N69-16737
NASA CR-73608

JET PROPULSION LABORATORY
CALIFORNIA INSTITUTE OF TECHNOLOGY
PASADENA, CALIFORNIA

RE-ORDER NO. 68-546

HEAT RELEASE RATE FOR THE LIQUID N_2O_4/N_2H_4

REACTION BY SOMOGYI AND FEILER'S METHOD

FINAL REPORT SN-114

Prepared for

California Institute of Technology
Jet Propulsion Laboratory, Contract No. 952197
(Subcontract under NASA Contract No. NAS7-100)

By B. R. Lawver and E. A. Tkachenko

19 JAN. - 12 APRIL 1968

DYNAMIC SCIENCE
A Division of Marshall Industries
1900 Walker Avenue
Monrovia, California 91016

10f 15

FOREWORD

This report was prepared for NASA, Jet Propulsion Laboratory. The Project Monitor on this contract is Dr. J. Houseman, Liquid Propulsion Section of Jet Propulsion Laboratory, California Institute of Technology, Pasadena, California

This effort was conducted for the Jet Propulsion Laboratory Contract No. 952197 (Subcontract under NASA Contract NAS7-100) for the period 19 January 1968 to 12 April 1968. This report deals with the measurement of liquid propellant heat release rates needed for characterizing the separation of impinging streams of hypergolic propellants.

2

TABLE OF CONTENTS

I. SUMMARY

In this study the heat release rate for the liquid phase reaction of nitrogen tetroxide and hydrazine was measured. The basic method and apparatus employed were those of Somoguyi and Feiler as described in NASA Technical Note No. D-469, September 1960. An important modification of the apparatus as employed in the present study consists of an arrangement to measure directly the driving piston velocity. Prior to carrying out measurements for the system N_2O_4/N_2H_4, the propellant combination HNO_3/N_2H_4 was utilized to check out the apparatus.

The heat release rate values for N_2O_4/N_2H_4 obtained in this study were found to depend on injection velocity. The range of heat release rate values for the system N_2O_4/N_2H_4 found in this study is very nearly the same as that determined by Somogyi and Feiler for HNO_3/N_2H_4.

II. INTRODUCTION

Knowledge of the heat release rate for the liquid-liquid reaction in the system N_2O_4/N_2H_4 is important for the determination of jet separation after impingement of these propellants during injection. A theoretical model yielding separation criteria by utilizing the heat release rate as an input parameter has been developed by R. Kushida and J. Houseman (Ref. 1.) An empirical mixing/separation criterion, agreeing well with the Kushida-Houseman results, has been determined by W. Lawver, and B. Breen (Ref. 2.).

The object of the present study was to measure the heat release rate for the liquid phase reaction of N_2O_4/N_2H_4 and compare it to the rate for the system HNO_3/N_2H_4.

The apparatus employed was that of Somogyi and Feiler (Ref. 3.) Fundamentally, the apparatus is a constant volume calorimeter, at the same time serving as a rapid-mixing injection device. The two liquid reactants are injected through a fixed mixing chamber, and then through variable length mixing cups into the calorimetric fluid, which also serves as a reaction quenching medium. Measurement of the temperature rise in the calorimetric fluid, and of the injection velocity, and knowledge of the mixing cup lengths makes possible calculation of the effective heat release rate.

III. DISCUSSION

The basic method of measurement, apparatus, and underlying assumptions for the present study are described in Ref. 3. The subsequent discussion treats the experimental modification, measurements, and the interpretation of measured results obtained in this study.

A. Apparatus and Procedure

In Figure 1 is depicted the original heat release measurement apparatus of Somogyi and Feiler with one important modification. The change consists of a device to measure the actual travel distance and time of the driving piston, in order to obtain directly values of the liquid injection velocity. The necessity for this modification became clear during the check out tests with HNO_3/N_2H_4. During these tests it was found that use of the jet velocity-driving pressure calibration curve (Figure 3, Ref. 3.) yielded excessive scatter of heat release values as functions of driving pressure. This difficulty was diagnosed as stemming from mechanical factors such as irregular driving piston travel and related pressure guage recordings. In order to eliminate such inconsistencies, a system recording the actual piston travel was devised.*

For the modified apparatus, piston travel was recorded (oscilloscope) by means of electrical signals actuated upon passage of the driving piston past a known initial and final station in the piston housing.

