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RESEARCH MEMORANDUM

EFFECT OF HIGH PRESSURE ON SMOKING TENDENCY OF DIFFUSION FLAMES

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NATIONAL ADVISORY COMMITTEE
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SUMMARY

The variation in smoking tendency of a diffusion flame was measured over a pressure range of 4 to 20 atmospheres (abs) for the two fuel types ethane and ethylene. The fuels were burned as diffusion flames inside a pressure vessel equipped with windows for observation of the flame. It was found that the changes in flame height, which measures the relative amount of fuel that can be burned without producing smoke, vary inversely with the pressure.

INTRODUCTION

A previous investigation of the relation between smoking tendency of a diffusion flame and variations in pressure has been reported (ref. 1). In that work the relative smoking tendency was determined for several pure fuels and blends of fuels from pressures of 1/2 to 12 atmospheres (abs). The results indicate that over this pressure range the maximum smoke-free fuel flow is inversely proportional to the pressure. The purpose of the present study was to obtain a more complete relation between smoking tendency and pressure by extending the pressure range to 20 atmospheres.

At the NACA Lewis laboratory two gaseous fuels, ethane and ethylene, were investigated over a pressure range of approximately 4 to 20 atmospheres. Smoke was defined as the release of unburned carbon from the flame. Smoking tendencies were determined by burning the fuels as diffusion flames in a pressure tank and measuring the maximum relative flame height at which the fuels could be burned without producing smoke.

APPARATUS AND PROCEDURE

The apparatus used in the investigation is shown in figure 1. The pressure tank is similar to the tank used previously (ref. 1) but has been designed for higher pressure. The tank is 7 inches in diameter and 17 inches high. Lucite windows 2 inches in diameter and 2 inches thick served as observation ports. Air was supplied near the bottom of the tank from a cylinder of compressed air. Combustion products were removed through a valve in the top of the tank. Air flow during a run was adjusted to give the flame an adequate supply of fresh air. It has been determined that air flow within the ranges used had no effect on the smoking tendency (ref. 1).

The fuels, under high pressure, were supplied to the pressure tank from cylinders. The flow of fuel was adjusted by a valve in the line between the fuel cylinder and the pressure tank. The fuels were burned from a 2-millimeter-inside-diameter tube with a 0.5-millimeter wall. For measurement at a given pressure, the rate of fuel flow was adjusted until the flame was at its incipient smoking point. The height of the flame above the base of the burner was then measured with a cathetometer. The ethane used was Matheson Co., Inc. c.p. grade, and the ethylene was Ohio Chemical & Mfg. Co. c.p. grade.

Variation in the size of the burner may change the amount of fuel which can be burned smoke-free. Therefore, the data obtained in this investigation show only the relative variations in smoking tendency at various pressures.

RESULTS AND DISCUSSION

In figure 2, the maximum flame height at which the fuels could be burned without smoking is plotted against pressure. In table I and figure 2, it may be observed that the flame height at the smoking point decreases consistently up to the highest pressure studied.

It was previously found (ref. 1) that below the smoking point, an increase in pressure did not change the flame height for a constant mass fuel flow. This confirmed the observations reported in other literature (ref. 2). When the fuel flow to a flame is increased until the flame reaches the smoking point, there is a gradual change in the flame height. However, at the smoking point there is an abrupt change in the flame height. Consequently, measurements of the flame height very close to the smoking point may have a lower precision than measurements of the fuel flow which were reported previously (ref. 1). However, because of the difficulties in calibrating flow meters for use at these pressures, flame heights were measured in these experiments. The precision of measurements may be observed in figure 2 from the measurement of the smoking tendency at nearly equal pressures.

The amount of fuel burned is directly related to the flame height. Therefore, the amount of fuel which can be burned smoke-free decreases progressively up to the highest pressure studied of 20 atmospheres. The results shown in table I and the general shape of the curve in figure 2 indicate that the relation between smoking tendency and pressure which was observed previously (ref. 1) is also present up to pressures of 20 atmospheres.

In previous work (ref. 1), a plot of smoke-free fuel flow against reciprocal pressure gave a straight line for each fuel. It was concluded that the smoke-free fuel flow could be correlated with the change in the diffusion coefficient since the diffusion coefficient is inversely proportional to pressure. In figure 3, flame height is plotted against reciprocal pressure up to 20 atmospheres for the fuels investigated. The straight lines indicate that the change in the fuel flow at the smoking point is inversely proportional to the pressure.

