	385	1825	1165	82.0	
333	1.000	134	79.0	.0219	33.7	72	420	1845	1185	77.0	
334	1.000	134	82.6	.0229	39.5	71	439	1874	1214	75.8	
335	1.000	134	88.5	.0246	46.7	71	471	1885	1225	71.6	
336	1.000	134	91.3	.0253	——	72	485	1880	1220	69.4	Blow-out
337	1.301	178	30.1	.0064	20.7	72	123	852	192	38.9	
338	1.303	178	37.8	.0080	23.8	73	153	972	312	51.0	
339	1.300	178	45.3	.0097	25.8	72	186	1092	432	58.8	Resonance
340	1.300	178	52.4	.0112	25.5	72	215	1168	508	60.4	Resonance
341	1.300	178	59.3	.0127	25.8	71	243	1238	578	61.0	Resonance
342	1.301	178	65.8	.0140	26.7	70	268	1298	638	61.5	
343	1.301	178	72.3	.0154	27.2	70	295	1332	672	59.3	
344	1.301	178	78.7	.0168	32.9	69	322	1360	700	56.9	
345	1.302	178	85.0	.0181	41.7	69	347	1383	723	54.8	
346	1.300	178	91.7	.0196	50.7	68	375	1410	750	52.8	
347	1.301	178	95.2	[illegible]	60.7	68	402	1412	752	49.6	
348	1.301	178	104.2	.0222	62.7	68	425	1420	760	47.6	
349	1.301	178	106.0	.0226	63.0	68	433	1408	748	46.0	Blow-out

[redacted]

TABLE II - PERFORMANCE DATA FROM SINGLE COMBUSTOR OPERATING WITH SEVERAL HYDROCARBON FUELS - Continued

[Combustor-inlet total pressure, 14.3 inches mercury absolute.]

(c) Cyclohexane.

Run	Air flow (lb/sec)	Combustor reference velocity (nominal) (ft/sec)	Fuel flow (lb/hr)	Fuel-air ratio	Fuel-nozzle pressure differential (lb/sq in.)	Fuel temperature (°F)	Heat input (Btu/lb air)	Mean combustor-outlet temperature (°R)	Mean temperature rise through combustor (°F)	Combustion efficiency (percent)	Remarks
Combustor-inlet total temperature, 500° R											
350	0.603	61	30.7	0.0141	23.8	66	284	1350	850	82.3	
351	.603	61	23.0	.0106	21.9	68	198	1065	565	71.0	
352	.603	61	17.5	.0081	22.7	67	152	838	338	54.7	
353	.603	61	38.5	.0177	25.9	67	331	1553	1053	82.9	
354	.602	61	46.2	.0213	26.6	64	399	1705	1205	80.2	Resonance
355	.602	61	53.7	.0248	27.6	63	464	1850	1350	78.5	Resonance
356	.601	61	57.4	.0265	27.9	65	496	1930	1430	76.5	Resonance, blow-out
357	.799	81	48.7	.0169	26.6	64	316	1452	952	77.8	
358	.799	81	41.1	.0143	26.7	64	268	1297	797	75.9	
359	.799	81	33.4	.0116	24.9	65	217	1095	595	68.6	
360	.799	81	25.6	.0089	24.7	65	167	863	363	53.6	
361	.799	81	19.0	.0066	22.7	66	124	707	407	40.6	
362	.799	81	56.3	.0196	27.8	63	367	1592	1092	78.1	
363	.799	81	61.9	.0215	27.4	63	402	1708	1208	79.7	
364	.799	81	71.1	.0247	27.7	62	462	1795	1295	75.3	
365	.799	81	78.3	.0272	29.5	62	509	1860	1360	72.5	
366	.799	81	82.9	.0288	32.8	61	539	1905	1405	71.2	
367	.799	81	87.0	.0303	37.6	61	567	1810	1310	63.0	Resonance
368	.799	81	90.8	.0316	41.3	60	591	1820	1320	61.0	Blow-out
369	.999	81	36.0	.0100	28.7	67	187	910	410	54.1	
370	1.000	101	28.0	.0078	21.6	68	146	762	262	43.9	
371	1.000	101	22.3	.0062	22.0	68	116	670	170	35.6	Blow-out
372	1.000	101	43.6	.0121	25.7	67	226	1090	590	65.2	
373	1.000	101	51.1	.0142	26.6	68	266	1195	695	65.3	
374	1.000	101	58.9	.0164	27.6	68	307	1300	800	66.7	
375	1.001	101	64.1	.0178	26.9	68	333	1381	881	68.2	
376	1.001	101	71.1	.0197	28.2	68	369	1480	980	69.3	
377	1.001	101	78.8	.0219	29.9	67	410	1545	1045	67.1	
378	1.000	101	85.6	.0238	36.2	67	445	1590	1090	64.8	Resonance
379	1.000	101	92.9	.0258	43.3	67	483	1640	1140	63.0	Resonance
380	1.000	101	101.1	.0281	51.7	67	526	1640	1140	58.1	
381	1.002	101	105.4	.0292	----	67	547	1600	1100	54.0	Blow-out
382	1.300	133	46.2	.0099	26.5	70	185	755	255	33.7	
383	1.301	133	57.2	.0079	24.3	70	148	688	188	31.0	
384	1.301	133	56.3	.0120	27.4	70	225	858	358	39.4	
385	1.301	133	66.4	.0142	26.9	70	266	982	482	45.3	
386	1.302	133	75.9	.0162	28.1	70	303	1072	572	47.6	
387	1.303	133	85.5	.0182	35.2	70	341	1155	655	49.0	
388	1.303	133	94.3	.0201	44.7	70	376	1210	710	48.4	Blow-out
Combustor-inlet total temperature, 660° R											
389	0.599	81	30.7	0.0142	24.7	76	267	1538	878	86.3	
390	.599	81	25.6	.0119	22.1	77	222	1400	740	86.0	
391	.599	81	20.4	.0095	21.7	78	177	1240	580	83.2	
392	.599	81	14.4	.0067	19.9	80	125	1062	402	80.4	
393	.600	81	36.0	.0167	25.0	76	312	1655	995	84.6	
394	.600	81	41.1	.0190	26.1	76	356	1790	1130	85.4	
395	.600	81	46.2	.0214	26.9	74	400	1915	1255	85.4	Occasional resonance
396	.600	81	51.2	.0237	25.9	74	444	2022	1362	84.7	Resonance
397	.601	81	56.3	.0260	26.6	73	487	2125	1465	83.9	
398	.601	81	61.4	.0284	26.9	73	531	2232	1572	83.5	
399	.601	81	66.3	.0306	26.1	72	574	2330	1670	83.1	
400	.601	81	71.1	.0328	27.7	72	615	2405	1745	81.7	
401	.601	81	73.0	.0337	27.9	72	631	2435	1775	81.2	Blow-out
402	.802	107	25.6	.0089	21.5	75	166	1180	520	79.3	
403	.802	107	17.5	.0061	21.2	76	113	977	317	69.5	
404	.801	107	33.4	.0116	23.9	76	217	1355	695	82.5	
405	.801	107	41.1	.0143	25.7	75	267	1510	850	83.3	
406	.800	107	48.7	.0169	26.8	74	317	1663	1003	84.2	
407	.800	107	56.3	.0196	26.5	73	366	1802	1142	84.1	
408	.800	107	63.9	.0222	26.9	73	415	1937	1277	84.0	
409	.800	107	71.1	.0247	27.5	72	462	2060	1400	83.9	
410	.800	107	78.3	.0272	29.7	72	509	2166	1506	83.0	
411	.801	107	42.4	.0147	25.2	70	275	1542	882	84.0	
412	.801	107	58.9	.0204	25.4	70	382	1853	1193	84.6	
413	.801	107	79.5	.0276	29.9	70	518	2172	1512	82.2	
414	.801	107	82.0	.0284	31.7	71	532	2117	1457	76.8	
415	.803	107	85.6	.0296	35.5	71	554	2108	1448	73.5	
416	.804	107	89.0	.0308	38.9	71	576	2110	1450	71.0	
417	.804	107	92.6	.0321	42.6	71	600	2110	1450	66.5	
418	.804	107	93.3	.0322	----	71	604	2085	1425	66.7	Blow-out
419	1.004	134	30.8	.0085	21.6	70	159	1100	440	69.6	
420	1.001	134	22.6	.0063	21.7	74	118	963	303	63.9	
421	1.002	134	16.0	.0044	19.3	74	82	825	165	49.4	
422	1.001	134	38.6	.0107	24.7	73	200	1258	598	76.2	
423	1.001	134	46.2	.0128	25.9	73	240	1395	735	72.4	
424	1.003	134	53.8	.0149	25.9	73	279	1518	858	80.8	
425	1.002	134	61.4	.0170	26.4	73	318	1630	970	80.8	
426	1.001	134	68.8	.0191	26.9	73	358	1738	1078	80.9	
427	1.000	134	75.9	.0211	28.0	71	395	1833	1173	80.5	
428	1.001	134	83.1	.0231	32.8	71	432	1885	1225	77.4	
429	.999	134	90.3	.0251	39.9	71	470	1915	1255	73.5	
430	.999	134	97.8	.0272	47.1	70	509	1915	1255	68.2	
431	.999	134	105.0	.0292	56.4	70	547	1882	1222	62.0	
432	.999	134	106.4	.0296	----	70	554	1855	1195	59.8	Blow-out
433	1.300	178	33.4	.0071	22.7	74	133	928	268	50.2	
434	1.300	178	23.1	.0049	21.2	76	92	834	174	46.8	
435	1.300	178	43.6	.0093	24.7	75	174	1042	382	55.2	Resonance
436	1.300	178	53.7	.0115	25.2	73	215	1138	478	56.5	Resonance
437	1.301	178	63.9	.0136	25.8	72	255	1228	568	57.3	Resonance
438	1.301	178	73.5	.0157	26.7	71	294	1290	630	55.6	Resonance
439	1.301	178	83.1	.0177	31.7	71	331	1372	712	56.2	Resonance
440	1.301	178	92.8	.0198	41.7	70	371	1412	752	53.5	Resonance
441	1.301	178	102.6	.0219	53.0	70	410	1432	772	50.0	Resonance
442	1.301	178	112.0	.0239	65.7	70	447	1435	775	46.2	Resonance
443	1.301	178	113.9	.0243	67.7	70	455	1405	745	43.7	Blow-out

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TABLE II - PERFORMANCE DATA FROM SINGLE COMBUSTOR OPERATING WITH SEVERAL HYDROCARBON FUELS - Continued

[Combustor-inlet total pressure, 14.3 inches mercury absolute.]

(d) Methylcyclohexane.

