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High Performance

N_2O_4/Amine Elements - "Blowapart"

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INTRODUCTION AND SUMMARY

The objective of this program is to develop an understanding of the mechanisms controlling hypergolic propellant blowapart and with that understanding develop a model containing the parameters controlling blowapart which will aid the design of stable high performing injectors. The mechanisms will be defined through test and analysis of subscale injectors using principally N_2O_4/MMH propellants and injectors and test conditions representative of the OME and Space Tug applications.

The program consists of three tasks. The objectives of the Task I effort are; to critique all existing models relating to blowapart, to summarize and review all associated experimental data and formulate updated models. The Task II effort consist of preparing a detailed program plan. The objectives of the Task III effort are to define the mechanisms governing blowapart through the design, fab, test and analysis of single element injectors.

This document summarizes the work performed during the Task I, Model and Data Review, effort. Results of the model review indicate that neither of the two existing blowapart models (JPL model and ALRC model) adequately correlate the experimental data. New data correlations show that the parameters exhibiting a controlling influence over blowapart are the chamber pressure, orifice diameter, and propellant temperature. The data plots indicate the existence of four reactive impingement regimes;

- Mixing
- Popping (cyclic blowapart)
- Low pressure separation ($P_c < 300$ psia)
- High pressure separation ($P_c > 300$ psia)

New models of reactive impingement were formulated to account for all four modes.

II PROBLEM DESCRIPTION

Popping and RSS are important design considerations because they can adversely affect performance and stability.

RSS has been observed to significantly reduce the performance of the following types of impinging injectors:

- Unlike Doublet
- Triplet
- Like Doublet

Experimental test results from the various OMS Engine Technology Programs have provided quantitative data of the effect of RSS on performance caused by increasing the fuel temperature from ambient to a level simulating operation with a fuel regeneratively-cooled chamber (~200°F). In many cases, the injector performance decreased almost linearly with increasing fuel temperature as shown in Figure 1.

The energy release efficiency decreased from 2 to 5% as the fuel temperature was increased from 50 to 240°F with two ALRC subscale OMS unlike doublet injectors (Figure 1). Similar results were also obtained with a full-scale OMS unlike doublet injector.

Other types of impinging element OMS injectors have also exhibited RSS, on contract NAS 9-12803 a F-O-F triplet injector demonstrated a C*

II Problem Description (cont.)

decrease from 1/2 to 1% with heated propellants. On Contract NAS9-12802 subscale tests with like-doublet elements in a short chamber showed a 5-7% decrease in C* with heated fuel.

Performance Reductions due to RSS have been found to be influenced by:

- Propellant Temperature
- Element Size
- Element Spacing
- Chamber Length

The effect of RSS was lessened with increasing chamber length and decreasing orifice size as shown in Figure 2. RSS was noted with both N_2O_4/A-50 and N_2O_4/MMH propellants.

Random high amplitude short duration (less than a millisecond) pressure and accelerometer disturbances were observed with the N_2O_4/Amine fueled Apollo Spacecraft engines during their development phase and more recently on some OMS development engines. These disturbances, called pops, are undesirable because they may trigger damaging combustion instability. In all of the Apollo engines the pops were eliminated or reduced to acceptable levels through trial and error testing since there were no design criteria by which logical element or pattern changes could be made. The pops were generally attributed to random accumulation and monopropellant explosion of fuel pockets or zones caused by such things as poor element or pattern design, orifice flow instabilities (hydraulic flip), plugged oxidizer orifices, or fuel leakage through weld cracks. Although these causes are certainly possible recent investigations demonstrate that the observed pops are related to combustion phenomena associated with unlike hypergolic propellant stream impingement. For instance it has been shown (Ref. 1-5) that

small local explosions of fuel and oxidizer, rather than monopropellant fuel explosions, are the source of pop triggers. The pops and/or pop triggers can upset engine stability by driving the feed system dynamics and/or chamber acoustics and by modifying the energy release profile as illustrated in Figure 3.

Pops have been found to be influenced by:

- Propellant temperature
- Chamber Pressure
- Injection Velocity
- Orifice Size
- Stagnation Pressure Ratio

Although the mechanisms controlling pops and RSS are not thoroughly understood at present, a significant amount of effort has been expended which forms the basis for this understanding. The results of a critical review of the related work is presented in the following section.

III LITERATURE REVIEW

A summary of the literature reviewed is contained in Table I. The key finding of each investigator is summarized under the comments heading. A summary of the range of parameters covered in these studies is shown in Table II.

Past investigations have:

- Identified four operating regimes for hypergolic stream impingement.

III Literature Review (cont.)

- Demonstrated techniques of identifying and measuring RSS and pops.
- Identified many of the design and operating parameters influencing RSS and pops.
- Provided a multitude of RSS and pop data.
- Postulated two theoretical models for the prediction of one or more of the reactive impingement regimes.

Experimental studies have identified four operating regimes for reactive stream impingement as illustrated in Figure 4. The occurrence of any of these regimes was found to be dependent on many engine operating and design parameters. The following conditions were found to be conducive to the occurrence of each operating regime:

- Mixing -

  Lower Propellant Temperatures

  Lower Reactivity Propellants

  Smaller Orifice Size

  Unequal Stream Dynamic Pressures

- Separation -

  High Fuel Temperature

  High Oxidizer Temperature (oxidizer vaporization)

  Highly Reactive Propellants

  Larger Orifice Size

- Penetration -

  Low Reactivity Propellants

  Small Orifice Size

  Low Injection Velocity

III Literature Review (cont.)

- Popping -

  Lower Propellant Temperatures

  Lower Chamber Pressure (200 psia or less)

  Larger Orifice Size

  Higher Contact Time (D/V)

  Reactive Propellants

  Equal Stream Dynamic Pressures

Quantitative description of these operating regimes has been lacking.

The following sensing techniques have been used to identify the various impingement regimes in past investigations:

- PHOTOGRAPHIC

Color	Still Photography
B&W	Emission Spectra
	High Speed Movies

- PERFORMANCE MEASUREMENT

  Conventional Chamber
  Baffled Chamber

- PRESSURE MEASUREMENT
- ACCELEROMETERS
- MASS SPECTROMETER
- THERMOCOUPLES

Photographic techniques provide a qualitative measure of the reactive stream flow characteristics and were used in the first reported evidence of

stream separation (Ref. 6). High speed movies were also instrumental in the identification of cyclic blowapart of single doublet elements (Refs. 2, 3, 5 and 7). The performance measurement technique with conventional chambers provided a psuedo-quantitative measurement of stream separation by comparing the performance of a system while varying the parameter which influences stream separation (Ref. 8). For example, the decrease in performance with increasing fuel temperature resulted presumably from increasing reactive stream separation. Performance measurements with a baffle chamber provided more conclusive quantitative measurement and are capable of identifying the mixed, separated, and penetrated flow regimes (Ref. 9). The P_c and accelerometer measurements have been used to identify the "popping" regime (Refs. 1, 3, 5, and 9). Finally, the mass spectrometer and thermocouple measurement techniques were used to measure the mixture ratio distribution downstream of the reactive stream impingement providing a quantitative measurement of the reactive stream mixing process (Ref. 11).

IV DATA COMPILATION AND ANALYSIS

The data generated by the following investigators were tabulated for computerized data analysis:

- Lee and Houseman
- Zung and White
- Nurick and Cordill

A computer program was written to summarize the data and to calculate and plot correlation parameters. The computer listing and data summaries are included in the Appendix. An example of the computer correlation plots is shown in Figure 5. Of all the correlations plotted the factors providing the best correlation are:

IV Data Compilation and Analysis (cont.)

- Chamber Pressure
- Orifice Diameter
- Propellant Temperature

These factors were found to exhibit the controlling influence over the occurrence of the mix, pop, and separation regimes.

DATA CORRELATIONS

The data were used to construct correlation plots to define the first order controlling parameters. This was done by plotting the data versus several parameters including:

- $1/T$ vs $(D/V)_f$
- P vs D_f
- P/D vs T
- P/D vs $(D/V)_f$
- P/D^2 vs T
- P vs $1/V_f$
- P vs T

The most interesting correlations were obtained with the P vs $1/V_f$ and P vs T plots. Examination of the P vs $1/V_f$ plots shown in Figures 6 and 7 indicate the occurrence of RSS and popping to be independent of the injection velocity which seemingly conflicts with previously reported data. However, this is not the case if a distinction is made between the limits of pop occurrence and the characterization of the pops within these limits. Houseman (Ref. 5) and Nurick (Ref. 4) found a definite correlation between pop rate (pops/sec) and velocity (D/V) which lends to the characterization of the pops but does not describe the limits of occurrence.

IV Data Compilation and Analysis (cont.)

The limits of occurrence are observed to be primarily dependent on the chamber pressure and orifice diameter. The orifice diameter seems to exhibit an overwhelming influence on the pop limit as shown in Figures 8, 9 and 10. These plots also indicate the existence of two distinct modes of RSS; a high-pressure mode and a low-pressure mode as previously reported by Zung (Ref. 3). The low pressure mode is associated with N_2O_4 boiling which prevents stream penetration and mixing. The second mode of RSS occurs at pressures above 300 psia. Modeling of this RSS mode is discussed in the subsequent section.

In summary the data correlations show four distinct modes of reactive stream impingement;

- Mixing
- Popping
- Low Pressure RSS ($P_c < 300$ psia)
- High Pressure RSS ($P_c > 300$ psia)

V MODEL REVIEW AND CRITIQUE

The following two models are the only ones reported in the literature for predicting the occurrence of RSS and pops;

- JPL Model
- ALRC Model

The first model is that developed by Kushida and Houseman (Ref. 12). It postulates two regimes of RSS, (1) a low pressure separation due to liquid phase reactions, and (2) a high pressure separation due to gas phase reactions.

V Model Review and Critique (cont.)

The model defines the regimes of mix and separation in terms of the chamber pressure, propellant temperature, and impingement contact time (D/V) as shown in Figure 11.

The rationale behind the development of this model is as follows:

The low-pressure-separation condition occurs when the liquid phase reactions heat the propellants to the bubble point. This condition exists when:

$$T_{P_i} \geq T_B$$

where:

T_{P_i} = propellant temperature at the impingement point

T_B = propellant boiling temperature

Although Kushida does not develop this portion of the model in detail it can be done as follows. T_{P_i} is determined by the liquid phase heat release rate and the contact time within the impingement zone.

$$T_{P_i} = T_{P_o} + \Delta T_P$$

where:

T_{P_o} = propellant injection temperature

ΔT_P = temperature rise due to liquid phase reactions

ΔT_P = $\dot{Q}$ tr M_R/M_H C_P

$\dot{Q}$ = liquid phase heat release rate, Kcal/sec-mole of oxidizer

M_R = mass of propellant reacted, moles

M_H = mass of propellant heated, moles

V Model Review and Critique (cont.)

C_p = specific heat of propellant, cal/mole-°K

tr = contact time, sec.

using:

C_p = 23 cal/mole-°K for hydrazine

$\dot{Q}$ = 83×10^3 kcal/sec-mole of oxidizer*

ΔT_p = 3.6×10^6 °K/sec x tr x M_R/M_H

The average contact time is:

$$tr = D/V$$

where:

D = jet diameter, feet

V = jet velocity, ft/sec

To calculate ΔT_p requires that the ratio M_R/M_H be assumed. Although Kushida does not report the value used it was calculated to be about 0.5 as follows. Figure 11 shows separation is predicted to occur below pressures of about 38 psia for a contact time of 40μ sec and 40°F propellants. Using this contact time and the N_2O_4 saturation temperature at 38 psia, the assumed ratio of M_R/M_H is about 0.5.

The second mode of stream separation is postulated to occur at high pressure due to gas phase reactions at the propellant stream interface. The interface is modeled as a stable gas film separating the liquid streams. The rate of fuel and oxidizer transport into the film is presumed to be limited by vaporization.

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*Kushida's reported value of 83 Kcal/sec-mole of oxidizer is in error.

The reaction film thickness is determined by a momentum balance on the reaction volume. Using a hydrazine/N_2O_4 reaction mechanism and rate reported by Sawyer and Glassman (Ref. 13) Kushida is able to develop a relationship between the contact time (D/V) and the pressure through the gas density.

Separation is postulated to occur if:

$$D/V > 35 \quad (100/P)^{-1.5}$$

where:

P = chamber pressure, psia

The weakness of this model is that it assumes the existence of a stable gas film with laminar flow at the contact point. Recent cold flow and reactive impingement experiments (Refs. 3, 4, and 5) show the impingement process to be highly unstable and cyclic in nature.

The RSS/pop data summarized in the Appendix were plotted on the pressure/contact time coordinates (Figure 12) to check the Kushida model. It is evident that the model does not adequately correlate the mix and separation regimes.

ALRC MODEL

The second model, developed by Lawver (Ref. 1) describes regimes of mix, pop, and separation for reactive stream impingement as well as describing inter-element spacing requirements for preventing coupling of single-element pops with adjacent element sprays. Reactive stream impingement is postulated to be controlled by liquid-phase reaction kinetics and mixing.

V Model Review and Critique (cont.)

The onset of stream separation is postulated to occur when the stream residence time exceeds the ignition delay time:

$$\tau_{RES} \geq \tau_{ign}$$

where:

$$\tau_{RES} = D/V$$

and:

$$\tau_{ign} = Y\, e^{E/RT}$$

Y = reaction rate constant

E = activation energy

R = Universal gas constant

T = Propellant temperature

The pops are postulated to be due to the ignition of well-mixed fuel and oxidizer within the ligament formation zone. Pops occur when:

$$\tau_{lig} \geq \tau_{ign}$$

where:

$$\tau_{lig} = (200/V)\ (D/V)$$

For a complete derivation see Reference 1.

The regimes of mix, pop, and separation are defined by plotting (1/T) versus (D/V) as illustrated in Figure 8.

Using this model of reactive stream impingement, a stream separation parameter, I, was defined such that:

V Model Review and Critique (cont.)

$$I = (\tau_{ign})_{SEP}/(\tau_{ign})$$

where:

$(\tau_{ign})_{SEP}$ = ignition delay at separation limit

τ_{ign} = ignition delay as determined by fuel temperature

A large set of Apollo engine pop data, in the 100-150 psia range, were correlated with this parameter (Ref. 1) to define regimes of engine popping. The data correlations showed that most engines operate within the regime of element popping, therefore, it became necessary to prevent interelement coupling to eliminate the engine pops. On the basis of high speed movies (Ref. 2) which showed the element pops to be highly localized explosions it was theorized that the pops behave as spherical blastwaves in which the pressure decays rapidly with distance. With this theory it was possible to develop the following element spacing parameter.

$$D = R/S$$

where:

R = $49.2\ (D_f/P_c^{1/3})$ in.

D_f = fuel orifice diameter

P_c = chamber pressure

S = element spacing, in.

See Ref. 1 for a complete development. Coupling occurs when:

$$D \geq 1.2$$

Application of this spacing criteria to the Apollo SPS IOS injector (Ref. 1) eliminated the popping.

V Model Review and Critique (cont.)

The RSS data tabulated in the Appendix were plotted on the (1/T) versus (D/V) coordinates to check the Lawver theory. The results showed poor correlation especially at higher pressures. The atmospheric pressure data are shown in Figure 9. It is evident that this model does not adequately define the mix, pop, and separate regimes.

The model's failure to adequately correlate the various regimes does not invalidate its ability to accurately predict pop coupling. The pop blast-wave coupling model merely states that given a regime of element popping, coupling will or will not occur given certain conditions of chamber pressure, element size and spacing. The successful application on the Apollo IOS and the ALRC OME engine studies is ample verification.

Since neither the Kushida/Housman or Lawver models adequately correlate the operating regimes it was desirable to develop a new model of reactive stream impingement.

VI NEW MODEL CONCEPTS

A new model of reactive stream impingement was formulated in parallel with the proposal effort through the examination of the new RSS data correlations and re-examination of the physical and chemical processes involved. The new model presumes four regimes of reactive impingement:

- Mixing or Penetration
- Popping (cyclic blowapart)
- Low pressure separation
- High pressure separation

VI New Model Concepts (cont.)

The existence of these regimes is a consequence of the complex reaction mechanisms of the N_2O_4/Amine propellants. Although reaction can occur in four basic modes;

- High enthalpy gas-phase oxidation reaction
- Low enthalpy surface reactions
- Monopropellant decomposition
- Liquid phase reactions

true liquid-phase reactions have only been observed with dilute mixtures of N_2O_4 and N_2H_4 (Ref. 14). They are not likely to occur under reactive stream impingement conditions due to their immiscibility and the apparent low degree of liquid/liquid mixing observed with liquid stream impingement. The controlling reaction mechanisms for each of the four regimes is illustrated in Figure 15. The pop is postulated to be a consequence of the transition from a low enthalpy surface reaction mode to a high enthalpy gas-phase reaction mode with attendant ignition of explosive intermediate formed during the pre-ignition phase. The transition is a consequence of self-heating by the surface reactions. The heat-up time and the amount of heating both depend on the orifice size. Small orifices produce smaller ligaments which can heat to the ignition point before appreciable amounts of intermediates are formed. They also restrict the contact time (i.e., heat-up time). Larger jets produce correspondingly larger ligaments which allows sufficient self-heating and intermediate accumulation to produce pops. The self-heating by surface reaction is controlled by the volume to surface ratio and is therefore a function of the orifice. diameter (D).

Stream mixing occurs when the orifice diameter is sufficiently small to prevent pops or when the pressure is sufficiently high to suppress transition from surface reaction to vapor-phase reaction until the ligaments are shed into droplets.

Low-pressure RSS occurs when the N_2O_4 temperature exceeds its saturation temperatures. The resultant two-phase stream enhances surface and/or gas phase reactions which prevent interdispersion of propellant droplets.

High-pressure RSS is postulated to be a consequence of monopropellant decomposition of the fuel vapor due to recirculation gas heating of the fuel stream ahead of impact. The resultant decomposition produces gas-phase reactions upon contact with the oxidizer stream. This mode of separation is controlled by the fuel vapor pressure.

POSTULATED POP MECHANISMS

Studies to date have identified the following pop characteristics:

- Cyclic nature
- Explosions originate close to impingement point
- Explosions emit high velocity blastwaves
- Explosions have been classified as to their strength
- Frequency of occurrence and strength depends on diameter, D/V, and fuel

Nurick and Cordill (Ref. 4) suggest the possibility that the explosions may be due to either ignition by impact of explosive intermediates or ignition of mixed propellants. The possibility of ignition of shock-sensitve intermediates

by impact is not likely since the calculated impact forces for typical stream velocities are orders of magnitude lower than that required. For instance the maximum impact force for a 0.040 in. diameter jet at 50 ft/sec velocity is 43×10^{-8} ft-lb. A minimum of 4 ft-lb is required (Ref. 16). Also it is observed that the popping frequency and strength decrease with increasing velocity which is the inverse of that expected for an impact ignition mechanism.

The explosions could also be triggered by compression of the gas bubbles formed as a result of the surface reactions. Adiabatic compression of the gas bubbles by liquid stream impact could produce sufficiently high temperatures to trigger the explosive intermediates. This process would be expected to be highly random in nature. However, the propensity for pop would be expected to increase with orifice diameter and decrease with pressure. This theory can be investigated by saturating the fuel with pressurant gas or injecting gas into the manifold to produce gas bubbles at the impingement point. Popping would be expected to worsen with bubble injection.

It is more likely that the explosions are due to ignition by hypergolic self-heating through interfacial surface reactions as described below.

During the proposal phase, high speed color movies were taken of cold flow stream impingement using streams of water and dyed water in an effort to more fully understand the impingement process. It was found that the cyclic nature is due in part to the normal stream breakup process. The formation of surface waves is evident in the film sequence. The stream breakup process is controlled by the stream hydraulic and interfacial forces.

VI New Model Concepts (cont.)

Examination of the movie sequence shows the existence of distinct globs of water and dyed water indicating a lack of liquid-phase mixing. Therefore nonreactive impingement appears to be dominated by interfacial forces. Likewise reactive stream impingement of immiscible fluids is not expected to produce extensive liquid-phase mixing. This conclusion was also reached by Breen et. al., (Ref. 17), on the basis of reactive tests. Also reaction kinetic data derived from N_2O_4/N_2H_4 stream impingement data (Ref. 18) were found to agree well with the gas kinetic data of Sawyer and Glassman (Ref.13). This observation along with that of Weiss, et. al., (Ref. 19) showing N_2O_4/N_2H_4 to be immiscible led Breen to the conclusion that the reaction between liquid surfaces may be controlled by vapor phase kinetics.

Evidence in support of this theory is provided by the results of the liquid phase mixing experiments of Rodriguez (Ref. 20). The liquid-phase heat release rates reported by Rodriguez would suggest that MMH is more reactive than N_2H_4 which seemly conflicts with the impingement test results. However, his results are reasonable if in fact a gas-phase reaction is measured. A rather clear correlation is provided by comparing the vapor pressure to the measured heat release rate as in Table III.

Hypergolic surface reactions were first described by Lawver (Ref. 21) during a study of N_2H_4 droplet combustion. Droplet ignition was observed to occur through a surface reaction which produces a white milky substance on the droplet surface which has since been identified as ammonium nitrate. Ignition proceeds by surface reactions which heat the liquid fuel to the ignition point as shown in Figure 16. At the ignition point the reaction changes from the surface to that of a droplet diffusion flame.

In a later study Zung (Ref. 22) characterized N_2O_4/N_2H_4 ignition. Photographs taken during this study clearly show surface reaction phenomenon. Ignition was found to be a transition from low enthalpy surface reaction to high enthalpy vapor phase reaction as illustrated in Figure 17. Zung found the ignition point to depend on the N_2O_4 concentration and the N_2H_4 temperature, as shown in Figure 18.

At N_2H_4 temperatures below 107°F, ignition (i.e., transition from surface reaction to diffusion flame) is controlled by diffusion of N_2O_4 vapor to the liquid N_2H_4 surface. At temperatures higher than this, ignition is controlled by vapor phase kinetics. Above 187°F ignition is influenced by N_2H_4 decomposition kinetics.

On the basis of these observations it is postulated that pops are due to a transition from low enthalpy surface reactions to high enthalpy vapor-phase reactions. The explosions result from rapid combustion of explosive intermediates formed during the pre-ignition surface reaction phase.

POSTULATED HIGH PRESSURE RSS MECHANISM

During an examination of the data correlations in the proposal phase it was noted that high pressure RSS occurs above 300 psia for N_2O_4/N_2H_4. It was also noted that the N_2H_4 saturation temperature (450°F) at this pressure coincides with the N_2H_4 vapor decomposition temperature (Ref. 15). This observation suggested a monopropellant decomposition mechanism for high-pressure RSS. It was postulated that RSS could occur as illustrated in Figure 19 by recirculation gas heating of the surface film of N_2H_4 to the boiling point prior to impact. At 300 psia this would result in monopropellant decomposition of the surface film thus preventing stream mixing. This mechanism of RSS would be expected to be independent of jet size and fuel temperature as the data indicate. Extending the theory

to other fuels would suggest that separation with MMH, A-50, due to their higher vapor pressures as shown in Table IV.

It was decided to analytically verify this theory during the contract Task I effort. The results of the modeling presented in the following section indicates inadequate heating of the free stream to heat the fuel stream to the saturation temperature. The theory will be evaluated by testing with elements having zero free stream length (i.e., zero impingement distance) and by temperature probing of the fuel stream.

VII HIGH PRESSURE RSS MODEL

High pressure RSS was theorized to be result of monopropellant decomposition mechanism as illustrated in Figure 19. Combustion recirculation gas heats the surface film of fuel to the boiling point in the free-stream ahead of impact. The resultant surface film monopropellant decomposition prevents inter-propellant stream mixing.

The fuel stream liquid temperature and fuel vapor temperature were calculated using the heat and mass transfer equations developed by Priem in NASA-TR67 for droplet vaporization. A cross-section of the fuel jet is illustrated in Figure 20 showing the vaporization mechanism. Also shown for reference are the typical temperature profiles for fuel vaporization with and without monopropellant decomposition of the fuel vapor. The influence of the decomposition is to accelerate the heat flux by steepening of the temperature gradient. The equations describing the heat and mass transfer are shown in Figure 21. These equations were computer coded for a finite difference calculation as illustrated in Figure 21. The Nusselt numbers used are shown

in Figure 22. The classic Ranz-Marshall correlation is used for fuel vaporization without decomposition and a predicted Nusselt no. which accounts for decomposition is used for the case of monopropellant decomposition. A computer listing is included in the Appendix.

The computer results indicate that for a hydrazine free-jet length of 4 L/D's injected at 50 ft/sec the liquid temperature rise would be on the order of only 10°F for jets from .027 to .060 inches diameter at 300 psia chamber pressure. Less than .1 percent of the liquid mass would be expected to vaporize prior to impingement. These calculations indicate that insufficient pre-impingement heating occurs to heat the fuel stream to the saturation temperature. Thus it is concluded that free-stream heating by recirculation gas does not control high pressure RSS.

However, it may be possible that recirculation gas heating within the fan development zone before fan breakup may account for the observed separation. Assuming that liquid phase fan mixing is minimal it can be theorized that the higher surface area/volume fan (compared to the cylindrical free-stream (jet) has sufficient time to heat to the saturation temperature. Fuel boiling and monopropellant decomposition would than prohibit subsequent mixing by creating a gas buffer zone. Experimental data will provide clarification of this theory. High pressure RSS occurring through this mechanism would be expected to be primarily a function of chamber pressure with jet diameter and fuel temperature exhibiting secondary influences which is consistent with the trends shown by the data of Zung.

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TABLE I

REACTIVE STREAM SEPARATION AND POPPING CHRONOLOGY

DATE	INVESTIGATORS	ORGAN.	CONTRACT NO.	REFERENCE	PROPELLANTS	SENSING TECHNIQUES	ELEMENT TYPES	ELEMENT SIZE	PC RANGE	TEMP. RANGE	COMMENTS
1959	Elverum & Staudhammer	JPL	NAS w-6	Prog. Rpt. 30-4	N_2O_4/N_2H_4	Photographic	Single Element Unlike Doublet	Not Given	Atmos.	Ambient	First report of stream separation with hypergolic propellants.
1965	Johnson	JPL	NAS7-100	TR No. 32-689	N_2O_4/N_2H_4, MMH, UDMH, Furfuryl Alch. Corporal	Performance with Baffled Chamber	Single Element Unlike Doublet	.0236 Dia. 2000 lbf/ Ele.	150 PSIA	Ambient	Quantitative performance measurement of stream separation. N_2O_4/N_2H_4, N_2O_4/MMH, and N_2O_4/UDMH showed some degree of blowapart. Corporal propellant showed blowapart to a lesser degree and N_2O_4/Furfural alcohol indicated no blow apart.
1966	Weiss & Klopoter	AFRPL	Proj. 624A	AFRPL-TR-66-51	N_2O_4/A-50, N_2O_4/N_2H_4 N_2O_4/MMH, N_2O_4/M-50	Pc Measurement	Transtage Quadlet	24 lbf/ ele.	100 PSI	37-86°F	Provides popping data for Transtage injectors. Includes variations in propellant combination, injector type, manufacturing variations, mixture ratio and film cooling.
1967	Evans, Stanford & Riebling	JPL	NAS7-100	TR No. 32-1178	N_2O_4/N_2H_4	Performance with Baffled Chamber	Unlike Doublet & Imping. Sheet	10,100, 2000 lb/ele .022,.064, .236 Dia.	150 PSIA	Ambient	Stream separation found to be element size dependent; increasing with increasing element size. Impinging sheets exhibited less blowapart than impinging jets.
1967	Burrows	NASA, Lewis	In-house	NASA TN D-52244	N_2O_4/N_2H_4	Photographic, Thermocouple and emission spectra	Quadlet	.068 in. Dia.	19 Atmos.	Ambient	Stream separation observed with a unlike impingement quadlet element. Combustion product gases eventually mixed approximately 18 in. downstream of the injection point. Mixing obtained with like-on-like impingement quadlet element.
1968	Tashida & Houseman	JPL	NAS7-100	NASA TM 33-395	N_2O_4/N_2H_4	None	Unlike Doublet	10-2000 lb/ele.	10-2000 PSIA	40-160°F	First theoretical model of stream separation for unlike doublet elements. Two separation regimes postulated; I liquid phase reactions controlling which applies at

Table I (cont.)