As the fuels burned in atmospheres of higher pressure, there was an increasing tendency for carbon to deposit on the lip of the burner. The formation was hard and coherent and when once started, it increased rapidly. During its growth, the carbon cone was maintained at a red heat by the flame. The tendency for the hard carbon to deposit on the burner occurred only when the flame was above the smoking point.

SUMMARY OF RESULTS

An investigation of the smoke-forming tendency of hydrocarbon diffusion flames over a pressure range of 4 to 20 atmospheres gave the following results:

1. The change in the amount of fuel, as measured by the flame height, which could be burned smoke-free was inversely proportional to pressure.

2. The same relative variation with pressure was observed for the two fuel types ethane and ethylene.

3. At higher pressure there was an increasing tendency for hard carbon deposits to form on the burner.

Lewis Flight Propulsion Laboratory
National Advisory Committee for Aeronautics
Cleveland, Ohio, May 3, 1954

REFERENCES

1. Schalla, Rose L., and McDonald, Glen E.: Effect of Pressure on the Smoking Tendency of Diffusion Flames. NACA RM E53E05, 1953.

2. Parker, W. G., and Wolfhard, H. G.: Carbon Formation in Flames, Pt. III. Jour. Chem. Soc. (London), Aug. 1950, pp. 2038-2044; discussion, pp. 2045-2049.

TABLE I. - VARIATION OF FLAME HEIGHT AT SMOKING POINT WITH PRESSURE

Ethane			Ethylene		
Pressure, atm abs	Flame height, cm	Reciprocal pressure, atm^{-1}	Pressure, atm abs	Flame height, cm	Reciprocal pressure, atm^{-1}
6.4	3.20	0.156	4.4	1.93	0.227
6.4	3.15	.156			
8.5	2.84	.118	7.8	1.09	.128
11.0	2.03	.091			
11.9	2.10	.084	11.9	.79	.084
14.6	1.74	.068	15.6	.67	.064
14.6	1.67	.068			
15.6	1.79	.064	18.7	.53	.053
18.0	1.48	.055			
21.4	1.71	.047	20.7	.48	.048
22.2	1.45	.045			