Run	Air flow (lb/sec)	Combustor reference velocity (nominal) (ft/sec)	Fuel flow (lb/hr)	Fuel-air ratio	Fuel-nozzle pressure differential (lb/sq in.)	Fuel temperature (°F)	Heat input (Btu/lb air)	Mean combustor-outlet temperature (°R)	Mean temperature rise through combustor (°F)	Combustion efficiency (percent)	Remarks
Combustor-inlet total temperature, 500° R											
444	0.599	61	24.6	0.0114	22.3	62	213	1115	615	72.4	
445	.599	61	29.9	.0139	20.9	62	259	1301	801	78.6	
446	.598	61	35.2	.0163	21.7	65	304	1466	966	82.2	
447	.600	61	40.6	.0188	25.2	66	351	1605	1105	82.7	Occasional resonance
448	.600	61	45.2	.0209	25.7	64	390	1709	1209	82.3	
449	.600	61	49.9	.0231	25.2	64	431	1778	1278	79.4	
450	.600	61	54.5	.0252	25.2	64	470	1860	1360	78.2	
451	.600	61	59.7	.0276	25.9	64	515	2005	1505	80.1	Blow-out
452	.600	61	58.9	.0273	25.9	65	509	1977	1477	79.4	Blow-out
453	.798	81	22.1	.0077	20.7	77	144	812	312	53.2	
454	.797	81	30.1	.0105	20.9	77	196	962	462	58.5	
455	.797	81	37.8	.0132	24.7	76	246	1175	675	69.2	
456	.797	81	45.2	.0158	24.6	76	295	1368	868	75.6	
457	.797	81	52.2	.0182	25.7	75	340	1524	1024	78.6	
458	.798	81	59.8	.0208	25.5	74	388	1668	1168	79.6	
459	.799	81	67.4	.0234	26.2	73	437	1745	1245	76.3	
460	.798	81	74.3	.0258	27.2	73	481	1820	1320	74.1	
461	.798	81	78.9	.0275	28.6	73	513	1830	1330	70.3	
462	.798	81	84.5	.0294	33.1	72	548	1770	1270	62.9	
463	.801	81	87.1	.0302	36.2	62	563	1710	1210	58.2	Blow-out
464	.998	101	18.6	.0052	20.2	75	97	705	205	50.8	
465	1.000	101	26.8	.0074	22.8	76	138	774	274	48.5	
466	.999	101	35.2	.0098	23.3	75	183	860	360	48.5	
467	1.000	101	42.9	.0119	25.7	74	222	1004	504	56.6	
468	1.000	101	49.9	.0139	25.8	74	259	1145	645	62.7	
469	1.000	101	57.1	.0159	25.0	73	297	1280	780	67.1	
470	1.000	101	66.1	.0183	25.3	74	341	1429	929	70.5	
471	1.000	101	74.3	.0206	26.8	74	384	1547	1047	71.5	
472	1.000	101	81.6	.0227	29.0	73	423	1610	1110	69.4	
473	1.000	101	88.5	.0246	35.9	73	459	1634	1134	65.8	
474	1.000	101	95.7	.0266	41.4	72	496	1625	1125	60.6	
475	1.000	101	98.1	.0273	42.7	72	509	1620	1120	58.9	Blow-out
476	1.300	133	20.5	.0044	19.7	76	82	680	180	47.2	
477	1.296	133	28.8	.0062	21.1	75	116	705	205	43.1	
478	1.296	133	35.9	.0077	23.7	74	144	724	224	38.0	
479	1.296	133	43.2	.0093	24.6	75	173	770	270	38.1	
480	1.297	133	51.0	.0109	24.1	75	203	827	327	39.6	
481	1.297	133	58.4	.0125	24.3	74	233	897	397	42.2	
482	1.297	133	66.1	.0142	25.2	74	265	965	465	43.8	
483	1.302	133	73.4	.0157	24.9	72	293	1041	541	46.5	
484	1.301	133	81.1	.0173	29.5	72	323	1102	602	47.2	
485	1.301	133	87.6	.0187	34.8	72	349	1137	637	46.5	
486	1.301	133	93.3	.0199	40.2	72	371	1152	652	44.9	
487	1.301	133	100.3	.0214	47.7	72	399	1184	684	44.0	
488	1.302	133	105.5	.0225	54.7	72	420	1215	715	43.9	
489	1.302	133	112.0	.0239	61.7	72	446	1220	720	41.8	
490	1.303	133	113.5	.0242	——	72	451	1220	720	41.3	Blow-out
Combustor-inlet total temperature, 660° R											
491	0.601	81	15.8	0.0073	18.7	78	136	1062	402	73.9	
492	.601	81	21.6	.0100	21.2	74	187	1240	580	79.1	
493	.601	81	27.2	.0126	22.7	73	235	1433	773	85.2	
494	.601	81	33.8	.0156	22.4	71	291	1616	956	86.7	
495	.601	81	39.2	.0181	24.7	71	338	1732	1072	84.9	
496	.601	81	44.0	.0203	24.6	70	379	1864	1204	86.1	
497	.601	81	48.7	.0225	24.7	69	420	1968	1308	85.4	
498	.601	81	55.8	.0258	24.9	69	481	2097	1437	83.1	
499	.601	81	61.0	.0282	24.9	68	526	2212	1552	83.1	
500	.601	81	64.9	.0300	——	69	560	2273	1613	81.8	Blow-out
501	.801	107	18.8	.0065	18.8	72	121	1000	340	69.9	
502	.801	107	27.2	.0094	20.2	73	175	1171	511	73.8	
503	.801	107	37.9	.0131	22.7	73	244	1441	781	83.0	
504	.801	107	47.6	.0165	24.8	71	306	1652	992	85.4	
505	.801	107	57.1	.0198	24.9	70	369	1830	1170	85.6	
506	.801	107	67.4	.0234	24.7	70	437	1992	1332	83.9	
507	.801	107	76.4	.0265	26.5	68	494	2130	1470	83.1	
508	.801	107	84.5	.0293	31.0	68	547	2080	1420	72.9	Blow-out
508	1.001	134	18.8	.0052	18.9	75	97	912	252	64.3	
510	1.002	134	29.9	.0083	20.2	75	155	1073	413	67.0	
511	1.000	134	40.6	.0113	24.7	73	211	1262	602	73.0	
512	1.001	134	49.9	.0138	25.7	71	257	1433	773	78.0	
513	1.001	134	59.7	.0166	23.9	71	310	1587	927	79.1	
514	1.001	134	69.9	.0194	24.8	70	362	1725	1065	78.9	
515	1.001	134	78.9	.0219	26.1	69	409	1830	1170	77.8	
516	1.000	134	86.4	.0240	33.7	69	448	1912	1252	76.7	
517	1.000	134	90.7	.0252	38.4	69	470	1932	1272	74.6	
518	1.000	134	96.6	.0268	44.0	68	500	1887	1227	67.7	
519	1.000	134	100.0	.0278	——	68	519	1850	1190	63.3	Blow-out
520	1.299	178	31.1	.0067	20.5	69	125	932	272	54.1	
521	1.300	178	40.6	.0087	23.7	66	162	988	328	50.7	
522	1.300	178	49.9	.0107	25.7	65	200	1062	402	50.9	
523	1.300	178	59.7	.0128	25.7	66	239	1136	478	51.1	
524	1.300	178	69.9	.0149	24.7	64	278	1201	541	50.1	
525	1.300	178	78.9	.0169	27.2	63	315	1292	632	52.1	
526	1.300	178	88.5	.0189	35.0	62	353	1325	665	49.4	
527	1.300	178	95.5	.0204	41.9	62	381	1358	698	48.3	
528	1.300	178	102.3	.0219	49.7	62	409	1379	719	46.6	
529	1.300	178	108.8	.0232	58.7	62	433	1360	700	42.9	Blow-out

TABLE II - PERFORMANCE DATA FROM SINGLE COMBUSTOR OPERATING WITH SEVERAL HYDROCARBON FUELS - Continued

[Combustor-inlet total pressure, 14.3 inches mercury absolute.]

(e) Benzene.

Run	Air flow (lb/sec)	Combustor reference velocity (nominal) (ft/sec)	Fuel flow (lb/hr)	Fuel-air ratio	Fuel-nozzle pressure differential (lb/sq in.)	Fuel temperature (°F)	Heat input (Btu/lb air)	Mean combustor outlet temperature (°R)	Mean temperature rise through combustor (°F)	Combustion efficiency (percent)	Remarks
Combustor-inlet total temperature, 500° R											
530	0.598	61	19.1	0.0089	23.0	77	154	820	320	50.9	
531	.598	61	27.5	.0128	23.7	76	221	1170	670	75.8	
532	.598	61	35.8	.0166	26.2	74	287	1430	930	83.1	
533	.598	61	44.2	.0205	26.6	74	354	1650	1150	84.9	Occasional resonance
534	.600	61	50.7	.0235	26.7	74	406	1770	1270	82.8	Resonance
535	.599	61	59.8	.0277	27.2	74	478	1992	1492	84.3	Resonance
536	.599	61	61.0	.0283	27.5	74	489	1998	1498	83.0	Resonance
537	.599	61	61.7	.0286	27.8	74	494	1990	1490	81.7	Resonance
538	.794	81	35.7	.0125	24.5	74	216	1080	580	66.9	
539	.803	81	27.5	.0095	23.6	75	164	875	375	56.0	
540	.803	81	23.4	.0081	21.7	75	140	775	275	47.9	
541	.801	81	43.0	.0149	26.9	75	257	1245	745	73.1	
542	.801	81	43.0	.0149	27.5	71	357	1265	765	75.1	
543	.803	81	52.5	.0182	26.2	72	314	1455	955	78.1	
544	.803	81	63.5	.0220	27.0	72	380	1640	1140	78.5	
545	.805	81	73.6	.0254	27.8	72	439	1785	1285	77.8	
546	.801	81	82.5	.0286	28.4	72	494	1897	1397	76.1	
547	.799	81	91.5	.0318	32.7	72	549	1950	1450	71.7	
548	.799	81	95.9	.0333	36.7	72	575	1982	1482	70.3	Resonance
549	.799	81	100.2	.0348	42.2	72	601	1898	1398	63.3	Blow-out
550	.800	81	101.7	.0353	43.4	72	609	1910	1410	63.0	Blow-out
551	1.004	101	41.6	.0115	25.7	67	199	920	420	52.1	
552	1.000	101	62.5	.0174	26.2	67	300	1255	755	63.7	
553	.998	101	77.2	.0215	26.9	67	371	1495	995	69.5	
554	1.002	101	22.6	.0063	23.5	71	109	638	138	30.7	
555	1.003	101	27.5	.0076	22.7	71	131	682	182	33.7	
556	1.000	101	33.4	.0093	24.8	71	161	768	268	40.8	
557	1.001	101	39.3	.0109	26.7	70	188	870	370	48.3	
558	1.000	101	43.9	.0122	27.6	69	211	962	462	54.2	
559	1.002	101	49.0	.0136	26.4	70	235	1045	545	57.7	
560	1.002	101	53.7	.0149	27.0	70	257	1120	620	60.3	
561	.999	101	60.0	.0167	27.2	70	288	1230	730	64.0	
562	1.000	101	66.8	.0186	27.5	71	321	1343	843	67.1	
563	1.000	101	72.4	.0201	27.7	71	347	1432	932	69.1	
564	1.000	101	78.4	.0218	27.8	71	376	1530	1030	71.1	
565	1.000	101	84.6	.0235	29.2	71	406	1625	1125	72.7	
566	1.000	101	88.9	.0247	31.7	70	426	1660	1160	71.6	
567	1.002	101	92.3	.0256	34.7	70	442	1688	1188	71.0	
568	1.002	101	98.6	.0273	39.8	70	471	1730	1230	69.3	
569	1.001	101	104.5	.0290	46.7	70	501	1765	1265	67.5	
570	1.000	101	110.3	.0306	52.9	70	528	1777	1277	64.8	
571	1.000	101	118.0	.0328	61.9	70	566	1780	1280	60.8	Blow-out
572	1.000	101	119.4	.0332	64.9	72	573	1785	1285	60.4	Blow-out
573	1.300	133	47.8	.0102	27.0	71	176	781	281	39.0	
574	1.300	133	40.8	.0087	25.7	71	150	722	222	36.0	
575	1.302	133	34.4	.0073	25.9	68	126	675	175	33.7	
576	1.302	133	30.1	.0064	24.2	68	111	632	132	28.9	
577	1.302	133	56.6	.0121	27.2	67	209	855	355	41.7	
578	1.301	133	64.3	.0137	26.5	67	237	925	425	44.4	
579	1.300	133	72.4	.0155	27.4	67	268	1010	510	47.5	
580	1.299	133	81.5	.0174	27.9	67	300	1120	620	51.9	
581	1.303	133	80.9	.0172	27.8	74	297	1090	590	49.8	
582	1.301	133	91.3	.0195	32.5	75	337	1180	680	51.1	
583	1.301	133	100.6	.0215	41.5	75	371	1255	755	51.9	
584	1.301	133	106.5	.0227	47.8	72	392	1330	830	54.4	
585	1.302	133	123.4	.0263	----	73	454	1290	790	44.8	Blow-out

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TABLE II - PERFORMANCE DATA FROM SINGLE COMBUSTOR OPERATING WITH SEVERAL HYDROCARBON FUELS - Concluded

[Combustor-inlet total pressure, 14.3 inches mercury absolute.]

(e) Benzene - concluded.

Run	Air flow (lb/sec)	Combustor reference velocity (nominal) (ft/sec)	Fuel flow (lb/hr)	Fuel-air ratio	Fuel-nozzle pressure differential (lb/sq in.)	Fuel temperature (°F)	Heat input (Btu/lb air)	Mean combustor outlet temperature (°R)	Mean temperature rise through combustor (°F)	Combustion efficiency (percent)	Remarks
Combustor-inlet total temperature, 660° R											
586	0.601	81	17.9	0.0083	20.7	81	143	1165	505	88.4	
587	.601	81	24.5	.0113	23.7	82	195	1347	687	89.8	
588	.601	81	32.8	.0152	23.2	82	262	1544	884	87.7	
589	.602	81	41.6	.0192	25.9	79	331	1758	1098	88.0	
590	.601	81	51.1	.0236	27.4	79	407	1964	1304	86.8	Occasional resonance
591	.600	81	60.0	.0278	27.2	79	480	2135	1475	84.8	Resonance
592	.597	81	27.5	.0128	21.7	86	221	1425	765	89.0	
593	.597	81	38.0	.0177	25.1	72	306	1668	1008	86.9	
594	.600	81	47.8	.0221	25.9	70	381	1885	1225	86.4	
595	.601	81	57.5	.0266	25.9	69	459	2085	1425	85.2	Resonance
596	.601	81	63.7	.0294	25.9	68	508	2184	1524	83.3	Resonance
597	.601	81	67.5	.0312	26.2	68	539	2235	1575	81.6	Resonance
598	.601	81	72.4	.0335	26.5	68	579	2315	1655	80.6	Resonance
599	.601	81	77.2	.0357	26.9	68	616	2410	1750	80.7	Blow-out
600	.600	81	80.7	.0374	27.2	68	646	2462	1802	79.8	Blow-out
601	.601	81	81.9	.0378	27.4	69	653	2485	1825	80.1	Blow-out
602	.800	107	15.0	.0052	19.7	80	90	920	260	71.4	
603	.800	107	25.0	.0087	23.0	80	150	1160	500	83.6	
604	.800	107	35.8	.0124	24.0	80	214	1365	705	84.3	
605	.800	107	46.6	.0162	27.4	79	280	1585	925	86.4	
606	.800	107	55.5	.0193	27.2	78	333	1740	1080	86.0	
607	.800	107	66.3	.0230	26.7	77	397	1912	1252	85.1	
608	.800	107	76.0	.0264	27.7	76	456	2068	1408	84.7	
609	.800	107	86.4	.0300	30.8	76	518	2218	1558	83.7	
610	.800	107	98.0	.0340	41.9	76	587	2165	1505	71.7	
611	.800	107	101.3	.0352	----	76	608	2170	1510	69.7	Blow-out
612	1.002	134	28.2	.0078	21.5	78	135	1052	392	72.6	
613	1.001	134	20.5	.0057	21.8	80	98	892	232	58.1	
614	1.001	134	38.7	.0107	26.6	80	185	1230	570	78.1	
615	1.001	134	48.8	.0135	27.4	78	233	1397	737	81.3	
616	1.001	134	58.8	.0163	26.7	77	281	1542	882	81.7	
617	1.001	134	68.8	.0191	26.9	77	330	1675	1015	81.3	
618	1.001	134	78.1	.0217	27.7	76	375	1795	1135	81.0	
619	1.001	134	89.1	.0247	33.7	76	426	1938	1278	81.3	
620	1.001	134	99.3	.0276	44.7	75	476	2018	1358	78.1	
621	1.001	134	109.2	.0303	56.6	75	523	2020	1360	71.6	
622	1.001	134	120.4	.0334	----	75	577	1985	1325	63.5	Blow-out
623	1.299	178	98.0	.0210	38.9	65	363	1425	765	55.1	
624	1.300	178	108.9	.0233	52.2	65	402	1495	835	54.7	
625	1.300	178	91.1	.0195	33.5	67	337	1415	755	58.4	
626	1.300	178	81.9	.0175	26.9	67	302	1365	705	60.3	
627	1.300	178	120.8	.0258	66.2	67	445	1538	878	52.3	
628	1.300	178	65.0	.0139	24.7	70	240	1250	590	62.7	
629	1.300	178	75.0	.0160	25.8	70	276	1335	675	62.9	
630	1.302	178	86.9	.0185	29.5	69	319	1438	778	63.4	
631	1.299	178	100.1	.0214	42.7	68	369	1450	790	58.0	
632	1.301	178	25.7	.0055	20.6	79	95	820	160	41.5	
633	1.300	178	35.1	.0075	24.5	79	130	944	284	54.4	
634	1.300	178	45.6	.0097	25.7	77	167	1062	402	60.1	
635	1.300	178	58.0	.0124	25.9	77	214	1200	540	64.0	
636	1.303	178	70.2	.0150	26.3	77	259	1318	658	65.2	
637	1.303	178	82.4	.0176	27.7	75	304	1425	765	65.4	
638	1.303	178	95.0	.0203	37.7	74	350	1517	857	64.2	
639	1.303	178	105.8	.0226	50.6	74	390	1510	850	57.4	
640	1.303	178	115.9	.0247	62.5	74	426	1515	855	53.1	
641	1.303	178	128.3	.0274	79.0	73	473	1520	860	48.4	
642	1.303	178	131.6	.0281	----	72	485	1535	875	48.1	Blow-out