DATE	INVESTIGATORS	ORGAN.	CONTRACT NO.	REFERENCE	PROPELLANTS	SENSING TECHNIQUES	ELEMENT TYPES	ELEMENT SIZE	PC RANGE	TEMP. RANGE	COMMENTS
											lower pressures where separation is dependent on contact time (D/V) and propellant temperature, and II gas phase reaction controlling which applies at higher pressures where separation is dependent on (D/V) and independent on propellant temperature. model correlates previous JPL separation data.
1968	Burrows	NASA/ Lewis	In-House	NASA TMX-52483	N_2O_4/N_2H_4	Photographic	O-F-O & F-O-F Triplet	.025-.035-.025 Dia.	150-250 PSIA	Ambient	Stream separation observed for triplet elements.
1968	Lawver & Breen	Dynamic Science	NAS7-467	NASA-CR-72444	N_2O_4/N_2H_4	Photographic	Unlike Doublet	.025, .050, .100 in.	Atmos.	40-90°F	Developed a semi-empirical model in which separation is controlled by liquid phase mixing and kinetics, (D/V) and propellant temperature. A combustion "popping" regime was noted at lower temperatures and higher D/V values. Popping appeared to be caused by ignition within the entire impingement region of mixed liquid ligaments.
1969	Breen, Zung, Lawver, Kosvic & Coats	Dynamic Science	F04611-68-C-0040	AFRPL-TR-69-48	N_2O_4/N_2H_4 N_2O_4/MMH N_2O_4/A-50 ClF_5/N_2H_4	Photographic	Unlike Doublet Triplet	.025, .050, .150 Dia.	15-500 PSI	40-120 °F	Separation limits were defined for N_2O_4/N_2H_4 experimentally which were correlated with the liquid phase reaction chemical kinetics. Stream separation was observed to be independent of chamber pressure. Separation limits were observed at higher temperatures with N_2O_4/A-50 and N_2O_4/MMH as compared with the N_2O_4/N_2H_4 system. ClF_5/N_2H_4 always exhibited stream separation "Popping" was postulated to be a function of element mixing level as well as (D/V) and propellant temperature.

TABLE I (cont.)

DATE	INVESTIGATORS	ORGAN.	CONTRACT NO.	REFERENCE	PROPELLANTS	SENSING TECHNIQUES	ELEMENT TYPES	ELEMENT SIZE	PC RANGE	TEMP. RANGE	COMMENTS
1969	Rupe, Dipprey, Kushida, & Clayton	JPL	NAS7-100	CPIA Publ. No. 192	N_2O_4/A-50	Pc Measurement	Unlike Doublet	.142 & .073 Dia.	120 PSIA	30-105°F	Postulated that unlike doublet streams with equal stagnation pressure result in unstable operation or "pop" Correlation was demonstrated when a single element in an injector containing 72 elements was designed to operate at the unity pressure ratio. Pop free operation was attained without the element; 8 pops/second were obtained with the element.
1969	Houseman	JPL	NAS7-100	CPIA Publ. No. 192	N_2O_4/N_2H_4	Mass Spectrometer & C* Performance	Unlike Doublet	.020, .029, .073 Dia.	75-185 PSIA	40°F	Showed experimentally that jet mixing of hypergolic fluids can result in either penetrated, mixed, or separated regimes while operating at optimum cold flow mixing conditions.
1969	Lawver	ALRC	NAS9-8285	ALRC TCER 9642:0106	N_2O_4/A-50	Photographic & Pc and Accelerometer measurements	Unlike Doublet (Apollo IOS)	21.5 lbf/ele	100 PSIA	Ambient	Developed semi-empirical model in which "popping" is the result of spray detonation which is triggered by a blastwave generated by small explosions associated with hypergolic stream impingement. High speed movie of a single doublet element impinging N_2O_4 and A-50 verified the cyclic separation or "popping" which could provide the trigger source. Model showed three conditions must be met for the occurrence of engine popping; (1) stream impingement process must produce triggers, (2) element spacing must provide for coupling of the trigger explosion, and (3) element mixing efficiency must be adequate to promote "pop". Pop criteria were developed using data from LEM, SPS, SPS IOS, and JPL engines.

TABLE I (cont.)

DATE	INVESTIGATORS	ORGAN.	CONTRACT NO.	REFERENCE	PROPELLANTS	SENSING TECHNIQUES	ELEMENT TYPES	ELEMENT SIZE	PC RANGE	TEMP. RANGE	COMMENTS
1970	Rodriguez and Axworthy	Rocket-dyne	NAS7-739	NASA-CR-115863	N_2O_4/N_2H_4 N_2O_4/MMH N_2O_4/UDMH	Calorimetric & PVT measurements	Unlike Doublet	.028 Dia.	Atmos.	50°F	Experimentally measured the heat and gas release rates from hypergolic propellants reacting in the liquid phase. The reactivity with N_2O_4 was found to increase from hydrazine to UDMH to MMH.
1970	Clayton	JPL	NAS7-100	JPL TR-32-1479	N_2O_4/A-50 N_2O_4/Furfuryl alcohol	Pc Measurement	Unlike Doublet	.042 & .073 Dia.	120-300 PSIA	40-100°F	Provides popping data from 130 tests with a 18 in. dia engine which was fired in a cylindrical and annular configuration. Separate flow control permitted changes in the relative boundary, outer core, and inner core, elements flow conditions. Concludes that impingement stream stagnation dynamics are significant in engine "popping". Equal dynamic pressure maximizes the tendency to produce pops. Popping occurrence and frequency was temperature sensitive. No pops were obtained at Pc = 300 psia and reduced popping was noted with furfuryl alcohol.
1970	Lee & Houseman	JPL	NAS7-100	Paper presented at West. States Comb. Inst. Meeting Oct. 1970	N_2O_4/N_2H_4 N_2O_4/MMH N_2O_4/UDMH	Pc Meas. & Photographic	Unlike Doublet	.073, .100, & .173 Dia.	Atmos. to 450 PSIA	40-140°F	Presented experimental data and correlations which show that Pc, D_j, and V_j are controlling parameters for "popping" with high pressure or low contact time (D/V) eliminating pops. N_2H_4 and MMH exhibit similar popping trends, UDMH has relatively little tendency to pop. Popping rate noted to decrease with temperature and stagnation pressure ratio had only a small effect on popping rate.

TABLE I (cont.)

DATE	INVESTIGATORS	ORGAN.	CONTRACT NO.	REFERENCE	PROPELLANTS	SENSING TECHNIQUES	ELEMENT TYPES	ELEMENT SIZE	PC RANGE	TEMP. RANGE	COMMENTS
1971	Zung & White	Dynamic Science	NAS3-12031	NAS CR-1704	N_2O_4/N_2H_4	Photographic & Chamber Pressure Measurement	Unlike Doublet	.027, .040, .055, & .060 Dia.	15-500 PSIA	40-140 °F	Presents results from nearly 500 tests with variation in temp. Pc, and D_j. Empirically determined operating regimes for "popping", stream mixing, and stream separation. The occurrence of popping was found to be chamber pressure and orifice size dependent; occuring at low Pc and Large D_j and absent at high Pc (>185 psia) and/or small D_j. Identified two regimes of separated flow; one at low pressures and N_2O_4 temperatures above the boiling point resulting in significant N_2O_4 vaporization prior to impingement and one at high pressures with conventional liquid-liquid impingement. Mixed flow was observed at low pressures (<230 psi) and temperatures below the N_2O_4 boiling point.
1971	Nurick & Cordill	Rocketdyne	NAS7-720	NASA-CR-119246	N_2O_4/N_2H_4 N_2O_4/A-50 IRFNA/UDMH ClF_5/N_2H_4	Photographic	Unlike Doublet	.030, .072, & .173 Dia.	Atmos. & 200 PSIA	-10 to 80°F	Observed cyclic blowapart ("popping") with N_2O_4/N_2H_4 (most violent), N_2O_4/A-50 and IRFNA/UDMH (least violent). Operating conditions reduced both the strength and frequency of "popping", decreasing with decreasing D_j and increasing V_j, chamber pressure (to 200 PSIA) had little effect of "popping". Dynamic pressure ratio (0.9-1.5) produced some variation in the popping frequency. No continuous stream separation noted with N_2O_4, but continuous stream separation was observed with ClF_5/N_2H_4 at all conditions except small D_j and high dynamic pressure ratio.

TABLE I (cont.)

DATE	INVESTIGATORS	ORGAN.	CONTRACT NO.	REFERENCE	PROPELLANTS	SENSING TECHNIQUES	ELEMENT TYPES	ELEMENT SIZE	PC RANGE	TEMP. RANGE	COMMENTS
1973	OMS Program	ALRC	In-House	-	N_2O_4/MMH N_2O_4/A-50	Performance Measurement (Isp &C*)	Unlike Doublet	D_O=.033, D_F=.028; D_O=.031, D_F=.028; D_O=.024, D_F=.020	125-150 PSIA	40-250°F Fuel Ambient Oxidizer	Subscale (1000 lbf) and fullscale (6000 lbf) OMS injectors demonstrated decreasing performance with increasing fuel temperature. Performance data showed a continuously decreasing performance efficiency with increasing fuel temperature. Performance decrease is lessened with increasing chamber length (4-12 in.). A-50 data showed slight increase in efficiency to 100°F then continuously decreasing efficiency.
1973	OMS Program	Rocketdyne	NAS9-12802	ASR73-27	N_2O_4/MMH	Performance Measurement (C*)	Like-on-Like Doublet	D_O=.026, D_F=.024	100-140 PSIA	80-250°F Fuel Ambient Oxidizer	Single element testing with a 3.9 inch chamber showed continuous C* efficiency decrease with increasing fuel temperature for all elements tested. No performance change noted with full scale OMS injector tested with long chambers (12-20 in.)
1973	OMS Program	Bell Aero-Space Co.	NAS9-12803	Data Dump	N_2O_4/MMH	Performance Measurement (C*)	F-O-F Triplet	D_O=.05, D_F=.03	125 PSIA	40-200°F Fuel Ambient Oxidizer	C* efficiency decrease of 1/2-1% as fuel temperature increased from ambient to 200°F.
1973	OMS Program	ALRC	In-House	-	N_2O_4/MMH	Performance & Pc Measurement	Like-On-Like Doublet	D_O=.027, D_F=.025	110-140 PSIA	50-210°F Fuel Ambient Oxidizer	Full scale OMS injector showed slight decrease (0.1%) in performance efficiency from ambient to hot fuel with long chamber (16 in.). Axial Pc measurements indicate lower combustion near injector with hot fuel which is nearly damped at the end of the combustion chamber.

TABLE II

POP STUDY PARAMETER SUMMARY

PARAMETER	RANGE INCLUDED IN STUDIES
Propellant Combination	N_2O_4/N_2H_4, N_2O_4/MMH, N_2O_4/A-50, N_2O_4/UDMH, N_2O_4/M-50, N_2O_4/Furfuryl Alcohol, IRFNA/UDMH, ClF_5/N_2H_4
Element Type	Unlike Doublet, Like Doublet, Quadlet, F-O-F and O-F-O Triplets
Element Size	.020 to .236 in. Dia.
Element Mixing Efficiency	0.1 to 1.0
Element Spacing	Not Specified
Injection Velocity	5 to 145 ft/sec
Chamber Pressure	Atmospheric to 500 psia
Fuel Temperature	40 to 250°F
Oxidizer Temperature	-10 to 140°F
Mixture Ratio	0.5 to 3.0
Stream Dynamic Pressure Ratio	0.3 to 8.0 Fuel/Oxidizer

TABLE III

COMPARISON OF HEAT RELEASE RATES AND VAPOR PRESSURE

Fuel	P_V(psia) at 100°F	Heat Release Rate Kcal/sec-mole of NTO
N_2H_4	0.65	4×10^4
UDMH	11.0	14×10^4
MMH	2.1	20×10^4

TABLE IV

EXPECTED HIGH PRESSURE SEPARATION LIMITS

Fuel	Separation Limit (psia)
N_2H_4	300 (measured)
MMH	400
A-50	500
UDMH	700

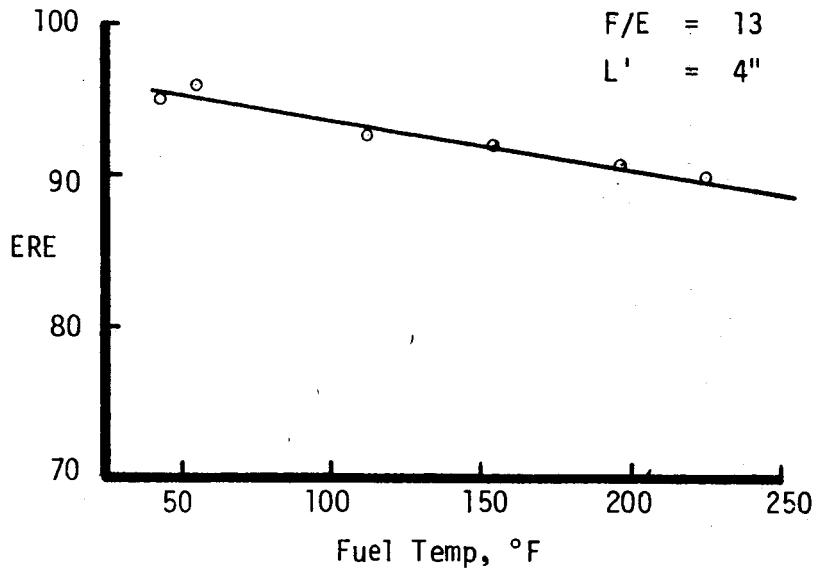


Figure 1. Effect of Fuel Temperature on ERE

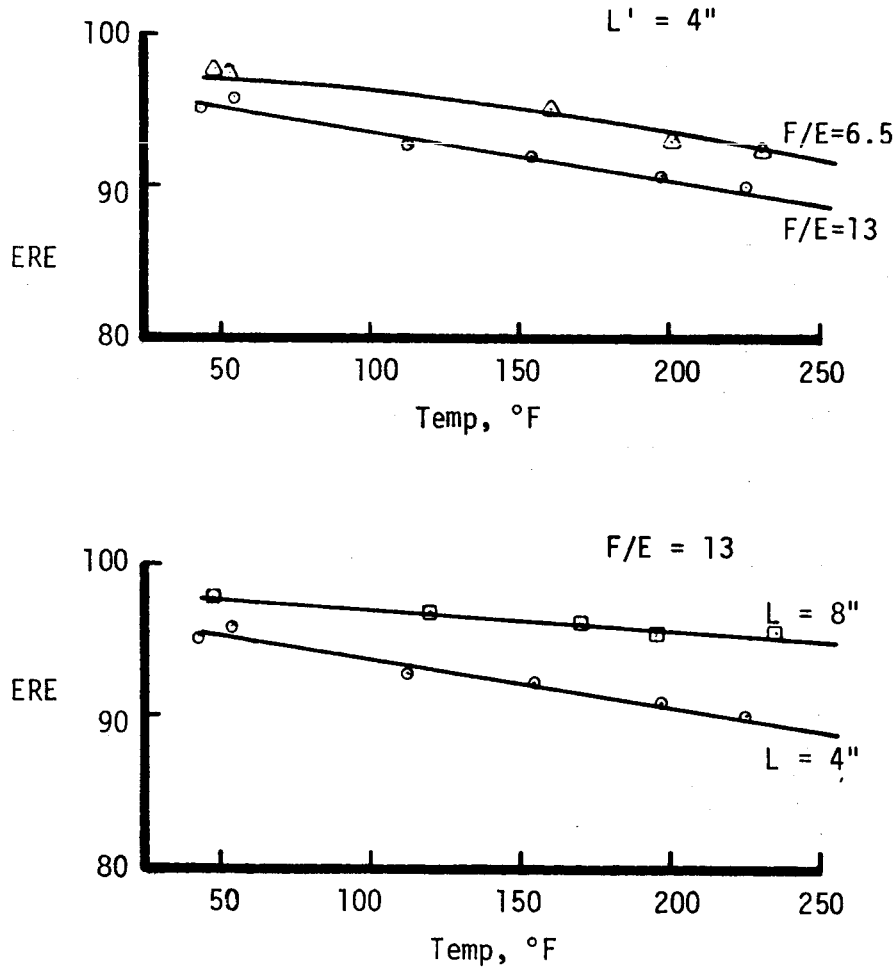


Figure 2. Effect of F/E and Chamber Length on ERE

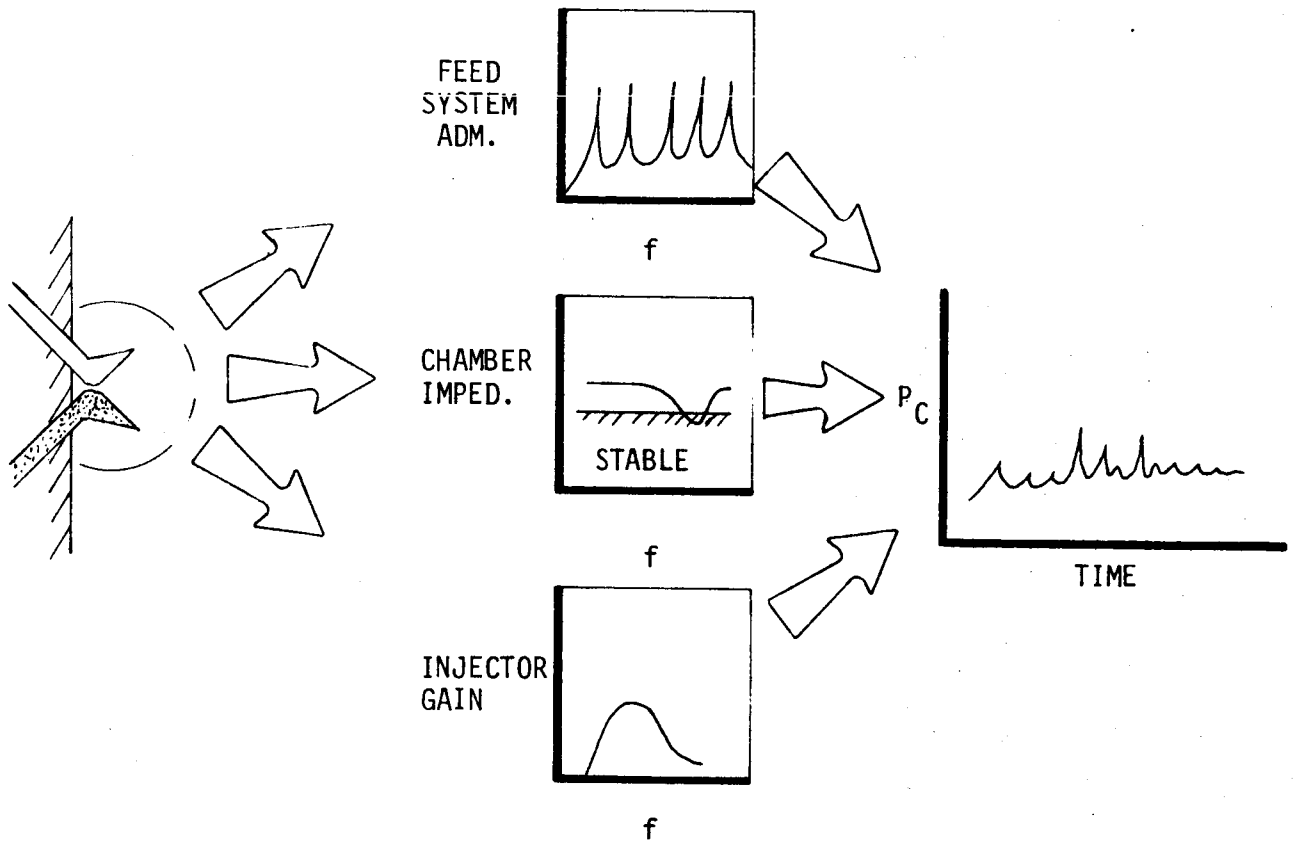
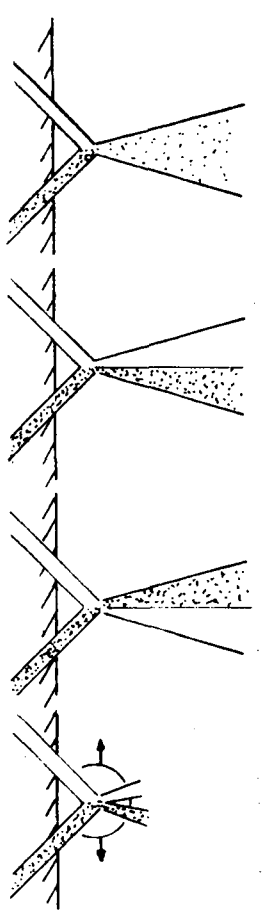


Figure 3. Effect of Pops on Stability



- MIXED - Injection process results in uniform mixture of fuel and oxidizer and high combustion efficiency.

- SEPARATED - Injection process results in the separation of fuel and oxidizer before mixing with the propellants remaining in their respective side of the element. Results in a low combustion efficiency which will improve to some degree with increasing chamber length.

- PENETRATED - Injection process results in the penetration of the fuel and oxidizer with propellants unmixed on the opposite side of the element. Same effect on combustion efficiency as separated flow regime.

- POPPING - Cyclic blowapart of a single element or the spray detonation of a large group of elements. Random occurrence which could lower the overall time averaged combustion efficiency and effect combustion stability.