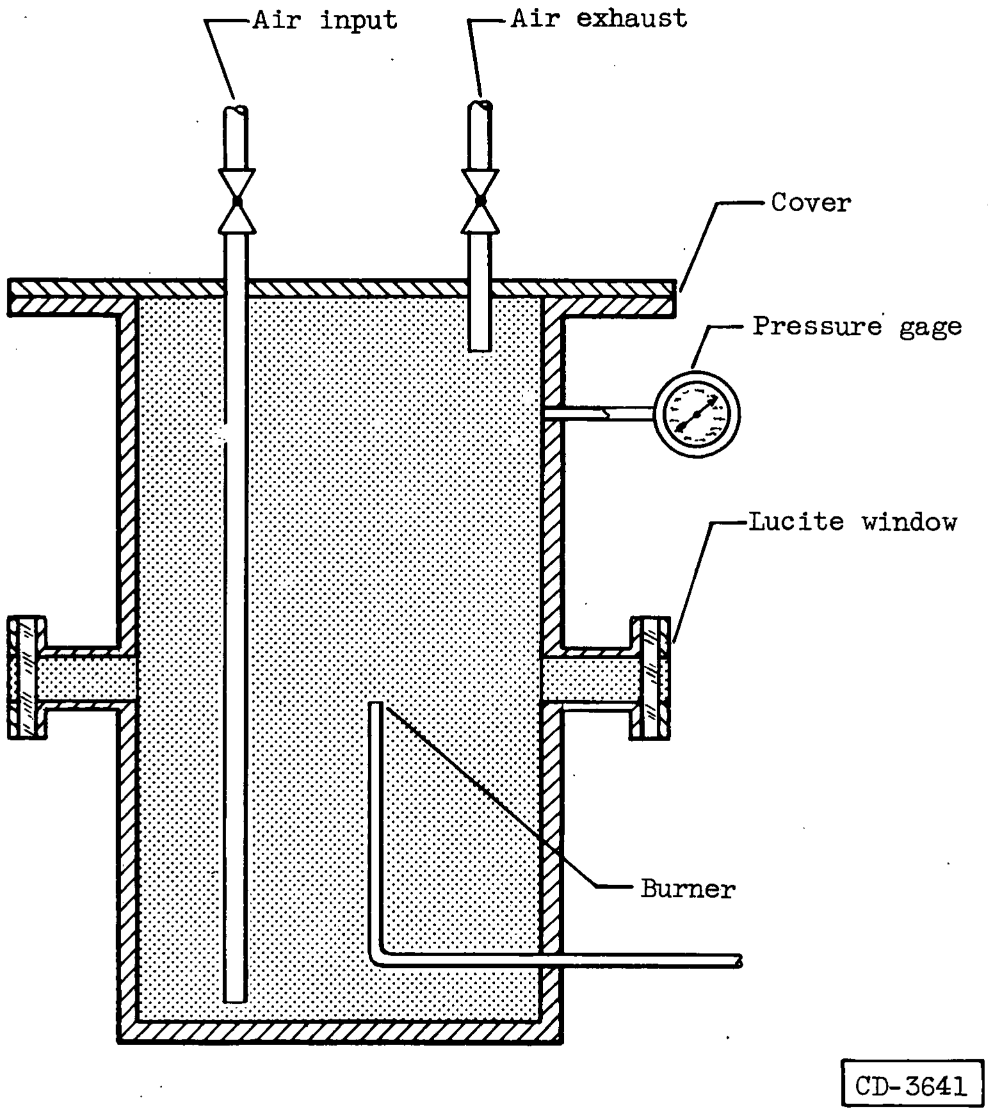

Figure 1. - Apparatus for determining smoking tendency at high pressure.

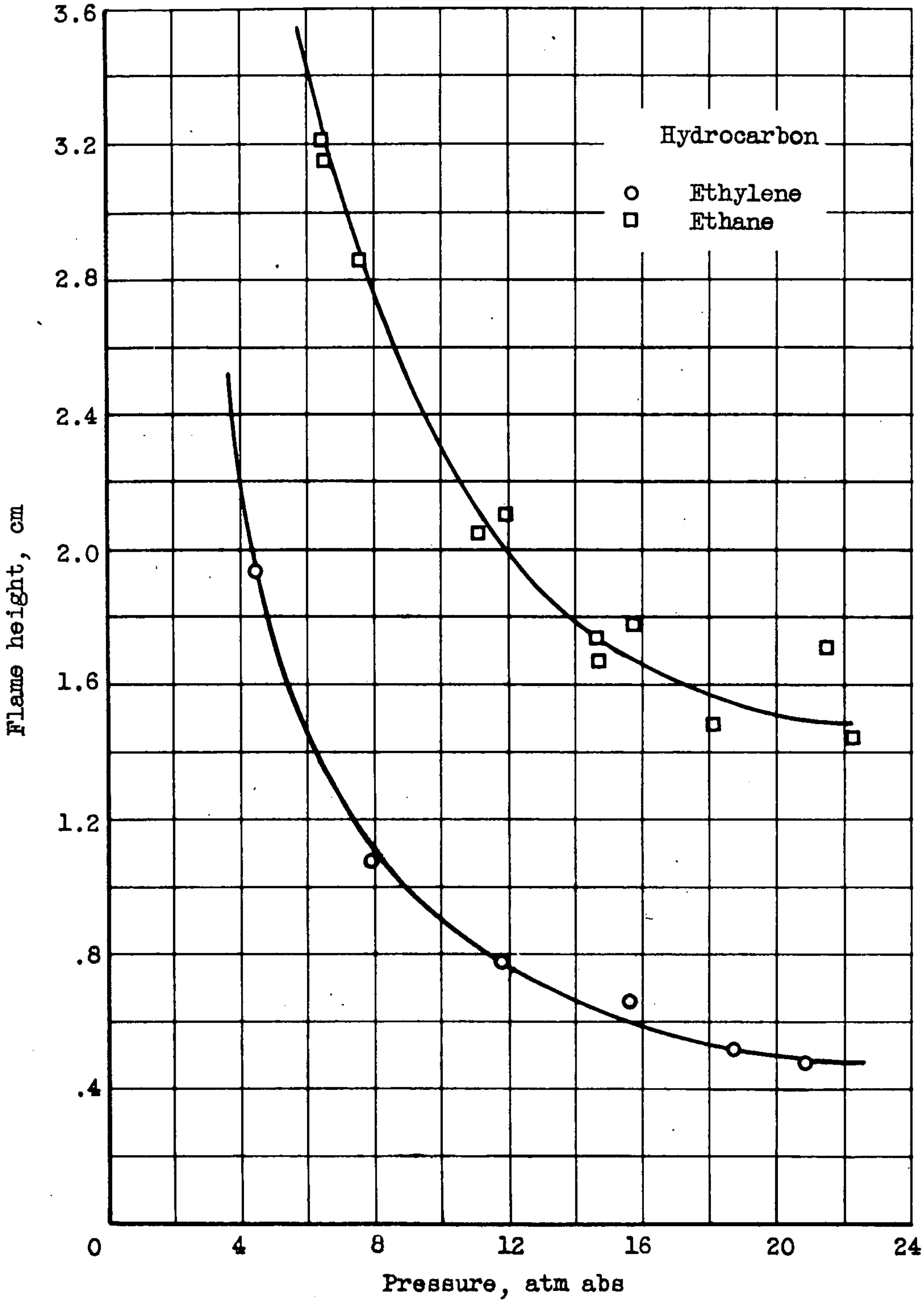

Figure 2. - Flame height at smoking point against pressure. Flame height proportional to fuel flow.