[redacted]

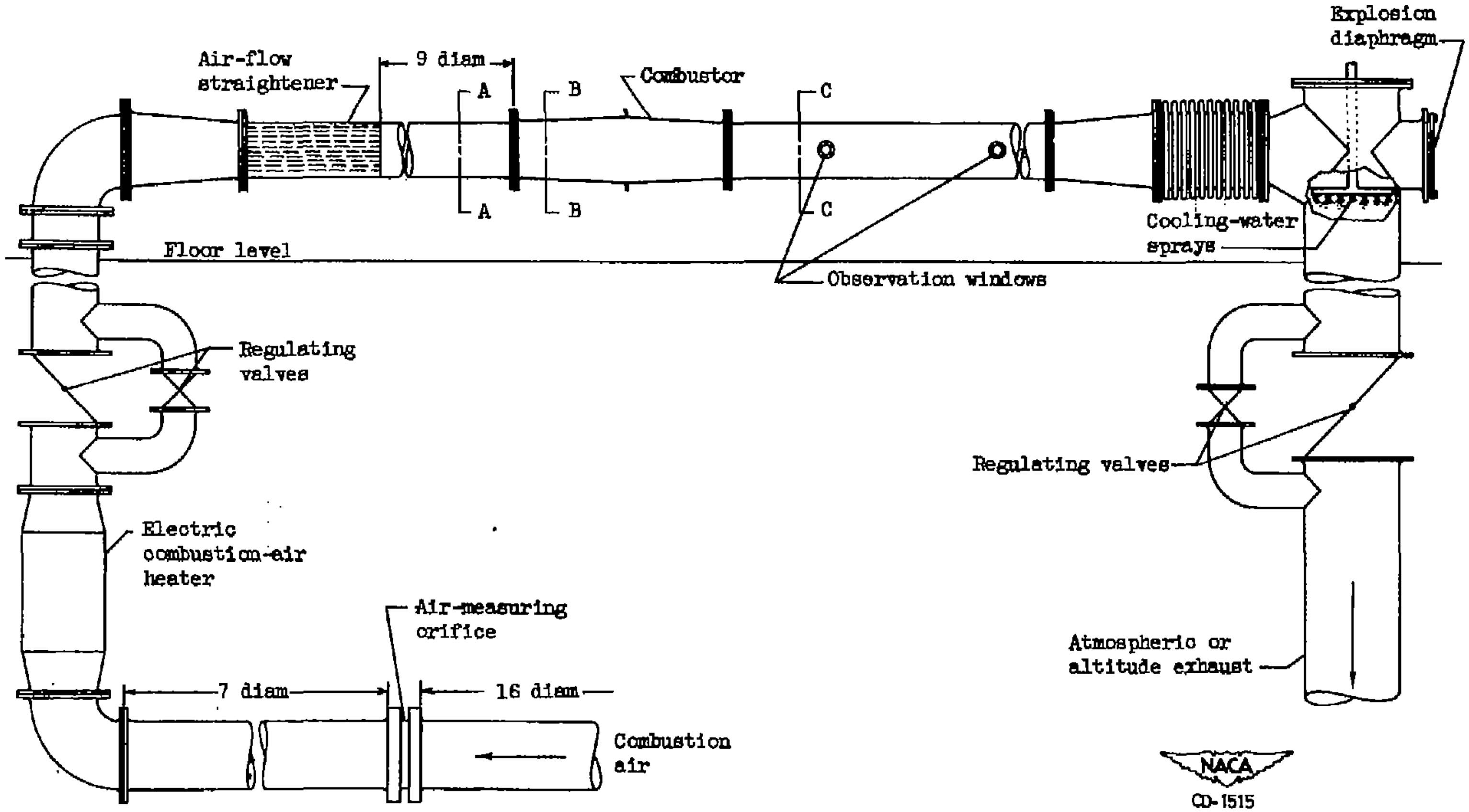

Figure 1. - Single-combustor installation and auxiliary equipment. Instrumentation planes, A-A, B-B, and C-C.

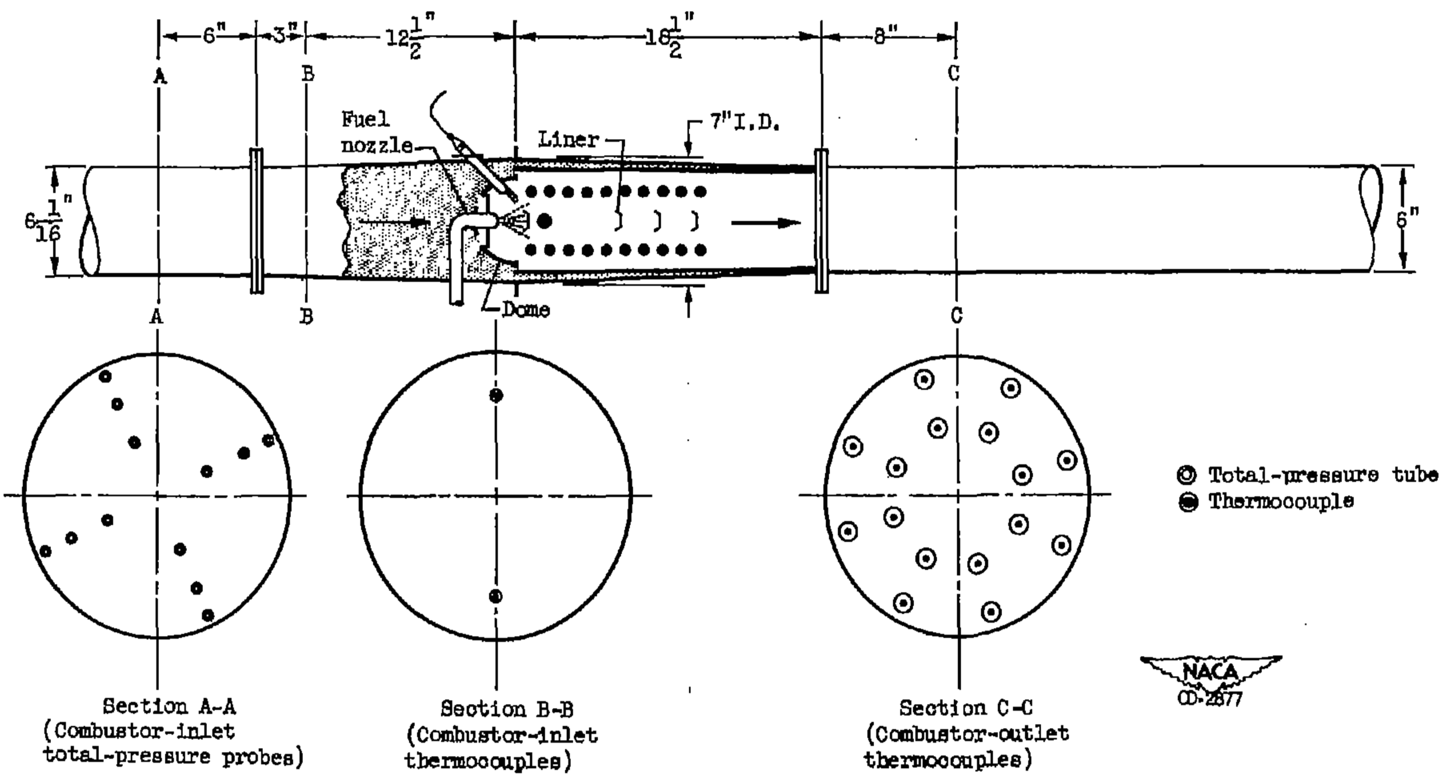

Figure 2. - Cross section of single-combustor installation showing auxiliary ducting and location of temperature- and pressure-measuring instruments in instrumentation planes.

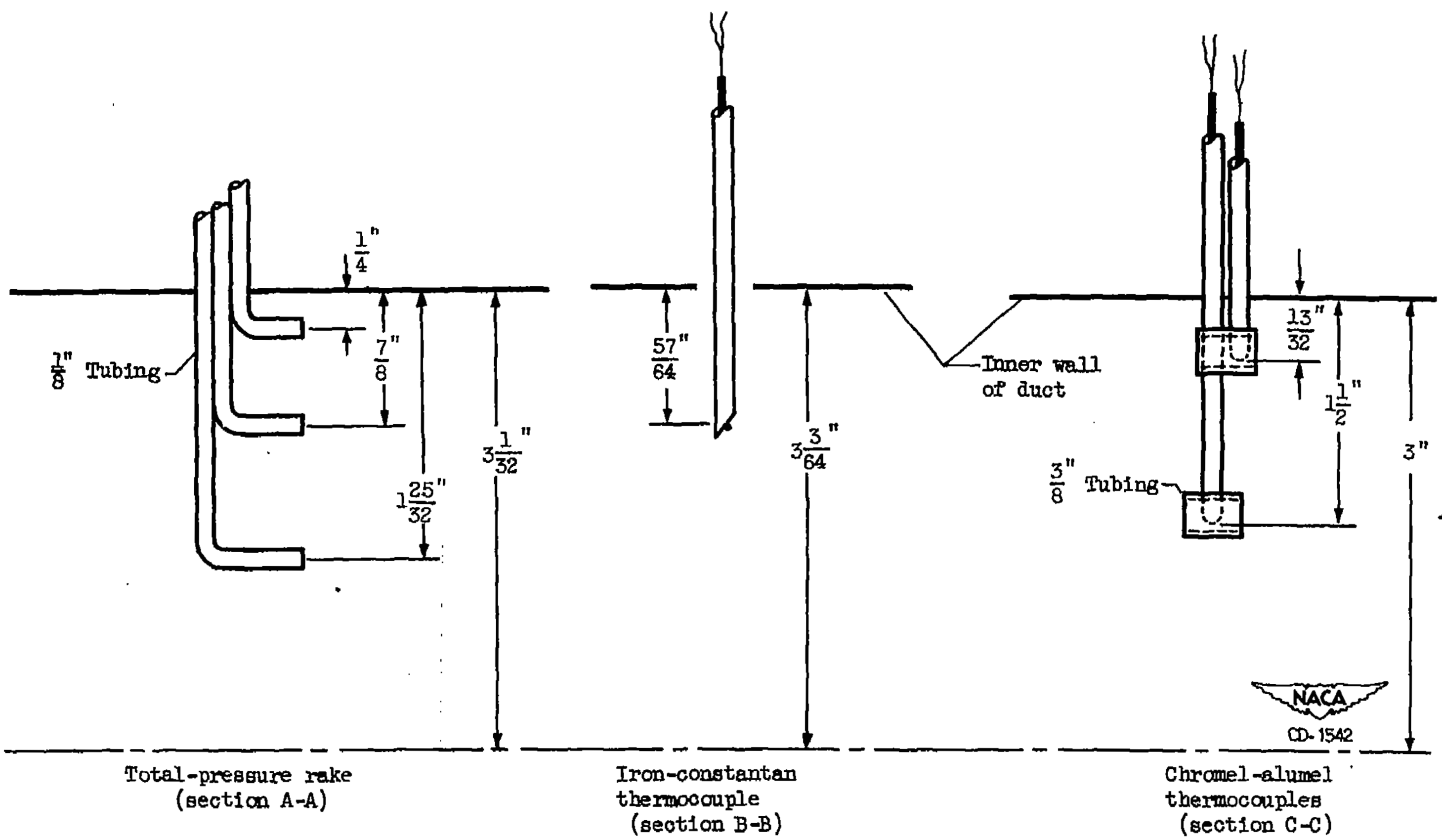

Figure 3. - Construction details of temperature- and pressure-measuring instruments.

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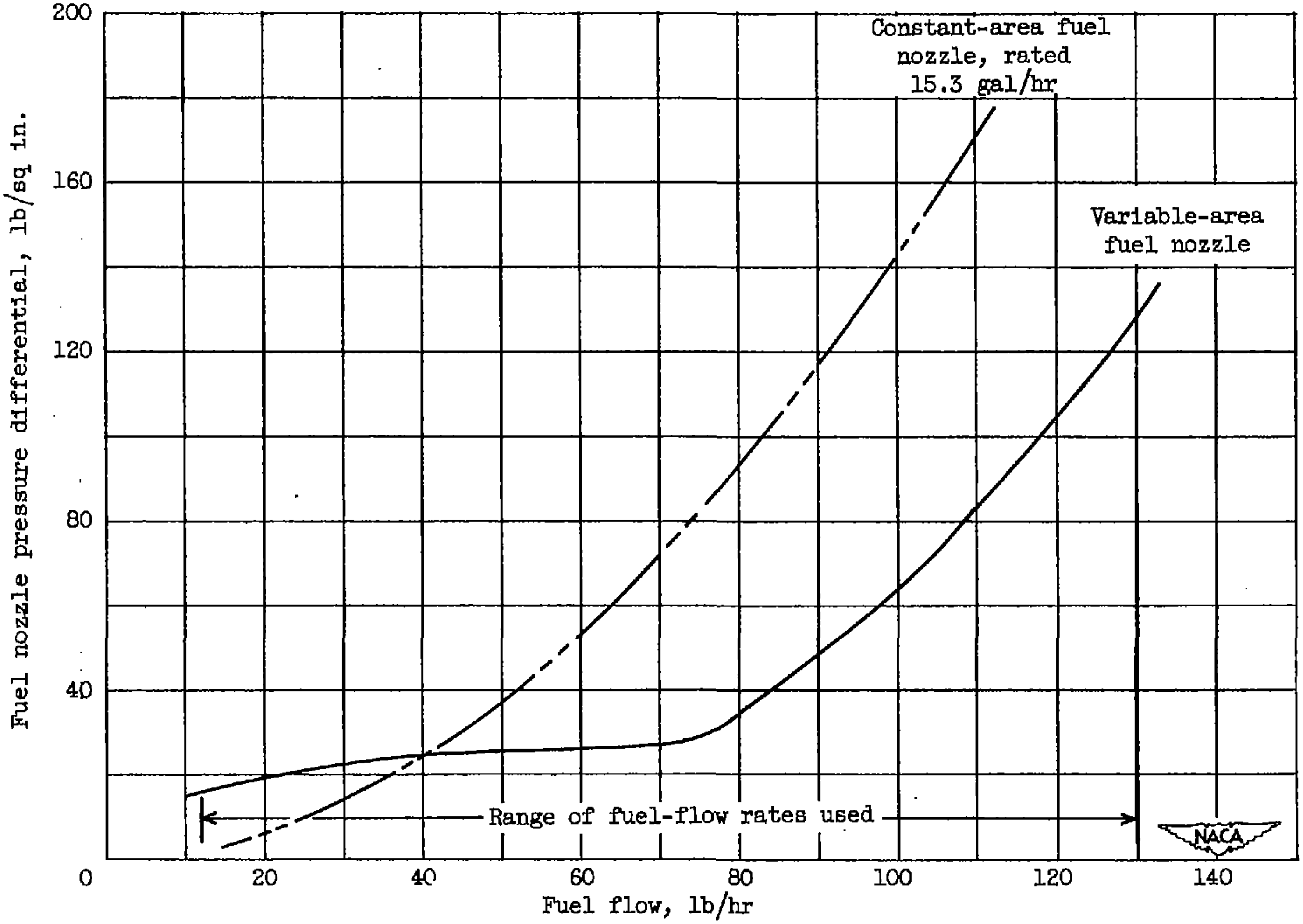

Figure 4. - Comparison of nozzle pressure differential of two types of fuel nozzles at various values of fuel flow rates.