Figure 4. Reactive Stream Impingement Regime

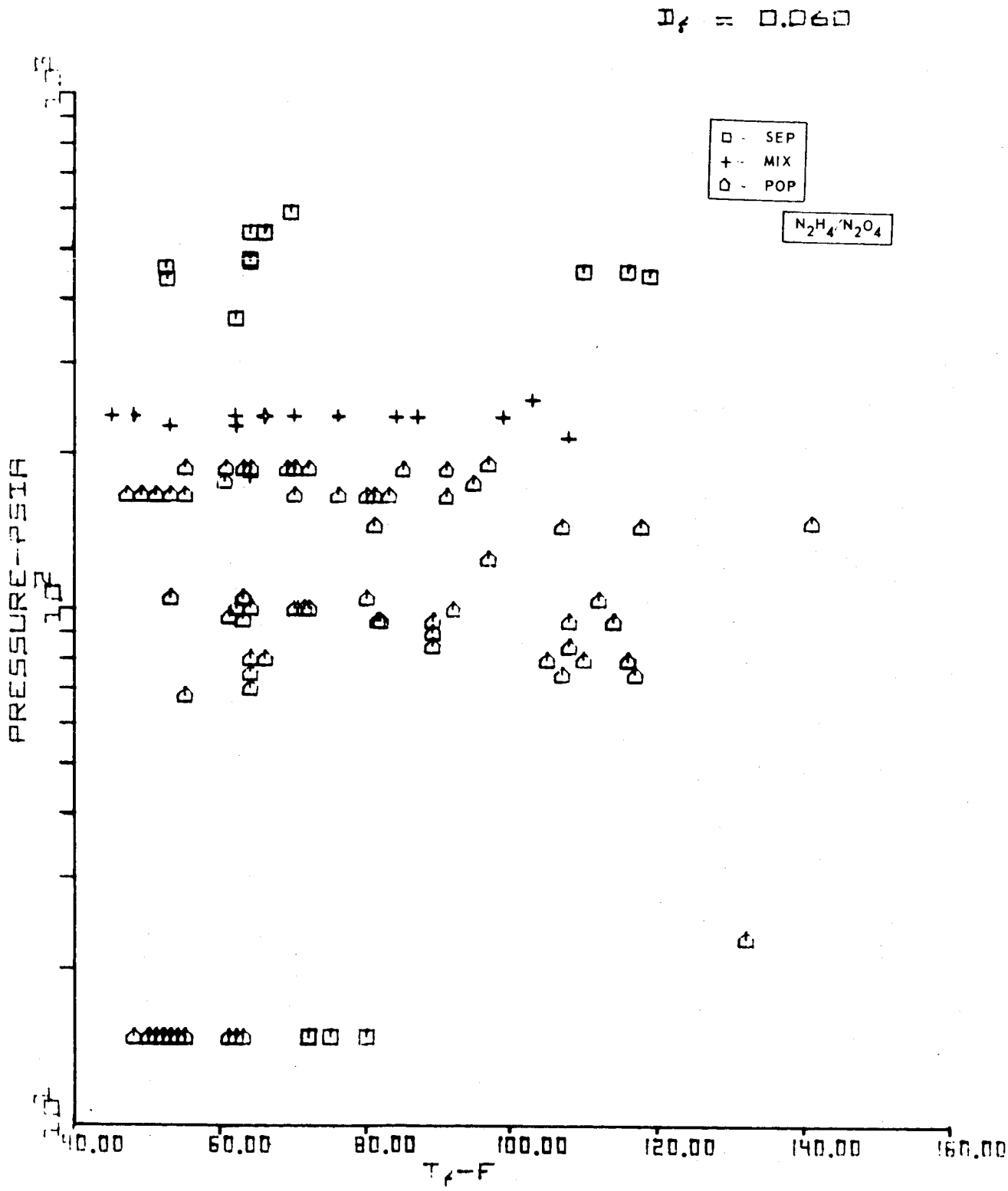


Figure 5. RSS Computer Data Plot

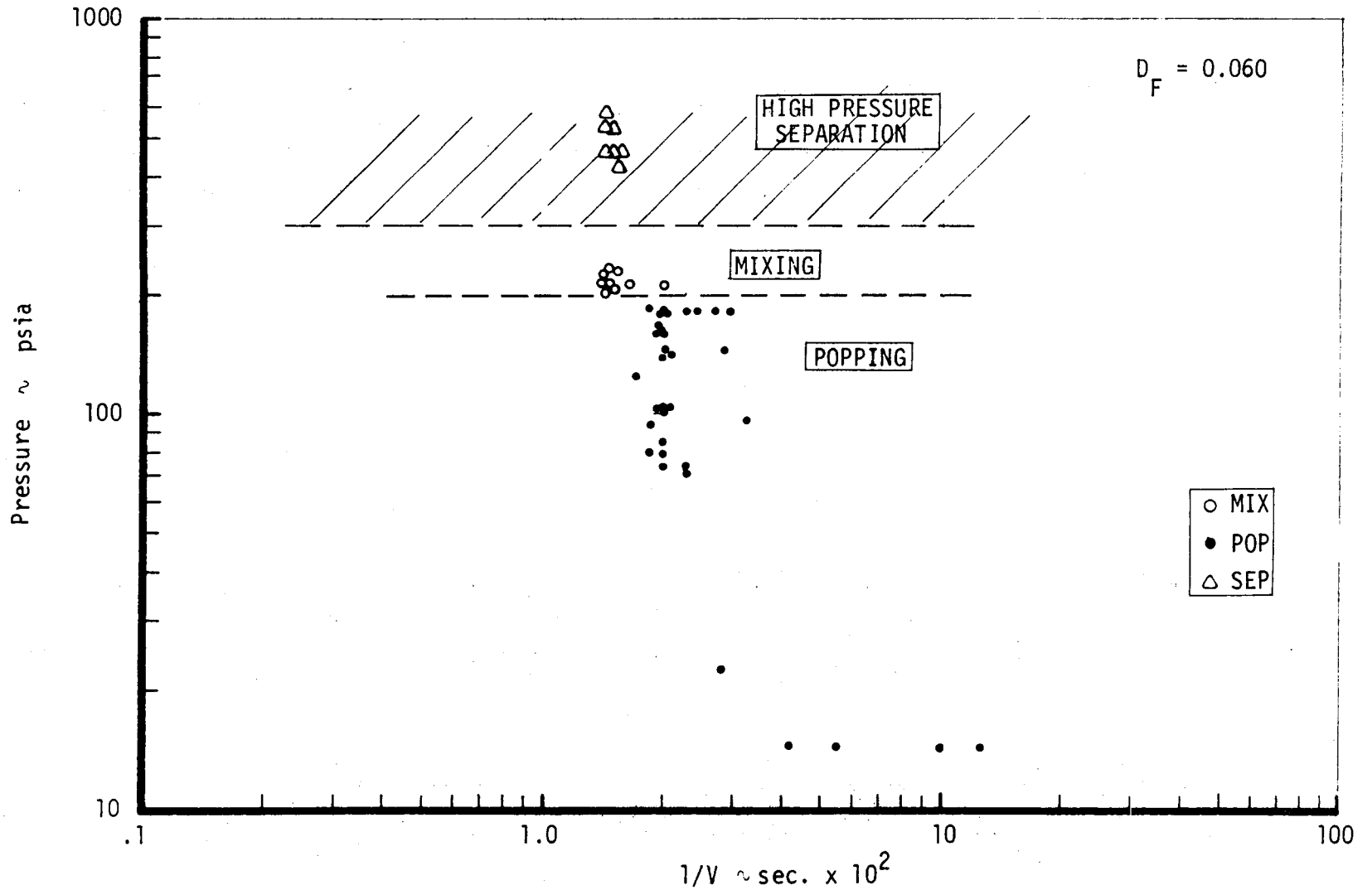


Figure 6. Pressure vs $1/V_f$-D_f = 0.060

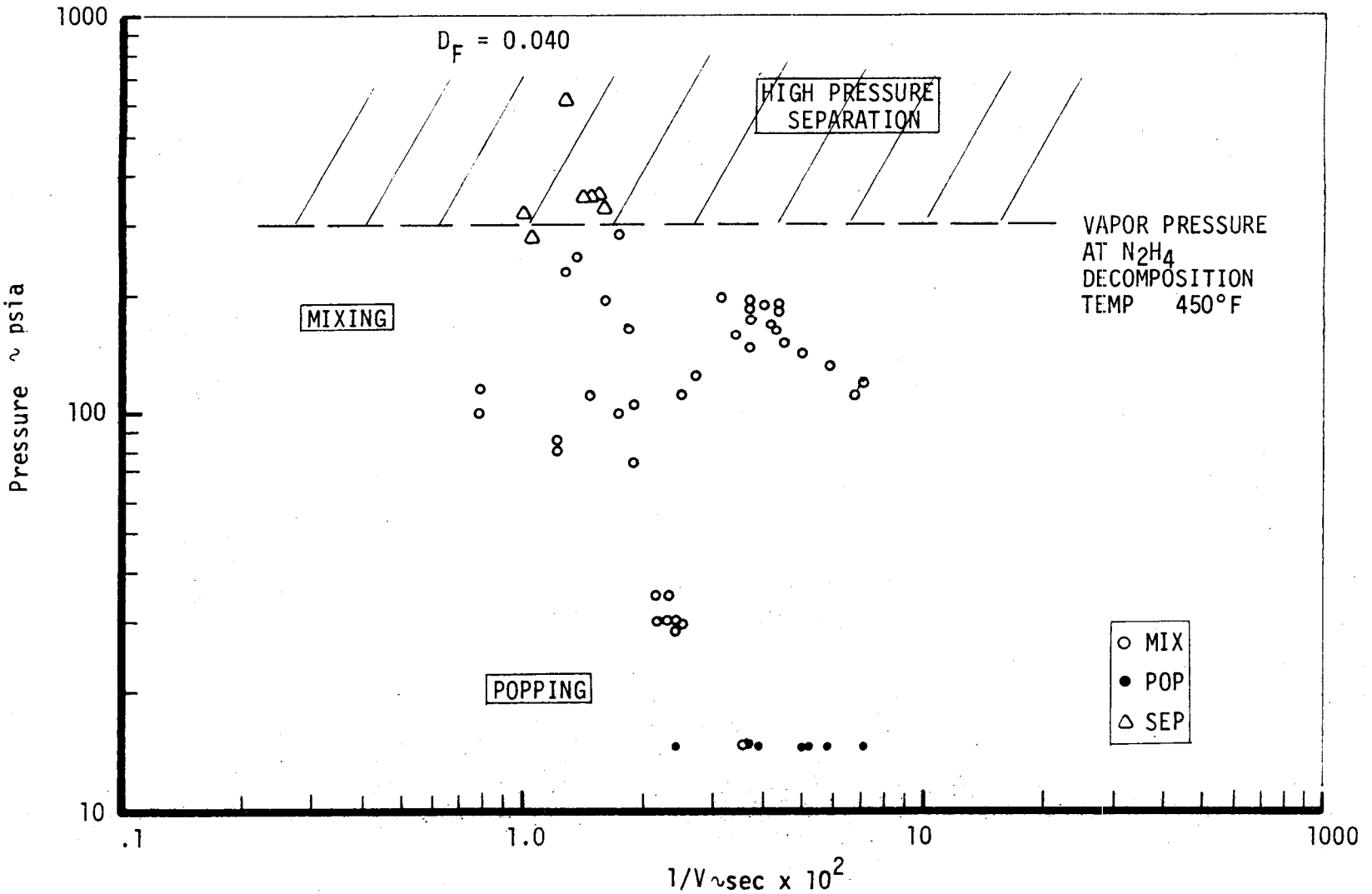


Figure 7. Pressure vs $1/V_f$-D_f = 0.040

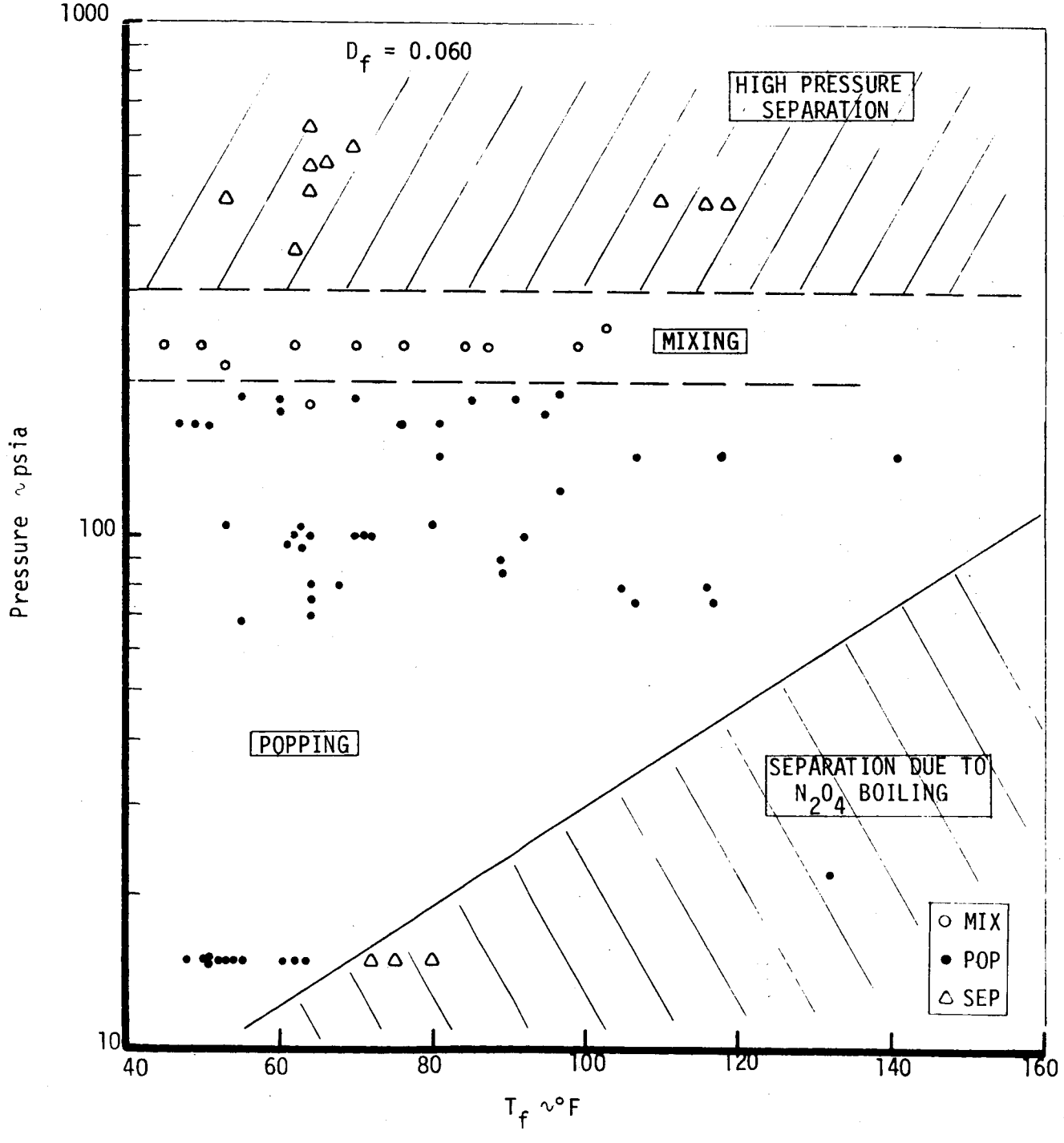


Figure 8. Pressure vs Temperature - D_f = 0.060

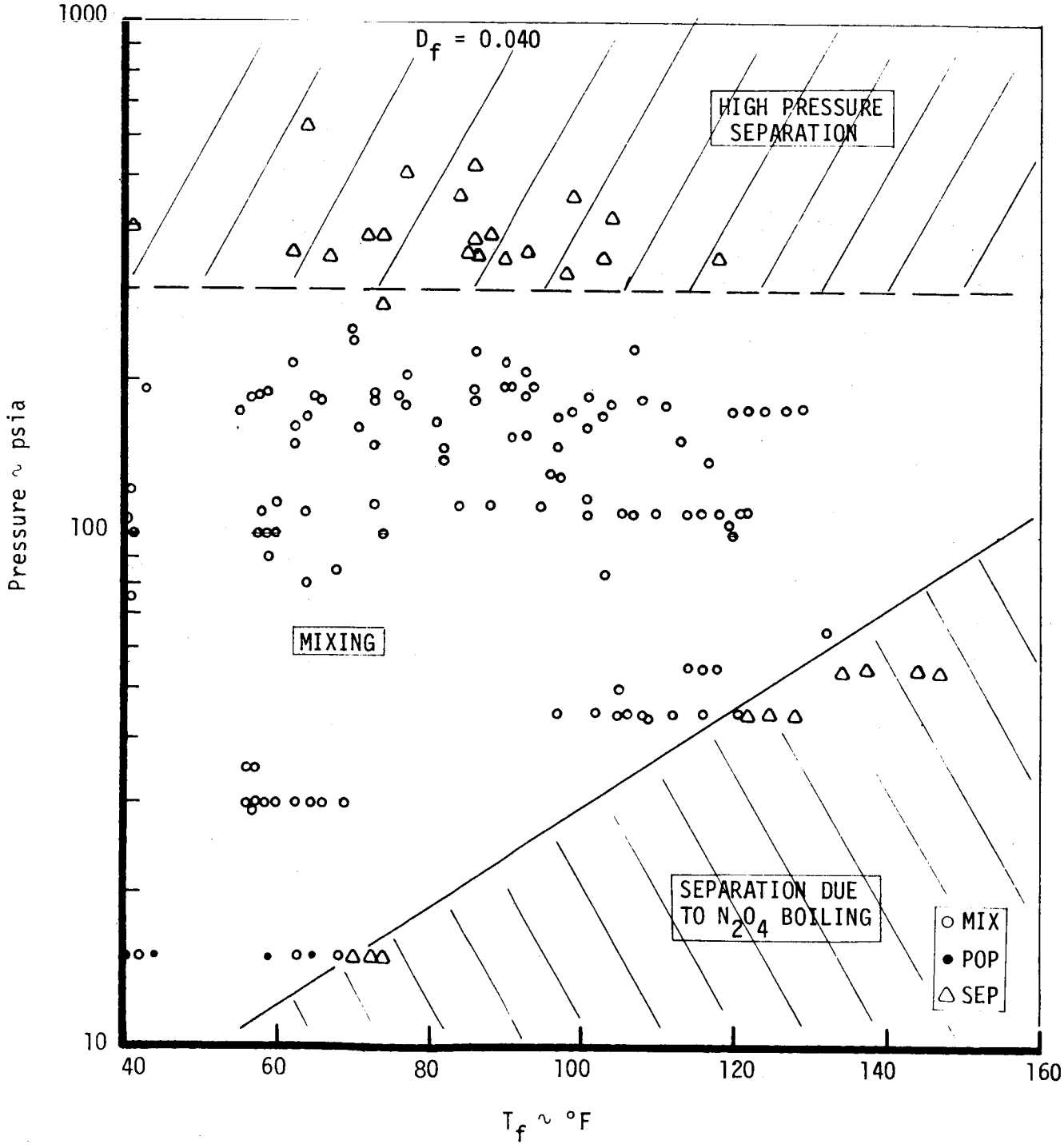


Figure 9. Pressure vs Temperature - D_f = 0.040

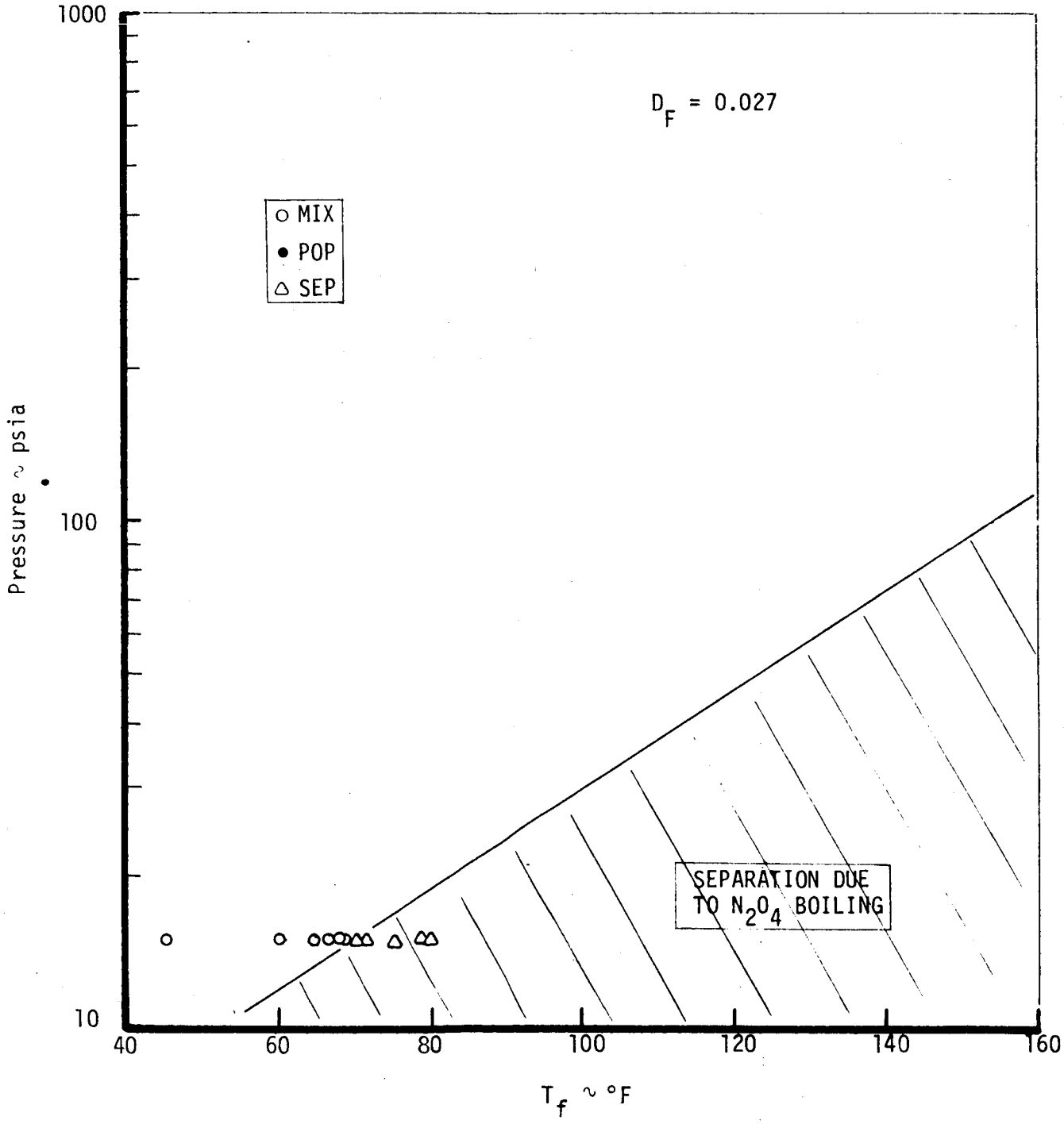


Figure 10. Pressure vs Temperature - D_f = 0.027

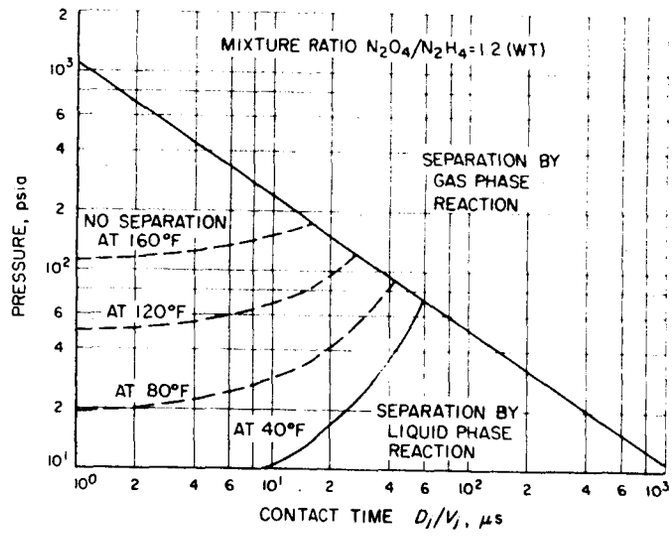


Figure 11. Predicted RSS Limits - JPL Model

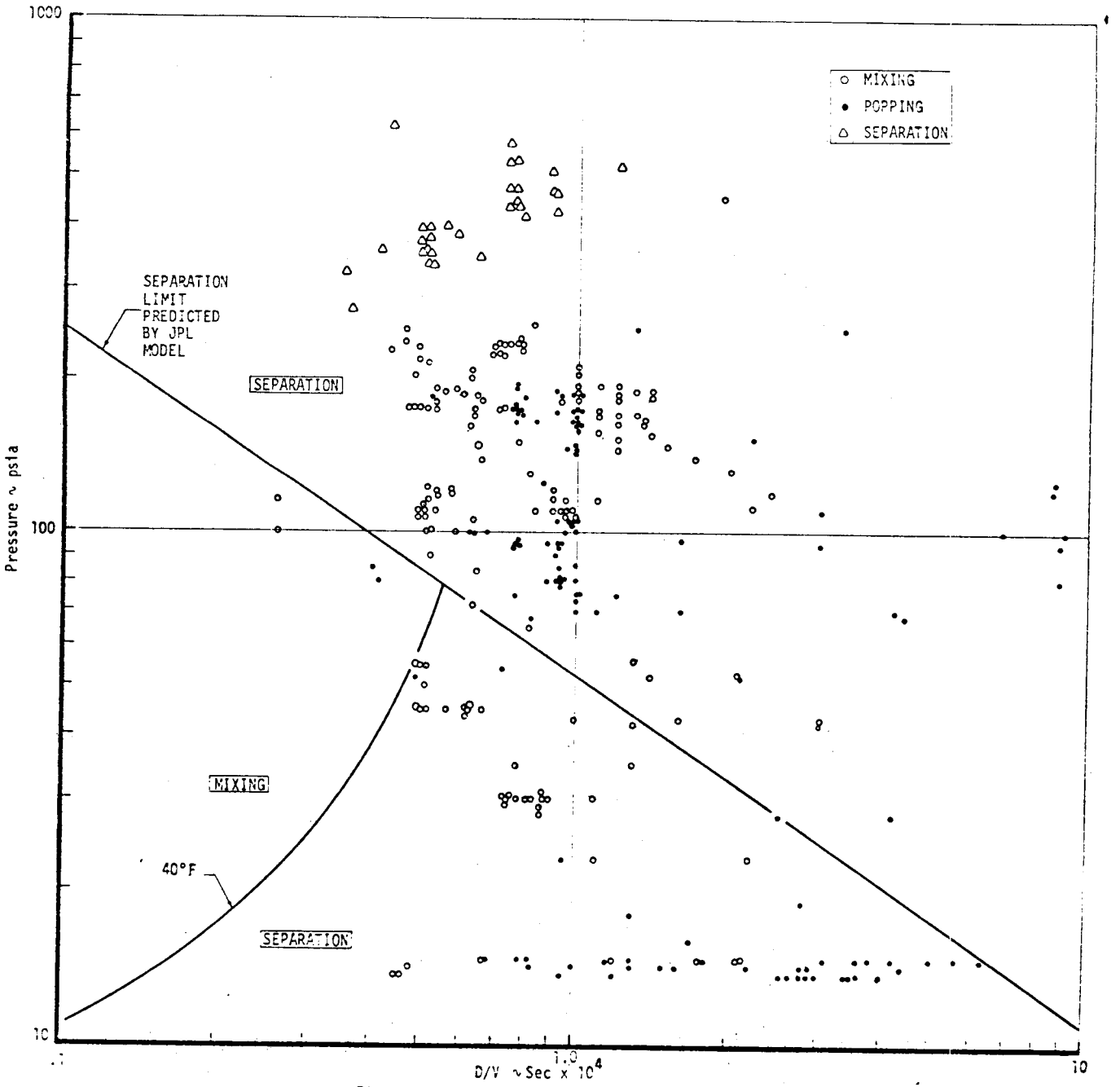


Figure 12. RSS Data Correlation - JPL Model

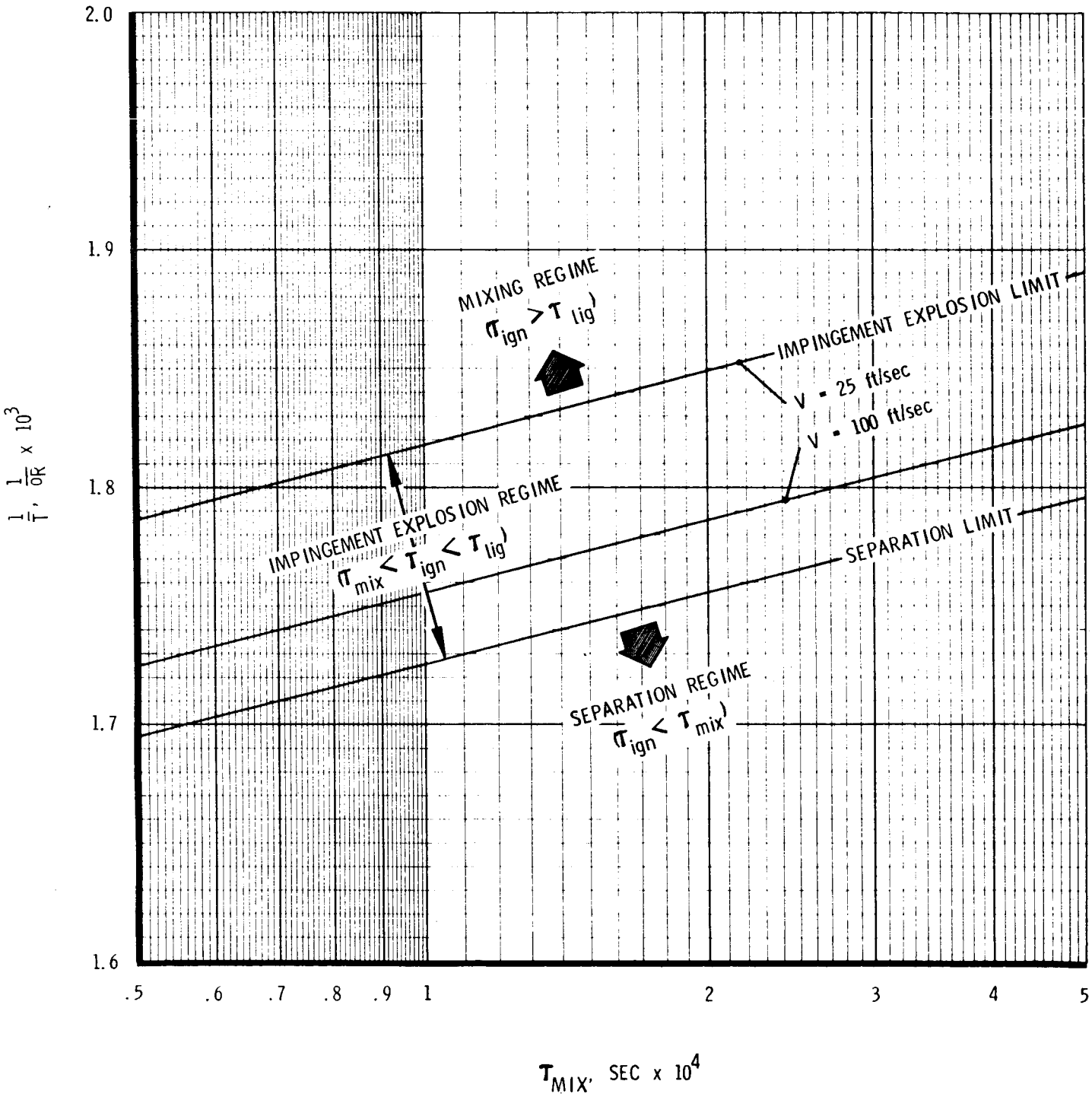


Figure 13. Predicted RSS and Pop Limits - ALRC Model

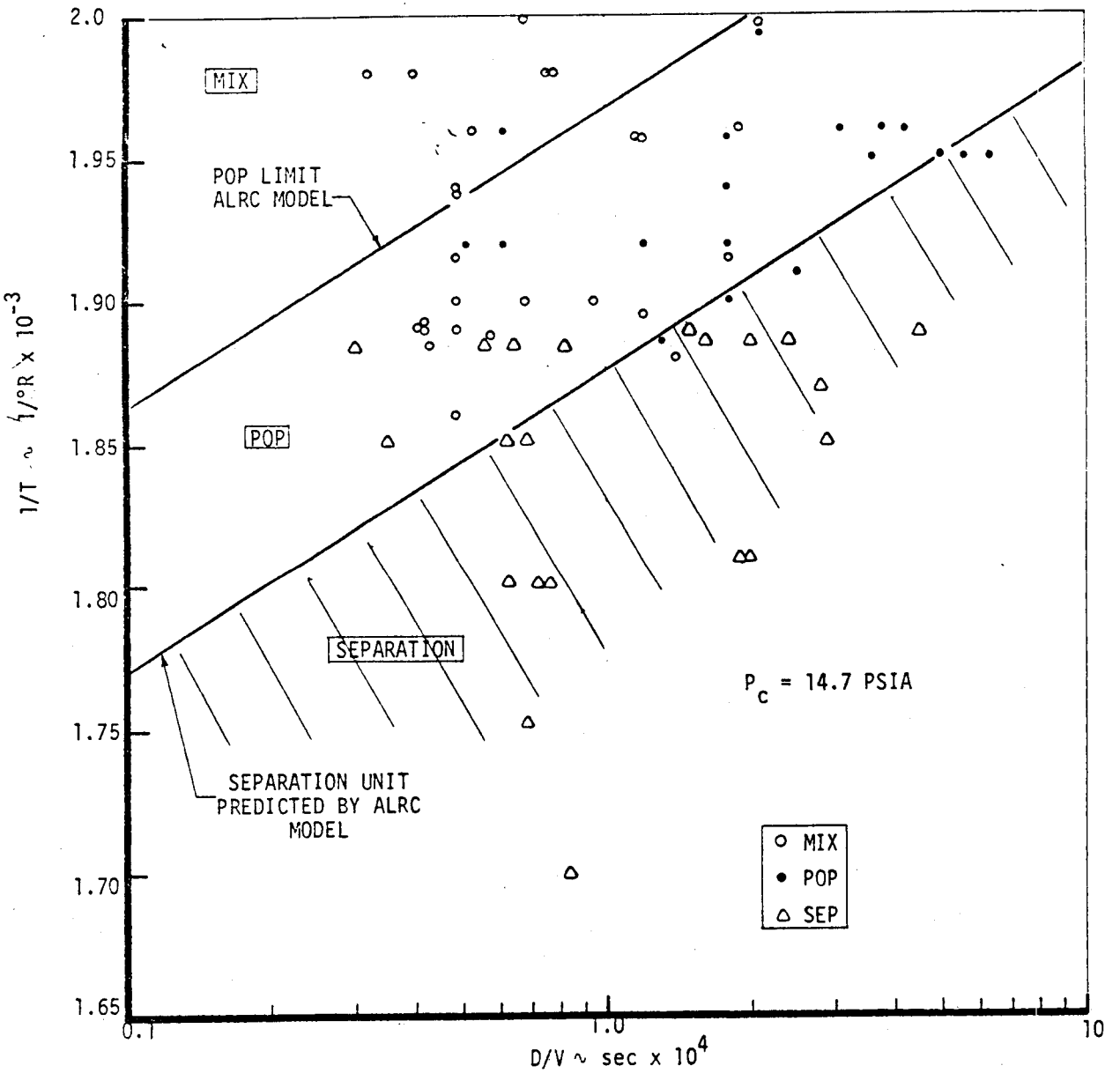


Figure 14. RSS and Pop Data Correlations - ALRC Model

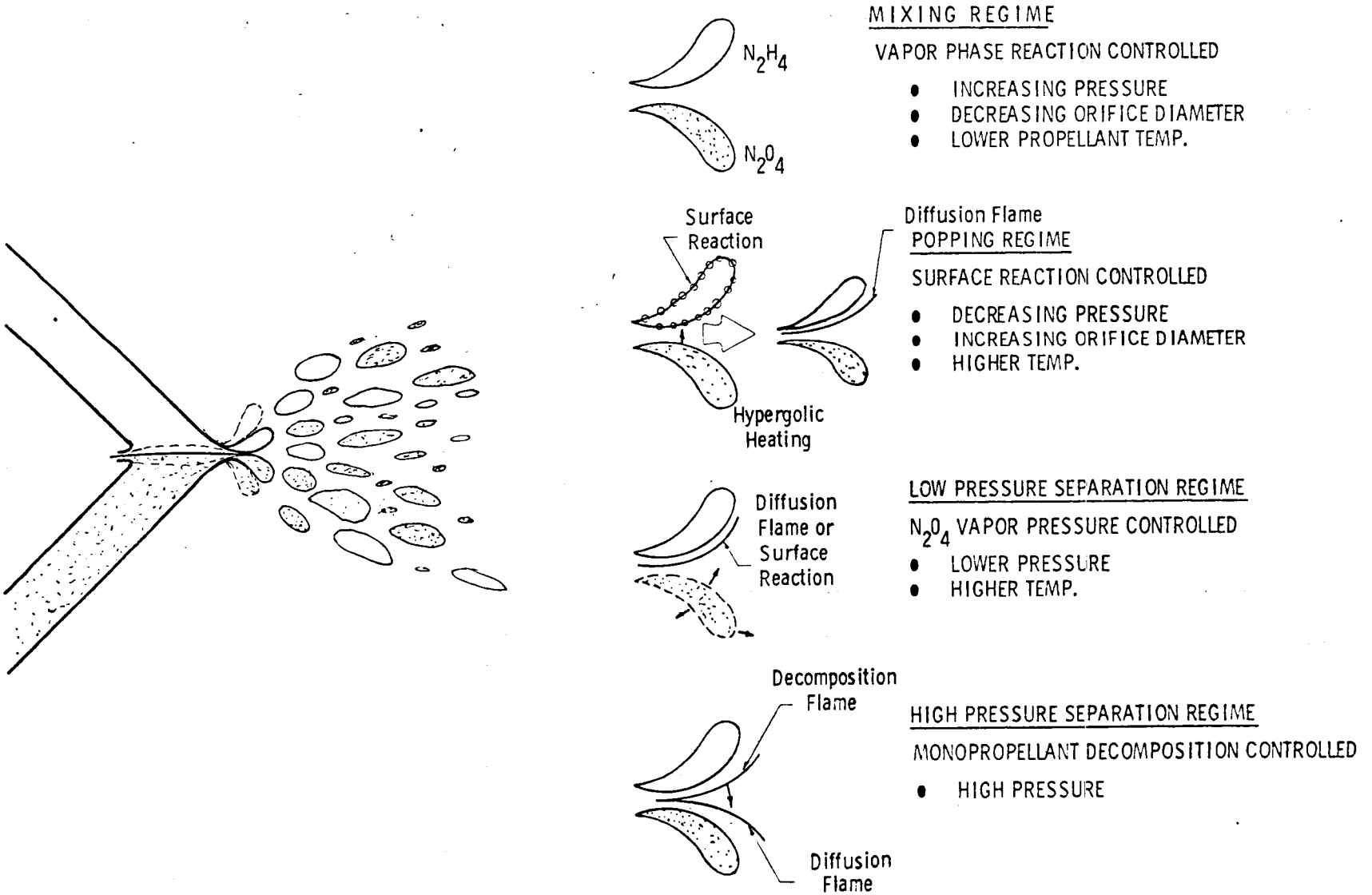
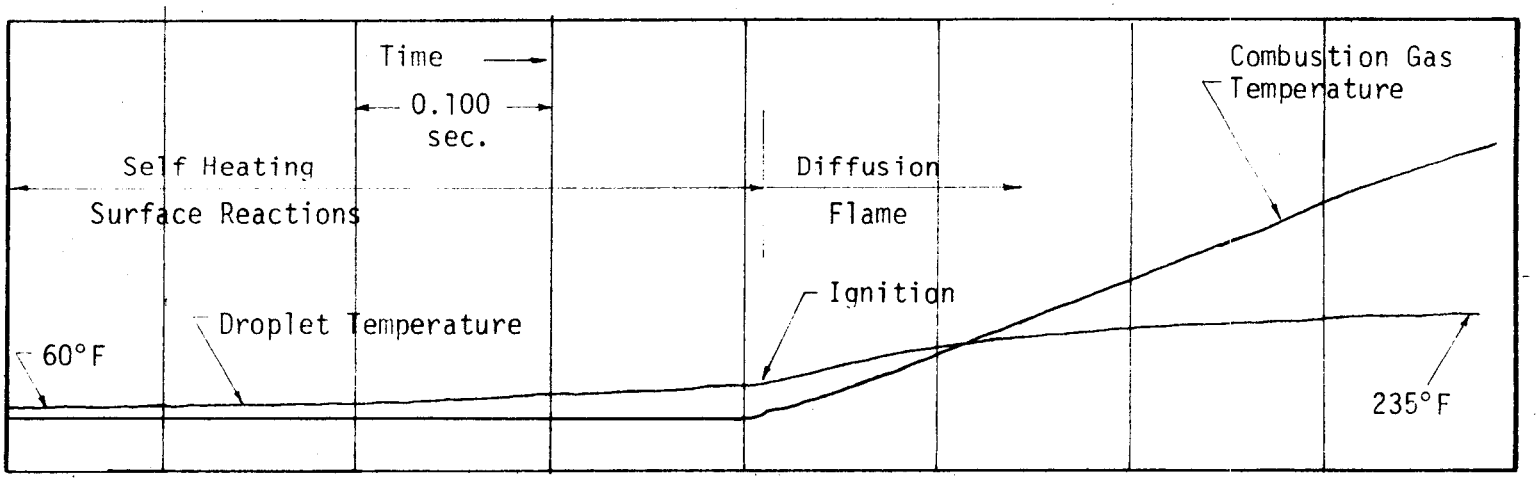


Figure 15. RSS and Pop Controlling Mechanisms

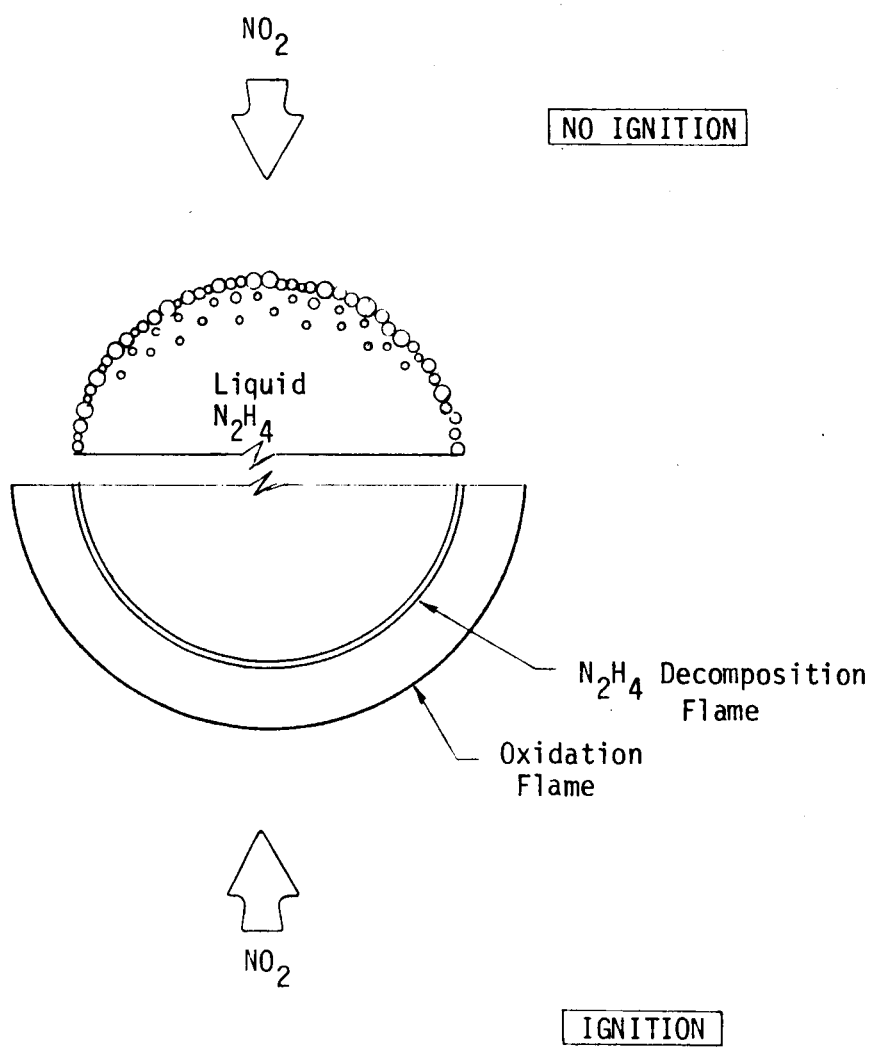


DROPLET TEMPERATURE HISTORY FOR N_2H_4

Figure 16. N_2H_4 Droplet Temperature History

Surface Reactions

$$4NO_2 + 4\ N_2H_4 \longrightarrow 2\ N_2O + NO + 2.5\ N_2 + 2H_2O + 4H_2 + NH_4NO_3$$



Vapor Phase Reactions

$$2NO_2 + 2N_2H_4 \longrightarrow 3N_2 + 4H_2O$$

Figure 17. Hypergolic Ignition Process

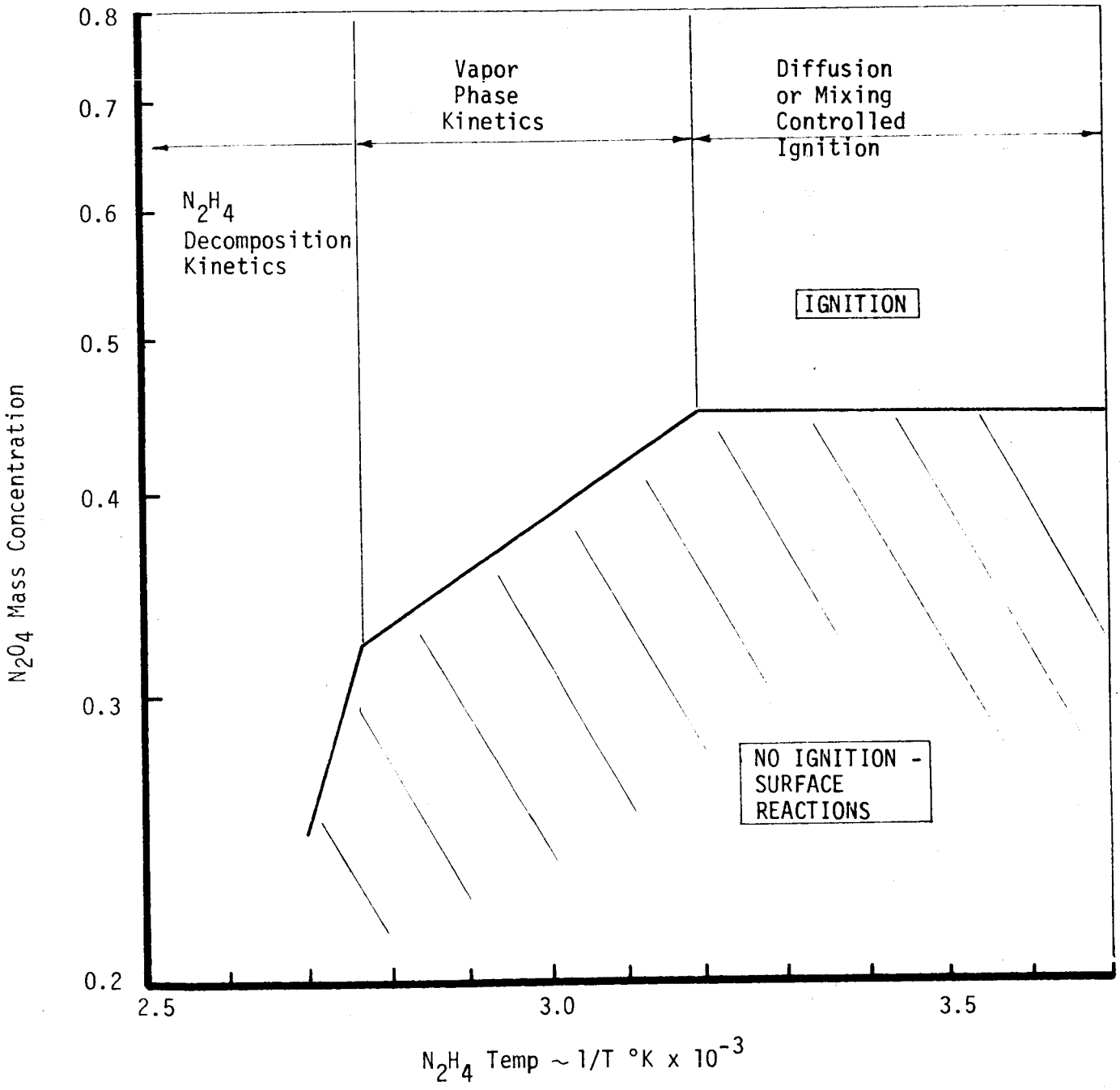


Figure 18. N_2H_4/N_2O_4 Ignition Limits

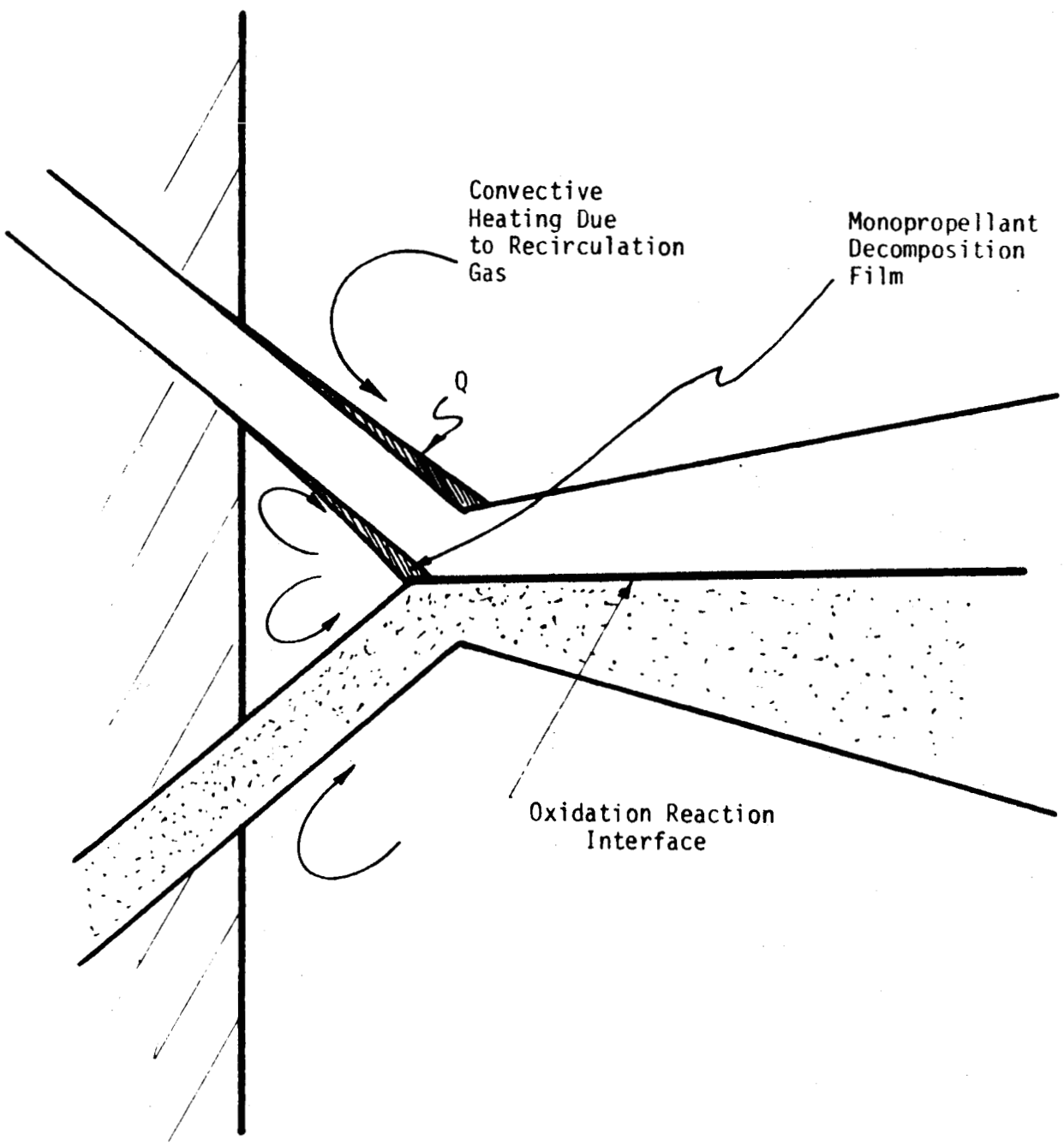


Figure 19. High Pressure Separation Model

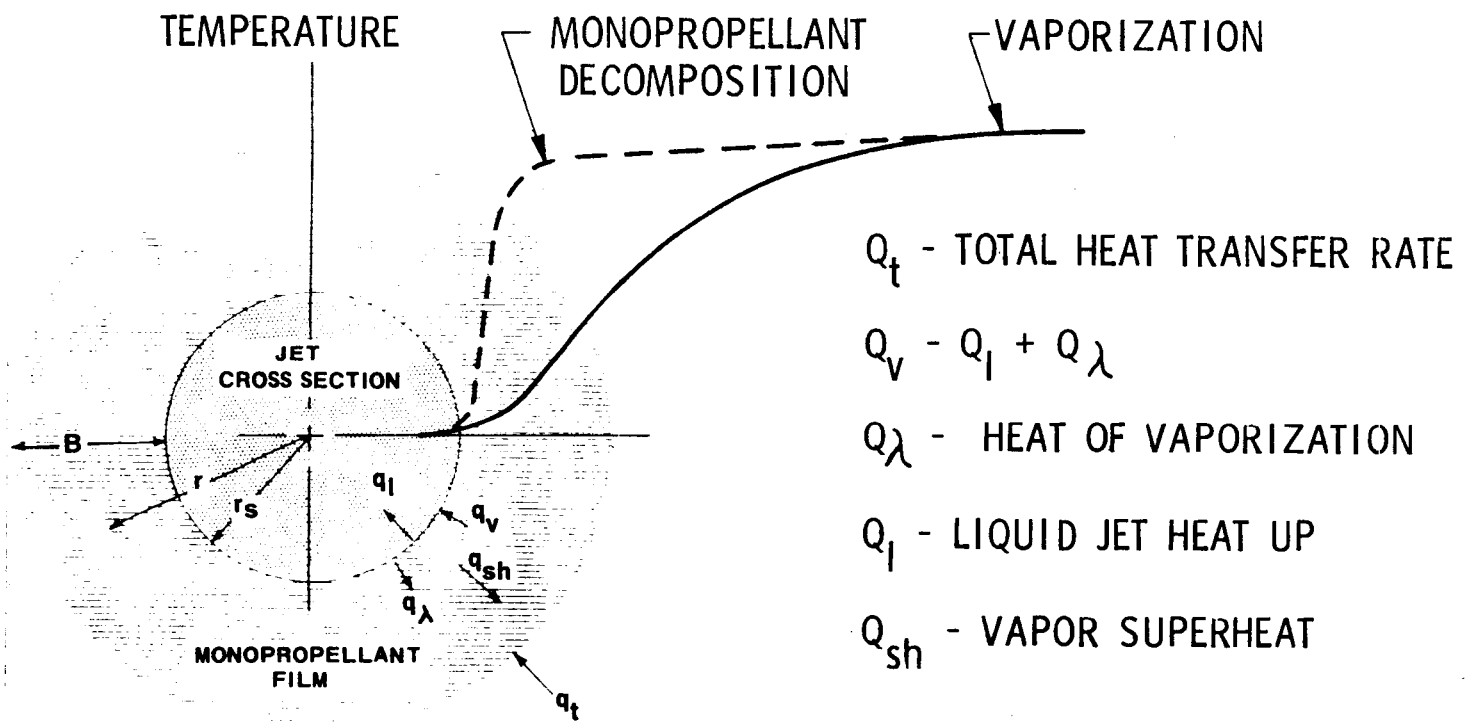


Figure 20. Heat and Mass Transfer Model

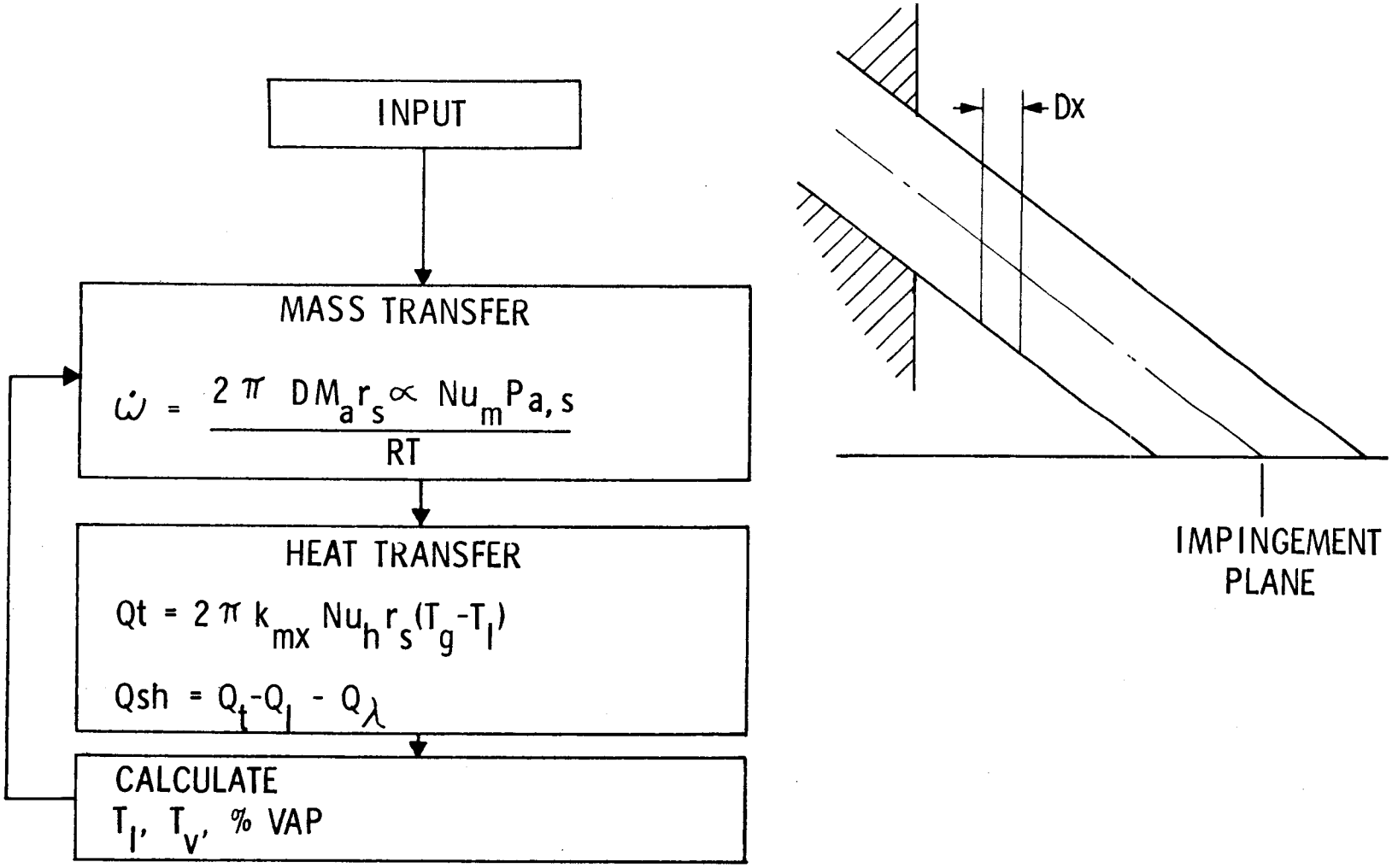


Figure 21. Model Calculational Procedure

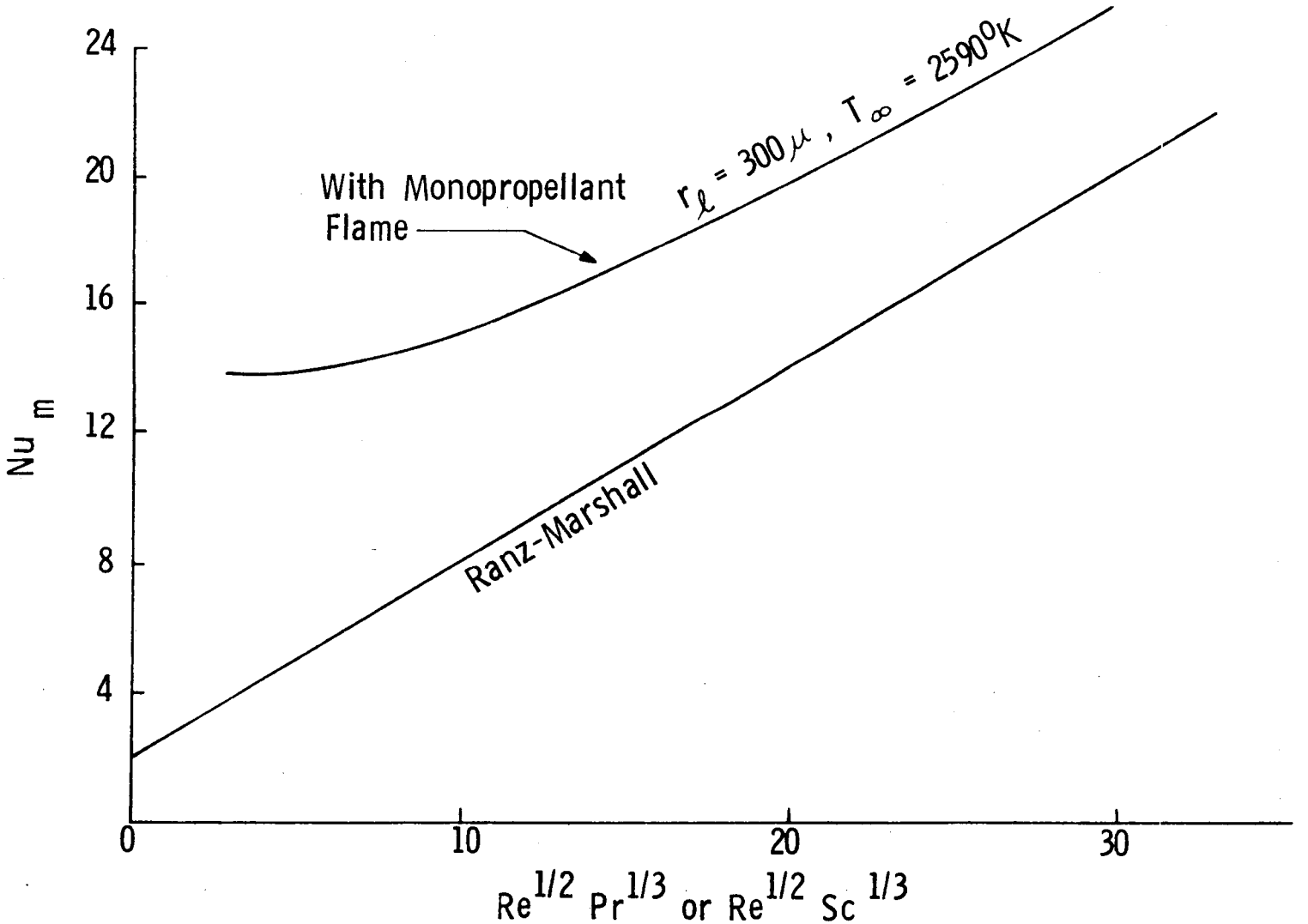


Figure 22. Nusselet Number Correlations

APPENDIX A

COMPUTER LISTINGS AND DATA SUMMARIES

HYPERGOLIC STREAM IMPINGMENT DATA COMPLIATION

INVESTIGATOR NURICK

A L R C MODEL CORRELATION PARAMETERS

FUEL TYPE	TEST NO.	DO (IN)	DF (IN)	L/D	IMP ANGLE (DEG)	PC (PSIA)	VO (FT/S)	VF (FT/S)	TO (F)	TF (F)	MR	MF/MO	COMMENTS	*	PD	IS	R (IN)	EM	SPR	DV (SEC)
N2H4	9	.173	.173	100.	45.	13.7	33.0	43.0	55.0	60.0	.000	.860	POP	*	79.2	.115	3.560	.987	1.173	.34-03
N2H4	10	.173	.173	100.	45.	13.7	33.0	43.0	55.0	62.0	.000	.860	POP	*	79.2	.135	3.560	.988	1.172	.34-03
N2H4	11	.173	.173	100.	45.	13.7	33.0	41.0	55.0	58.0	.000	.910	POP	*	79.2	.103	3.560	.998	1.067	.35-03
N2H4	12	.173	.173	100.	45.	13.7	33.0	41.0	52.0	67.0	.000	.930	POP	*	79.2	.210	3.560	.998	1.060	.35-03
N2H4	13	.173	.173	100.	45.	13.7	30.0	36.0	55.0	55.0	.000	1.000	POP	*	79.2	.091	3.560	1.000	.997	.40-03
N2H4	14	.173	.173	100.	45.	13.7	30.0	36.0	55.0	55.0	.000	1.000	POP	*	79.2	.091	3.560	1.000	.997	.40-03