The minimum mixing cup length was 0.36 inches and the maximum, 1.36 inches for both the check out test and the N_2O_4/N_2H_4 measurements. Driving piston velocity values ranging between 4 ft/sec and 21 ft/sec were obtained. In all tests 1.0 ml of each reactant was employed; and in the case of N_2O_4, chilling of the fluid as well as reactant block was used to prevent evaporative loss, because of the high vapor pressure of N_2O_4 near room temperature. For the study of the effect of reactant temperature on heat release (N_2O_4/N_2H_4) the temperature of the reactant block was monitored by means of a thermocouple.

---

* According to Dr. C. E. Feiler (personal communication) the planned next step in refining the Somogyi-Feiler apparatus would have been to incorporate a way of measuring independently the driving piston velocity.

B. Results

The experimental and derived results stem from these systematic steps:

(1) Putting into good working order the original Somogyi-Feiler apparatus,

(2) Check-out tests employing HNO_3/N_2H_4

a) with original apparatus,

b) with modified apparatus,

(3) Preliminary tests using N_2O_4/N_2H_4,

(4) Heat release measurements for N_2O_4/N_2H_4, varying mixing cup lengths, piston velocities, and reactant temperatures.

Figures 2 through 5 summarize the results obtained with the modified apparatus (enabling piston velocity measurement).

Figures 2 shows the relationship of experimental heat release as a function of mixing cup length, at different driving piston velocities. Both HNO_3/N_2H_4 and N_2O_4/N_2H_4 data points are included. The shortest experimental mixing cup length has the dimension 0.36 inches, and the largest 1.35 inches. At the hypothetical 0.0 mixing cup length,is plotted the heat release value obtained when first, one reactant is mixed separately with the calorimetric fluid (H_2O), and second, the other reactant is introduced into the water solution of the first. This heat release value for zero mixing cup length obtained is in excellent agreement with that cited by Somogyi and Feiler (Figure 4., Ref. 3.).

It is evident in Figure 2 that at constant mixing cup length, the heat release first increases with piston velocity, and then falls to lower values when velocity is increased further. This general behavior is in agreement with Somogyi and Feiler's results.

In Figure 3 is depicted the variation of heat release with piston velocity at constant values of mixing cup length. The extremes of minimum and maximum mixing cup lengths are shown, however, in each case the passage through a maximum value of the heat release as a function of piston velocity is evident.

Figure 4 shows the effect of propellant temperature on the heat release for several constant piston velocities. At all values of piston velocity the heat release decreases with increasing propellant temperature.

Derived values of heat release rate as functions of driver piston velocity are presented in Figure 5. The general behavior indicates an initially increasing heat release rate with increasing driver piston velociy, eventually reaching a plateau, or a tendency to fall in value.

IV. CONCLUSIONS

The results described above and the conclusions drawn from these must be viewed from the standpoint that the present study (a) does not constitute an exhaustive effort to map in detail the heat release rate-jet velocity relationship for N_2O_4/N_2H_4, and (b) cannot directly be compared to Somogyi and Feiler's reported data, because of the modification of the velocity measurement method. Nevertheless, since heat release values for both systems, N_2O_4/N_2H_4 and HNO_3/N_2H_4 were measured in the present study under the same conditions, comparative results for these two systems should be valid. The general heat release characteristics obtained in this study fit Somogyi and Feiler's suggested combustion mechanism as well as aspects of Breen and Lawver's mix/separate concepts.

In brief, phenomena operative in the heat release process characteristic of the apparatus used are:

(1) degree of mixing as a function liquid velocity,

(2) degree of mixing as a function of reactant temperature.

At a given initial propellant temperature, the increase in heat release rate with injection velocity (at low velocities) can be attributed to an increase in contact, or interfacial area. At relatively high velocities gas evolution may become so large that separation of the liquid reactants occurs, resulting in a decreasing heat release.

In suumary,

1. The systems N_2O_4/N_2H_4 and HNO_3/N_2H_4 yielded nearly identical heat release rate--piston velocity relationship as determined by Somogyi and Feiler's apparatus modified to make possible direct measurement of driving piston velocity.