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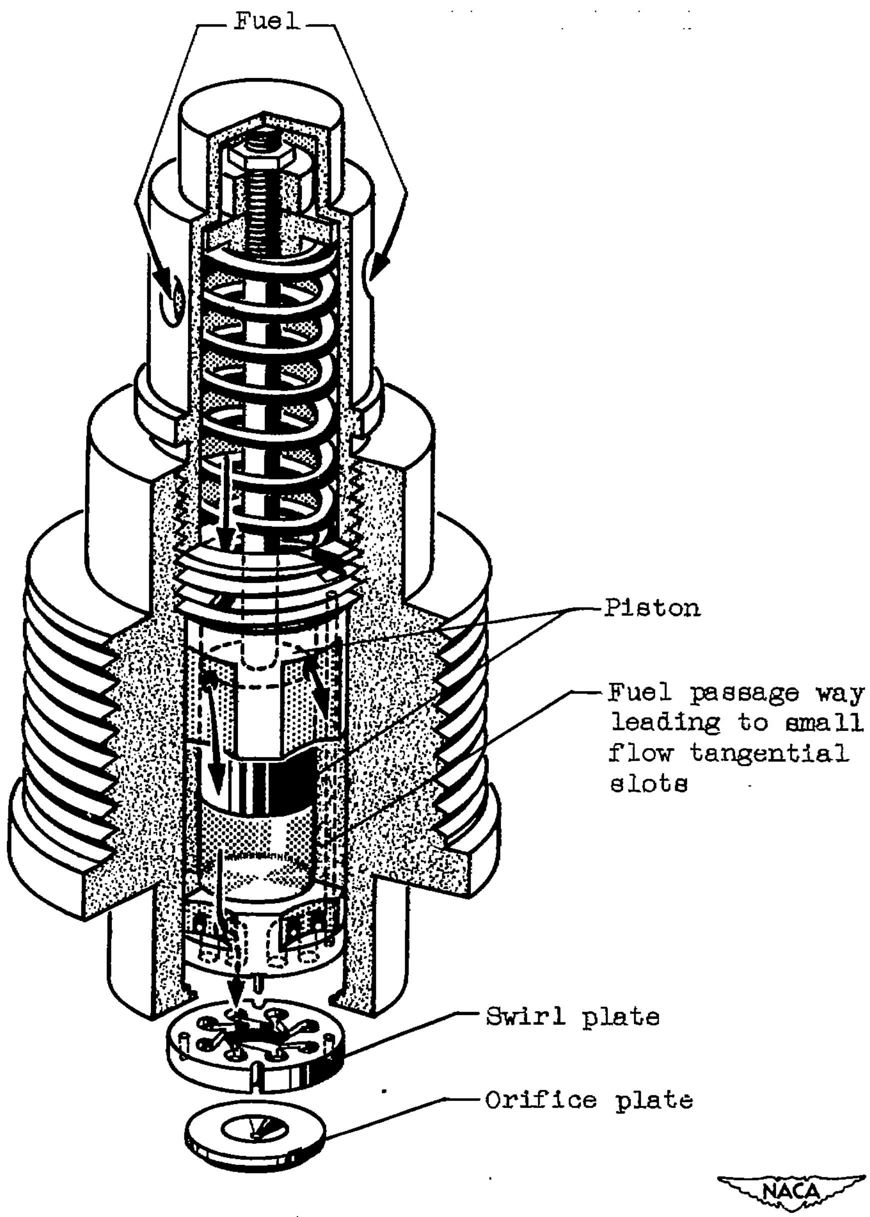


Figure 5. - Diagrammatic cross section of variable-area fuel nozzle.

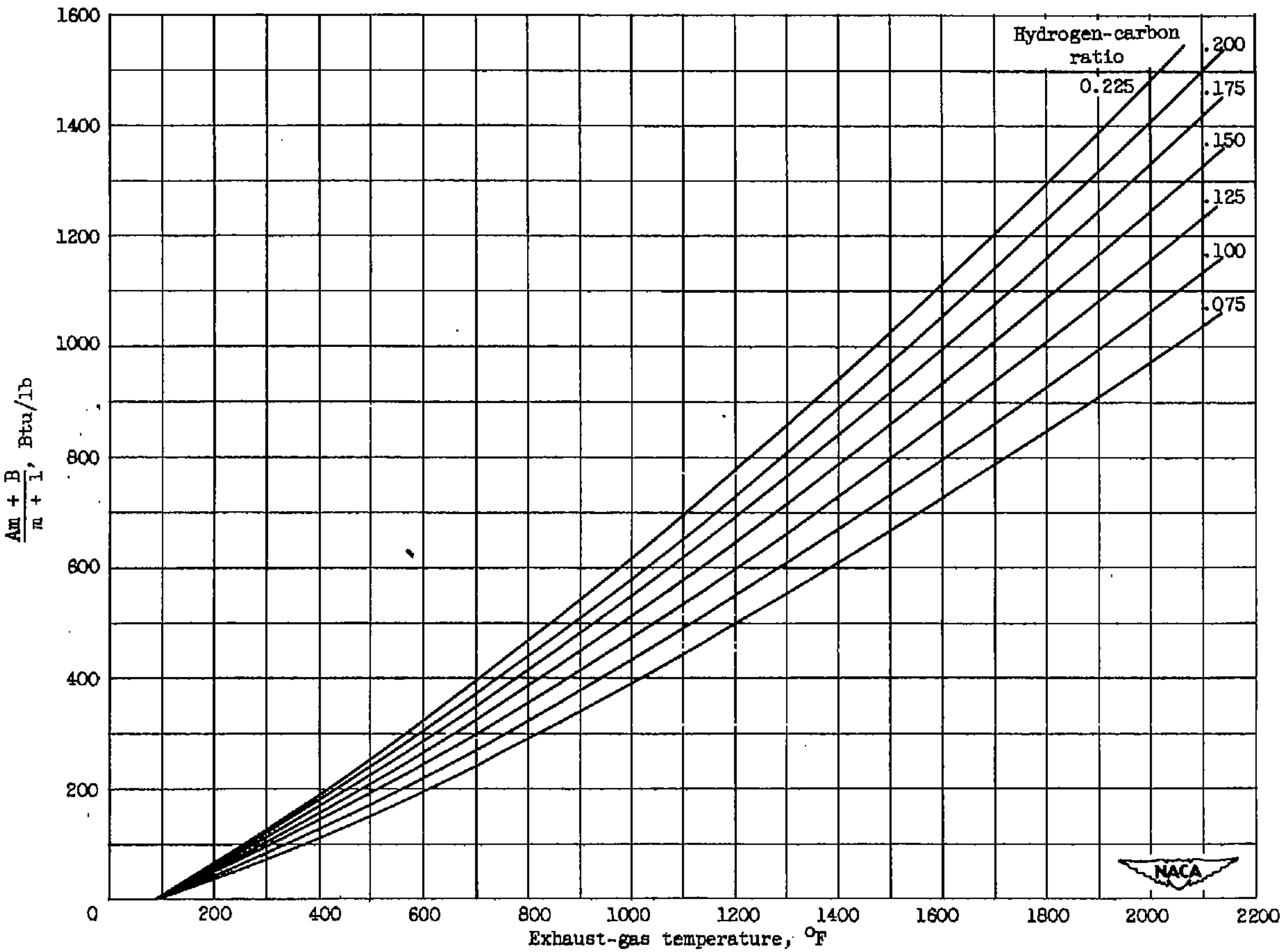
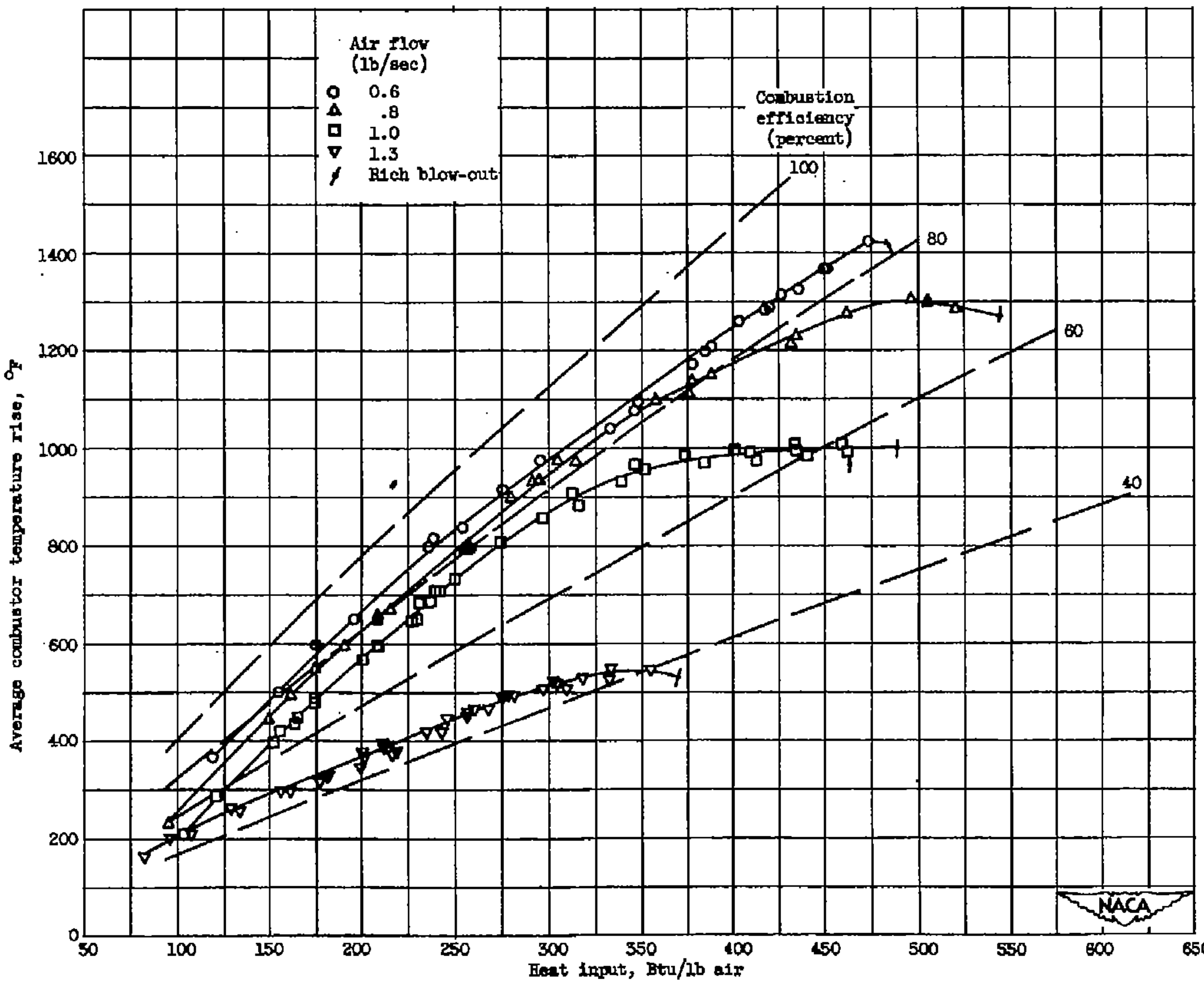


Figure 6. - Chart used for computing enthalpy of leaner than stoichiometric combustion gases.