N2H4	15	.173	.173	100.	45.	13.7	30.0	40.0	55.0	55.0	.000	.850	POP	*	79.2	.082	3.560	.979	1.231	.36-03
N2H4	16	.173	.173	100.	45.	13.7	28.0	41.0	55.0	65.0	.000	.690	POP	*	79.2	.180	3.560	.927	1.477	.35-03
N2H4	17	.173	.173	100.	45.	13.7	28.0	43.0	55.0	65.0	.000	.630	POP	*	79.2	.171	3.560	.890	1.625	.34-03
N2H4	18	.173	.173	100.	45.	13.7	30.0	43.0	55.0	65.0	.000	.830	POP	*	79.2	.171	3.560	.942	1.416	.34-03
N2H4	19	.173	.173	100.	45.	13.7	32.0	43.0	55.0	65.0	.000	.880	POP	*	79.2	.171	3.560	.976	1.244	.34-03
N2H4	20	.173	.173	100.	45.	13.7	33.0	43.0	55.0	65.0	.000	.910	POP	*	79.2	.171	3.560	.988	1.170	.34-03
N2H4	21	.173	.173	100.	45.	13.7	33.0	43.0	55.0	65.0	.000	.910	POP	*	79.2	.171	3.560	.988	1.170	.34-03
N2H4	22	.072	.072	100.	60.	13.7	38.0	50.0	45.0	55.0	.000	.850	POP	*	190.3	.021	1.482	.985	1.189	.12-03
N2H4	23	.072	.072	100.	60.	13.7	51.0	63.0	45.0	55.0	.000	.940	POP	*	190.3	.017	1.482	.999	1.048	.95-04
N2H4	24	.030	.030	100.	60.	13.7	47.0	56.0	45.0	55.0	.000	1.000	MIX	*	456.7	.008	.617	1.000	.975	.45-04
N2H4	25	.030	.030	100.	60.	13.7	47.0	56.0	45.0	55.0	.000	1.000	MIX	*	456.7	.008	.617	1.000	.975	.45-04
N2H4	26	.030	.030	100.	60.	13.7	46.0	54.0	45.0	55.0	.000	1.030	MIX	*	456.7	.008	.617	.998	.946	.46-04
N2H4	27	.173	.173	100.	60.	13.7	41.6	56.2	40.0	40.0	.000	1.260	POP	*	79.2	.013	3.560	.974	1.257	.26-03
N2H4	28	.173	.173	100.	60.	13.7	40.3	51.9	40.0	40.0	.000	1.150	POP	*	79.2	.014	3.560	.991	1.142	.28-03
N2H4	29	.173	.173	100.	60.	13.7	40.5	51.9	40.0	40.0	.000	1.140	POP	*	79.2	.014	3.560	.992	1.131	.28-03
N2H4	30	.173	.173	100.	60.	13.7	42.3	48.5	40.0	40.0	.000	.900	POP	*	79.2	.015	3.560	.995	.905	.30-03
N2H4	32	.173	.173	100.	60.	13.7	41.3	50.1	40.0	40.0	.000	1.020	POP	*	79.2	.014	3.560	1.000	1.014	.29-03
N2H4	33	.173	.173	100.	60.	13.7	39.2	49.2	40.0	40.0	.000	1.090	POP	*	79.2	.014	3.560	.997	1.085	.29-03
A-50	44	.173	.173	100.	60.	13.7	38.0	52.0	40.0	50.0	.000	1.280	POP	*	79.2	.032	3.560	.990	1.151	.28-03
A-50	45	.173	.173	100.	60.	13.7	40.2	51.3	40.0	50.0	.000	1.040	POP	*	79.2	.032	3.560	1.000	1.001	.28-03
A-50	46	.173	.173	100.	60.	13.7	40.2	51.6	40.0	50.0	.000	1.050	POP	*	79.2	.032	3.560	1.000	1.012	.28-03
A-50	47	.173	.173	100.	60.	13.7	40.2	51.4	40.0	50.0	.000	1.040	POP	*	79.2	.032	3.560	1.000	1.005	.28-03
A-50	53	.173	.173	100.	60.	235.0	39.8	64.5	40.0	45.0	.000	1.500	POP	*	1358.4	.017	1.382	.892	1.617	.22-03
A-50	54	.173	.173	100.	60.	225.0	39.8	55.0	40.0	45.0	.000	1.100	POP	*	1300.6	.020	1.402	.987	1.176	.26-03
A-50	55	.173	.173	100.	60.	225.0	40.4	53.0	40.0	45.0	.000	.990	POP	*	1300.6	.021	1.402	.998	1.060	.27-03
A-50	56	.173	.173	100.	60.	220.0	40.4	52.0	40.0	45.0	.000	.960	POP	*	1271.7	.021	1.412	1.000	1.020	.28-03

