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FLAME RADIATION

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INTRODUCTION

The objectives of this in-house program were to obtain total radiation and heat flux data incident on a combustor liner by advanced instrumentation. If the results obtained by the special instrumentation are considered to be representative of the total radiation and heat flux, then the effect of variation of engine operating parameters and of fuel type can be more easily obtained.

INSTRUMENTATION

The special instrumentation used for these investigations consisted of five total radiometers (Medtherm) and two total heat flux gages (Gardon type). The radiometers were arranged axially and circumferentially through sliding air seals in the outer liner. The two heat flux gages were welded in the outer liner between two circumferential radiometers. Static pressures were obtained on both the cold and the hot side of the outer liner in the area of the heat flux gages. Liner metal temperatures were also obtained.

OPERATING CONDITIONS AND FUELS

The combustor inlet pressure was varied over a nominal range of 0.5 to 2.07 MPa, inlet air temperature from 550 to 670 K, and fuel-air ratio from about 0.015 to 0.040. The nominal gas temperatures for these fuel air ratios are 1120 and 1950 K, respectively. Two fuels were used for a majority of the tests, ASTM Jet A and a fuel designated as ERBS V. The ERBS fuel had about twice the aromatic content of the Jet A and a boiling end point about 50 K higher.

RESULTS

The results presented show the output from some of the special instrumentation and the effects of combustion pressure, fuel type, and fuel-air ratio.

A statement of approach to the investigations is as follows:

(1) Measure flame radiation and liner heat flux in an annular combustor at pressures to 20 atmospheres and fuel-air ratios to 0.040.

(2) Conduct research with a standard fuel, Jet A, and an experimental fuel, ERBS V.

(3) Evaluate the effects of pressure, fuel-air ratio, and fuel type on radiation and liner heat flux.

A cross-sectional sketch of the combustion system is shown in figure 1. Fuel was injected by two rows of counterswirl low-injection-pressure fuel modules. Figure 2 shows the position of the radiometers. In figure 3 the positions of four of the radiometers and the two heat flux gages are shown on the hot gas side of the outer liner.

Comparison of total radiation and total heat flux obtained at two fuel-air ratios and over a combustor pressure range is shown in figure 4 for Jet A fuel. At a fuel-air ratio of 0.04 and a pressure of 0.5 MPa, total radiation was about 46 percent of total heat flux. As the combustor pressure was increased to 1.6 MPa, total radiation increased to about 92 percent of total heat flux.

The radiation values obtained from the three radiometers positioned axially along the liner using Jet A are shown in figure 5. As the combustion pressure increased, the rate of radiation increase with pressure was greater for the radiometer closest to the fuel modules (4.6 cm from injection plane) than for the other two radiometers (9.7 and 15.1 cm from the injection plane).

A comparison of a few of the characteristics of the Jet A and ERBS V fuels used in the investigations (table I) indicates that the aromatic content of the ERBS V is about twice that of the Jet A. Also the final boiling point of the ERBS V is about 50 K greater than that of Jet A.

Figure 6 is a plot of total radiation data obtained from the three in-line radiometers using ERBS V fuel. Again, the radiation obtained from the radiometer closest to the fuel modules was greater than that obtained from the other two radiometers.

Comparison of the radiation data obtained from the three in-line radiometers for the two fuels is presented in figures 7 to 9. Figure 7 shows data for the closest position, 4.6 cm from the fuel injection plane; figure 8, 9.7 cm; and figure 9, 15.1 cm. As shown in figure 7, the radiation data obtained with Jet A are somewhat greater than those obtained with ERBS V, at the two values of fuel-air ratio. The difference is more pronounced at the higher pressure levels. At the 9.7- and 15.1-cm positions, the values obtained with the two fuels were similar, except at the low combustor pressure condition, where the Jet A fuel showed higher radiation than with the ERBS V.

Liner differential temperatures (liner metal temperature minus inlet air temperature) as shown in figure 10 are slightly higher with the ERBS V fuel than with Jet A at the higher fuel-air ratio of 0.04. Temperatures were similar at a fuel-air ratio of 0.015.

Figures 11 and 12 present smoke number (SN) data for the two fuels at three fuel-air ratios of 0.02, 0.03, and 0.04 over the pressure range. The smoke numbers obtained with the ERBS V fuel were generally greater than those obtained with Jet A. The highest SN obtained was 25, with ERBS V fuel, 2.07 MPa pressure, and a fuel-air ratio of 0.04.