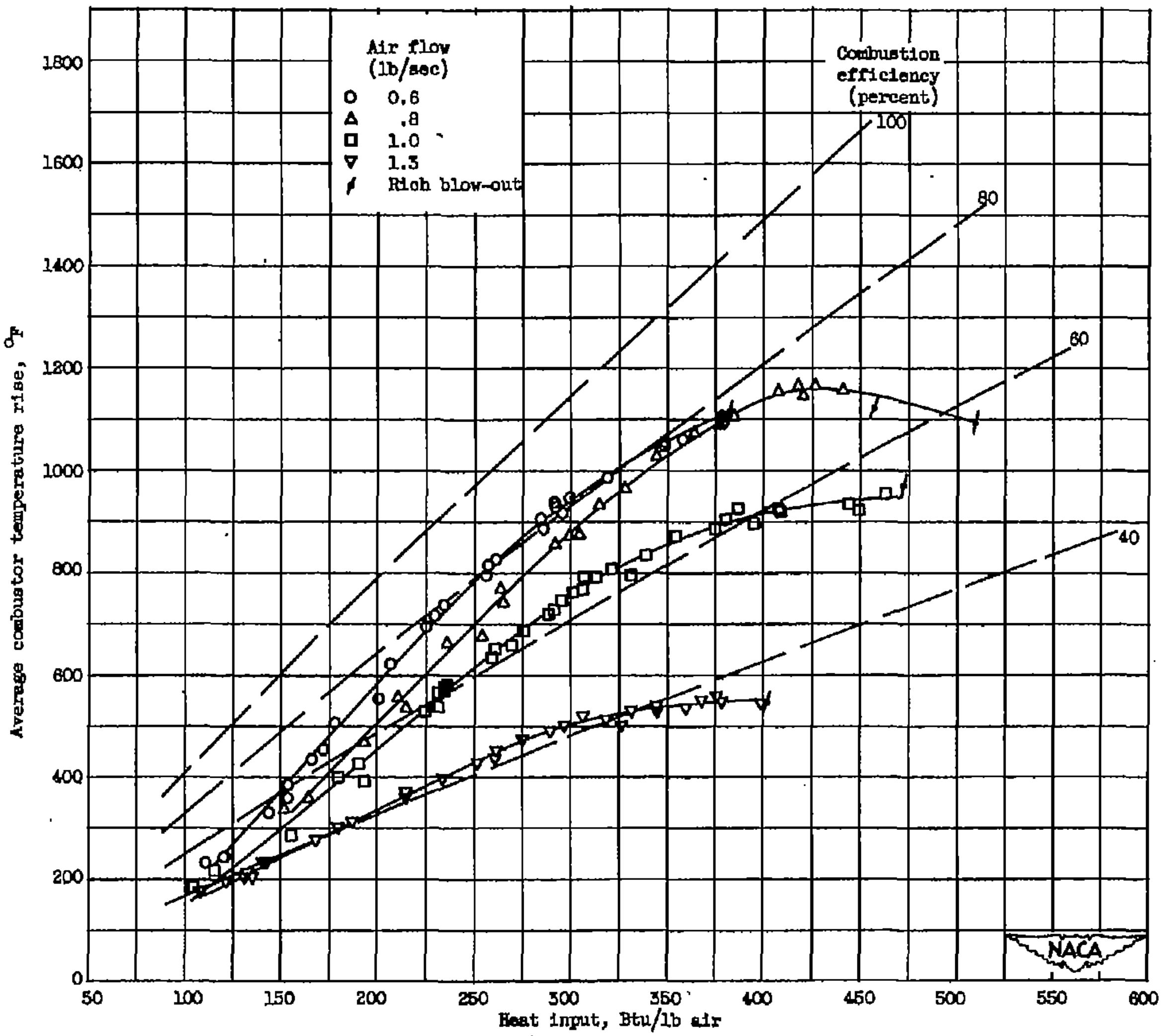
[redacted]



(a) Inlet-air temperature, 200° F.

Figure 7. - Variation of average combustor temperature rise and combustion efficiency with heat input for four values of inlet-air mass flow. Fuel, isooctane.

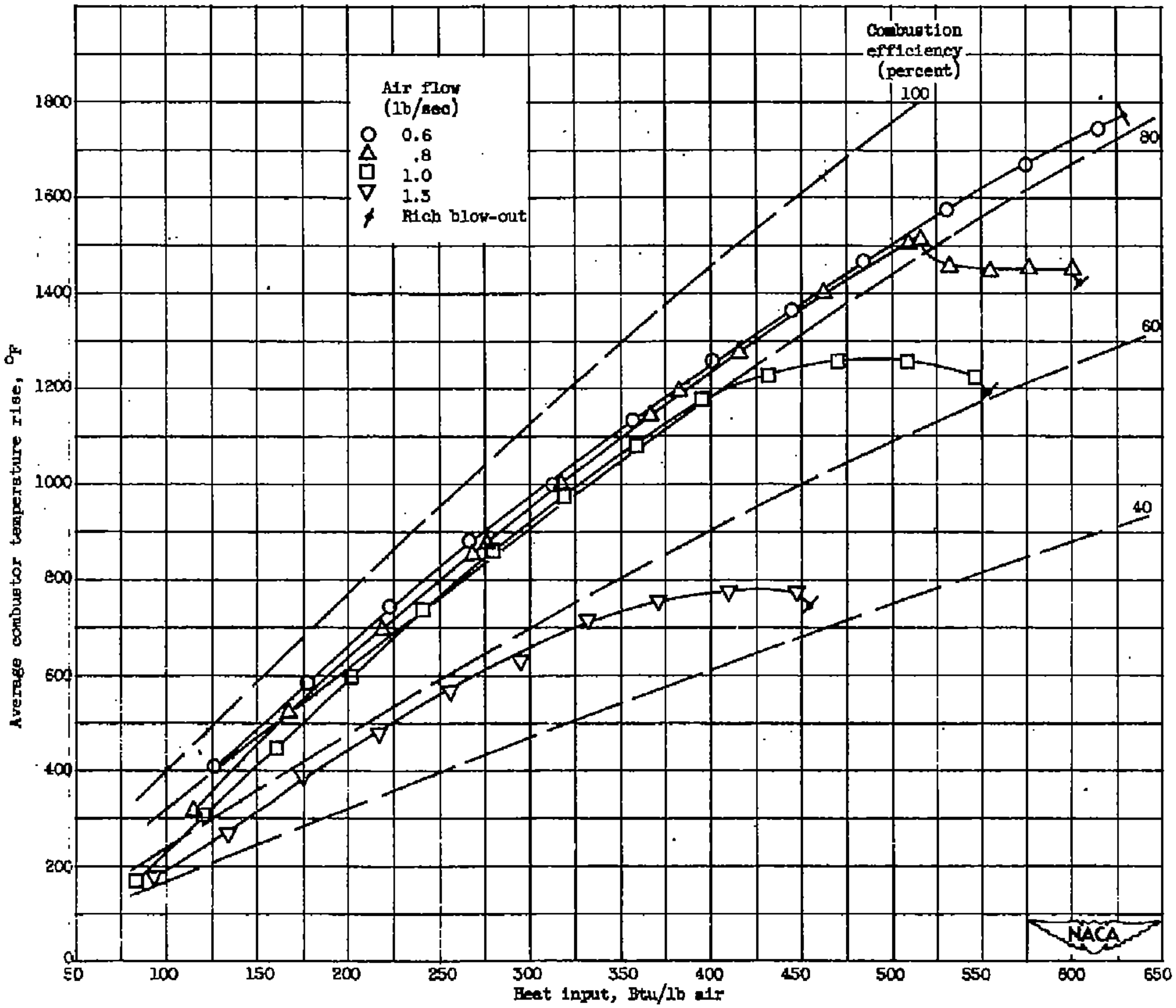
[redacted]



(b) Inlet-air temperature, 40° F.

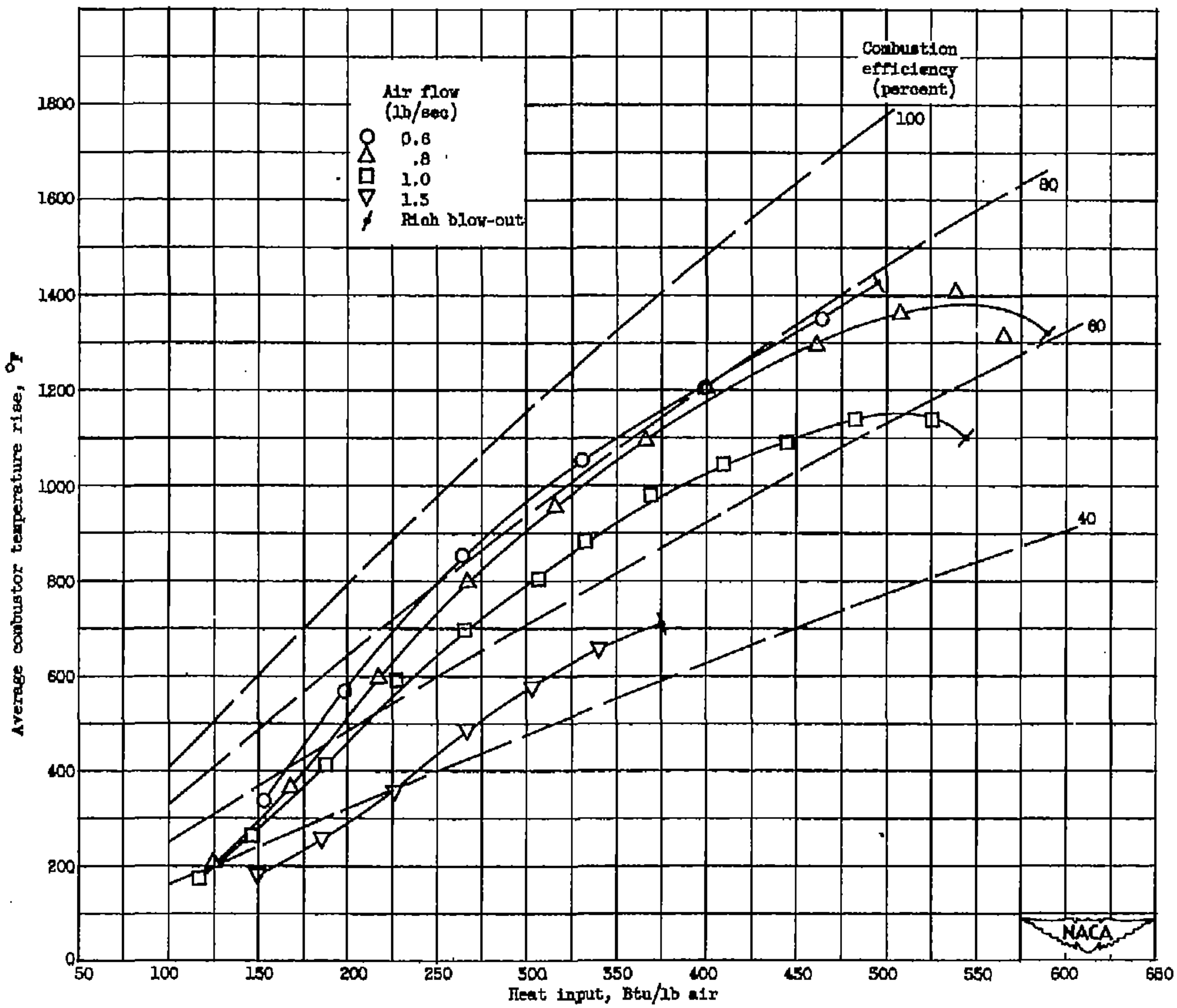
Figure 7. - Concluded. Variation of average combustor temperature rise and combustion efficiency with heat input for four values of inlet-air mass flow. Fuel, isooctane.

[redacted]



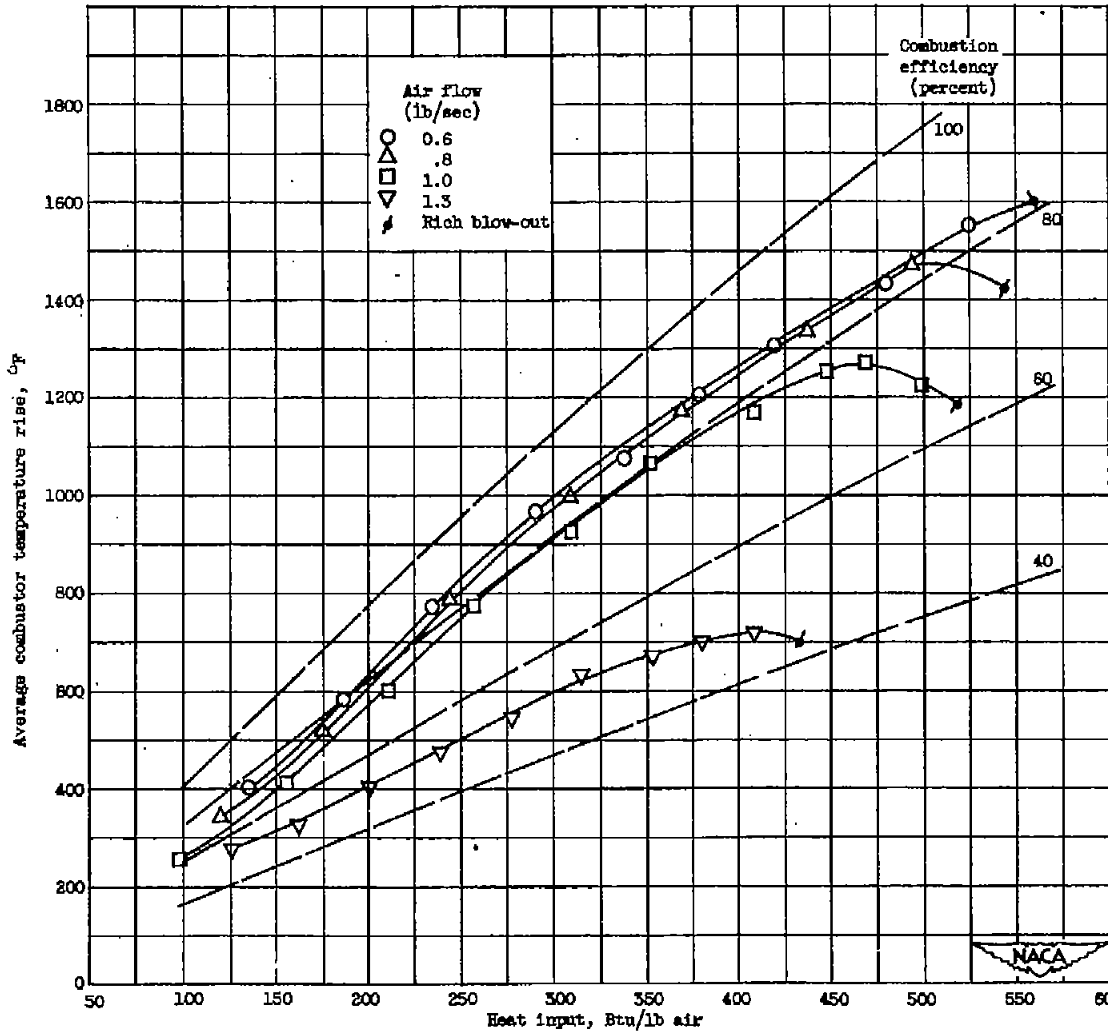
(a) Inlet-air temperature, 200° F.

Figure 8. - Variation of average combustor temperature rise and combustion efficiency with heat input for four values of inlet-air mass flow. Fuel, cyclohexane.



(b) Inlet-air temperature, 40° F.

Figure 8. - Concluded. Variation of average combustor temperature rise and combustion efficiency with heat input for four values of inlet-air mass flow. Fuel, cyclohexane.