HYPERGOLIC STREAM IMPINGMENT DATA COMPLIATION

INVESTIGATOR HOUSEMAN

A L R C MODEL CORRELATION PARAMETERS

FUEL TYPE	TEST NO.	DO (IN)	DF (IN)	L/D	IMP ANGLE (DEG)	PC (PSIA)	VO (FT/S)	VF (FT/S)	TO (F)	TF (F)	MR	MF/MO	COMMENTS	*	PD	IS	R (IN)	EM	SPR	DV (SEC)
N2H4	1	.073	.073	100.	45.	14.2	38.2	38.2	70.0	70.0	1.200	1.000	POP	*	194.5	.120	1.484	.937	.696	.16-03
N2H4	2	.073	.073	100.	45.	16.0	36.1	36.1	70.0	70.0	1.200	1.000	POP	*	219.2	.127	1.427	.937	.696	.17-03
N2H4	3	.073	.073	100.	45.	42.0	36.8	36.8	70.0	70.0	1.200	1.000	MIX	*	575.3	.125	1.035	.937	.696	.17-03
N2H4	4	.073	.073	100.	45.	14.2	46.3	46.3	70.0	70.0	1.200	1.000	POP	*	194.5	.099	1.484	.937	.696	.13-03
N2H4	5	.073	.073	100.	45.	18.0	45.1	45.1	70.0	70.0	1.200	1.000	POP	*	246.6	.102	1.372	.937	.696	.13-03
N2H4	6	.073	.073	100.	45.	56.0	46.3	46.3	70.0	70.0	1.200	1.000	MIX	*	767.1	.099	.940	.937	.696	.13-03
N2H4	7	.073	.073	100.	45.	14.2	58.2	58.2	70.0	70.0	1.200	1.000	POP	*	194.5	.079	1.484	.937	.696	.10-03
N2H4	8	.073	.073	100.	45.	23.0	55.9	55.9	70.0	70.0	1.200	1.000	MIX	*	315.1	.082	1.264	.937	.696	.11-03
N2H4	9	.073	.073	100.	45.	73.0	60.8	60.8	70.0	70.0	1.200	1.000	POP	*	1000.0	.076	.861	.937	.696	.10-03
N2H4	10	.073	.073	100.	45.	14.2	73.0	73.0	70.0	70.0	1.200	1.000	POP	*	194.5	.063	1.484	.937	.696	.83-04
N2H4	11	.073	.073	100.	45.	29.0	70.8	70.8	70.0	70.0	1.200	1.000	MIX	*	397.3	.065	1.170	.937	.696	.86-04
N2H4	12	.073	.073	100.	45.	14.2	127.8	127.8	70.0	70.0	1.200	1.000	MIX	*	194.5	.036	1.484	.937	.696	.48-04
N2H4	13	.073	.073	100.	45.	52.0	123.9	123.9	70.0	70.0	1.200	1.000	POP	*	712.3	.037	.964	.937	.696	.49-04
N2H4	14	.073	.073	100.	45.	120.0	115.2	115.2	70.0	70.0	1.200	1.000	MIX	*	1643.8	.040	.729	.937	.696	.53-04
N2H4	15	.100	.100	100.	45.	14.2	19.1	19.1	70.0	70.0	1.200	1.000	POP	*	142.0	.330	2.034	.937	.696	.44-03
N2H4	16	.100	.100	100.	45.	28.0	19.8	19.8	70.0	70.0	1.200	1.000	POP	*	280.0	.318	1.622	.937	.696	.42-03
N2H4	17	.100	.100	100.	45.	68.0	19.0	19.0	70.0	70.0	1.200	1.000	POP	*	680.0	.332	1.207	.937	.696	.44-03
N2H4	18	.100	.100	100.	45.	14.2	28.5	28.5	70.0	70.0	1.200	1.000	POP	*	142.0	.221	2.034	.937	.696	.29-03
N2H4	19	.100	.100	100.	45.	19.0	29.6	29.6	70.0	70.0	1.200	1.000	POP	*	190.0	.213	1.846	.937	.696	.28-03
N2H4	20	.100	.100	100.	45.	42.0	27.9	27.9	70.0	70.0	1.200	1.000	POP	*	420.0	.226	1.417	.937	.696	.30-03
N2H4	21	.100	.100	100.	45.	110.0	28.3	28.3	70.0	70.0	1.200	1.000	POP	*	1100.0	.223	1.028	.937	.696	.29-03
N2H4	22	.100	.100	100.	45.	14.2	37.3	37.3	70.0	70.0	1.200	1.000	POP	*	142.0	.169	2.034	.937	.696	.22-03
N2H4	23	.100	.100	100.	45.	23.0	38.6	38.6	70.0	70.0	1.200	1.000	MIX	*	230.0	.163	1.732	.937	.696	.22-03
N2H4	24	.100	.100	100.	45.	52.0	39.9	39.9	70.0	70.0	1.200	1.000	POP	*	520.0	.158	1.320	.937	.696	.21-03
N2H4	25	.100	.100	100.	45.	154.0	37.8	37.8	70.0	70.0	1.200	1.000	POP	*	1540.0	.167	.919	.937	.696	.22-03
N2H4	26	.100	.100	100.	45.	14.2	66.3	66.3	70.0	70.0	1.200	1.000	POP	*	142.0	.095	2.034	.937	.696	.13-03
N2H4	27	.100	.100	100.	45.	35.0	62.9	62.9	70.0	70.0	1.200	1.000	MIX	*	350.0	.100	1.506	.937	.696	.13-03
N2H4	28	.100	.100	100.	45.	250.0	63.2	63.2	70.0	70.0	1.200	1.000	POP	*	2500.0	.100	.782	.937	.696	.13-03
N2H4	29	.100	.100	100.	45.	54.0	117.4	117.4	70.0	70.0	1.200	1.000	POP	*	540.0	.054	1.303	.937	.696	.71-04
N2H4	30	.100	.100	100.	45.	118.0	145.0	145.0	70.0	70.0	1.200	1.000	MIX	*	1180.0	.043	1.005	.937	.696	.57-04
N2H4	31	.073	.073	100.	45.	14.2	40.0	40.0	70.0	70.0	1.200	1.000	POP	*	194.5	.115	1.484	.937	.696	.15-03
N2H4	32	.073	.073	100.	45.	450.0	32.3	32.3	70.0	70.0	1.200	1.000	POP	*	6164.4	.142	.470	.937	.696	.19-03
N2H4	33	.073	.073	100.	45.	14.2	21.6	21.6	70.0	70.0	1.200	1.000	POP	*	194.5	.213	1.484	.937	.696	.28-03
N2H4	34	.073	.073	100.	45.	94.0	20.5	20.5	70.0	70.0	1.200	1.000	POP	*	1287.7	.224	.791	.937	.696	.30-03
N2H4	35	.073	.073	100.	45.	250.0	18.7	18.7	70.0	70.0	1.200	1.000	POP	*	3424.7	.246	.571	.937	.696	.33-03
N2H4	36	.073	.073	100.	45.	28.0	71.0	71.0	70.0	70.0	1.200	1.000	MIX	*	383.6	.065	1.184	.937	.696	.86-04
N2H4	37	.073	.073	100.	45.	28.0	24.0	24.0	70.0	70.0	1.200	1.000	POP	*	383.6	.192	1.184	.937	.696	.25-03
N2H4	38	.100	.100	100.	45.	28.0	20.0	20.0	70.0	70.0	1.200	1.000	POP	*	280.0	.315	1.622	.937	.696	.42-03
N2H4	39	.173	.173	100.	45.	28.0	5.4	5.4	70.0	70.0	1.200	1.000	POP	*	161.8	2.019	2.806	.937	.696	.27-02
N2H4	40	.073	.073	100.	45.	43.0	60.0	60.0	70.0	70.0	1.200	1.000	MIX	*	589.0	.077	1.026	.937	.696	.10-03

HYPERGOLIC STREAM IMPINGMENT DATA COMPLIATION

INVESTIGATOR HOUSEMAN

A L R C MODEL CORRELATION PARAMETERS

FUEL TYPE	TEST NO.	DO (IN)	DF (IN)	L/D	IMP ANGLE (DEG)	PC (PSIA)	VO (FT/S)	VF (FT/S)	TO (F)	TF (F)	MR	MF/MO	COMMENTS	*	PD	IS	R (IN)	EM	SPR	DV (SEC)
N2H4	41	.073	.073	100.	45.	43.0	37.0	37.0	70.0	70.0	1.200	1.000	MIX	*	589.0	.124	1.026	.937	.696	.16-03
N2H4	42	.100	.100	100.	45.	43.0	28.0	28.0	70.0	70.0	1.200	1.000	MIX	*	430.0	.225	1.406	.937	.696	.30-03
N2H4	43	.100	.100	100.	45.	43.0	28.0	28.0	70.0	70.0	1.200	1.000	MIX	*	430.0	.225	1.406	.937	.696	.30-03
N2H4	44	.173	.173	100.	45.	43.0	8.0	8.0	70.0	70.0	1.200	1.000	POP	*	248.6	1.363	2.433	.937	.696	.18-02
N2H4	45	.073	.073	100.	45.	52.0	124.0	124.0	70.0	70.0	1.200	1.000	POP	*	712.3	.037	.964	.937	.696	.49-04
N2H4	46	.073	.073	100.	45.	52.0	44.0	44.0	70.0	70.0	1.200	1.000	MIX	*	712.3	.105	.964	.937	.696	.14-03
N2H4	47	.100	.100	100.	45.	52.0	40.0	40.0	70.0	70.0	1.200	1.000	MIX	*	520.0	.158	1.320	.937	.696	.21-03
N2H4	48	.100	.100	100.	45.	52.0	40.0	40.0	70.0	70.0	1.200	1.000	POP	*	520.0	.158	1.320	.937	.696	.21-03
N2H4	49	.173	.173	100.	45.	52.0	10.0	10.0	70.0	70.0	1.200	1.000	POP	*	300.6	1.090	2.283	.937	.696	.14-02
N2H4	50	.073	.073	100.	45.	70.0	61.0	61.0	70.0	70.0	1.200	1.000	POP	*	958.9	.075	.873	.937	.696	.10-03
N2H4	51	.100	.100	100.	45.	70.0	51.0	51.0	70.0	70.0	1.200	1.000	POP	*	700.0	.124	1.195	.937	.696	.16-03
N2H4	52	.100	.100	100.	45.	70.0	20.0	20.0	70.0	70.0	1.200	1.000	POP	*	700.0	.315	1.195	.937	.696	.42-03
N2H4	53	.073	.073	100.	45.	100.0	91.0	91.0	70.0	70.0	1.200	1.000	POP	*	1369.9	.051	.775	.937	.696	.67-04
N2H4	54	.100	.100	100.	45.	100.0	80.0	80.0	70.0	70.0	1.200	1.000	POP	*	1000.0	.079	1.062	.937	.696	.10-03
N2H4	55	.173	.173	100.	45.	100.0	21.0	21.0	70.0	70.0	1.200	1.000	POP	*	578.0	.519	1.837	.937	.696	.69-03
N2H4	56	.173	.173	100.	45.	100.0	16.0	16.0	70.0	70.0	1.200	1.000	POP	*	578.0	.682	1.837	.937	.696	.90-03
N2H4	57	.073	.073	100.	45.	120.0	115.0	115.0	70.0	70.0	1.200	1.000	MIX	*	1643.8	.040	.729	.937	.696	.53-04
N2H4	58	.100	.100	100.	45.	120.0	145.0	145.0	70.0	70.0	1.200	1.000	MIX	*	1200.0	.043	.999	.937	.696	.57-04
N2H4	59	.173	.173	100.	45.	120.0	17.0	17.0	70.0	70.0	1.200	1.000	POP	*	693.6	.641	1.728	.937	.696	.85-03

HYPERGOLIC STREAM IMPINGMENT DATA COMPLIATION

INVESTIGATOR ZUNG

A L R C MODEL CORRELATION PARAMETERS

FUEL TYPE	TEST NO.	DO (IN)	DF (IN)	L/D	IMP ANGLE (DEG)	PC (PSIA)	VO (FT/S)	VF (FT/S)	TO (F)	TF (F)	MR	MF/MO	COMMENTS	*	PO	IS	P (IN)	EM	SPR	DV (SEC)
N2H4	15	.027	.027	100.	60.	14.7	23.0	35.0	70.0	70.0	.940	1.620	SEP	*	544.4	.037	.543	.893	1.612	.64-04
N2H4	28	.027	.027	100.	60.	14.7	44.0	75.0	70.0	70.0	.840	2.050	SEP	*	544.4	.017	.543	.784	2.023	.30-04
N2H4	58	.027	.027	100.	60.	14.7	55.0	46.0	69.0	69.0	1.780	.470	MIX	*	544.4	.026	.543	.776	.487	.49-04
N2H4	61	.027	.027	100.	60.	14.7	42.0	40.0	70.0	70.0	1.500	.640	SEP	*	544.4	.033	.543	.901	.632	.56-04
N2H4	63	.027	.027	100.	60.	14.7	41.0	52.0	67.0	70.0	1.140	1.100	MIX	*	544.4	.025	.543	.994	1.117	.43-04
N2H4	64	.027	.027	100.	60.	14.7	45.0	53.0	65.0	68.0	1.210	1.020	MIX	*	544.4	.021	.543	.999	.963	.42-04
N2H4	68	.027	.027	100.	60.	14.7	71.0	78.0	70.0	70.0	1.290	.860	SEP	*	544.4	.017	.543	.985	.840	.29-04
N2H4	79	.027	.027	100.	60.	14.7	20.0	25.0	70.0	70.0	1.110	1.160	SEP	*	544.4	.052	.543	.996	1.088	.90-04
N2H4	80	.027	.027	100.	60.	14.7	41.0	54.0	68.0	68.0	1.090	1.220	MIX	*	544.4	.021	.543	.982	1.207	.42-04
N2H4	81	.027	.027	100.	60.	14.7	34.0	53.0	70.0	70.0	.910	1.750	SEP	*	544.4	.025	.543	.872	1.692	.42-04
N2H4	82	.027	.027	100.	60.	14.7	40.0	52.0	70.0	70.0	.020	1.700	SEP	*	544.4	.025	.543	.987	1.177	.43-04
N2H4	83	.027	.027	100.	60.	14.7	41.0	52.0	70.0	70.0	1.080	1.200	SEP	*	544.4	.025	.543	.994	1.120	.43-04
N2H4	85	.027	.027	100.	60.	14.7	38.0	48.0	70.0	70.0	1.020	1.080	SEP	*	544.4	.027	.543	.994	1.111	.47-04
N2H4	89	.027	.027	100.	60.	14.7	19.0	24.0	67.0	68.0	1.100	1.180	MIX	*	544.4	.046	.543	.995	1.109	.94-04
N2H4	90	.027	.027	100.	60.	14.7	53.0	94.0	67.0	67.0	.820	2.180	MIX	*	544.4	.011	.543	.742	2.188	.24-04
N2H4	91	.027	.027	100.	60.	14.7	53.0	94.0	70.0	70.0	.820	2.180	SEP	*	544.4	.014	.543	.741	2.190	.24-04
N2H4	92	.027	.027	100.	60.	14.7	65.0	92.0	70.0	70.0	1.020	1.380	SEP	*	544.4	.014	.543	.946	1.395	.24-04
N2H4	93	.027	.027	100.	60.	14.7	43.0	60.0	60.0	60.0	1.040	1.310	MIX	*	544.4	.010	.543	.956	1.351	.37-04
N2H4	94	.027	.027	100.	60.	14.7	39.0	56.0	45.0	45.0	1.310	.830	MIX	*	544.4	.003	.543	.940	1.423	.40-04
N2H4	95	.027	.027	100.	60.	14.7	61.0	67.0	45.0	45.0	1.310	.830	MIX	*	544.4	.003	.543	.983	.832	.34-04
N2H4	96	.027	.027	100.	60.	14.7	22.0	29.0	45.0	45.0	1.080	1.230	MIX	*	544.4	.006	.543	.984	1.199	.78-04
N2H4	98	.027	.027	100.	60.	14.7	23.0	29.0	45.0	45.0	1.110	1.170	MIX	*	544.4	.006	.543	.996	1.097	.78-04
N2H4	99	.027	.027	100.	60.	14.7	40.0	64.0	80.0	80.0	.890	1.800	SEP	*	544.4	.044	.543	.846	1.789	.35-04
N2H4	100	.027	.027	100.	60.	14.7	20.0	33.0	75.0	80.0	.840	2.200	SEP	*	544.4	.085	.543	.818	1.894	.68-04
N2H4	101	.027	.027	100.	60.	14.7	20.0	36.0	79.0	83.0	.800	2.280	SEP	*	544.4	.097	.543	.724	2.259	.62-04
N2H4	102	.027	.027	100.	60.	14.7	18.0	24.0	78.0	82.0	1.100	1.200	UNDEF	*	544.4	.135	.543	.977	1.239	.94-04
N2H4	108	.027	.027	100.	60.	14.7	47.0	36.0	70.0	95.0	1.890	.410	SEP	*	544.4	.231	.543	.671	.403	.62-04
N2H4	109	.027	.027	100.	60.	14.7	42.0	30.0	70.0	95.0	2.010	.410	SEP	*	544.4	.277	.543	.591	.351	.75-04
N2H4	110	.027	.027	100.	60.	14.7	25.0	31.0	70.0	95.0	1.180	1.060	SEP	*	544.4	.268	.543	.998	1.057	.73-04
N2H4	111	.027	.027	100.	60.	14.7	23.0	24.0	65.0	65.0	1.380	.760	MIX	*	544.4	.037	.543	.962	.757	.94-04
N2H4	112	.027	.027	100.	60.	14.7	27.0	33.0	65.0	65.0	1.160	1.070	MIX	*	544.4	.027	.543	.999	1.038	.68-04
N2H4	113	.027	.027	100.	60.	14.7	24.0	33.0	70.0	110.0	1.040	1.330	SEP	*	544.4	.708	.543	.968	1.290	.68-04
N2H4	114	.027	.027	100.	60.	14.7	18.0	27.0	70.0	105.0	.960	1.590	SEP	*	544.4	.617	.543	.912	1.539	.83-04
N2H4	116	.027	.027	100.	60.	14.7	18.0	22.0	70.0	105.0	.960	1.580	UNDEF	*	544.4	.757	.543	1.000	1.022	.10-03
N2H4	117	.027	.027	100.	60.	14.7	16.0	25.0	70.0	80.0	.960	1.580	UNDEF	*	544.4	.112	.543	.872	1.691	.90-04
N2H4	118	.060	.060	100.	60.	14.7	52.0	70.0	70.0	80.0	1.070	1.280	UNDEF	*	245.0	.089	1.206	.975	1.255	.71-04
N2H4	119	.060	.060	100.	60.	14.7	14.0	17.0	70.0	80.0	1.230	.950	SEP	*	245.0	.365	1.206	1.000	1.022	.29-03
N2H4	120	.060	.060	100.	60.	14.7	17.0	22.0	70.0	80.0	1.120	1.150	UNDEF	*	245.0	.282	1.206	.989	1.160	.23-03
N2H4	121	.060	.060	100.	60.	14.7	36.0	48.0	70.0	80.0	1.090	1.210	UNDEF	*	245.0	.129	1.206	.979	1.232	.10-03
N2H4	122	.060	.060	100.	60.	14.7	68.0	93.0	70.0	80.0	1.060	1.280	UNDEF	*	245.0	.067	1.206	.967	1.296	.54-04

HYPERGOLIC STREAM IMPINGMENT DATA COMPLIATION

INVESTIGATOR ZUNG

A L R C MODEL CORRELATION PARAMETERS

FUEL TYPE	TEST NO.	DO (IN)	DF (IN)	L/D	IMP ANGLE (DEG)	PC (PSIA)	VO (FT/S)	VF (FT/S)	TO (F)	TF (F)	MR	MF/MO	COMMENTS	*	PD	IS	R (IN)	EM	SPR	DV (SEC)
N2H4	123	.060	.060	100.	60.	14.7	13.0	18.0	75.0	75.0	1.160	1.060	SEP	*	245.0	.236	1.206	.959	1.337	.28-03
N2H4	124	.060	.060	100.	60.	14.7	8.3	13.0	71.0	72.0	.950	1.060	SEP	*	245.0	.260	1.206	.868	1.708	.38-03
N2H4	125	.060	.060	100.	60.	14.7	6.6	11.0	71.0	72.0	.890	1.810	SEP	*	245.0	.307	1.206	.808	1.934	.45-03
N2H4	126	.060	.060	100.	60.	14.7	5.4	8.6	72.0	72.0	.900	1.770	SEP	*	245.0	.393	1.206	.852	1.767	.58-03
N2H4	127	.060	.060	100.	60.	14.7	4.3	5.6	72.0	72.0	1.100	1.170	SEP	*	245.0	.603	1.206	.986	1.182	.89-03
N2H4	128	.060	.060	100.	60.	14.7	13.0	16.0	40.0	50.0	1.110	1.150	POP	*	245.0	.036	1.206	.999	1.038	.31-03
N2H4	129	.060	.060	100.	60.	14.7	9.1	14.0	42.0	52.0	.960	1.560	POP	*	245.0	.049	1.206	.890	1.623	.36-03
N2H4	130	.060	.060	100.	60.	14.7	8.3	10.0	42.0	52.0	1.180	1.010	POP	*	245.0	.068	1.206	1.000	.996	.50-03
N2H4	131	.060	.060	100.	60.	14.7	8.0	9.0	42.0	52.0	1.270	.880	POP	*	245.0	.076	1.206	.990	.868	.56-03
N2H4	132	.060	.060	100.	60.	14.7	10.0	7.9	45.0	52.0	1.830	.430	POP	*	245.0	.086	1.206	.706	.429	.63-03
N2H4	133	.060	.060	100.	60.	14.7	9.9	12.0	45.0	50.0	1.180	1.000	POP	*	245.0	.049	1.206	1.000	1.011	[illegible]-03
N2H4	134	.060	.060	100.	60.	14.7	9.3	13.0	47.0	50.0	1.000	1.420	POP	*	245.0	.044	1.206	.957	1.347	.38-03
N2H4	135	.060	.060	100.	60.	14.7	4.3	8.6	63.0	62.0	.710	2.810	POP	*	245.0	.179	1.206	.606	2.779	.58-03
N2H4	136	.060	.060	100.	60.	14.7	12.0	14.0	54.0	54.0	1.170	1.050	POP	*	245.0	.057	1.206	.998	.942	.36-03
N2H4	137	.060	.060	100.	60.	14.7	8.2	12.0	55.0	55.0	1.040	1.540	POP	*	245.0	.073	1.206	.926	1.483	.42-03
N2H4	139	.060	.060	100.	60.	14.7	9.6	12.0	61.0	61.0	1.130	1.110	POP	*	245.0	.119	1.206	.997	1.084	.42-03
N2H4	140	.060	.060	100.	60.	14.7	14.0	20.0	63.0	63.0	.980	1.470	POP	*	245.0	.083	1.206	.941	1.417	.25-03
N2H4	141	.040	.040	100.	60.	14.7	22.0	26.0	66.0	70.0	1.200	.990	POP	*	367.5	.074	.804	1.000	.969	.13-03
N2H4	142	.040	.040	100.	60.	14.7	18.0	21.0	70.0	70.0	1.220	.950	SEP	*	367.5	.092	.804	.999	.948	.16-03
N2H4	143	.040	.040	100.	60.	14.7	13.0	17.0	70.0	70.0	1.070	1.250	SEP	*	367.5	.114	.804	.985	1.191	.20-03
N2H4	144	.040	.040	100.	60.	14.7	12.0	14.0	70.0	70.0	1.180	1.030	SEP	*	367.5	.138	.804	.999	.948	.24-03
N2H4	148	.040	.040	100.	60.	14.7	21.0	17.0	72.0	92.0	1.710	.490	SEP	*	367.5	.585	.804	.736	.452	.20-03
N2H4	149	.040	.040	100.	60.	14.7	24.0	28.0	68.0	68.0	1.210	.970	MIX	*	367.5	.059	.804	.999	.947	.12-03
N2H4	150	.040	.040	100.	60.	14.7	24.0	28.0	67.0	59.0	1.200	.980	POP	*	367.5	.029	.804	.999	.950	.12-03
N2H4	151	.040	.040	100.	60.	14.7	16.0	19.0	62.0	65.0	1.220	1.290	POP	*	367.5	.069	.804	1.000	.978	.18-03
N2H4	152	.040	.040	100.	60.	14.7	14.0	19.0	63.0	63.0	1.010	1.400	MIX	*	367.5	.059	.804	.970	1.279	.18-03
N2H4	164	.040	.040	100.	60.	149.0	16.0	22.0	69.0	73.0	1.070	1.250	MIX	*	3725.0	.111	.372	.964	1.313	.15-03
N2H4	165	.040	.040	100.	60.	189.0	23.0	23.0	67.0	73.0	1.440	.690	MIX	*	4725.0	.106	.344	.936	.693	.14-03
N2H4	166	.040	.040	100.	60.	187.0	24.0	23.0	66.0	73.0	1.470	.650	MIX	*	4675.0	.106	.345	.904	.636	.14-03
N2H4	167	.040	.040	100.	60.	189.0	23.0	25.0	47.0	59.0	1.350	.790	MIX	*	4725.0	.032	.344	.978	.811	.13-03
N2H4	169	.040	.040	100.	60.	209.0	24.0	27.0	40.0	52.0	1.310	.840	UNDEF	*	5225.0	.017	.332	.990	.867	.12-03
N2H4	170	.040	.040	100.	60.	111.0	15.0	15.0	40.0	58.0	1.450	.680	MIX	*	2775.0	.050	.410	.930	.683	.22-03
N2H4	171	.040	.040	100.	60.	191.0	23.0	27.0	43.0	58.0	1.250	.920	MIX	*	4775.0	.028	.342	.998	.943	.12-03
N2H4	174	.040	.040	100.	60.	172.0	22.0	27.0	54.0	64.0	1.200	.990	MIX	*	4300.0	.045	.354	.999	1.038	.12-03
N2H4	175	.040	.040	100.	60.	187.0	22.0	27.0	57.0	65.0	1.200	.990	MIX	*	4675.0	.048	.345	.999	1.040	.12-03
N2H4	179	.040	.040	100.	60.	163.0	21.0	23.0	56.0	63.0	1.300	.840	MIX	*	4075.0	.048	.361	.982	.828	.14-03
N2H4	180	.040	.040	100.	60.	165.0	19.0	24.0	76.0	81.0	1.550	1.070	MIX	*	4125.0	.186	.359	.995	1.111	.14-03
N2H4	181	.040	.040	100.	60.	140.0	18.0	20.0	77.0	82.0	1.230	.940	MIX	*	3500.0	.240	.380	.989	.860	.17-03
N2H4	182	.040	.040	100.	60.	259.0	20.0	19.0	81.0	87.0	1.470	.660	UNDEF	*	6475.0	.365	.309	.899	.629	.18-03
N2H4	183	.040	.040	100.	60.	157.0	19.0	29.0	85.0	93.0	.940	1.610	MIX	*	3925.0	.368	.365	.890	1.625	.11-03