SUMMARY OF RESULTS

1. At a fuel-air ratio of 0.040, total radiation increased from about 46 percent of total heat flux at a pressure of 0.5 MPa to 92 percent of total heat flux at 1.6 MPa pressure.

2. The rate of total radiation increase with increase in pressure was greatest at the sample position closest to the fuel injection plane (4.6 cm).

3. Total radiation measured at the 4.6 cm position was slightly greater with Jet A than with ERBS V over the pressure range.

4. Smoke numbers obtained with ERBS V were somewhat greater than those obtained with Jet A over the pressure range.

FUEL PROPERTIES

	ASTM JET A	ERBS V
GRAVITY, ^{o}API	43.1	36.6
AROMATICS, (D1319), vol.%	15.5	30.2
H/C RATIO, wt.	0.161	0.147
NET HEAT OF COMBUSTION, (D1405) kJ/kg	43.27	42.44
ASTM DISTILLATION (D86), K		
INITIAL BOILING POINT	433	444
50 PERCENT EVAPORATED	483	486
FINAL BOILING POINT	547	594

Table I

CROSS-SECTIONAL SKETCH OF HIGH-PRESSURE COMBUSTOR AND LINER

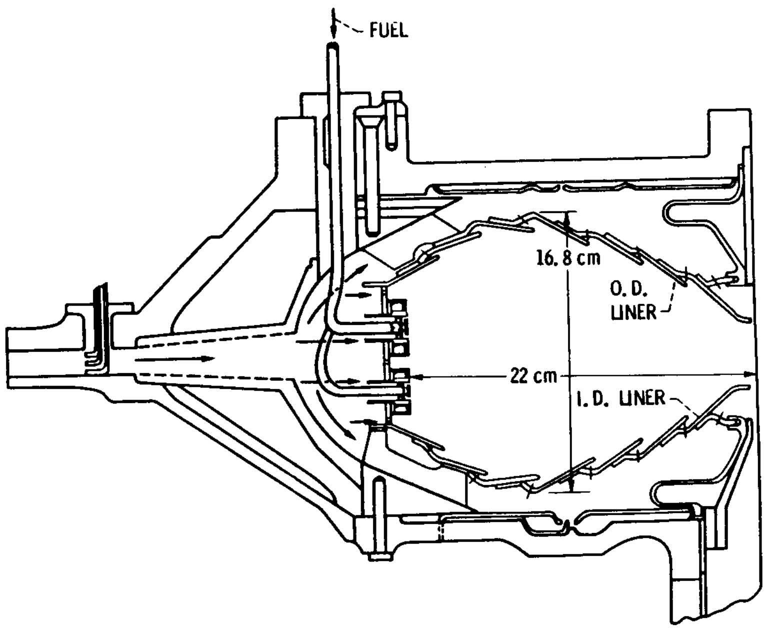

Figure 1

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RADIATION INSTRUMENTATION

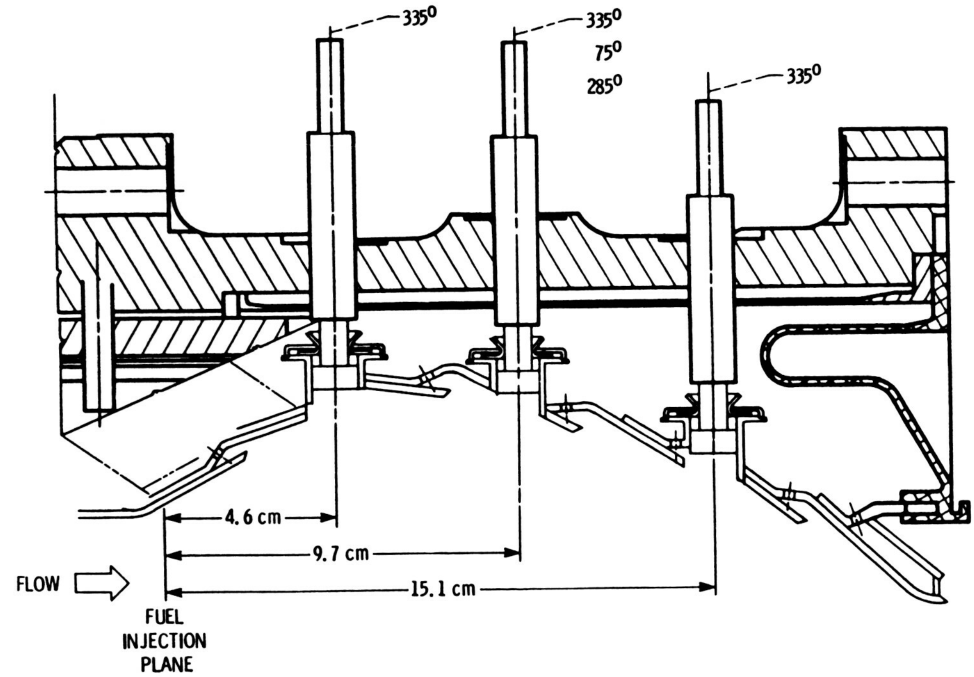