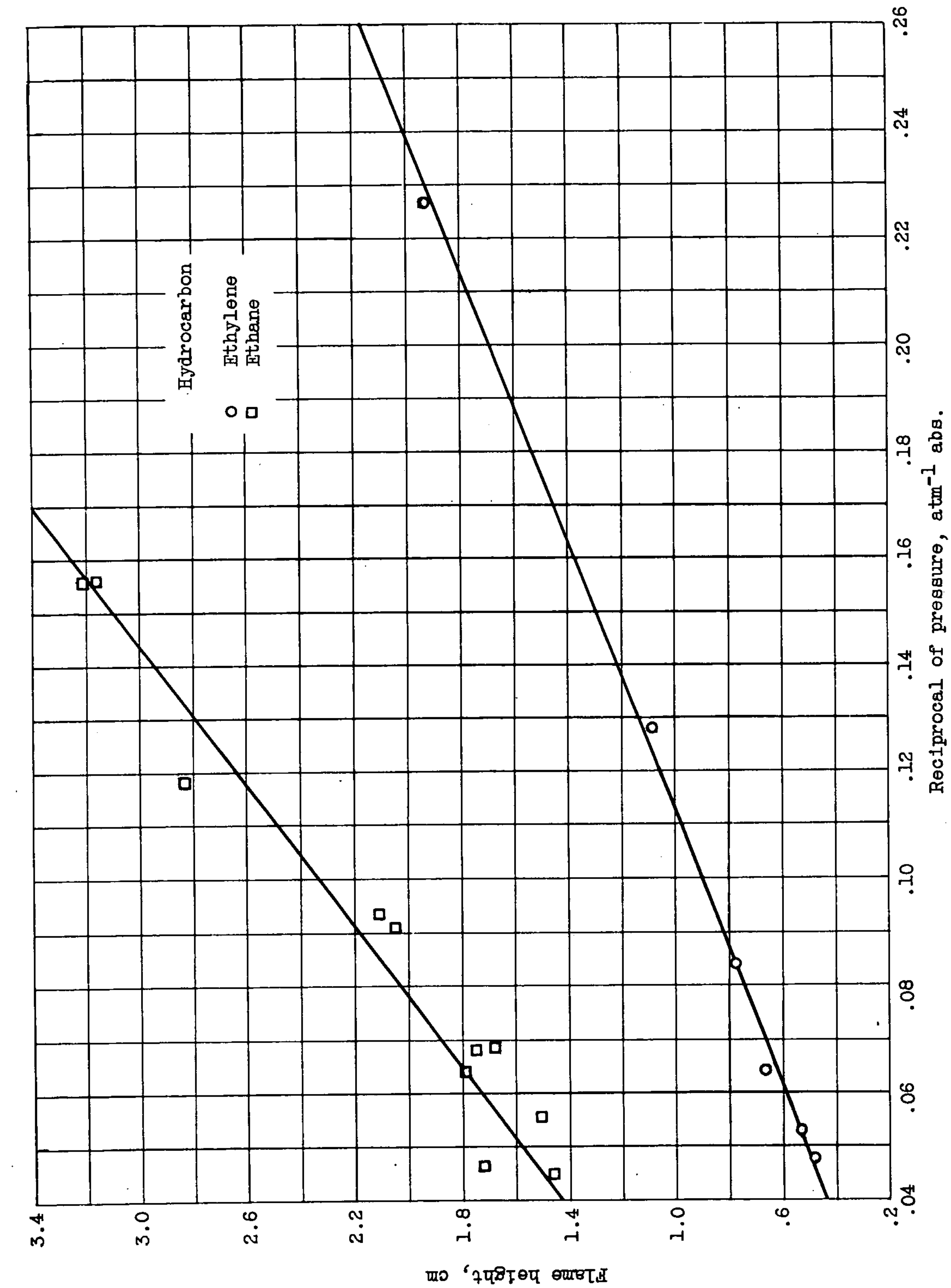

Figure 3. - Flame height at smoking point against reciprocal pressure. Flame height proportional to fuel flow.