2. The maximum measured heat release rate value for N_2O_4/N_2H_4 is 65K cal/mole N_2O_4, sec.

3. Heat release values decreased with increasing propellant temperature at constant piston velocity for the system N_2O_4/N_2H_4.

4. At constant mixing cup length heat release increases initially with piston velocity reaching a maximum, and then decreases. Extent of interfacial area, heat dissipation and gas formation can be effective in causing the observed heat release characteristics.

V. REFERENCES

1. R. Kushida and J. Houseman, "Criteria for Separation of Impinging Streams of Hypergolic Propellants," Jet Propulsion Laboratory, Pasadena, California, presented at the Combustion Institute, Western States Section, Paper WSCI-67-38.

2. B. P. Breen and B. R. Lawver, "Unlike Hypergolic Impingement Model," in Quarterly Report SN-95 (NAS7-467), October 1967, Dynamic Science, Monrovia, California.

3. Somogyi, Dezso and C. E. Feiler, "Liquid-Phase Heat Release Rates of the Systems Hydrazine-Nitric Acid and Unsymmetrical Dimethyllydrazine-Nitric Acid," NASA Tech. Note D-469, September 1960.

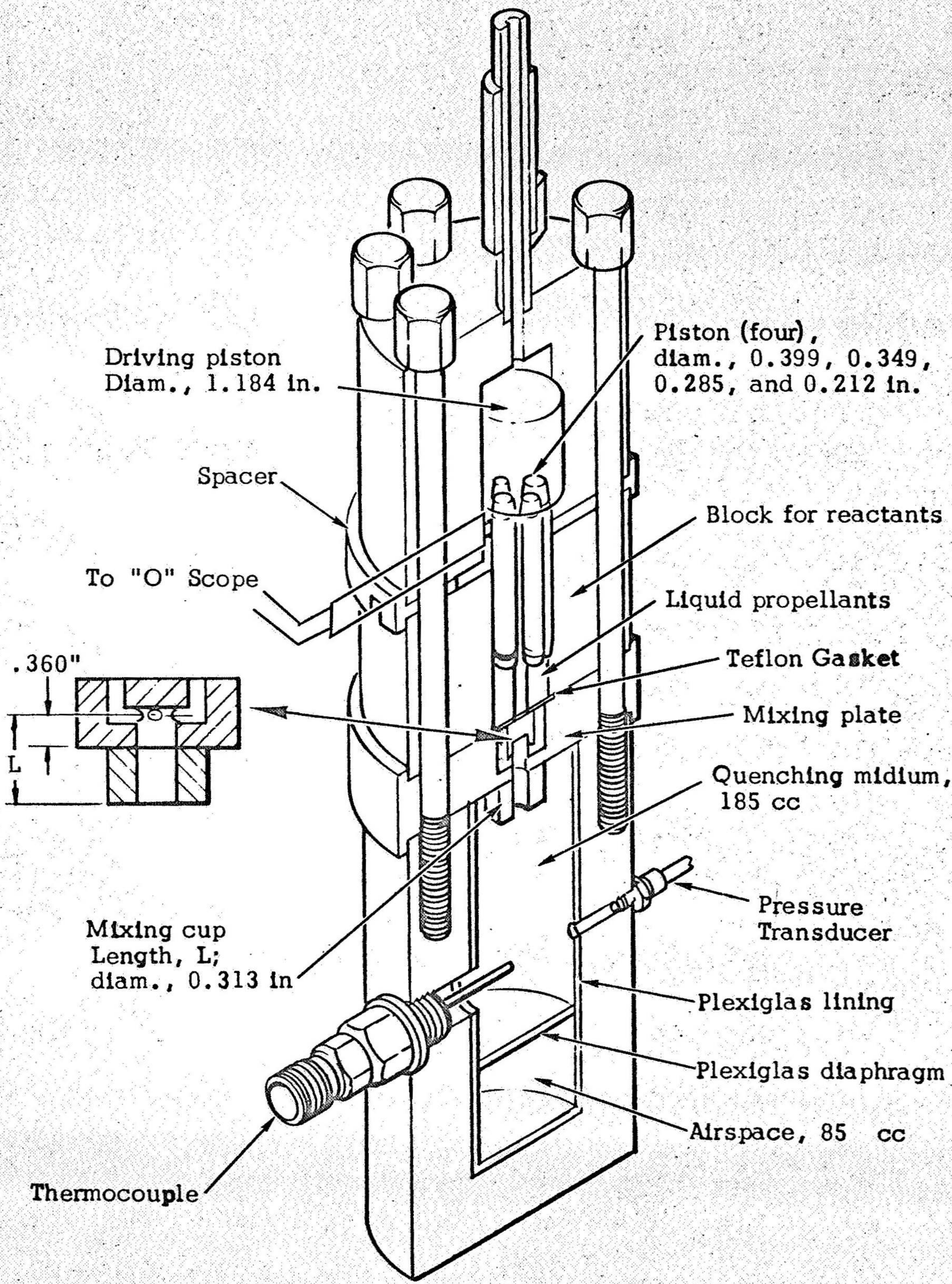

Figure 1. Heat Release Measurement Apparatus

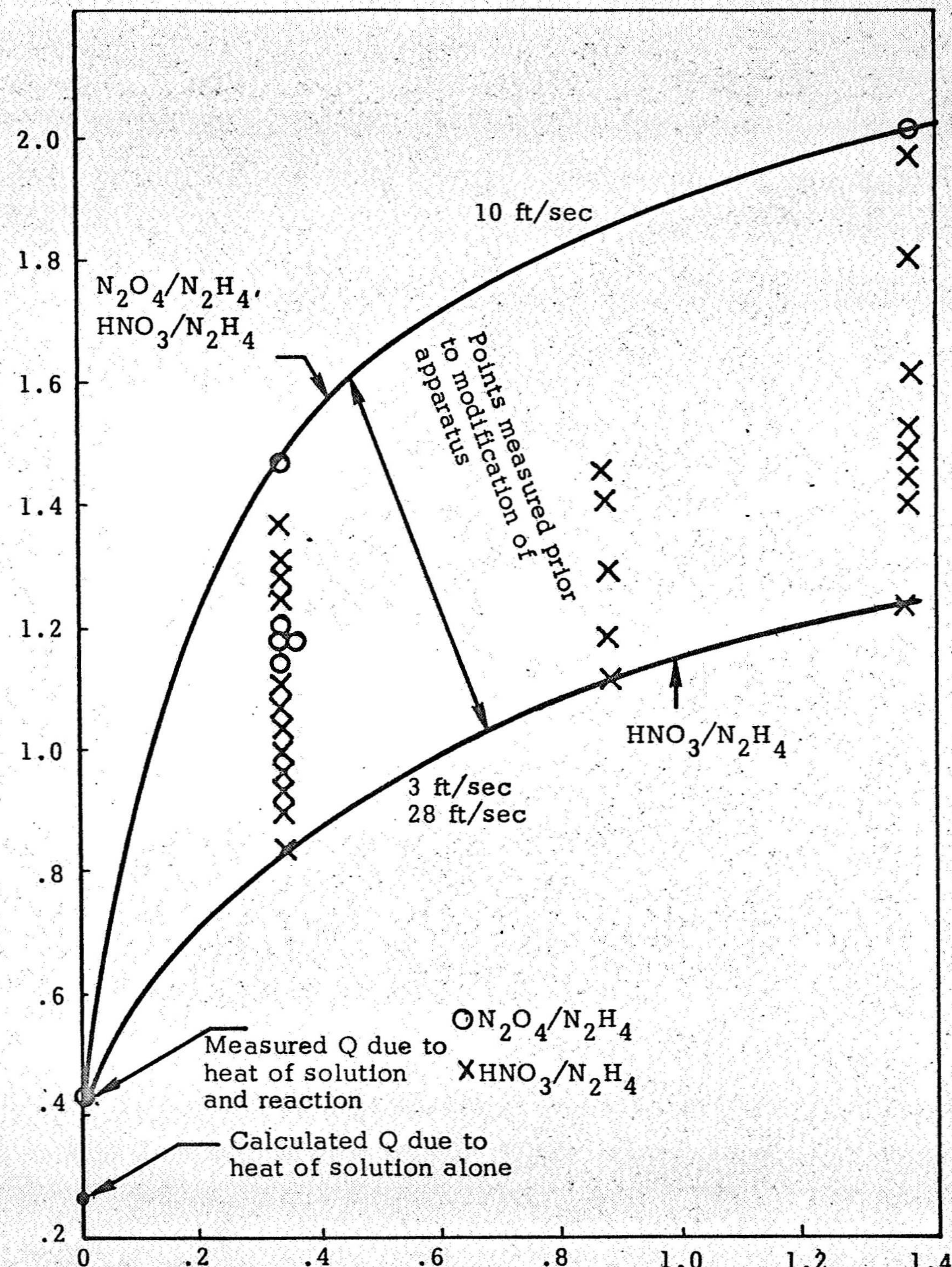