HYPERGOLIC STREAM IMPINGMENT DATA COMPLIATION

INVESTIGATOR ZUNG

A L R C MODEL CORRELATION PARAMETERS

FUEL TYPE	TEST NO.	DO (IN)	DF (IN)	L/D	IMP ANGLE (DEG)	PC (PSIA)	VO (FT/S)	VF (FT/S)	TO (F)	TF (F)	MR	MF/MO	COMMENTS	*	PD	IS	P (IN)	EM	SPR	DV (SEC)
N2H4	184	.040	.040	100.	60.	119.0	17.0	14.0	95.0	101.0	1.830	.430	MIX	*	2975.0	1.338	.401	.763	.475	.24-03
N2H4	185	.040	.040	100.	60.	131.0	17.0	17.0	107.0	96.0	1.410	.720	MIX	*	3275.0	.777	.388	.943	.710	.20-03
N2H4	186	.040	.040	100.	60.	155.0	22.0	24.0	77.0	91.0	1.310	.840	MIX	*	3875.0	.386	.367	.982	.825	.14-03
N2H4	187	.040	.040	100.	60.	194.0	27.0	27.0	91.0	91.0	1.410	.720	MIX	*	4850.0	.343	.341	.940	.702	.12-03
N2H4	188	.040	.040	100.	60.	194.0	26.0	29.0	86.0	90.0	1.240	.920	MIX	*	4850.0	.297	.341	.990	.870	.11-03
N2H4	191	.040	.040	100.	60.	170.0	25.0	25.0	96.0	103.0	1.420	.710	MIX	*	4250.0	.860	.356	.939	.701	.13-03
N2H4	192	.040	.040	100.	60.	152.0	24.0	27.0	104.0	113.0	1.270	.890	MIX	*	3800.0	1.566	.369	.993	.889	.12-03
N2H4	193	.040	.040	100.	60.	174.0	25.0	31.0	94.0	99.0	1.140	1.100	MIX	*	4350.0	.526	.353	.997	1.078	.11-03
N2H4	194	.040	.040	100.	60.	169.0	24.0	30.0	100.0	104.0	1.130	1.120	MIX	*	4225.0	.769	.357	.996	1.098	.11-03
N2H4	196	.040	.040	100.	60.	194.0	24.0	32.0	76.0	94.0	1.090	1.210	MIX	*	4850.0	.358	.341	.979	1.229	.10-03
N2H4	197	.040	.040	100.	60.	187.0	16.0	32.0	106.0	76.0	.720	2.790	MIX	*	4675.0	.096	.345	.588	2.866	.10-03
N2H4	198	.040	.040	100.	60.	164.0	24.0	27.0	91.0	101.0	1.250	.920	MIX	*	4100.0	.694	.360	.992	.884	.12-03
N2H4	199	.040	.040	100.	60.	181.0	23.0	32.0	93.0	108.0	1.030	1.360	MIX	*	4525.0	.945	.349	.956	1.349	.10-03
N2H4	200	.040	.040	100.	60.	203.0	23.0	32.0	64.0	77.0	1.040	1.320	MIX	*	5075.0	.103	.335	.959	1.336	.10-03
N2H4	201	.040	.040	100.	60.	178.0	20.0	32.0	62.0	77.0	.920	1.680	MIX	*	4450.0	.103	.350	.853	1.764	.10-03
N2H4	204	.040	.040	100.	60.	110.0	31.0	36.0	52.0	64.0	1.230	.950	MIX	*	2750.0	.033	.411	.997	.927	.93-04
N2H4	205	.040	.040	100.	60.	115.0	33.0	35.0	76.0	84.0	1.360	1.360	MIX	*	2875.0	.159	.405	.970	.782	.95-04
N2H4	206	.040	.040	100.	60.	115.0	33.0	30.0	91.0	95.0	1.590	1.590	MIX	*	2875.0	.410	.405	.863	.579	.11-03
N2H4	207	.040	.040	100.	60.	110.0	29.0	34.0	110.0	107.0	1.230	1.230	MIX	*	2750.0	.831	.411	1.000	.973	.98-04
N2H4	208	.040	.040	100.	60.	110.0	28.0	40.0	102.0	108.0	.990	1.440	MIX	*	2750.0	.756	.411	.937	1.434	.83-04
N2H4	209	.040	.040	100.	60.	110.0	29.0	35.0	105.0	110.0	1.190	.990	MIX	*	2750.0	.989	.411	1.000	1.025	.95-04
N2H4	210	.040	.040	100.	60.	110.0	29.0	37.0	121.0	110.0	1.120	1.130	MIX	*	2750.0	.935	.411	.989	1.162	.90-04
N2H4	211	.040	.040	100.	60.	110.0	30.0	35.0	121.0	116.0	1.240	.930	MIX	*	2750.0	1.472	.411	.999	.969	.95-04
N2H4	212	.040	.040	100.	60.	110.0	30.0	35.0	121.0	118.0	1.240	.930	MIX	*	2750.0	1.678	.411	.999	.968	.95-04
N2H4	215	.040	.040	100.	60.	110.0	56.0	68.0	108.0	118.0	1.170	.850	MIX	*	2750.0	.864	.411	.999	1.036	.49-04
N2H4	217	.040	.040	100.	60.	110.0	56.0	68.0	93.0	101.0	1.170	.850	MIX	*	2750.0	.275	.411	1.000	1.031	.49-04
N2H4	219	.040	.040	100.	60.	110.0	56.0	63.0	123.0	121.0	1.270	.790	MIX	*	2750.0	1.133	.411	.994	.900	.53-04
N2H4	220	.040	.040	100.	60.	110.0	54.0	68.0	117.0	122.0	1.130	.880	MIX	*	2750.0	1.119	.411	.993	1.121	.49-04
N2H4	221	.040	.040	100.	60.	110.0	59.0	68.0	103.0	110.0	1.240	.810	MIX	*	2750.0	.509	.411	.998	.933	.49-04
N2H4	222	.040	.040	100.	60.	110.0	55.0	68.0	119.0	114.0	1.160	.860	MIX	*	2750.0	.664	.411	.997	1.087	.49-04
N2H4	223	.040	.040	100.	60.	110.0	59.0	68.0	119.0	114.0	1.520	.800	UNDEF	*	2750.0	.664	.411	.998	.945	.49-04
N2H4	231	.040	.040	100.	60.	350.0	51.0	66.0	79.0	67.0	1.100	1.180	SEP	*	8750.0	.023	.280	.987	1.177	.51-04
N2H4	232	.040	.040	100.	60.	380.0	55.0	66.0	85.0	72.0	1.180	1.000	SEP	*	9500.0	.034	.272	1.000	1.015	.51-04
N2H4	234	.040	.040	100.	60.	353.0	68.0	68.0	118.0	118.0	1.120	.880	SEP	*	8825.0	.864	.279	.943	.709	.49-04
N2H4	235	.040	.040	100.	60.	353.0	50.0	68.0	84.0	103.0	1.050	.950	SEP	*	8825.0	.316	.279	.970	1.282	.49-04
N2H4	236	.040	.040	100.	60.	346.0	48.0	63.0	71.0	90.0	1.080	.920	SEP	*	8650.0	.137	.281	.985	1.189	.53-04
N2H4	237	.040	.040	100.	60.	362.0	56.0	68.0	63.0	93.0	1.180	.840	SEP	*	9050.0	.157	.277	1.000	1.009	.49-04
N2H4	238	.040	.040	100.	60.	361.0	50.0	68.0	66.0	85.0	1.050	.950	SEP	*	9025.0	.088	.277	.971	1.274	.49-04
N2H4	239	.040	.040	100.	60.	145.0	22.0	27.0	72.0	82.0	1.190	1.000	MIX	*	3625.0	.178	.375	.999	1.044	.12-03
N2H4	240	.040	.040	100.	60.	238.0	65.0	68.0	63.0	67.0	1.370	.760	UNDEF	*	5950.0	.022	.318	.963	.759	.49-04

HYPERGOLIC STREAM IMPINGMENT DATA COMPLIATION

INVESTIGATOR ZUNG

A L R C MODEL CORRELATION PARAMETERS

FUEL TYPE	TEST NO.	DO (IN)	DF (IN)	L/D	IMP ANGLE (DEG)	PC (PSIA)	VO (FT/S)	VF (FT/S)	TO (F)	TF (F)	MR	MF/MO	COMMENTS	*	PD	IS	P (IN)	EM	SPR	DV (SEC)
N2H4	241	.040	.040	100.	60.	230.0	74.0	68.0	115.0	117.0	1.560	.590	MIX	*	5750.0	.809	.322	.877	.597	.49-04
N2H4	242	.040	.040	100.	60.	176.0	55.0	69.0	146.0	127.0	1.140	1.110	MIX	*	4400.0	1.518	.352	.991	1.140	.48-04
N2H4	243	.040	.040	100.	60.	176.0	55.0	69.0	117.0	122.0	1.140	1.110	MIX	*	4400.0	1.103	.352	.994	1.113	.48-04
N2H4	244	.040	.040	100.	60.	338.0	39.0	65.0	44.0	54.0	.870	1.890	SEP	*	8450.0	.008	.233	.815	1.907	.51-04
N2H4	246	.040	.040	100.	60.	400.0	57.0	61.0	39.0	41.0	1.310	.820	SEP	*	10000.0	.003	.268	.972	.788	.55-04
N2H4	247	.040	.040	100.	60.	215.0	58.0	66.0	51.0	62.0	1.250	.920	MIX	*	5375.0	.016	.329	.993	.891	.51-04
N2H4	248	.040	.040	100.	60.	115.0	61.0	65.0	51.0	60.0	1.340	.790	MIX	*	2875.0	.013	.405	.970	.782	.51-04
N2H4	250	.040	.040	100.	60.	218.0	61.0	68.0	58.0	70.0	1.290	.890	MIX	*	5450.0	.028	.328	.988	.856	.49-04
N2H4	251	.040	.040	100.	60.	384.0	56.0	65.0	62.0	74.0	1.230	.940	SEP	*	9600.0	.040	.271	.997	.930	.51-04
N2H4	252	.040	.040	100.	60.	307.0	45.0	50.0	65.0	76.0	1.280	.870	UNDEF	*	7675.0	.061	.292	.988	.853	.67-04
N2H4	253	.040	.040	100.	60.	507.0	35.0	38.0	68.0	77.0	1.290	.850	SEP	*	12675.0	.087	.247	.980	.816	.88-04
N2H4	254	.040	.040	100.	60.	520.0	36.0	28.0	77.0	86.0	1.330	.590	SEP	*	13000.0	.230	.245	.695	.420	.12-03
N2H4	255	.040	.040	100.	60.	84.0	49.0	52.0	106.0	103.0	1.320	.820	MIX	*	2100.0	.414	.450	.974	.796	.64-04
N2H4	256	.040	.040	100.	60.	100.0	56.0	65.0	126.0	120.0	1.260	.920	MIX	*	2500.0	1.029	.425	.999	.961	.51-04
N2H4	257	.040	.040	100.	60.	122.0	56.0	66.0	124.0	120.0	1.200	.980	MIX	*	3050.0	1.014	.397	1.000	.989	.51-04
N2H4	258	.040	.040	100.	60.	423.0	32.0	37.0	93.0	104.0	1.220	.950	SEP	*	10575.0	.623	.263	.998	.934	.90-04
N2H4	259	.040	.040	100.	60.	461.0	32.0	37.0	94.0	99.0	1.220	.840	SEP	*	11525.0	.441	.255	.998	.937	.90-04
N2H4	260	.040	.040	100.	60.	461.0	32.0	37.0	74.0	84.0	1.240	.920	SEP	*	11525.0	.150	.255	.997	.928	.90-04
N2H4	261	.040	.040	100.	60.	115.0	31.0	37.0	79.0	88.0	1.180	1.010	MIX	*	2875.0	.201	.405	1.000	.991	.90-04
N2H4	262	.040	.040	100.	60.	130.0	34.0	41.0	92.0	97.0	1.180	1.040	MIX	*	3250.0	.346	.339	1.000	1.018	.81-04
N2H4	263	.040	.040	100.	60.	149.0	40.0	52.0	90.0	97.0	1.100	1.180	MIX	*	3725.0	.273	.372	.986	1.181	.64-04
N2H4	264	.040	.040	100.	60.	169.0	46.0	53.0	90.0	97.0	1.240	.930	MIX	*	4225.0	.267	.357	.997	.928	.63-04
N2H4	265	.040	.040	100.	60.	188.0	51.0	61.0	84.0	93.0	1.170	1.030	MIX	*	4700.0	.175	.344	1.000	.997	.55-04
N2H4	266	.040	.040	100.	60.	203.0	56.0	69.0	83.0	93.0	1.160	.860	MIX	*	5075.0	.155	.335	.998	1.057	.48-04
N2H4	267	.040	.040	100.	60.	388.0	58.0	68.0	81.0	88.0	1.220	.950	SEP	*	9700.0	.110	.270	.999	.958	.49-04
N2H4	268	.040	.040	100.	60.	381.0	58.0	57.0	78.0	86.0	1.440	.680	SEP	*	9525.0	.113	.272	.924	.672	.58-04
N2H4	269	.040	.040	100.	60.	353.0	55.0	52.0	77.0	86.0	1.490	.670	SEP	*	8825.0	.124	.279	.894	.621	.64-04
N2H4	270	.040	.040	100.	60.	176.0	49.0	71.0	138.0	129.0	.970	1.520	MIX	*	4400.0	1.673	.352	.920	1.508	.47-04
N2H4	272	.040	.040	100.	60.	179.0	56.0	63.0	106.0	111.0	1.280	.870	MIX	*	4475.0	.587	.350	.993	.891	.53-04
N2H4	273	.040	.040	100.	60.	176.0	58.0	63.0	120.0	124.0	1.310	.820	MIX	*	4400.0	1.374	.352	.984	.836	.53-04
N2H4	274	.040	.040	100.	60.	176.0	55.0	46.0	117.0	120.0	1.700	.490	MIX	*	4400.0	1.454	.352	.785	.495	.72-04
N2H4	275	.040	.040	100.	60.	138.0	42.0	51.0	114.0	117.0	1.170	1.030	MIX	*	3450.0	1.079	.331	.999	1.042	.65-04
N2H4	276	.040	.040	100.	60.	279.0	75.0	73.0	70.0	70.0	1.450	.680	UNDEF	*	6975.0	.026	.302	.918	.660	.46-04
N2H4	278	.040	.040	100.	60.	237.0	61.0	73.0	70.0	70.0	1.190	.980	MIX	*	5925.0	.026	.319	1.000	.997	.46-04
N2H4	279	.040	.040	100.	60.	250.0	66.0	73.0	70.0	70.0	1.290	1.160	MIX	*	6250.0	.026	.313	.987	.852	.46-04
N2H4	281	.040	.040	100.	60.	100.0	101.0	127.0	69.0	74.0	1.130	1.120	MIX	*	2500.0	.021	.425	.996	1.098	.26-04
N2H4	282	.040	.040	100.	60.	115.0	117.0	127.0	69.0	73.0	1.540	.870	MIX	*	2875.0	.019	.405	.980	.818	.26-04
N2H4	283	.040	.040	100.	60.	326.0	84.0	98.0	84.0	98.0	1.220	.940	SEP	*	8150.0	.155	.286	.998	.946	.34-04
N2H4	284	.040	.040	100.	60.	282.0	76.0	93.0	54.0	74.0	1.160	1.060	SEP	*	7050.0	.023	.331	1.000	1.026	.36-04
N2H4	285	.040	.040	100.	60.	228.0	63.0	78.0	54.0	86.0	1.160	1.060	MIX	*	5700.0	.083	.323	.999	1.044	.43-04

HYPERGOLIC STREAM IMPINGMENT DATA COMPLIATION

INVESTIGATOR ZUNG

A L R C MODEL CORRELATION PARAMETERS

FUEL TYPE	TEST NO.	DO (IN)	DF (IN)	L/D	IMP ANGLE (DEG)	PC (PSIA)	VO (FT/S)	VF (FT/S)	TO (F)	TF (F)	MR	MF/MO	COMMENTS	*	PO	IS	R (IN)	EM	SPR	DV (SEC)
N2H4	286	.040	.040	100.	60.	192.0	51.0	63.0	54.0	86.0	1.140	1.060	MIX	*	4800.0	.102	.342	.999	1.040	.53-04
N2H4	287	.040	.040	100.	60.	182.0	44.0	51.0	55.0	86.0	1.250	.920	MIX	*	4550.0	.126	.348	.996	.916	.65-04
N2H4	288	.040	.040	100.	60.	186.0	46.0	52.0	62.0	57.0	1.890	.600	MIX	*	4650.0	.013	.345	.993	.889	.64-04
N2H4	289	.040	.040	100.	60.	174.0	49.0	53.0	62.0	55.0	1.320	.820	MIX	*	4350.0	.011	.353	.979	.815	.63-04
N2H4	290	.040	.040	100.	60.	186.0	54.0	56.0	96.0	101.0	1.030	.780	MIX	*	4650.0	.335	.345	.961	.754	.60-04
N2H4	291	.040	.040	100.	60.	162.0	44.0	54.0	106.0	71.0	1.130	1.090	MIX	*	4050.0	.039	.362	.997	1.082	.62-04
N2H4	293	.060	.060	100.	60.	362.0	92.0	121.0	60.0	62.0	1.090	1.200	SEP	*	6033.3	.013	.415	.984	1.199	.41-04
N2H4	294	.060	.060	100.	60.	180.0	46.0	54.0	60.0	64.0	1.240	.940	MIX	*	3000.0	.033	.524	.999	.954	.93-04
N2H4	295	.060	.060	100.	60.	14.7	64.0	73.0	59.0	53.0	1.440	.780	POP	*	245.0	.010	1.206	.995	.905	.68-04
N2H4	296	.060	.060	100.	60.	14.7	49.0	61.0	57.0	54.0	1.150	1.090	POP	*	245.0	.013	1.206	.997	1.076	.82-04
N2H4	297	.060	.060	100.	60.	68.0	49.0	61.0	57.0	55.0	1.230	1.010	POP	*	1133.3	.014	.724	.997	1.075	.82-04
N2H4	298	.040	.040	100.	60.	76.0	46.0	53.0	52.0	41.0	1.200	.960	MIX	*	1900.0	.003	.465	.997	.923	.63-04
N2H4	299	.040	.040	100.	60.	106.0	36.0	53.0	53.0	40.0	.930	1.590	MIX	*	2650.0	.003	.416	.919	1.509	.63-04
N2H4	300	.040	.040	100.	60.	122.0	46.0	37.0	53.0	41.0	1.110	1.050	MIX	*	3050.0	.005	.397	.733	.450	.90-04
N2H4	301	.040	.040	100.	60.	100.0	47.0	57.0	53.0	41.0	1.160	1.050	MIX	*	2500.0	.003	.425	1.000	1.024	.58-04
N2H4	302	.040	.040	100.	60.	192.0	36.0	57.0	55.0	43.0	1.070	1.740	MIX	*	4800.0	.004	.342	.858	1.746	.58-04
N2H4	304	.040	.040	100.	60.	14.7	29.0	42.0	37.0	37.0	1.040	1.410	POP	*	367.5	.003	.804	.935	1.443	.79-04
N2H4	305	.040	.040	100.	60.	14.7	13.0	16.0	43.0	42.0	1.000	1.270	MIX	*	367.5	.012	.804	.999	1.045	.21-03
N2H4	306	.040	.040	100.	60.	14.7	16.0	16.0	39.0	44.0	1.260	.800	POP	*	367.5	.014	.804	.932	.687	.21-03
N2H4	307	.040	.040	100.	60.	14.7	52.0	49.0	32.0	32.0	1.580	.590	MIX	*	367.5	.002	.804	.886	.610	.68-04
N2H4	308	.040	.040	100.	60.	14.7	49.0	55.0	58.0	59.0	1.300	.860	POP	*	367.5	.015	.804	.991	.873	.61-04
N2H4	309	.040	.040	100.	60.	14.7	58.0	66.0	58.0	59.0	1.250	.860	POP	*	367.5	.012	.804	.994	.897	.51-04
N2H4	310	.040	.040	100.	60.	14.7	58.0	68.0	70.0	78.0	1.250	1.170	MIX	*	367.5	.052	.804	.999	.953	.49-04
N2H4	311	.040	.040	100.	60.	14.7	58.0	68.0	60.0	66.0	1.250	1.170	MIX	*	367.5	.021	.804	.999	.951	.49-04
N2H4	312	.040	.040	100.	60.	14.7	64.0	68.0	66.0	61.0	1.250	.800	MIX	*	367.5	.014	.804	.972	.787	.49-04
N2H4	313	.040	.040	100.	60.	14.7	64.0	68.0	53.0	55.0	1.250	.800	MIX	*	367.5	.009	.804	.970	.780	.49-04
N2H4	314	.040	.040	100.	60.	14.7	63.0	68.0	53.0	55.0	1.290	.800	MIX	*	367.5	.009	.804	.977	.805	.49-04
N2H4	316	.040	.040	100.	60.	14.7	63.0	63.0	48.0	51.0	1.440	.700	MIX	*	367.5	.007	.804	.934	.690	.53-04
N2H4	317	.040	.040	100.	60.	14.7	54.0	55.0	45.0	51.0	1.450	.710	POP	*	367.5	.008	.804	.945	.714	.61-04
N2H4	318	.040	.040	100.	60.	14.7	23.0	28.0	48.0	51.0	1.150	1.090	SEP	*	367.5	.015	.804	1.000	1.022	.12-03
N2H4	319	.040	.040	100.	60.	14.7	27.0	28.0	45.0	51.0	1.360	.770	SEP	*	367.5	.015	.804	.956	.740	.12-03
N2H4	320	.040	.040	100.	60.	14.7	18.0	19.0	55.0	55.0	1.400	.760	POP	*	367.5	.031	.804	.967	.772	.18-03
N2H4	321	.040	.040	100.	60.	14.7	18.0	19.0	57.0	59.0	1.400	.760	POP	*	367.5	.042	.804	.967	.771	.18-03
N2H4	322	.040	.040	100.	60.	14.7	18.0	19.0	58.0	61.0	1.290	.820	MIX	*	367.5	.050	.804	.967	.771	.18-03
N2H4	323	.040	.040	100.	60.	14.7	19.0	19.0	50.0	51.0	1.460	.700	POP	*	367.5	.022	.804	.934	.691	.18-03
N2H4	324	.040	.040	100.	60.	14.7	18.0	18.0	50.0	51.0	1.570	.620	SEP	*	367.5	.023	.804	.934	.691	.19-03
N2H4	325	.040	.040	100.	60.	14.7	23.0	24.0	63.0	72.0	1.370	.780	SEP	*	367.5	.094	.804	.961	.753	.14-03
N2H4	326	.060	.060	100.	60.	14.7	22.0	24.0	58.0	51.0	1.300	.850	POP	*	245.0	.026	1.206	.982	.828	.21-03
N2H4	327	.060	.060	100.	60.	14.7	21.0	23.0	48.0	48.0	1.300	.840	POP	*	245.0	.021	1.206	.983	.829	.22-03
N2H4	328	.060	.060	100.	60.	14.7	22.0	24.0	47.0	55.0	1.310	.830	POP	*	245.0	.036	1.206	.980	.819	.21-03

HYPERGOLIC STREAM IMPINGMENT DATA COMPLIATION

INVESTIGATOR ZUNG

A L R C MODEL CORRELATION PARAMETERS

FUEL TYPE	TEST NO.	DO (IN)	DF (IN)	L/D	IMP ANGLE (DEG)	PC (PSIA)	VO (FT/S)	VF (FT/S)	TO (F)	TF (F)	MR	MF/MO	COMMENTS	*	PD	IS	P (IN)	EM	SPR	DV (SEC)
N2H4	329	.060	.060	100.	60.	14.7	21.0	24.0	47.0	53.0	1.270	.900	POP	*	245.0	.031	1.206	.994	.899	.21-03
N2H4	330	.060	.060	100.	60.	14.7	21.0	24.0	48.0	53.0	1.270	.900	POP	*	245.0	.031	1.206	.994	.900	.21-03
N2H4	331	.060	.060	100.	60.	14.7	27.0	31.0	64.0	61.0	1.240	.920	POP	*	245.0	.046	1.206	.996	.917	.16-03
N2H4	332	.060	.060	100.	60.	75.0	34.0	43.0	63.0	64.0	1.110	1.160	POP	*	1250.0	.042	.701	.995	1.110	.12-03
N2H4	333	.060	.060	100.	60.	80.0	40.0	50.0	63.0	64.0	1.130	1.120	POP	*	1333.3	.036	.686	.997	1.085	.10-03
N2H4	334	.060	.060	100.	60.	95.0	34.0	57.0	61.0	63.0	.820	2.080	POP	*	1583.3	.029	.648	.804	1.949	.88-04
N2H4	335	.060	.060	100.	60.	96.0	26.0	31.0	64.0	61.0	1.230	1.570	POP	*	1600.0	.046	.646	1.000	.989	.16-03
N2H4	336	.060	.060	100.	60.	70.0	34.0	44.0	63.0	64.0	1.110	1.150	POP	*	1166.7	.041	.717	.989	1.163	.11-03
N2H4	337	.060	.060	100.	60.	80.0	36.0	57.0	61.0	66.0	.890	1.780	POP	*	1333.3	.037	.686	.861	1.736	.88-04
N2H4	338	.060	.060	100.	60.	85.0	43.0	50.0	86.0	89.0	1.240	.940	POP	*	1416.7	.240	.672	.998	.946	.10-03
N2H4	339	.060	.060	100.	60.	125.0	45.0	58.0	108.0	97.0	1.110	1.160	POP	*	2083.3	.366	.591	.986	1.180	.86-04
N2H4	340	.060	.060	100.	60.	75.0	36.0	50.0	108.0	117.0	1.050	1.310	POP	*	1250.0	1.651	.701	.955	1.356	.10-03
N2H4	341	.060	.060	100.	60.	75.0	41.0	50.0	100.0	107.0	1.160	1.060	POP	*	1250.0	.848	.701	.999	1.044	.10-03
N2H4	342	.060	.060	100.	60.	145.0	42.0	50.0	99.0	107.0	1.210	.990	POP	*	2416.7	.848	.563	1.000	.994	.10-03
N2H4	343	.060	.060	100.	60.	145.0	41.0	50.0	103.0	118.0	1.160	1.060	POP	*	2416.7	1.762	.563	.999	1.041	.10-03
N2H4	344	.060	.060	100.	60.	145.0	43.0	50.0	80.0	81.0	1.240	.810	POP	*	2416.7	.134	.563	.998	.944	.10-03
N2H4	345	.060	.060	100.	60.	165.0	43.0	49.0	78.0	81.0	1.260	.900	POP	*	2750.0	.136	.539	.995	.905	.10-03
N2H4	346	.060	.060	100.	60.	165.0	45.0	50.0	76.0	76.0	1.280	.880	POP	*	2750.0	.092	.539	.989	.862	.10-03
N2H4	347	.060	.060	100.	60.	165.0	44.0	49.0	78.0	80.0	1.250	.920	POP	*	2750.0	.127	.539	.990	.865	.10-03
N2H4	348	.060	.060	100.	60.	165.0	32.0	50.0	83.0	83.0	.910	1.720	POP	*	2750.0	.155	.539	.868	1.708	.10-03
N2H4	349	.060	.060	100.	60.	165.0	33.0	51.0	90.0	91.0	.930	1.640	POP	*	2750.0	.272	.539	.877	1.675	.98-04
N2H4	350	.060	.060	100.	60.	185.0	40.0	51.0	94.0	91.0	1.120	1.130	POP	*	3083.3	.272	.519	.991	1.144	.98-04
N2H4	351	.060	.060	100.	60.	185.0	47.0	50.0	70.0	72.0	1.350	7.820	POP	*	3083.3	.068	.519	.972	.787	.10-03
N2H4	352	.060	.060	100.	60.	165.0	41.0	49.0	68.0	72.0	1.210	.980	UNDEF	*	2750.0	.069	.539	1.000	.992	.10-03
N2H4	353	.060	.060	100.	60.	165.0	42.0	49.0	66.0	70.0	1.230	.938	POP	*	2750.0	.059	.539	.998	.944	.10-03
N2H4	354	.060	.060	100.	60.	165.0	42.0	51.0	50.0	49.0	1.190	1.020	POP	*	2750.0	.010	.539	1.000	1.020	.98-04
N2H4	355	.060	.060	100.	60.	175.0	44.0	51.0	47.0	47.0	1.230	.930	UNDEF	*	2916.7	.009	.529	.997	.928	.98-04
N2H4	356	.060	.060	100.	60.	165.0	36.0	51.0	50.0	49.0	1.030	1.350	POP	*	2750.0	.010	.539	.948	1.388	.98-04
N2H4	357	.060	.060	100.	60.	165.0	41.0	49.0	50.0	51.0	1.210	.970	POP	*	2750.0	.013	.539	1.000	.987	.10-03
N2H4	358	.060	.060	100.	60.	165.0	42.0	51.0	50.0	51.0	1.190	1.020	POP	*	2750.0	.012	.539	1.000	1.019	.98-04
N2H4	359	.060	.060	100.	60.	165.0	42.0	51.0	48.0	47.0	1.190	1.020	POP	*	2750.0	.009	.539	1.000	1.019	.98-04
N2H4	360	.060	.060	100.	60.	165.0	33.0	60.0	57.0	53.0	.079	1.020	POP	*	2750.0	.012	.539	.715	2.295	.83-04
N2H4	361	.060	.060	100.	60.	165.0	42.0	51.0	55.0	55.0	1.020	1.190	POP	*	2750.0	.017	.539	1.000	1.021	.98-04
N2H4	362	.060	.060	100.	60.	105.0	40.0	52.0	55.0	53.0	1.120	1.140	POP	*	1750.0	.014	.627	.988	1.171	.96-04
N2H4	363	.060	.060	100.	60.	105.0	44.0	51.0	53.0	53.0	1.230	.930	POP	*	1750.0	.015	.627	.997	.930	.98-04
N2H4	364	.060	.060	100.	60.	105.0	44.0	52.0	60.0	63.0	1.230	.950	POP	*	1750.0	.032	.627	.999	.968	.96-04
N2H4	365	.060	.060	100.	60.	105.0	43.0	51.0	60.0	63.0	1.220	.960	POP	*	1750.0	.033	.627	1.000	.974	.98-04
N2H4	366	.060	.060	100.	60.	105.0	45.0	52.0	60.0	63.0	1.250	.920	POP	*	1750.0	.032	.627	.997	.925	.96-04
N2H4	367	.060	.060	100.	60.	105.0	45.0	52.0	76.0	80.0	1.250	.930	POP	*	1750.0	.119	.627	.997	.930	.96-04
N2H4	368	.060	.060	100.	60.	185.0	45.0	49.0	68.0	70.0	1.290	.850	POP	*	3083.3	.059	.519	.981	.824	.10-03