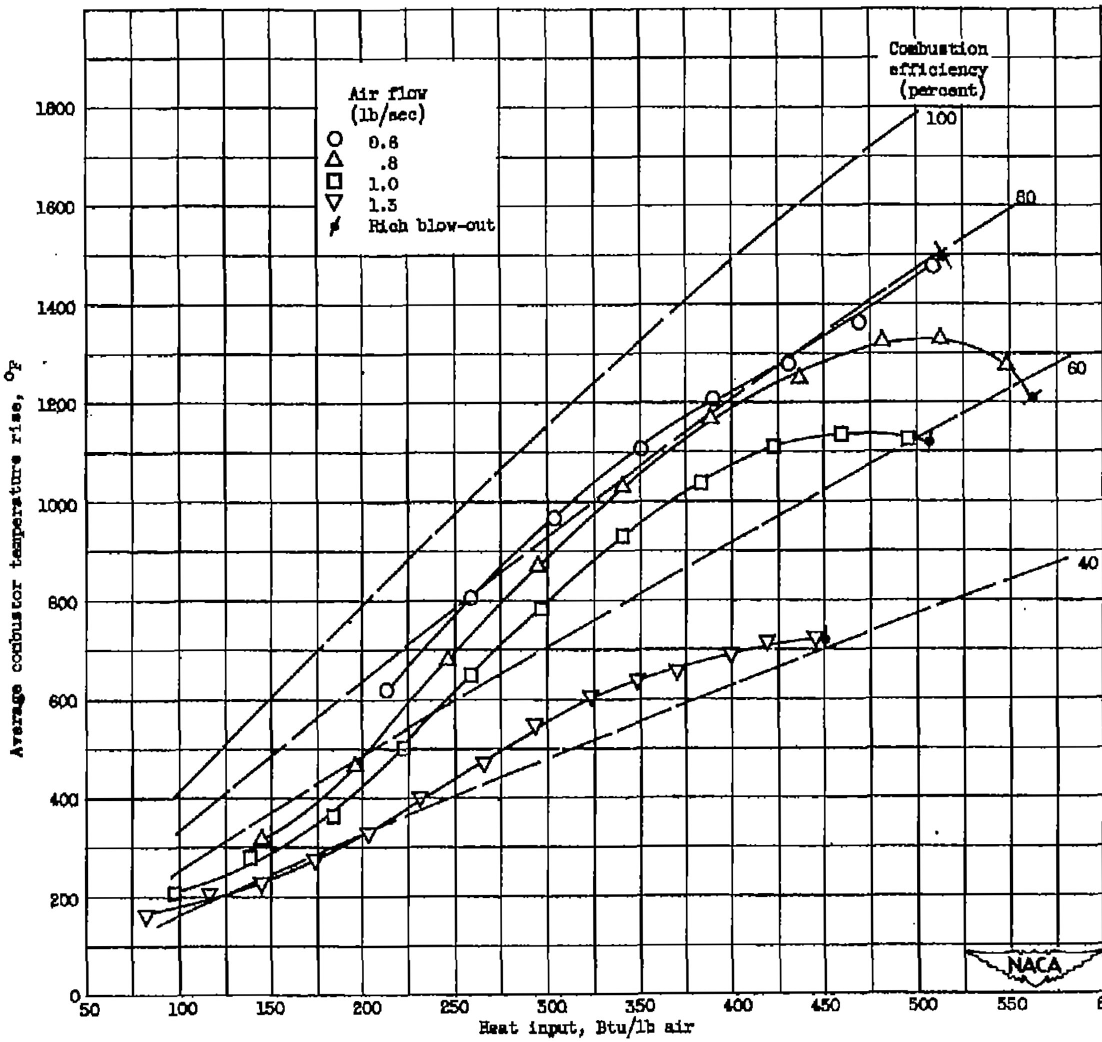


(a) Inlet-air temperature, 200° F.

Figure 9. - Variation of average combustor temperature rise and combustion efficiency with heat input for four values of inlet-air mass flow. Fuel, methylcyclohexane.

[redacted]

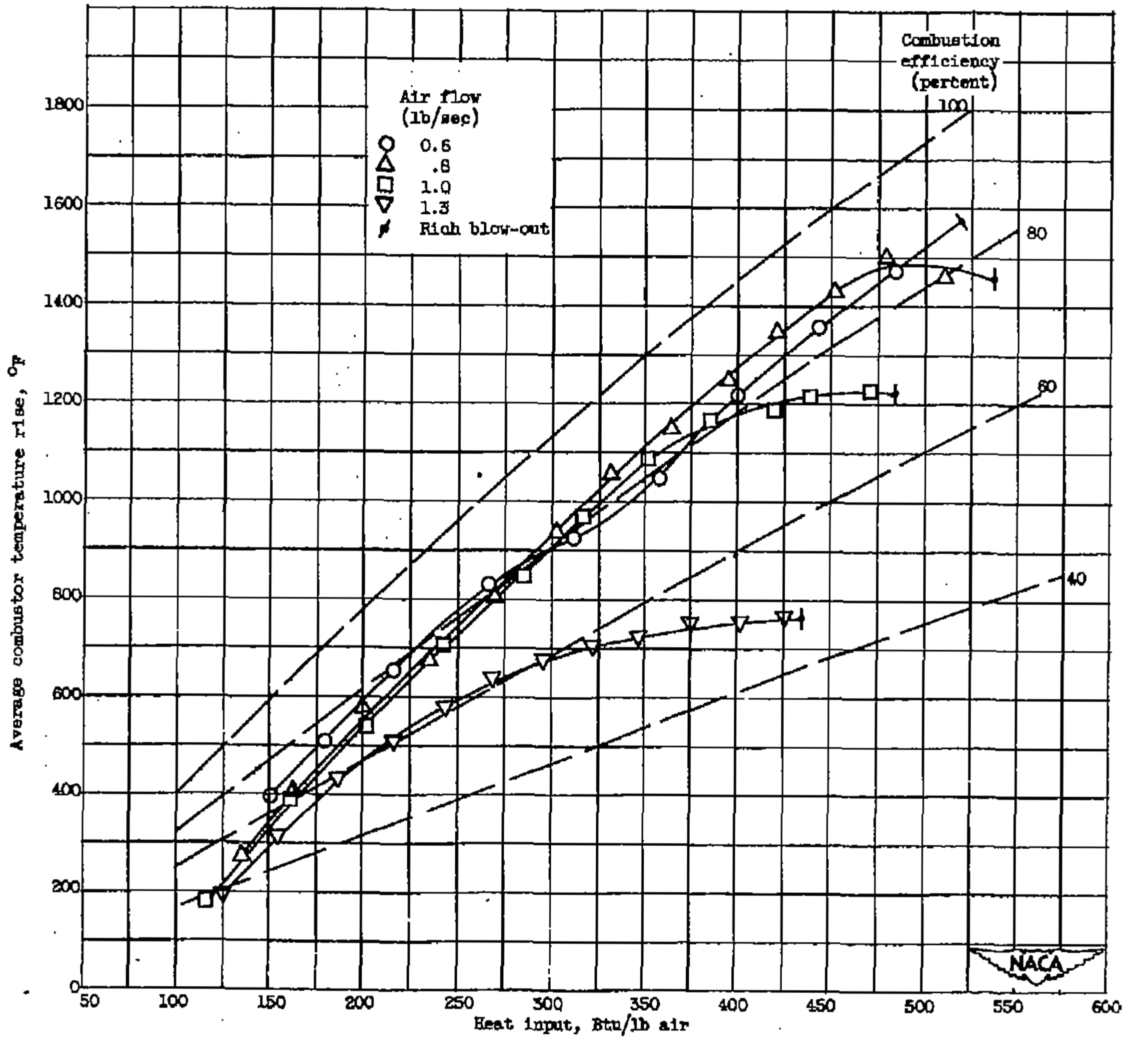
[redacted]



(b) Inlet-air temperature, 40° F.

Figure 9. - Concluded. Variation of average combustor temperature rise and combustion efficiency with heat input for four values of inlet air mass flow. Fuel, me.hylcyclohexane.

[redacted]



(a) Inlet-air temperature, 200° F.

Figure 10. - Variation of average combustor temperature rise and combustion efficiency with heat input for four values of inlet-air mass flow. Fuel, n-heptane.

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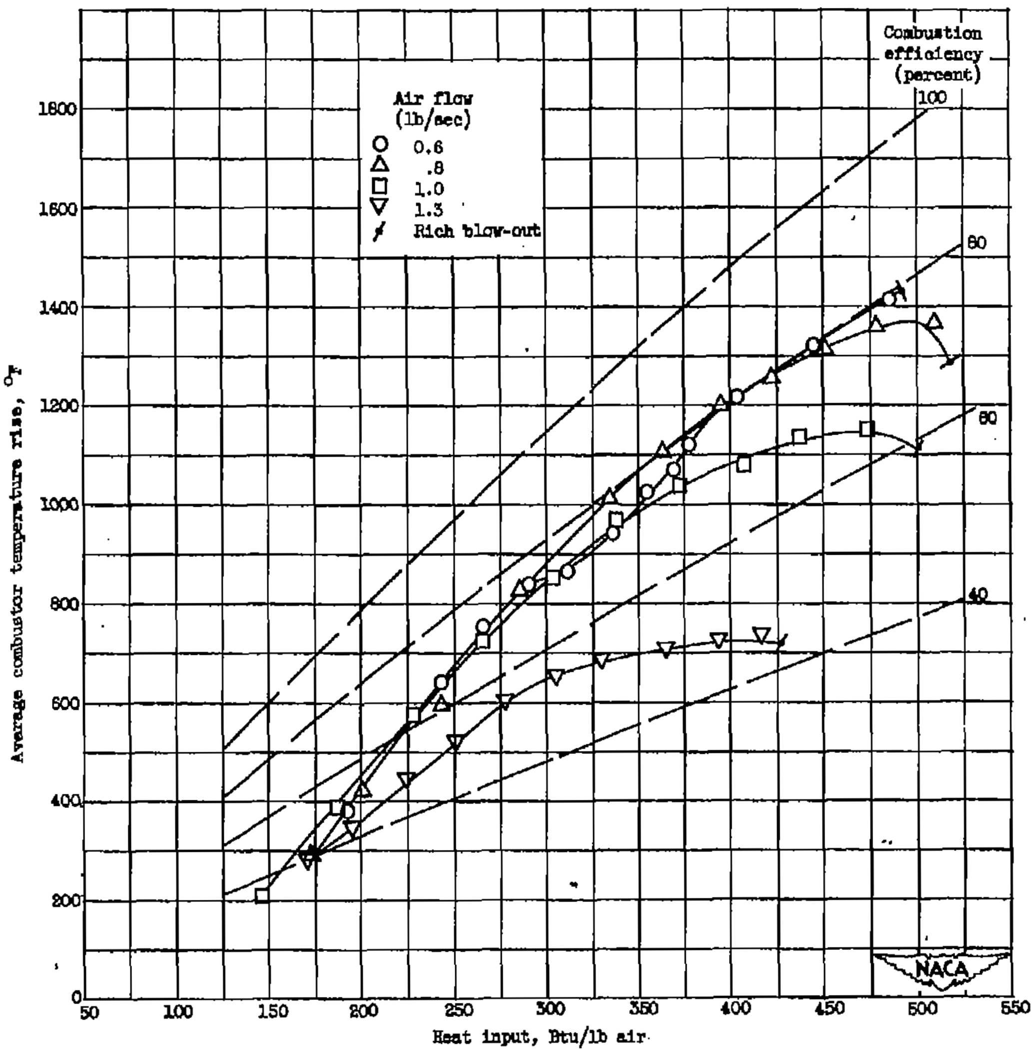
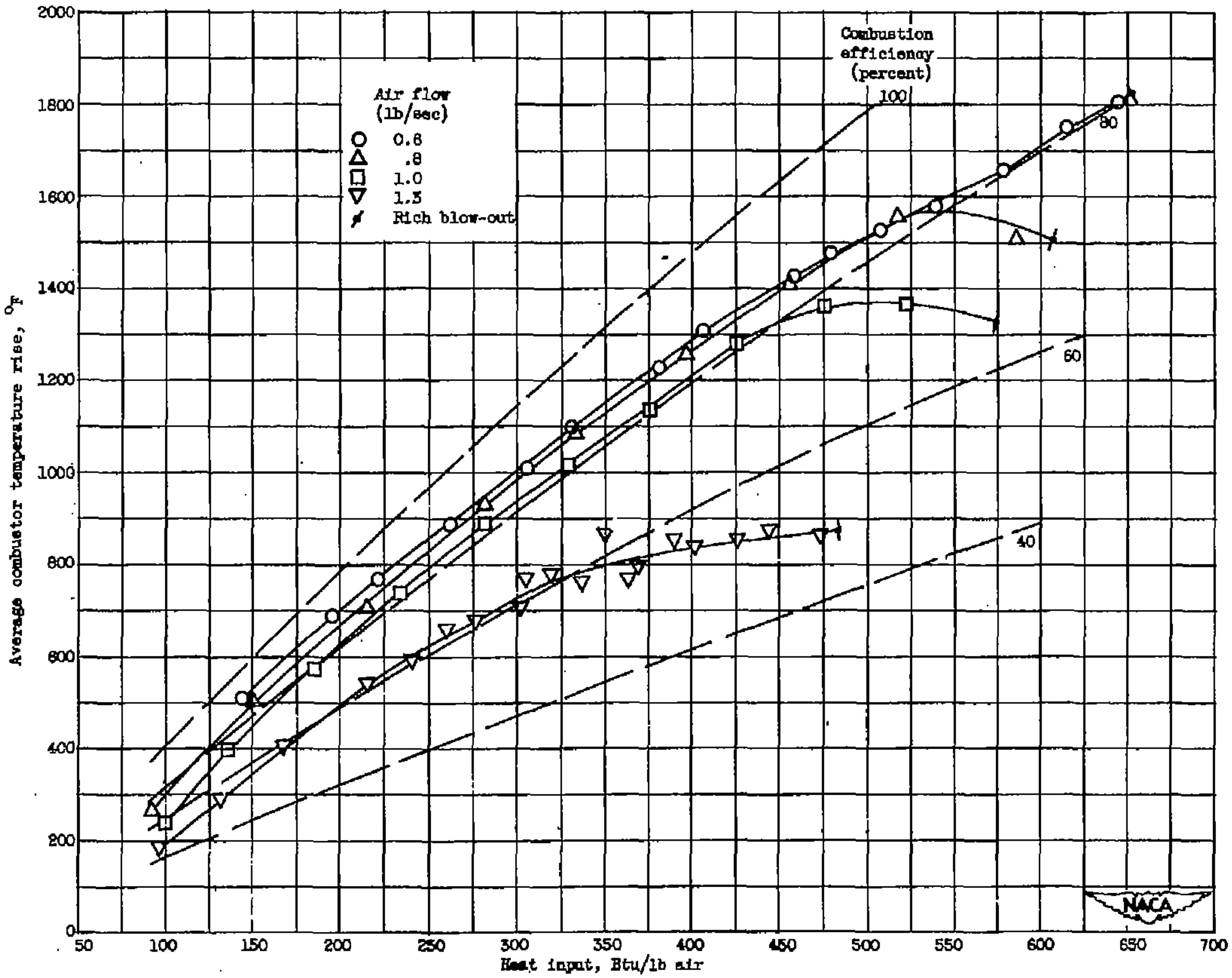


(b) Inlet-air temperature, 40° F.