Figure 2. Heat Release vs. Mixing Length

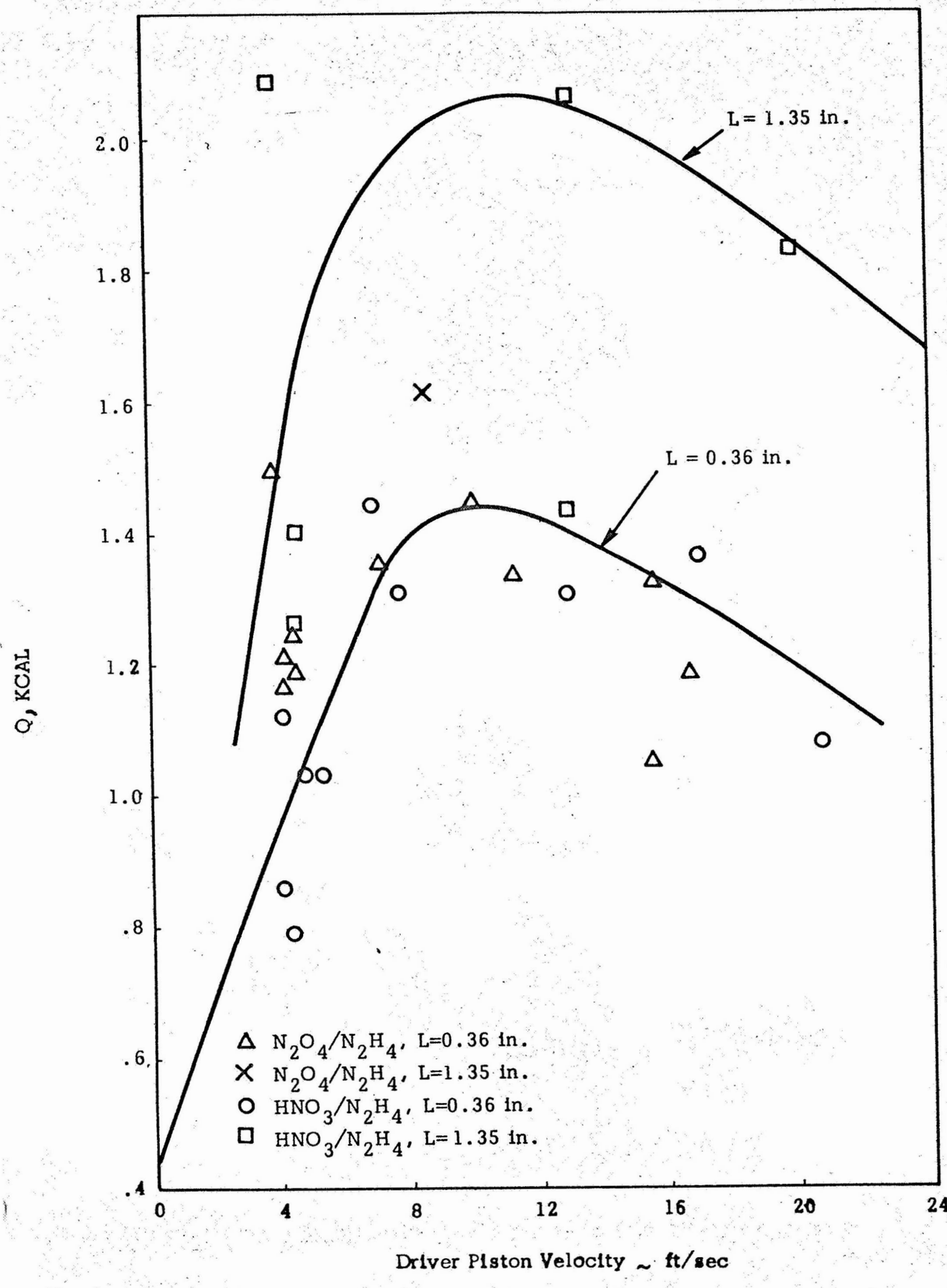

Figure 3. Heat Release vs. Piston Velocity

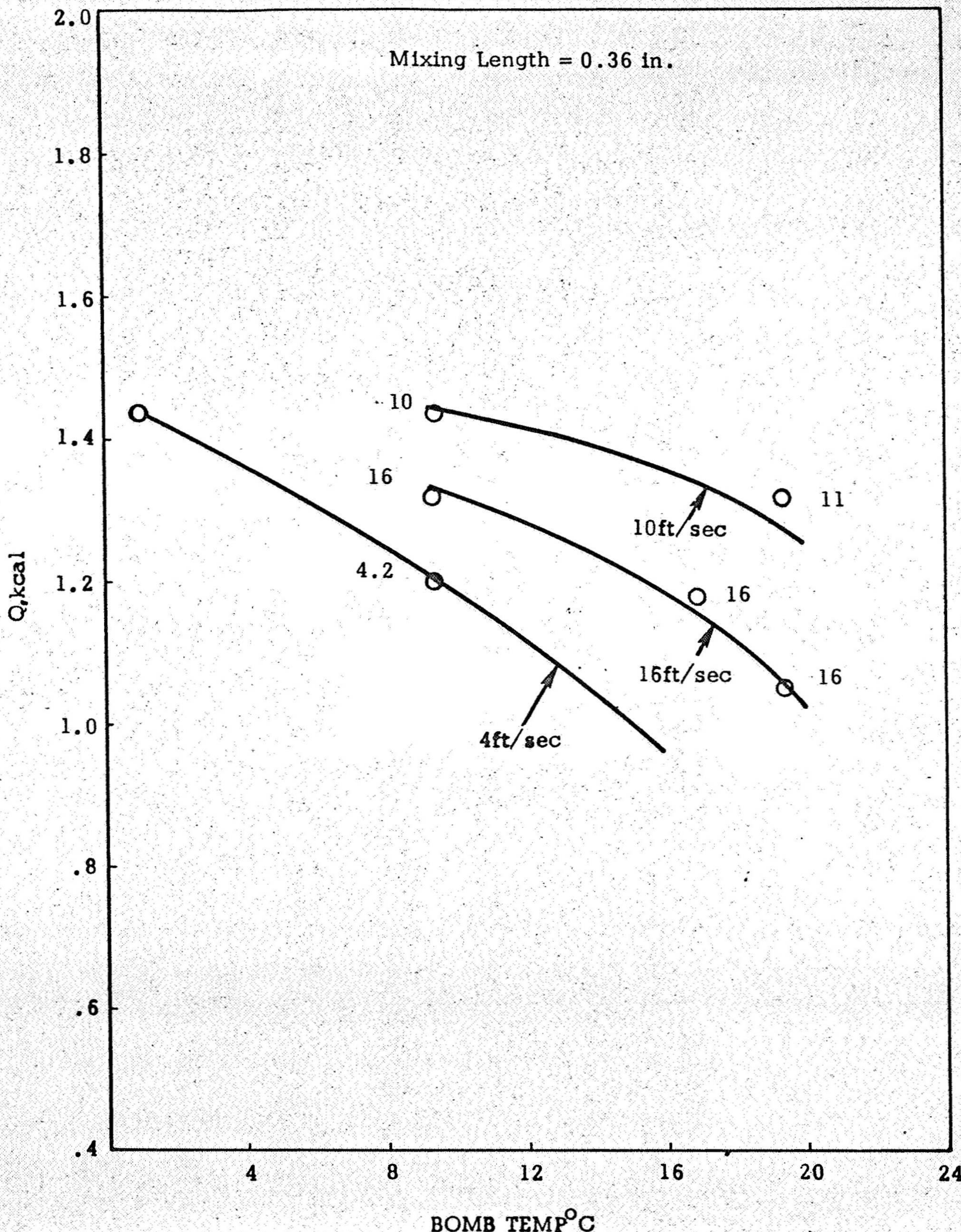

Figure 4. Heat Release vs Propellant Temperature

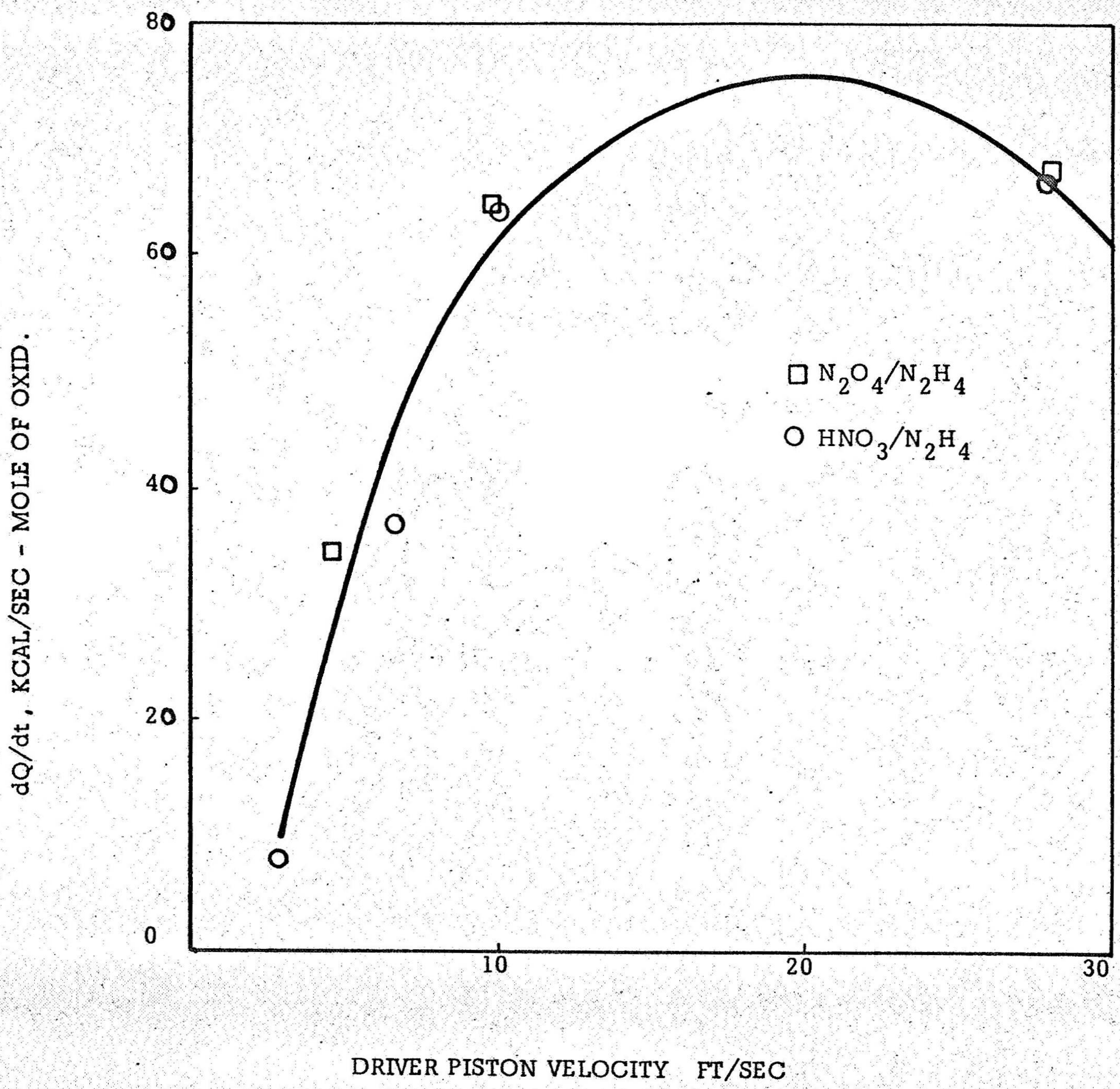

Figure 5. Heat Release Rate vs. Piston Velociy