HYPERGOLIC STREAM IMPINGMENT DATA COMPLIATION

INVESTIGATOR ZUNG

A L R C MODEL CORRELATION PARAMETERS

FUEL TYPE	TEST NO.	DO (IN)	DF (IN)	L/D	IMP ANGLE (DEG)	PC (PSIA)	VO (FT/S)	VF (FT/S)	TO (F)	TF (F)	MR	MF/MO	COMMENTS	*	PD	IS	R (IN)	EM	SPR	DV (SEC)
N2H4	369	.060	.060	100.	60.	185.0	43.0	50.0	70.0	69.0	1.240	.930	POP	*	3083.3	.054	.519	.998	.942	.10-03
N2H4	370	.060	.060	100.	60.	185.0	41.0	49.0	65.0	64.0	1.210	.980	POP	*	3083.3	.037	.519	1.000	.993	.10-03
N2H4	371	.060	.060	100.	60.	185.0	37.0	49.0	63.0	63.0	1.060	1.230	POP	*	3083.3	.034	.519	.981	1.218	.10-03
N2H4	372	.060	.060	100.	60.	185.0	34.0	49.0	55.0	55.0	.980	1.450	POP	*	3083.3	.018	.519	.936	1.438	.10-03
N2H4	373	.055	.055	100.	60.	95.0	52.0	60.0	63.0	64.0	1.230	1.030	POP	*	1727.3	.028	.594	.997	.924	.76-04
N2H4	374	.055	.055	100.	60.	95.0	51.0	60.0	63.0	64.0	1.190	.990	POP	*	1727.3	.028	.594	.999	.961	.76-04
N2H4	375	.055	.055	100.	60.	95.0	54.0	60.0	63.0	64.0	1.270	.790	POP	*	1727.3	.028	.594	.988	.857	.76-04
N2H4	376	.055	.055	100.	60.	165.0	54.0	60.0	63.0	64.0	1.290	.850	POP	*	3000.0	.028	.494	.988	.857	.76-04
N2H4	377	.055	.055	100.	60.	175.0	54.0	60.0	65.0	82.0	1.270	.880	POP	*	3181.8	.110	.485	.987	.851	.76-04
N2H4	378	.055	.055	100.	60.	175.0	56.0	61.0	68.0	89.0	1.310	.830	POP	*	3181.8	.181	.485	.980	.817	.75-04
N2H4	379	.055	.055	100.	60.	175.0	55.0	61.0	104.0	82.0	1.290	.860	POP	*	3181.8	.108	.485	.991	.877	.75-04
N2H4	380	.055	.055	100.	60.	175.0	53.0	61.0	114.0	105.0	1.240	.930	POP	*	3181.8	.556	.485	.998	.942	.75-04
N2H4	381	.055	.055	100.	60.	175.0	54.0	61.0	114.0	107.0	1.270	.880	POP	*	3181.8	.637	.485	.995	.907	.75-04
N2H4	382	.055	.055	100.	60.	175.0	52.0	61.0	111.0	110.0	1.210	1.080	POP	*	3181.8	.780	.485	1.000	.974	.75-04
N2H4	383	.055	.055	100.	60.	175.0	56.0	60.0	65.0	66.0	1.320	.810	POP	*	3181.8	.032	.485	.975	.797	.76-04
N2H4	384	.055	.055	100.	60.	175.0	55.0	60.0	88.0	78.0	1.290	.990	POP	*	3181.8	.082	.485	.985	.838	.76-04
N2H4	385	.055	.055	100.	60.	175.0	53.0	60.0	76.0	78.0	1.260	.910	POP	*	3181.8	.082	.485	.994	.893	.76-04
N2H4	388	.055	.055	100.	60.	175.0	42.0	46.0	48.0	51.0	1.290	.848	POP	*	3181.8	.012	.485	.982	.827	.10-03
N2H4	389	.055	.055	100.	60.	175.0	37.0	46.0	48.0	51.0	1.130	1.100	POP	*	3181.8	.012	.485	.998	1.066	.10-03
N2H4	390	.055	.055	100.	60.	175.0	35.0	46.0	48.0	51.0	1.710	.484	POP	*	3181.8	.012	.485	.985	1.191	.10-03
N2H4	391	.055	.055	100.	60.	195.0	49.0	60.0	48.0	52.0	1.170	1.040	POP	*	3545.5	.010	.467	.999	1.034	.76-04
N2H4	392	.055	.055	100.	60.	195.0	49.0	60.0	48.0	52.0	1.160	1.060	POP	*	3545.5	.010	.467	.999	1.034	.76-04
N2H4	393	.055	.055	100.	60.	415.0	37.0	59.0	55.0	60.0	.881	1.840	SEP	*	7545.5	.020	.364	.855	1.756	.78-04
N2H4	394	.060	.060	100.	60.	235.0	61.0	71.0	56.0	62.0	1.210	.967	MIX	*	3916.7	.022	.479	.998	.936	.70-04
N2H4	395	.060	.060	100.	60.	225.0	51.0	71.0	45.0	53.0	1.020	1.370	MIX	*	3750.0	.010	.486	.960	1.332	.70-04
N2H4	396	.060	.060	100.	60.	235.0	60.0	71.0	38.0	45.0	1.200	.991	MIX	*	3916.7	.005	.479	.999	.961	.70-04
N2H4	397	.060	.060	100.	60.	225.0	59.0	71.0	63.0	62.0	1.190	1.520	MIX	*	3750.0	.022	.486	1.000	1.006	.70-04
N2H4	398	.060	.060	100.	60.	235.0	56.0	71.0	71.0	70.0	1.350	.931	MIX	*	3916.7	.041	.479	.994	1.120	.70-04
N2H4	399	.060	.060	100.	60.	235.0	54.0	71.0	79.0	76.0	1.090	1.190	MIX	*	3916.7	.065	.479	.982	1.210	.70-04
N2H4	400	.060	.060	100.	60.	235.0	53.0	71.0	78.0	84.0	1.060	1.240	MIX	*	3916.7	.118	.479	.976	1.250	.70-04
N2H4	401	.060	.060	100.	60.	235.0	51.0	71.0	83.0	87.0	1.020	1.360	MIX	*	3916.7	.146	.479	.955	1.353	.70-04
N2H4	402	.060	.060	100.	60.	235.0	51.0	69.0	83.0	99.0	1.600	1.320	MIX	*	3916.7	.354	.479	.972	1.270	.72-04
N2H4	403	.060	.060	100.	60.	255.0	50.0	61.0	98.0	103.0	1.160	1.050	MIX	*	4250.0	.529	.466	.999	1.045	.82-04
N2H4	404	.060	.060	100.	60.	215.0	49.0	50.0	97.0	108.0	1.160	.882	MIX	*	3583.3	.907	.494	.951	.728	.10-03
N2H4	405	.060	.060	100.	60.	235.0	48.0	69.0	99.0	48.0	.993	1.440	MIX	*	3916.7	.007	.479	.924	1.492	.72-04
N2H4	406	.060	.060	100.	60.	235.0	56.0	66.0	63.0	66.0	1.020	.980	MIX	*	3916.7	.032	.479	.999	.963	.76-04
N2H4	407	.060	.060	100.	60.	235.0	52.0	65.0	63.0	66.0	1.140	1.090	MIX	*	3916.7	.033	.479	.997	1.084	.77-04
N2H4	408	.060	.060	100.	60.	235.0	54.0	65.0	63.0	66.0	1.110	1.080	MIX	*	3916.7	.033	.479	1.000	1.005	.77-04
N2H4	409	.060	.060	100.	60.	235.0	50.0	65.0	63.0	66.0	1.090	1.210	MIX	*	3916.7	.033	.479	.988	1.172	.77-04
N2H4	410	.060	.060	100.	60.	185.0	36.0	54.0	76.0	85.0	.946	1.620	POP	*	3083.3	.166	.519	.906	1.563	.93-04

HYPERGOLIC STREAM IMPINGMENT DATA COMPLIATION

INVESTIGATOR ZUNG

A L R C MODEL CORRELATION PARAMETERS

FUEL TYPE	TEST NO.	DO (IN)	DF (IN)	L/D	IMP ANGLE (DEG)	PC (PSIA)	VO (FT/S)	VF (FT/S)	TO (F)	TF (F)	MR	MF/MO	COMMENTS	*	PD	IS	R (IN)	EM	SPR	DV (SEC)
N2H4	411	.060	.060	100.	60.	175.0	34.0	55.0	89.0	95.0	.877	1.850	POP	*	2916.7	.336	.529	.836	1.829	.91-04
N2H4	412	.060	.060	100.	60.	190.0	36.0	55.0	87.0	97.0	.919	1.690	POP	*	3166.7	.386	.514	.889	1.627	.91-04
N2H4	413	.060	.060	100.	60.	90.0	40.0	55.0	83.0	89.0	1.030	1.340	POP	*	1500.0	.218	.660	.963	1.319	.91-04
N2H4	414	.060	.060	100.	60.	80.0	39.0	54.0	94.0	105.0	1.010	1.390	POP	*	1333.3	.685	.686	.958	1.339	.93-04
N2H4	415	.060	.060	100.	60.	85.0	44.0	54.0	98.0	108.0	1.140	1.090	POP	*	1416.7	.840	.672	.999	1.054	.93-04
N2H4	416	.060	.060	100.	60.	80.0	43.0	54.0	101.0	110.0	1.130	1.110	POP	*	1333.3	.961	.686	.995	1.106	.93-04
N2H4	417	.060	.060	100.	60.	80.0	41.0	55.0	109.0	116.0	1.050	1.130	POP	*	1333.3	1.405	.686	.972	1.267	.91-04
N2H4	418	.060	.060	100.	60.	80.0	39.0	55.0	102.0	116.0	.950	1.430	POP	*	1333.3	1.405	.686	.947	1.392	.91-04
N2H4	419	.060	.060	100.	60.	80.0	37.2	54.3	102.0	116.0	.980	1.490	POP	*	1333.3	1.424	.686	.924	1.491	.92-04
N2H4	423	.060	.060	100.	60.	105.0	51.7	54.3	109.0	112.0	1.350	.780	POP	*	1750.0	1.093	.627	.969	.778	.92-04
N2H4	424	.060	.060	100.	60.	95.0	50.3	54.3	103.0	114.0	1.320	.820	POP	*	1583.3	1.248	.648	.980	.817	.92-04
N2H4	425	.060	.060	100.	60.	95.0	37.2	53.5	75.0	89.0	.990	1.450	POP	*	1583.3	.225	.648	.938	1.433	.93-04
N2H4	426	.060	.060	100.	60.	95.0	36.2	53.5	64.5	81.5	.970	1.150	POP	*	1583.3	.130	.648	.920	1.505	.93-04
N2H4	427	.060	.060	100.	60.	95.0	34.9	54.7	79.0	81.9	.910	1.720	POP	*	1583.3	.131	.648	.866	1.714	.91-04
N2H4	428	.060	.060	100.	60.	95.0	39.7	54.7	104.0	108.0	1.040	1.330	POP	*	1583.3	.829	.648	.959	1.336	.91-04
N2H4	429	.060	.060	100.	60.	95.0	36.3	54.7	106.0	114.0	.950	1.590	POP	*	1583.3	1.239	.648	.897	1.596	.91-04
N2H4	430	.055	.055	100.	60.	185.0	48.7	58.2	68.0	75.0	1.190	1.000	POP	*	3363.6	.067	.476	1.000	.990	.79-04
N2H4	431	.055	.055	100.	60.	175.0	46.7	58.5	81.0	93.0	1.140	1.100	POP	*	3181.8	.251	.485	.996	1.090	.78-04
N2H4	432	.055	.055	100.	60.	215.0	65.4	74.0	92.5	101.0	1.260	.890	MIX	*	3909.1	.348	.453	.994	.895	.62-04
N2H4	433	.055	.055	100.	60.	215.0	64.4	73.5	97.5	106.0	1.230	.910	MIX	*	3909.1	.494	.453	.996	.912	.62-04
N2H4	434	.055	.055	100.	60.	175.0	51.0	64.5	101.0	114.0	1.200	1.060	MIX	*	3181.8	.963	.485	.994	1.119	.71-04
N2H4	435	.055	.055	100.	60.	75.0	50.1	60.4	96.0	106.0	1.180	1.020	POP	*	1363.6	.601	.643	1.000	1.017	.76-04
N2H4	436	.055	.055	100.	60.	95.0	45.2	59.8	72.5	86.5	1.080	1.230	POP	*	1727.3	.154	.594	.982	1.211	.77-04
N2H4	437	.055	.055	100.	60.	95.0	45.2	59.8	68.0	77.5	1.080	1.230	POP	*	1727.3	.079	.594	.982	1.212	.77-04
N2H4	438	.040	.040	100.	60.	45.0	54.1	50.8	99.0	105.0	1.520	.620	MIX	*	1125.0	.486	.554	.892	.619	.66-04
N2H4	439	.040	.040	100.	60.	45.0	49.5	53.4	94.0	112.0	1.320	.810	MIX	*	1125.0	.741	.554	.978	.810	.62-04
N2H4	440	.040	.040	100.	60.	45.0	57.4	59.7	97.5	102.0	1.370	.760	MIX	*	1125.0	.336	.554	.963	.759	.56-04
N2H4	441	.040	.040	100.	60.	45.0	48.8	53.4	91.0	97.0	1.300	.840	MIX	*	1125.0	.265	.554	.984	.838	.62-04
N2H4	442	.040	.040	100.	60.	45.0	56.5	53.4	107.0	116.0	1.580	.580	MIX	*	1125.0	.965	.554	.898	.628	.62-04
N2H4	443	.040	.040	100.	60.	45.0	54.1	53.4	114.0	125.0	1.450	.680	SEP	*	1125.0	1.727	.554	.932	.686	.62-04
N2H4	444	.040	.040	100.	60.	45.0	60.0	53.4	108.0	108.0	1.600	.550	MIX	*	1125.0	.566	.554	.847	.560	.62-04
N2H4	445	.040	.040	100.	60.	45.0	50.0	57.4	114.0	122.0	1.240	.930	SEP	*	1125.0	1.326	.554	.997	.929	.58-04
N2H4	446	.040	.040	100.	60.	45.0	49.3	57.4	116.0	128.0	1.240	.960	SEP	*	1125.0	1.944	.554	.999	.955	.58-04
N2H4	447	.040	.040	100.	60.	45.0	50.6	66.6	108.0	122.0	1.080	1.220	MIX	*	1125.0	1.143	.554	.981	1.215	.50-04
N2H4	448	.040	.040	100.	60.	55.0	54.1	66.6	104.0	114.0	1.160	1.060	MIX	*	1375.0	.678	.518	.998	1.063	.50-04
N2H4	449	.040	.040	100.	60.	55.0	57.2	66.7	106.0	116.0	1.160	1.060	MIX	*	1375.0	.773	.518	.999	.955	.50-04
N2H4	450	.040	.040	100.	60.	55.0	54.2	66.6	104.0	118.0	1.160	1.060	MIX	*	1375.0	.882	.518	.998	1.057	.50-04
N2H4	451	.040	.040	100.	60.	45.0	45.7	68.2	101.0	106.0	1.130	2.570	MIX	*	1125.0	.387	.554	.905	1.565	.49-04
N2H4	452	.040	.040	100.	60.	45.0	44.4	65.1	97.5	108.0	.970	1.510	MIX	*	1125.0	.465	.554	.921	1.504	.51-04
N2H4	453	.040	.040	100.	60.	50.0	44.9	65.1	91.0	105.0	.980	1.470	MIX	*	1250.0	.379	.535	.930	1.465	.51-04

HYPERGOLIC STREAM IMPINGMENT DATA COMPLIATION

INVESTIGATOR ZUNG

A L R C MODEL CORRELATION PARAMETERS

FUEL TYPE	TEST NO.	DO (IN)	DF (IN)	L/D	IMP ANGLE (DEG)	PC (PSIA)	VO (FT/S)	VF (FT/S)	TO (F)	TF (F)	MR	MF/MO	COMMENTS	*	PD	IS	R (IN)	EM	SPR	DV (SEC)
N2H4	454	.040	.040	100.	60.	65.0	49.8	40.9	114.0	132.0	1.000	1.430	MIX	*	1625.0	3.504	.490	.761	.473	.81-04
N2H4	455	.040	.040	100.	60.	50.0	67.7	68.2	122.0	134.0	1.410	.712	SEP	*	1250.0	2.379	.535	.946	.716	.49-04
N2H4	456	.040	.040	100.	60.	55.0	58.5	66.6	129.0	137.0	1.250	.913	SEP	*	1375.0	2.929	.518	.996	.919	.50-04
N2H4	457	.040	.040	100.	60.	55.0	60.5	66.3	135.0	144.0	1.290	.852	SEP	*	1375.0	4.493	.518	.988	.853	.50-04
N2H4	458	.040	.040	100.	60.	55.0	60.0	64.1	131.0	144.0	1.330	.801	SEP	*	1375.0	4.647	.518	.978	.808	.52-04
N2H4	459	.040	.040	100.	60.	55.0	58.5	62.3	137.0	147.0	1.340	.797	SEP	*	1375.0	5.715	.518	.977	.806	.54-04
N2H4	460	.060	.060	100.	60.	470.0	37.9	66.3	61.5	64.0	.814	2.150	SEP	*	7833.3	.027	.380	.758	2.122	.75-04
N2H4	461	.060	.060	100.	60.	535.0	65.1	66.9	62.5	66.0	1.340	.789	SEP	*	8916.7	.032	.364	.953	.732	.75-04
N2H4	462	.060	.060	100.	60.	535.0	48.4	68.8	62.5	66.0	1.000	1.420	SEP	*	8916.7	.031	.364	.945	1.401	.73-04
N2H4	463	.060	.060	100.	60.	535.0	46.6	68.8	67.0	64.0	.960	1.540	SEP	*	8916.7	.026	.364	.917	1.518	.73-04
N2H4	464	.060	.060	100.	60.	585.0	56.5	68.8	66.0	69.5	1.170	1.040	SEP	*	9750.0	.040	.354	1.000	1.029	.73-04
N2H4	465	.060	.060	100.	60.	475.0	61.3	68.8	67.0	64.0	1.260	.890	SEP	*	7916.7	.026	.379	.991	.877	.73-04
N2H4	466	.060	.060	100.	60.	435.0	54.9	65.7	46.5	52.5	1.190	1.000	SEP	*	7250.0	.011	.390	1.000	.986	.76-04
N2H4	467	.060	.060	100.	60.	455.0	55.9	65.7	48.0	52.5	1.210	.970	SEP	*	7583.3	.011	.385	.999	.952	.76-04
N2H4	468	.060	.060	100.	60.	455.0	61.9	65.7	108.0	110.0	1.350	.790	SEP	*	7583.3	.790	.385	.974	.795	.76-04
N2H4	469	.060	.060	100.	60.	455.0	60.4	68.8	114.0	116.0	1.250	.910	SEP	*	7583.3	1.124	.385	.996	.918	.73-04
N2H4	470	.060	.060	100.	60.	445.0	58.2	68.8	111.0	119.0	1.210	.980	SEP	*	7416.7	1.367	.387	1.000	.984	.73-04
N2H4	471	.060	.060	100.	60.	100.0	46.6	52.8	96.0	92.0	1.260	.900	POP	*	1666.7	.282	.637	.995	.904	.95-04
N2H4	472	.060	.060	100.	60.	100.0	42.6	52.6	64.5	72.0	1.150	1.070	POP	*	1666.7	.064	.637	.999	1.055	.95-04
N2H4	473	.060	.060	100.	60.	100.0	46.6	52.6	63.0	70.0	1.260	.900	POP	*	1666.7	.055	.637	.992	.882	.95-04
N2H4	474	.060	.060	100.	60.	100.0	42.8	52.6	59.5	62.0	1.160	1.060	POP	*	1666.7	.029	.637	.999	1.046	.95-04
N2H4	475	.040	.040	100.	60.	630.0	59.5	77.9	68.0	64.0	1.090	1.200	SEP	*	15750.0	.015	.230	.984	1.195	.43-04
N2H4	476	.040	.040	100.	60.	80.0	73.5	81.7	68.0	64.0	1.280	.870	MIX	*	2000.0	.015	.457	.989	.861	.41-04
N2H4	477	.040	.040	100.	60.	85.0	61.3	83.2	61.0	66.0	1.050	1.290	MIX	*	2125.0	.017	.448	.971	1.275	.40-04
N2H4	478	.040	.040	100.	60.	640.0	65.4	70.0	59.5	66.0	1.330	.807	MIX	*	16000.0	.020	.229	.973	.792	.48-04
N2H4	479	.060	.060	100.	60.	100.0	46.5	52.8	68.0	71.5	1.250	.905	POP	*	1666.7	.062	.637	.994	.896	.95-04
N2H4	480	.060	.060	100.	60.	100.0	48.4	53.7	88.0	64.0	1.280	.860	POP	*	1666.7	.034	.637	.991	.873	.93-04
N2H4	481	.060	.060	100.	60.	23.0	26.5	35.1	128.0	132.0	1.060	1.240	POP	*	383.3	6.125	1.039	.976	1.246	.14-03
N2H4	482	.060	.060	100.	60.	147.0	25.4	34.9	135.0	141.0	1.030	1.330	POP	*	2450.0	10.692	.560	.957	1.344	.14-03
N2H4	483	.060	.060	100.	60.	175.0	43.1	65.1	51.5	60.5	.946	1.600	POP	*	2916.7	.021	.529	.904	1.571	.77-04
N2H4	484	.060	.060	100.	60.	185.0	54.1	64.1	51.5	60.5	1.200	.986	POP	*	3083.3	.021	.519	.999	.967	.78-04
N2H4	485	.040	.040	100.	60.	220.0	54.1	62.6	57.5	60.5	1.230	.938	UNDEF	*	5500.0	.015	.327	.997	.927	.53-04
N2H4	486	.040	.040	100.	60.	90.0	54.1	64.1	54.5	58.5	2.510	.471	MIX	*	2250.0	.012	.440	1.000	.970	.52-04
N2H4	487	.040	.040	100.	60.	100.0	54.1	63.1	56.0	58.5	1.220	.952	MIX	*	2500.0	.012	.425	.998	.941	.53-04
N2H4	488	.040	.040	100.	60.	100.0	54.1	63.8	56.0	58.5	1.210	.970	MIX	*	2500.0	.012	.425	.999	.962	.52-04
N2H4	489	.040	.040	100.	60.	100.0	54.1	63.8	56.0	58.5	1.210	.970	MIX	*	2500.0	.012	.425	.999	.962	.52-04
N2H4	490	.040	.040	100.	60.	150.0	39.8	43.4	62.5	62.5	1.310	.830	MIX	*	3750.0	.025	.371	.982	.826	.77-04
N2H4	491	.040	.040	100.	60.	30.0	38.0	43.4	51.5	56.5	1.250	.910	MIX	*	750.0	.015	.634	.994	.900	.77-04
N2H4	492	.040	.040	100.	60.	30.0	38.6	41.4	64.5	60.0	1.370	.750	MIX	*	750.0	.021	.634	.976	.801	.81-04
N2H4	493	.040	.040	100.	60.	30.0	33.2	40.8	56.0	60.0	1.160	1.060	MIX	*	750.0	.021	.634	.999	1.044	.82-04

HYPERGOLIC STREAM IMPINGMENT DATA COMPILATION

INVESTIGATOR ZUNG

A L R C MODEL CORRELATION PARAMETERS

FUEL TYPE	TEST NO.	DO (IN)	DF (IN)	L/D	IMP ANGLE (DEG)	PC (PSIA)	VO (FT/S)	VF (FT/S)	TO (F)	TF (F)	MR	MF/MO	COMMENTS	*	PD	IS	P (IN)	EM	SPR	DV (SEC)
N2H4	494	.040	.040	100.	60.	30.0	33.9	40.8	56.0	62.0	1.160	1.040	MIX	*	750.0	.025	.634	1.000	1.000	.82-04
N2H4	495	.040	.040	100.	60.	35.0	38.3	43.4	56.0	64.5	1.260	.900	MIX	*	875.0	.029	.602	.993	.886	.77-04
N2H4	496	.040	.040	100.	60.	35.0	36.6	43.4	56.0	66.0	1.210	.980	MIX	*	875.0	.033	.602	1.000	.969	.77-04
N2H4	497	.040	.040	100.	60.	30.0	39.8	44.8	56.0	66.0	1.270	.890	MIX	*	750.0	.032	.634	.991	.873	.74-04
N2H4	498	.040	.040	100.	60.	30.0	39.8	44.8	58.0	66.0	1.270	.890	MIX	*	750.0	.032	.634	.991	.875	.74-04
N2H4	499	.040	.040	100.	60.	30.0	39.6	43.4	56.0	64.5	1.310	.830	MIX	*	750.0	.029	.634	.982	.829	.77-04
N2H4	500	.040	.040	100.	60.	30.0	39.6	43.4	56.0	66.0	1.310	.830	MIX	*	750.0	.033	.634	.982	.828	.77-04
N2H4	501	.040	.040	100.	60.	30.0	30.6	38.3	62.5	74.0	1.140	1.090	MIX	*	750.0	.069	.634	.997	1.082	.87-04
N2H4	502	.040	.040	100.	60.	30.0	33.2	37.3	64.5	69.0	1.270	.880	MIX	*	750.0	.048	.634	.991	.875	.89-04
N2H4	503	.040	.040	100.	60.	30.0	33.2	38.3	66.0	74.0	1.230	.930	MIX	*	750.0	.069	.634	.997	.922	.87-04
N2H4	504	.040	.040	100.	60.	30.0	33.7	31.2	64.5	74.0	1.540	.598	MIX	*	750.0	.084	.634	.874	.593	.11-03
N2H4	505	.040	.040	100.	60.	14.7	20.7	17.2	72.0	92.0	1.710	.488	SEP	*	367.5	.578	.804	.764	.476	.19-03
N2H4	506	.040	.040	100.	60.	14.7	21.4	21.7	72.0	72.0	1.400	.721	SEP	*	367.5	.104	.804	.946	.716	.15-03
N2H4	507	.027	.027	100.	60.	14.7	41.4	27.4	71.0	71.0	2.200	.296	SEP	*	544.4	.051	.543	.513	.305	.82-04
N2H4	508	.027	.027	100.	60.	14.7	40.3	39.2	68.0	70.0	1.480	.650	MIX	*	544.4	.033	.543	.917	.658	.57-04
N2H4	509	.027	.027	100.	60.	14.7	47.1	53.2	68.0	68.0	1.270	.890	MIX	*	544.4	.021	.543	.993	.888	.42-04