Figure 2

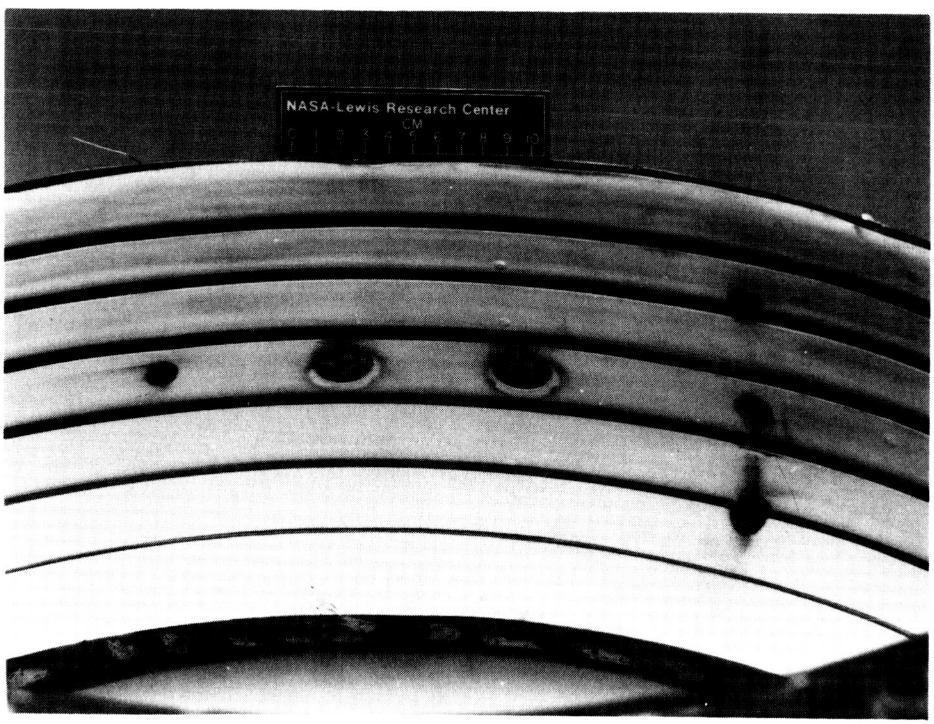

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Figure 3

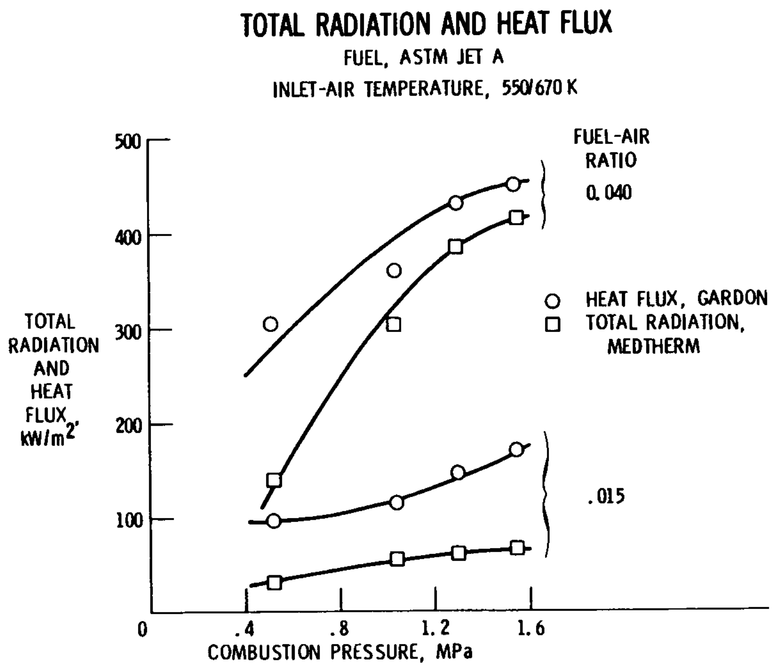

Figure 4

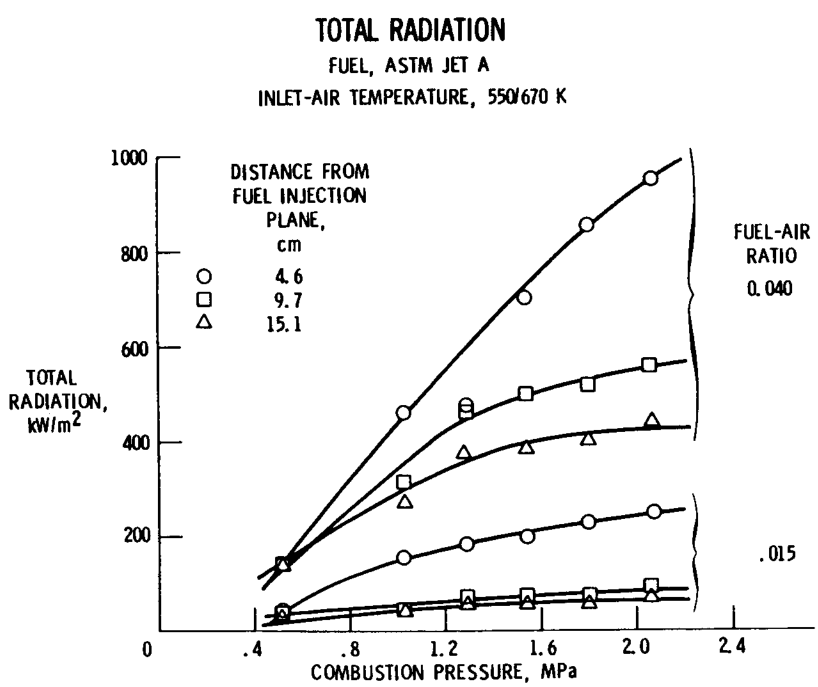

Figure 5

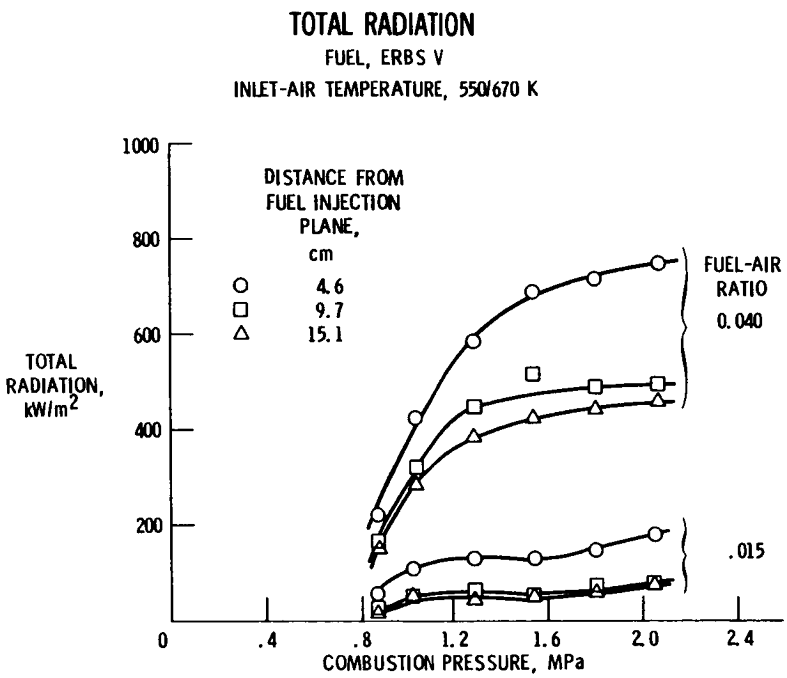

Figure 6

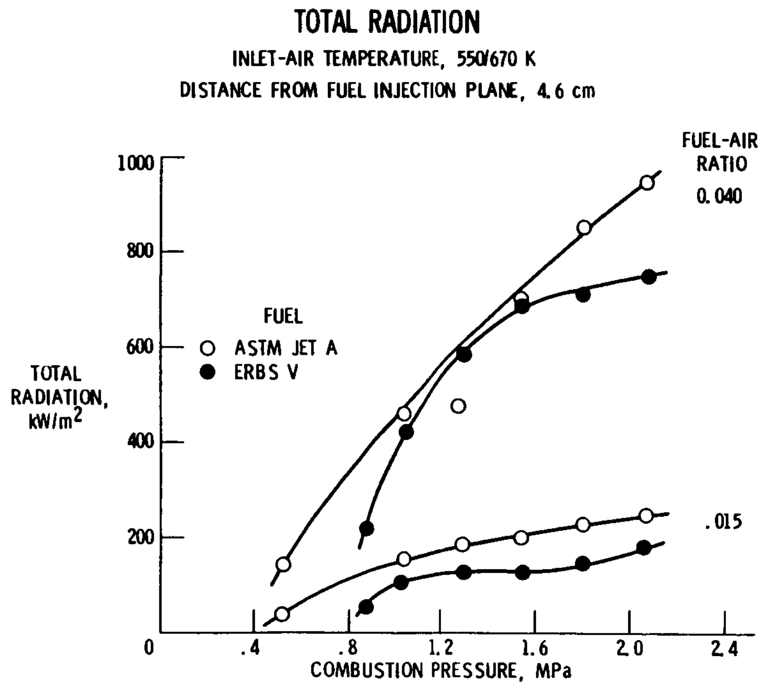

Figure 7

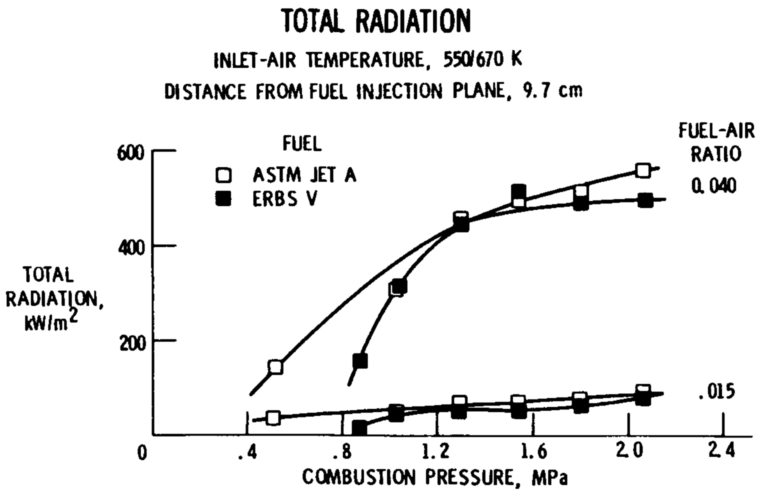

Figure 8.