Figure 10. - Concluded. Variation of average combustor temperature rise and combustion efficiency with heat input for four values of inlet-air mass flow. Fuel, n-heptane.

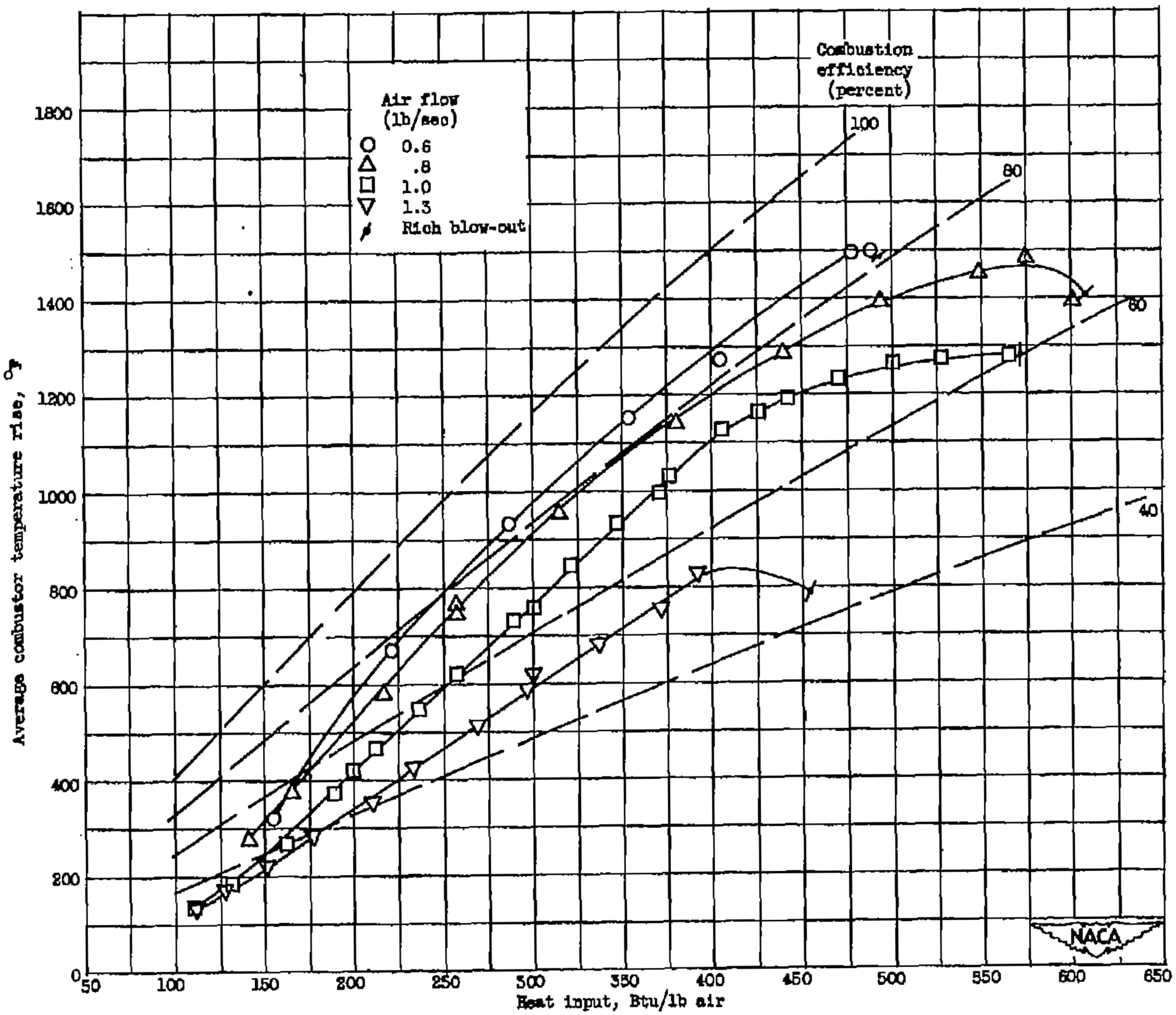
[redacted]



(a) Inlet-air temperature, 200° F.

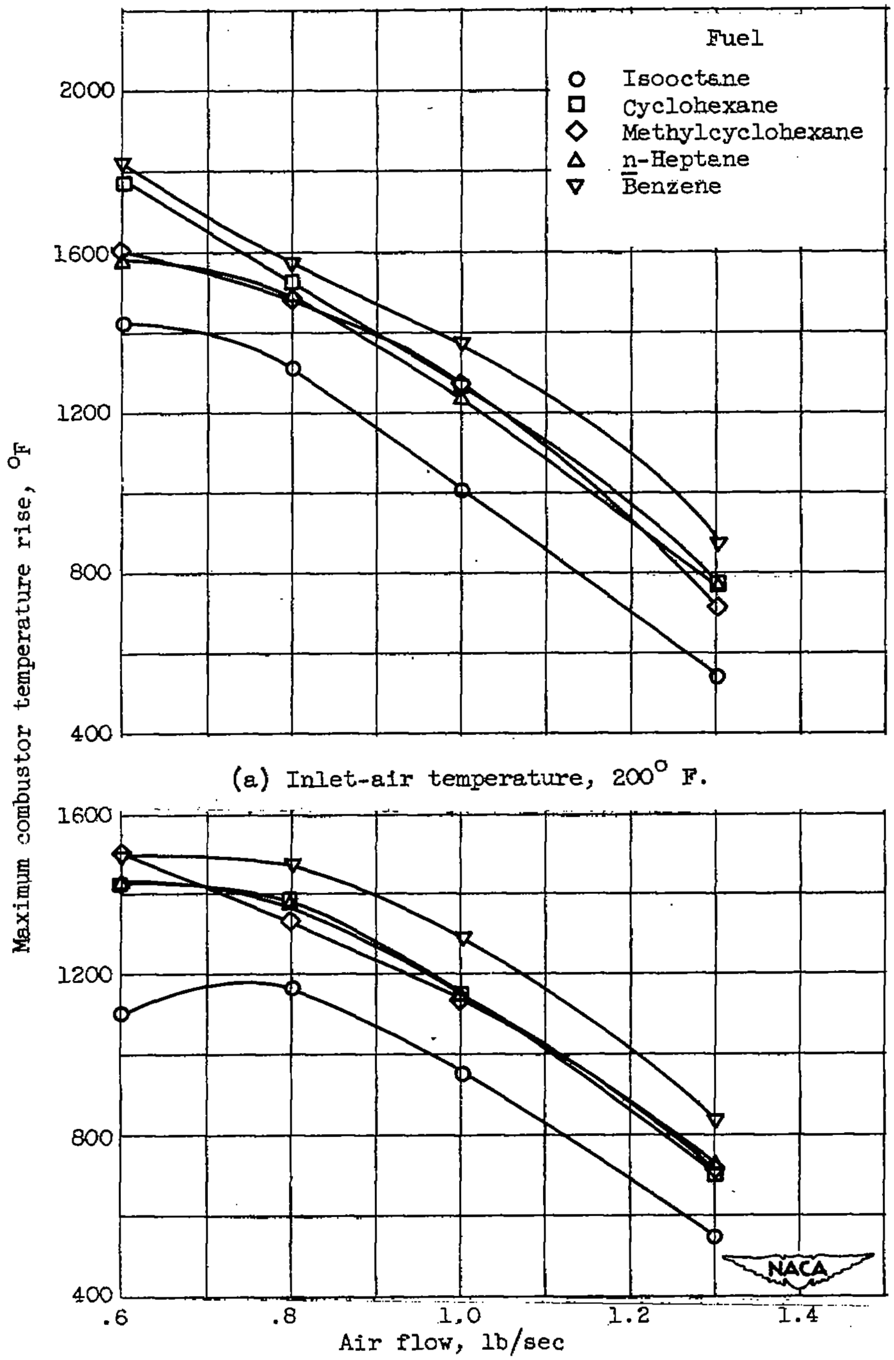
Figure 11. - Variation of average combustor temperature rise and combustion efficiency with heat input for four values of inlet air mass flow. Fuel, benzene.

[redacted]



(b) Inlet-air temperature, 40° F.

Figure 11. - Concluded. Variation of average combustor temperature rise and combustion efficiency with heat input for four values of inlet-air mass flow. Fuel, benzene.



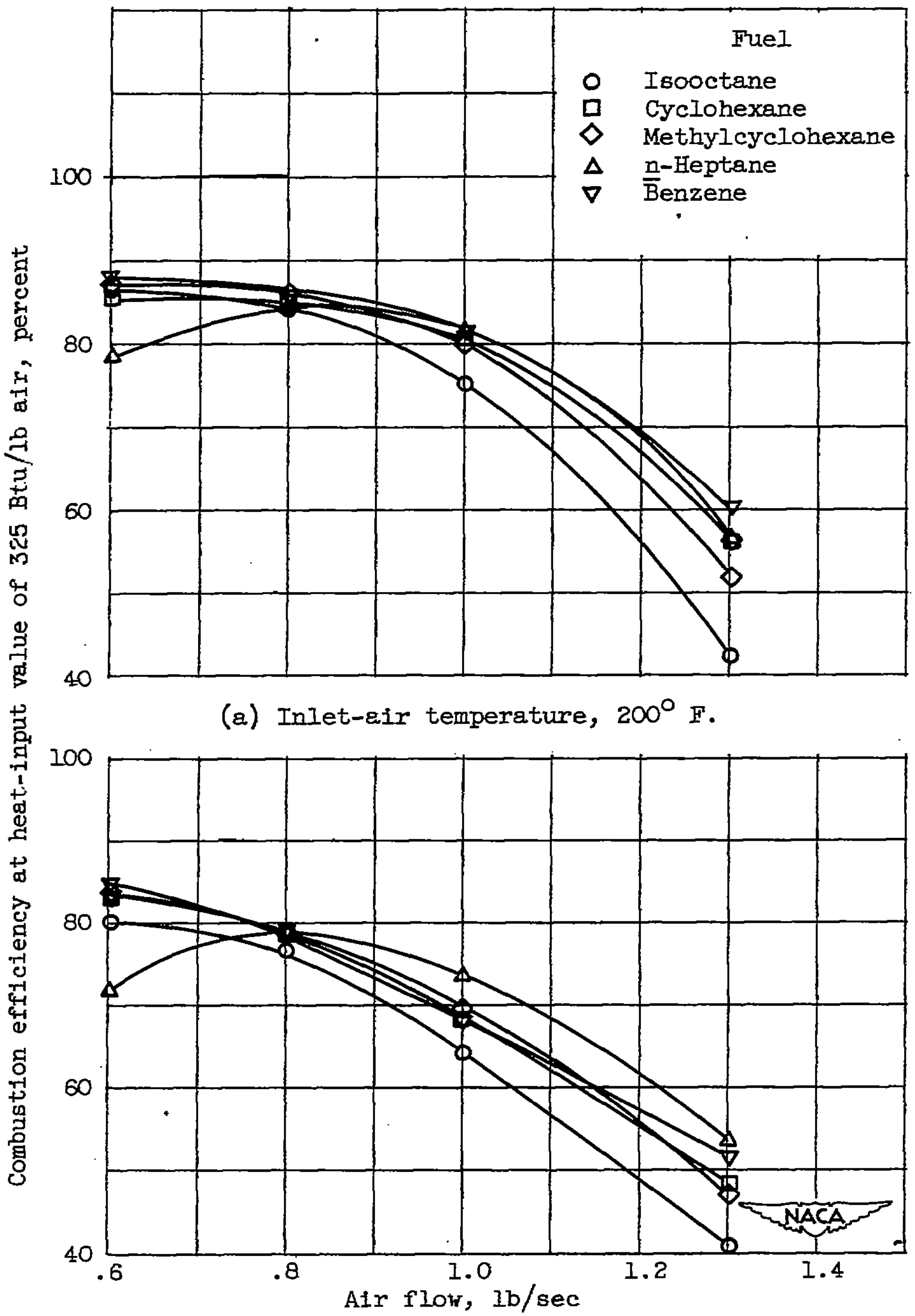
(a) Inlet-air temperature, 200° F.

(b) Inlet-air temperature, 40° F.

Figure 12. - Variation of maximum combustor temperature rise with inlet-air mass flow and inlet-air temperature for five hydrocarbon fuels.