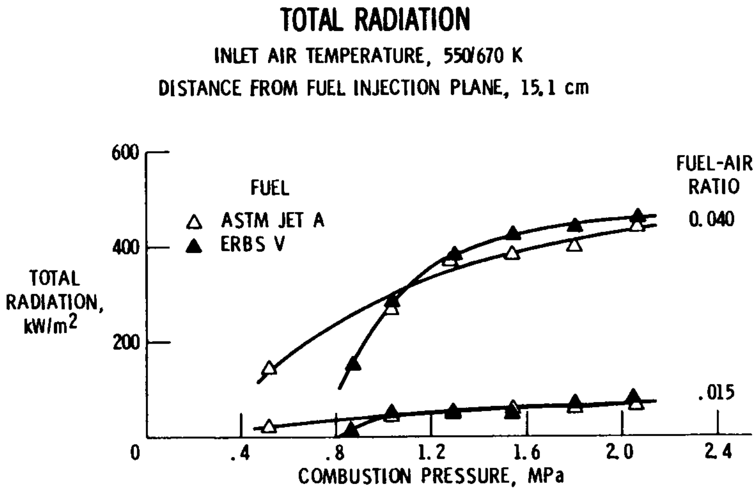

Figure 9

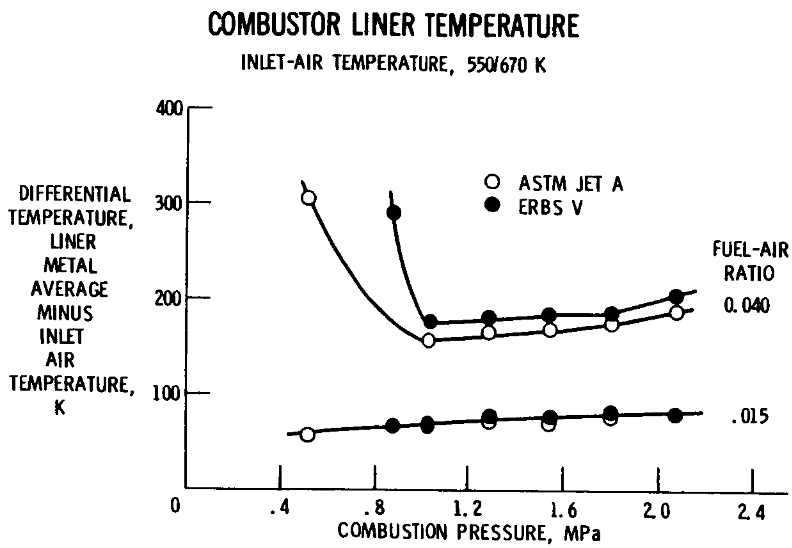

Figure 10.

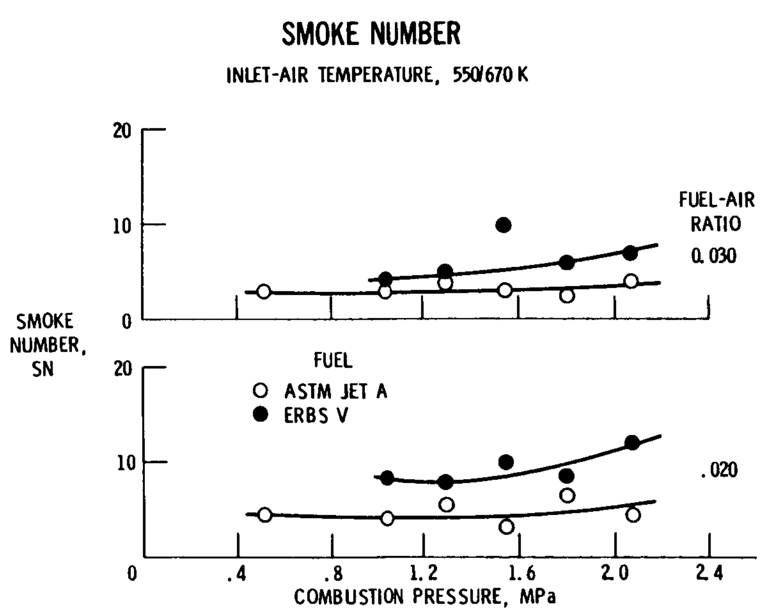

Figure 11

SMOKE NUMBER

INLET-AIR TEMPERATURE, 550/670 K

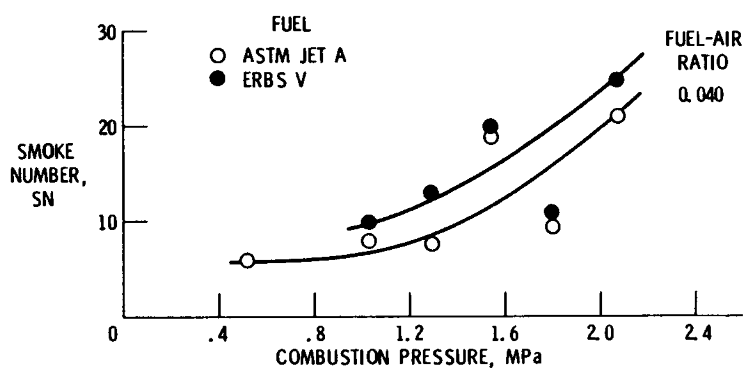

Figure 12