2892

2688

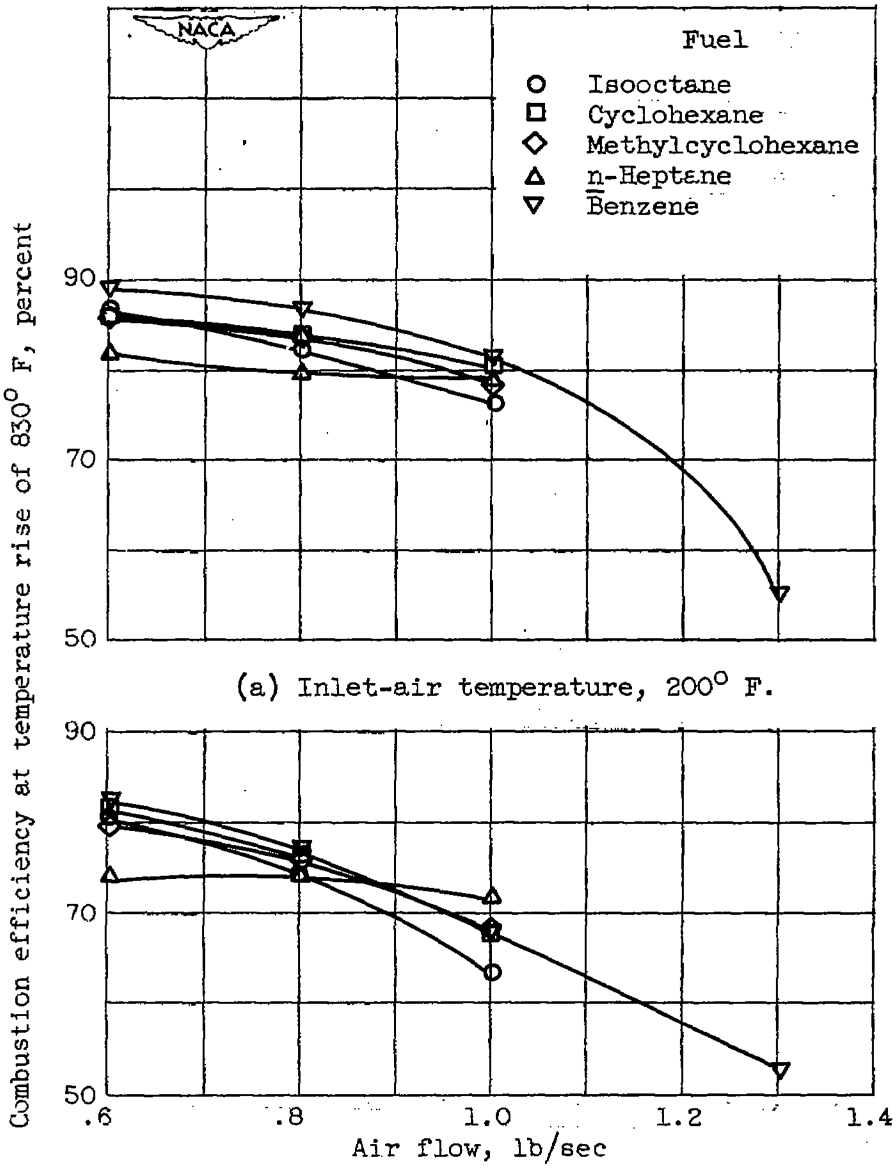


(a) Inlet-air temperature, 200° F.

(b) Inlet-air temperature, 40° F.

Figure 13. - Variation of combustion efficiency at heat-input value of 325 Btu per pound of air with inlet-air mass flow and inlet-air temperature for five hydrocarbon fuels.

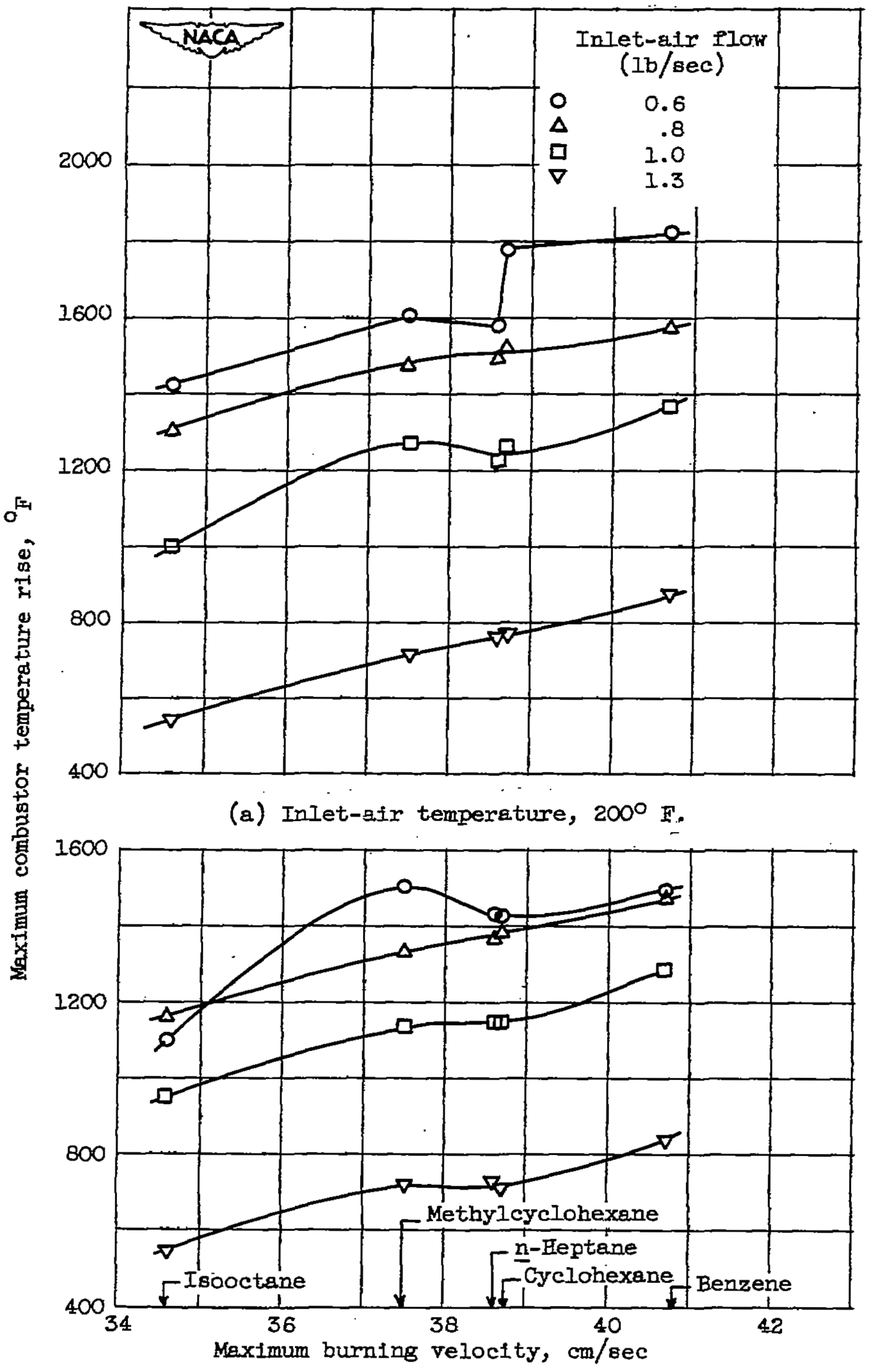
2688



(a) Inlet-air temperature, 200° F.

(b) Inlet-air temperature, 40° F.

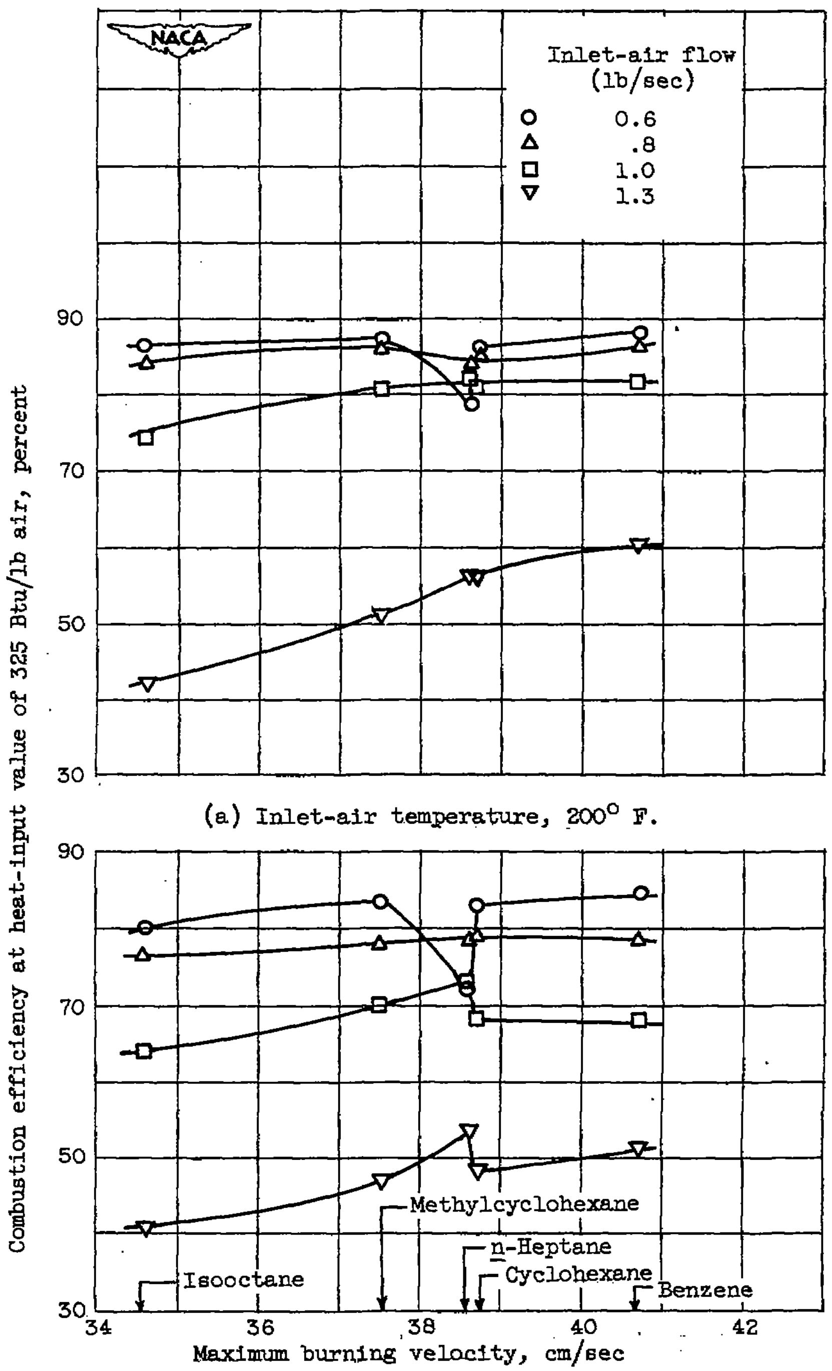
Figure 14. - Variation of combustion efficiency at temperature rise of 830° F with inlet-air mass flow and inlet-air temperature for five hydrocarbon fuels.



(a) Inlet-air temperature, 200° F.

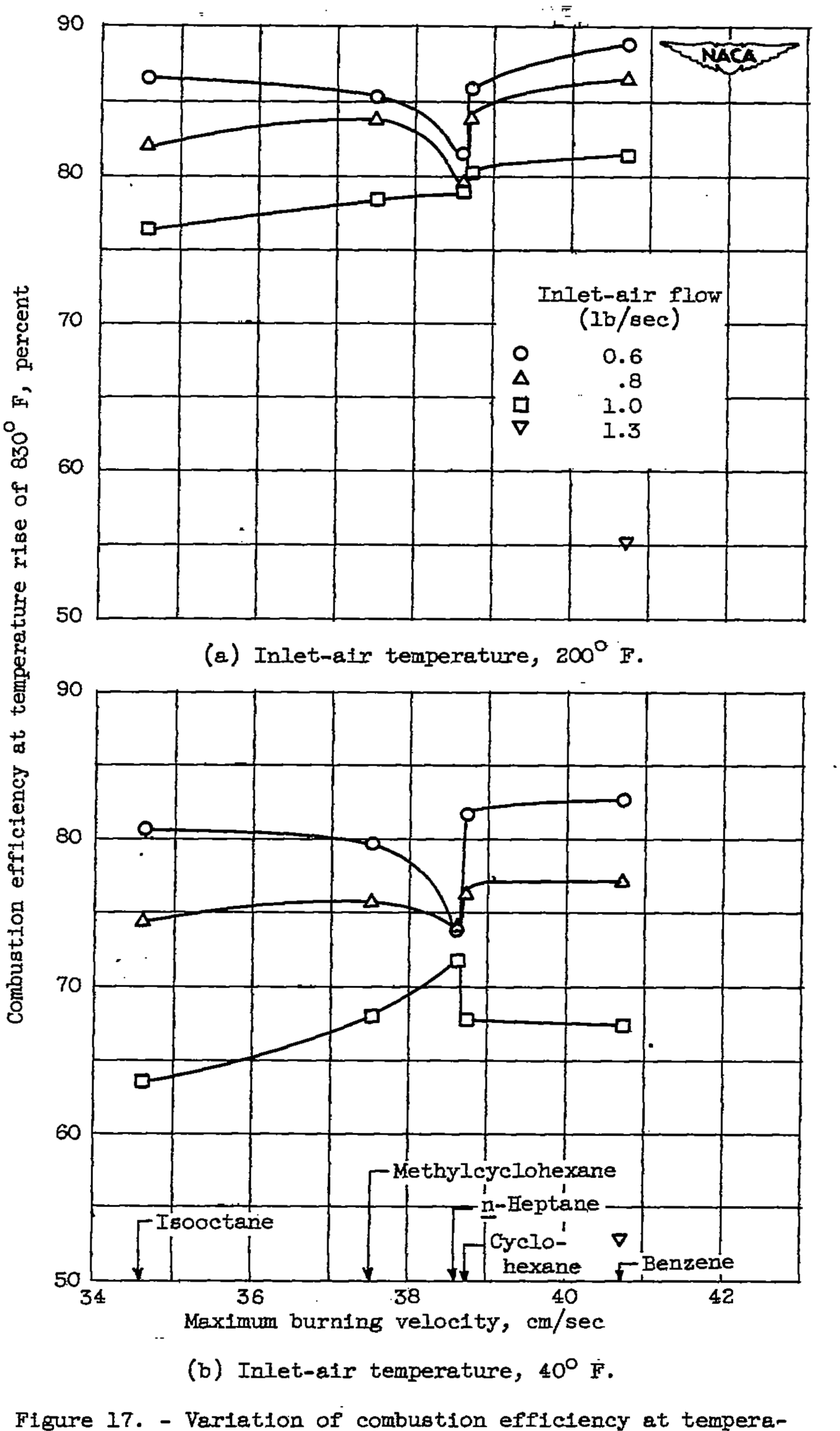
(b) Inlet-air temperature, 40° F.

Figure 15. - Variation of maximum combustor temperature rise with maximum burning velocity and inlet-air mass flow for two inlet-air temperatures.



(b) Inlet-air temperature, 40° F.

Figure 16. - Variation of combustion efficiency at heat-input value of 325 Btu per pound of air with maximum burning velocity and inlet-air mass flow for two inlet-air temperatures.



(a) Inlet-air temperature, 200° F.

(b) Inlet-air temperature, 40° F.

Figure 17. - Variation of combustion efficiency at temperature rise of 830° F with maximum burning velocity and inlet-air mass flow for two inlet-air temperatures.

SECURITY INFORMATION

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