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@IR FOR,* MAIN,MAIN                                                                    11 DEC 73   00:00:04.784
DATE, TIME, LEVEL OF OUTPUT ELEMENT: 11 DEC 73  11:14(03)
FORTRAN V:  ISD VERSION 2.9

   MAIN PROGRAM

   STORAGE USED (BLOCK, NAME, LENGTH)

         0001    *CODE    000423
         0000    *DATA    002565
         0002    *BLANK   000000
         0003    DATAI    000015
         0004    BLK2     000040


   EXTERNAL REFERENCES (BLOCK, NAME)

         0005    DATA
         0006    NRDU$
         0007    NIO1$
         0010    NIO2$
         0011    NRNL$
         0012    SIN
         0013    ALOG
         0014    EXP
         0015    NEXP6$
         0016    NWDU$
         0017    NSTOP$


   STORAGE ASSIGNMENT FOR VARIABLES (BLOCK, TYPE, RELATIVE LOCATION, NAME)

    0000    002365 1000F      0000    002366 1001F      0001    000006 117G       0001    000027 133G       0001    000053 142G
    0001    000414 2L         0000    002501 2001F      0001    000323 206G       0000    002525 3000F      0000    002530 5000F
    0003 R  000001 DF         0003 R  000000 DO         0000 R  002345 DV         0000 R  002334 DVF        0000 R  002341 EM
    0000 I  002330 I          0003 I  000011 ICOM       0000 I  002306 ICOMN      0003 I  000012 IFUEL      0000 I  002304 IFUELN
    0000 I  002324 II         0003 R  000013 IMP        0000 I  002327 INDEX      0000 I  000334 INV        0000 I  002331 INVEST
    0000 I  002312 INVN       0000 I  002321 IPAGE      0000 I  002346 IPRNT      0000 I  002326 IPROC      0000 R  002315 IS
    0000 I  000024 ITEST      0000 I  002316 I$         0000 I  002323 J          0000 I  002322 K          0003 R  000010 MOM
    0003 R  000007 MR         0000 I  002344 NN         0000 I  002317 NSETS      0000 I  002325 NTEST      0003 R  000002 PC
    0000 R  002342 PD         0000 R  002336 R          0003 R  000014 RHF        0000 R  002333 RHOO       0000 R  002340 RN
    0000 R  002337 RNN        0004 R  000030 SGA50      0004 R  000010 SGN2H      0000 R  002332 SGN2O4     0000 R  002343 SPR
    0000 R  002335 T          0004 R  000020 TA50       0003 R  000006 TF         0000 R  000000 TITLE      0004 R  000000 TN2H4
    0003 R  000005 TO         0003 R  000004 VF         0003 R  000003 VO         0000 R  002320 XLD


00101      1*          DIMENSION TITLE(20),ITEST(200),INV(1000),
00101      2*         1          IFUELN(2),ICOMN(4),INVN(3)
00101      3*    C
00103      4*          REAL IMP,MOM,MR,IS
00104      5*          COMMON/DATAI/DO,DF,PC,VO,VF,TO,TF,MR,MOM,ICOM,IFUEL,IMP,RHF
00105      6*          COMMON/BLK2/ TN2H4(8),SGN2H(8),TA50(8),SGA50(8)
00106      7*          DATA INVN/' ZUNG','NURICK','HOUSEM',/
00110      8*          DATA ICOMN/'  MIX ','  SEP ','  POP ',' UNDEF',/
00112      9*          DATA IFUELN/'N2H4','A-50 ',/
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00112   10*   C
00114   11*         NAMELIST/INPUT/TITLE,ITEST,NSETS,INV,
00114   12*   C
00115   13*         READ(5,1000) TITLE
00115   14*   C
00123   15*         READ(5,INPUT)
00123   16*   C                    HERE WE SET THE CASES TO BE PROCESSED
00123   17*   C                         NSETS  =  NO. OF GROUPS OF SEQUENCEIAL TESTS
00123   18*   C                         ITEST  =  RANGE OF TESTS IN SEQUENCE ITEST(I)-ITEST(N)
00123   19*   C                         INV    =  INVESTIGATORS  FLAG  1 ZUMG, 2 NURICK
00123   20*   C
00123   21*   C
00126   22*         XLD=100.
00127   23*         IPAGE=0
00130   24*         K=0
00131   25*         J=1
00132   26*         DO 1 II=1,NSETS
00135   27*         NTEST=ITEST(J+1)-ITEST(J)+1
00136   28*         IPROC=NTEST+ITEST(J)-1
00137   29*         INDEX=ITEST(J)
00140   30*         J=J+2
00140   31*   C
00140   32*   C                    HERE WE START PROCESSING EACH TEST OF NSETS
00140   33*   C
00141   34*         DO 2 I=INDEX,IPROC
00141   35*   C                          CHECK FOR INVESTIGATORS
00144   36*         IPAGE=IPAGE+1
00145   37*         K=K+1
00146   38*         INVEST=INV(K)
00147   39*         CALL DATA(INVEST,I)
00150   40*         IF(VO .LE. 0. ) IPAGE=IPAGE-1
00152   41*         IF(VO .LE. 0. ) GO TO 2
00152   42*   C
00152   43*   C                    CALCULATE ALRC MODEL CORRELATION PARAMETERS
00152   44*   C
00154   45*         SGN204=(12.5E-4*(11.6-TO)+1.515)+(11.2E-6*100.)
00155   46*         RHOO=SGN204*62.40
00156   47*         DVF = DF/12./VF/SIN(0.5*IMP/57.3)
00157   48*         T= TF+460.
00160   49*         IS  = EXP(ALOG(DVF)+(46.8 -(21800./T)))
00161   50*         R   = 49.2 * DF/ PC**0.333
00162   51*         RNN =(RHOO* VO * VO * DO)/( RHF * VF* VF * DF)
00163   52*         RN  = 1.0 / (1.0 + RNN )
00164   53*         EM  = (1.0- (1.0-2.0*RN)**2)**2
00165   54*         PD=PC/DF                                                          *NEW
00165   55*   C
00165   56*   C                    CALCULATE RUPE STAGNATION PRESSURE RATIO
00165   57*   C
00166   58*         SPR =(RHF * VF * VF)/(RHOO * VO * VO)
00166   59*   C
00166   60*   C                    CALCULATE JPL MODEL PARAMETERS
00166   61*   C
00167   62*         IF(INVEST .EQ. 3) NN='AN'
00171   63*         IF(INVEST .NE. 3) NN='
00173   64*         DV = DF/12.0/VF
00174   65*         IF(IPAGE .GT. 40) IPAGE=1
00176   66*         IF( K .GT. 1 .AND.(INV(K)-IPRNT) .NE. 0) IPAGE=1
00200   67*         IF( K .GT. 1 .AND. IPAGE .EQ. 1) WRITE(6,5000)
00203   68*         IF(IPAGE .EQ. 1) WRITE(6,3000) TITLE
00212   69*         IF(IPAGE .EQ. 1) WRITE(6,1001) INVN(INVEST),NN
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00217     70*          WRITE(6,2001) IFUELN(IFUEL),I,DO,DF,XLD,IMP,PC,VO,VF,TO,TF,MR,
00217     71*         1MOM,ICOMN(ICOM),PD,IS,R,EM,SPR,DV                                  *NEW
00245     72*          IPRNT=INVEST                                                       **-1
00246     73*        2 CONTINUE
00250     74*        1 CONTINUE
00252     75*     1000 FORMAT(20A4)
00253     76*     1001 FORMAT(//T50,'HYPERGOLIC  STREAM  IMPINGMENT  DATA  COMPLIATION',
00253     77*         1///T28,'INVESTIGATOR   ',A6,A2,T91,'A L R C MODEL CORRELATION PARA
00253     78*         AMETERS',
00253     79*         2    ///T32,'IMP',/T4,'FUEL TEST  DO    DF   L/D  ANGLE  PC    VO',
00253     80*         3T49,'VF    TO    TF     MR  MF/MO   COMMENTS * ',  T93,'PD',        *NEW
00253     81*         4T101,'IS',T108,'R',T114,'EM',T120,'SPR',T128,'DV',/                  *NEW
00253     82*         5T4,'TYPE  NO. (IN)  (IN)       (DEG)(PSIA)(FT/S)(FT/S) (F)   (F)',   **-2
00253     83*         6T68,            T107,'(IN)',T127'(SEC)',/)                           *NEW
00254     84*     2001 FORMAT(T4,A6,I3,2(F5.3,1X),2(F4.0,1X),5(F5.1,1X),2(F5.3,1X),T81,     **-1
00254     85*         1A6,T89,'*',T90, F7.1,T97,F6.3,1X,F6.3,1X,F5.3,1X,F6.3,E10.2)         *NEW
00255     86*     3000 FORMAT(//40X,20A4,/)                                                 **-1
00256     87*     5000 FORMAT(1H1)
00257     88*          END

     END OF UNIVAC 1108 FORTRAN V COMPILATION.     0 *DIAGNOSTIC* MESSAGE(S)
MAIN            SYMBOLIC                                  10 DEC 73  14:18(02)  0  00175000    14    87  (DELETED)
MAIN     CODE   RELOCATABLE                                10 DEC 73  14:18(02)  0  00177302    14    43  (DELETED)
                                                                                  1  00200434    36     1
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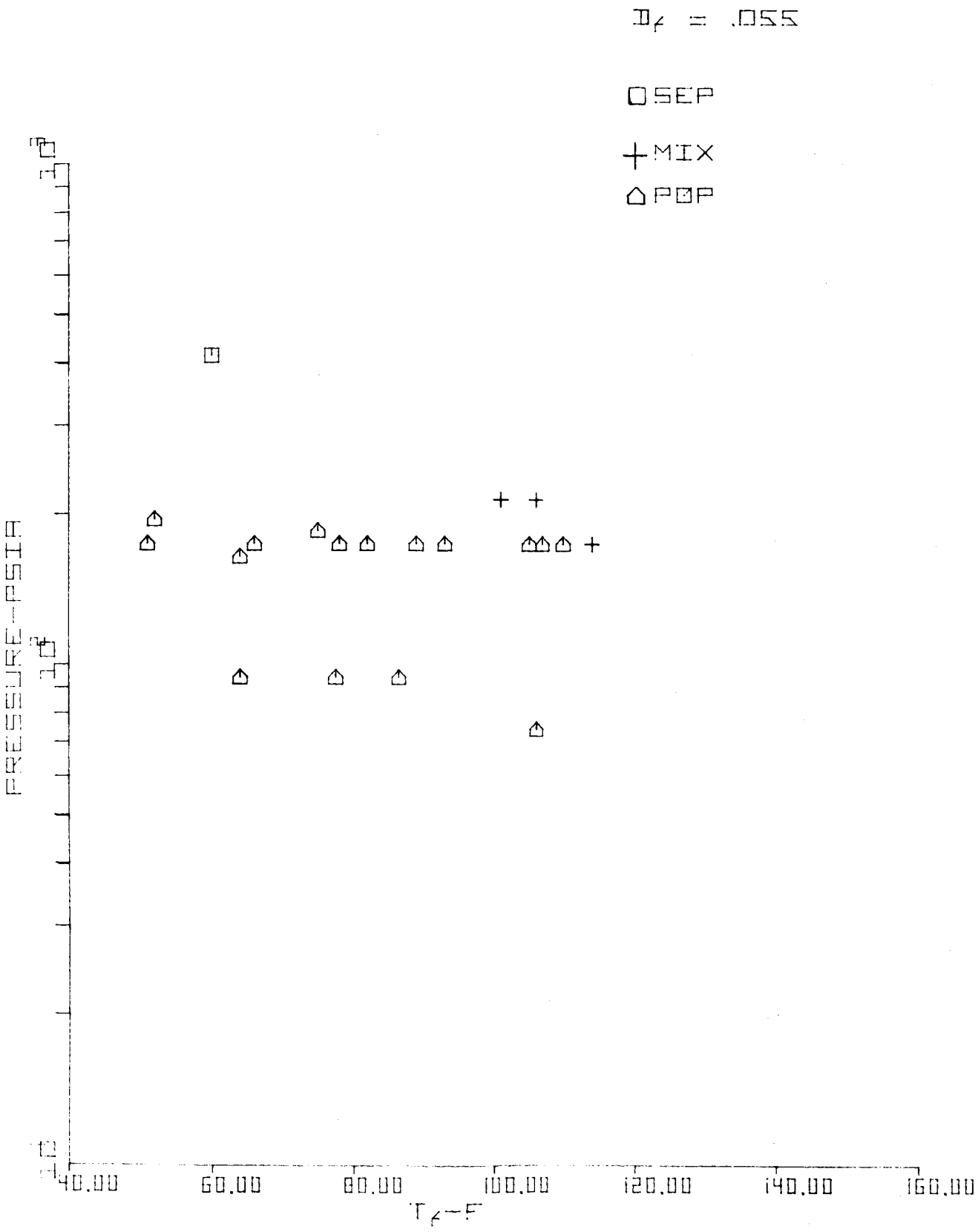
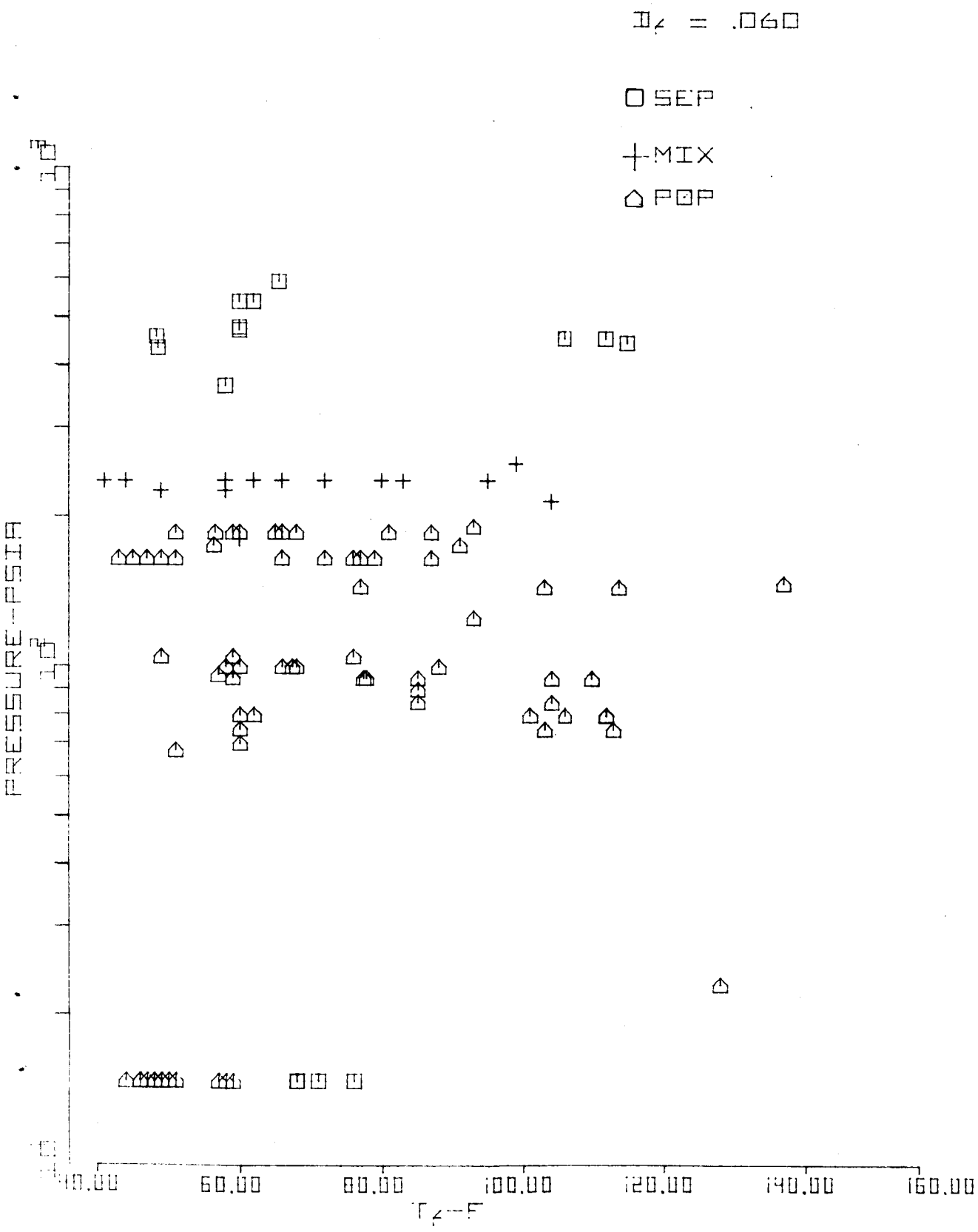
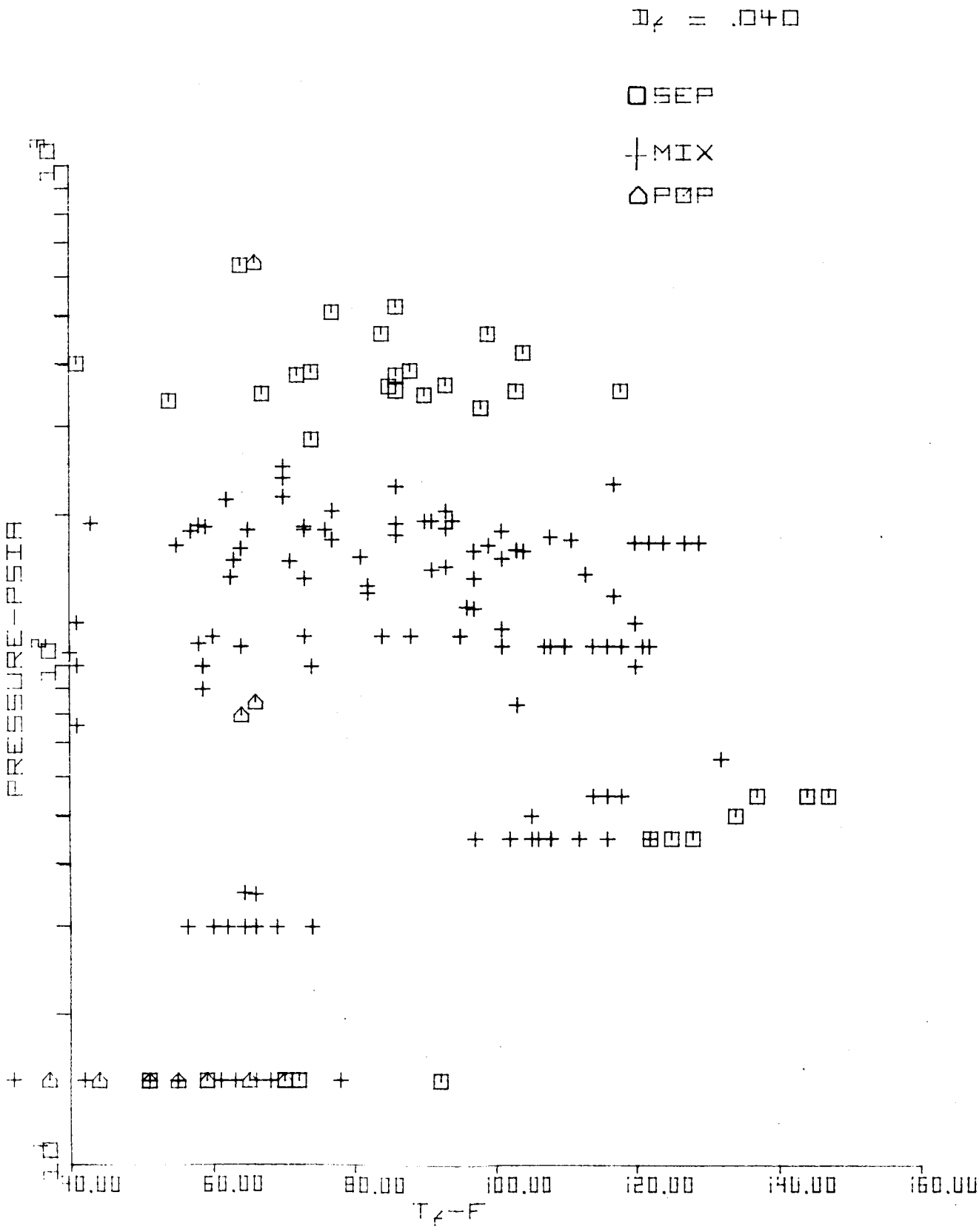
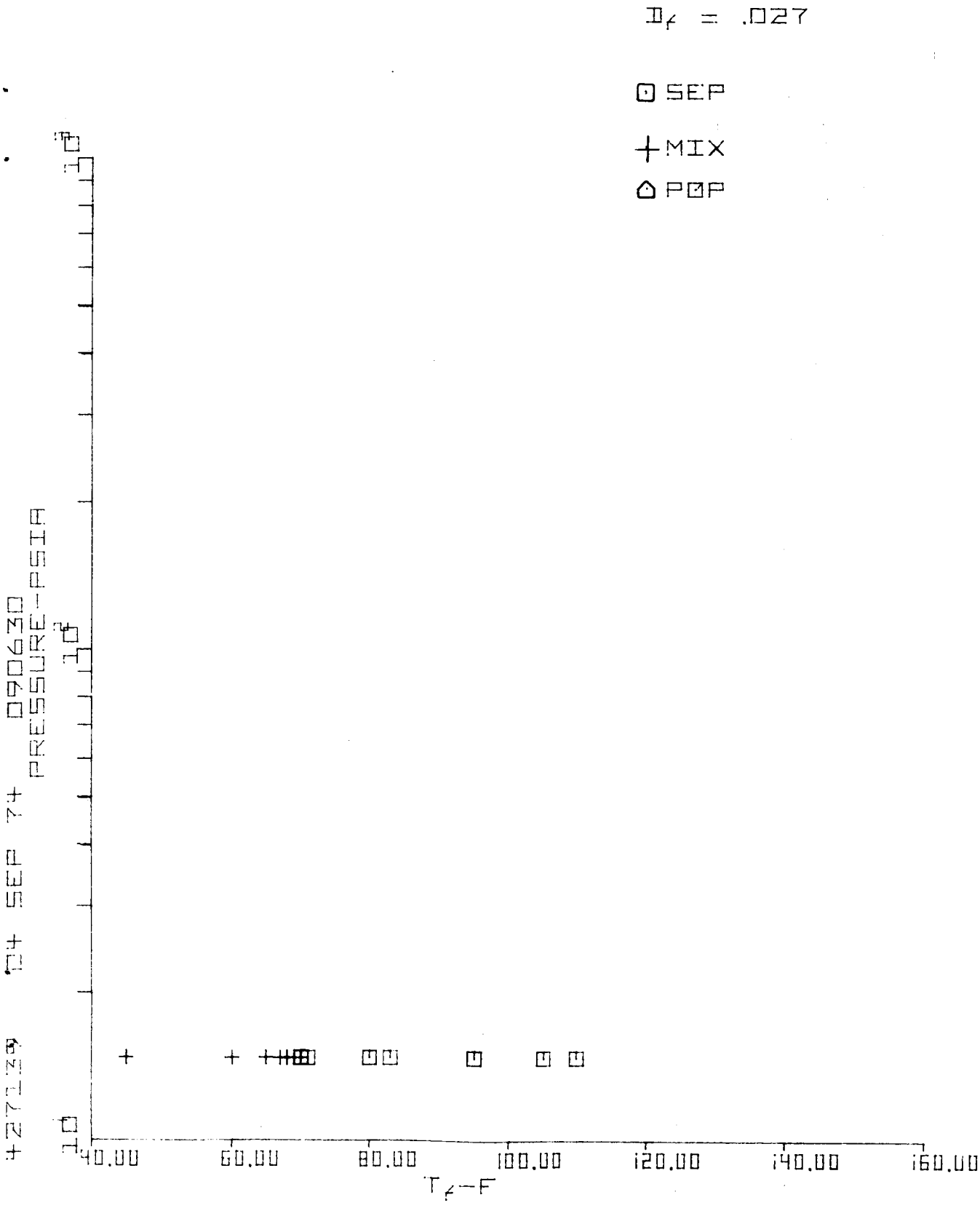
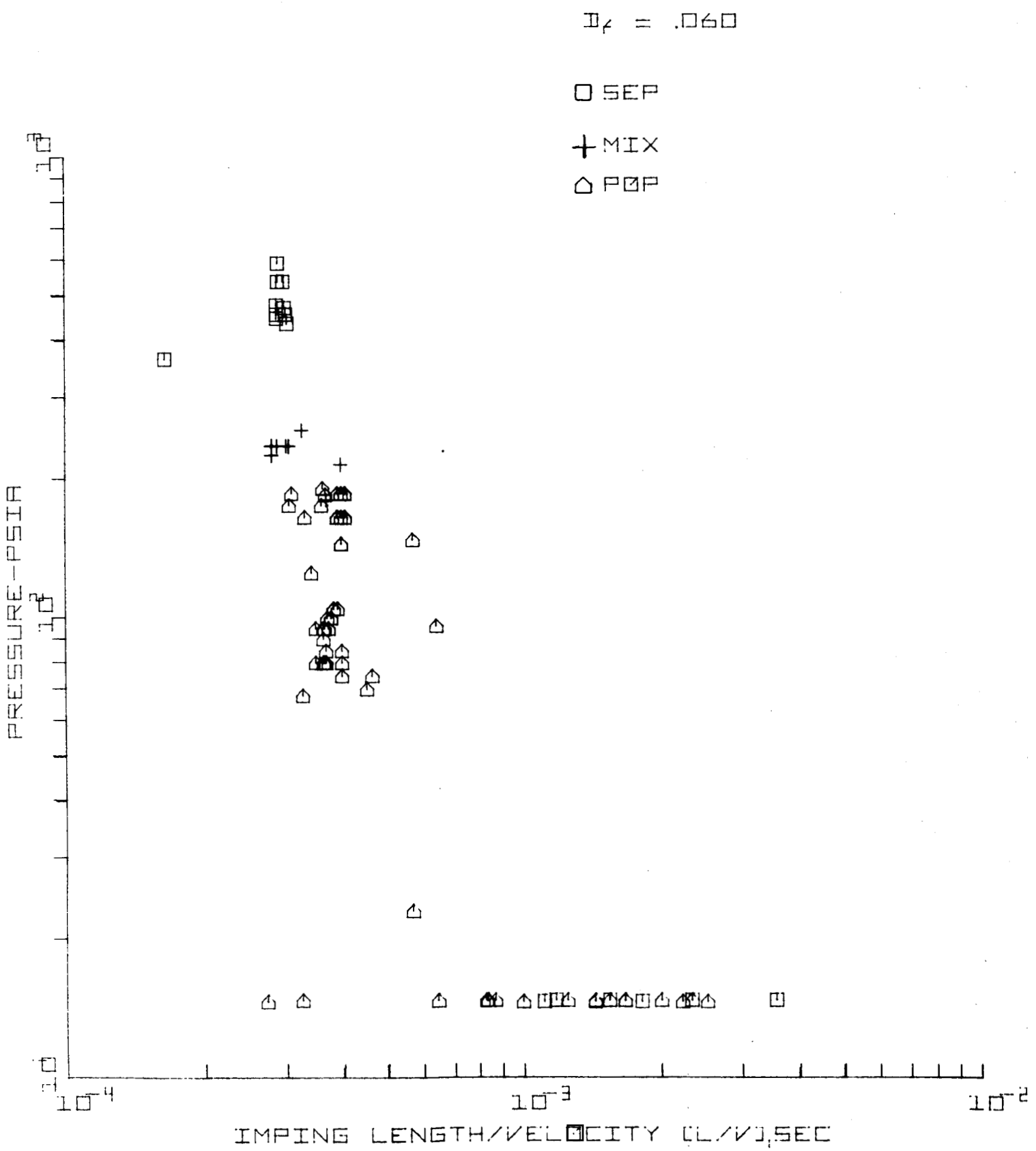
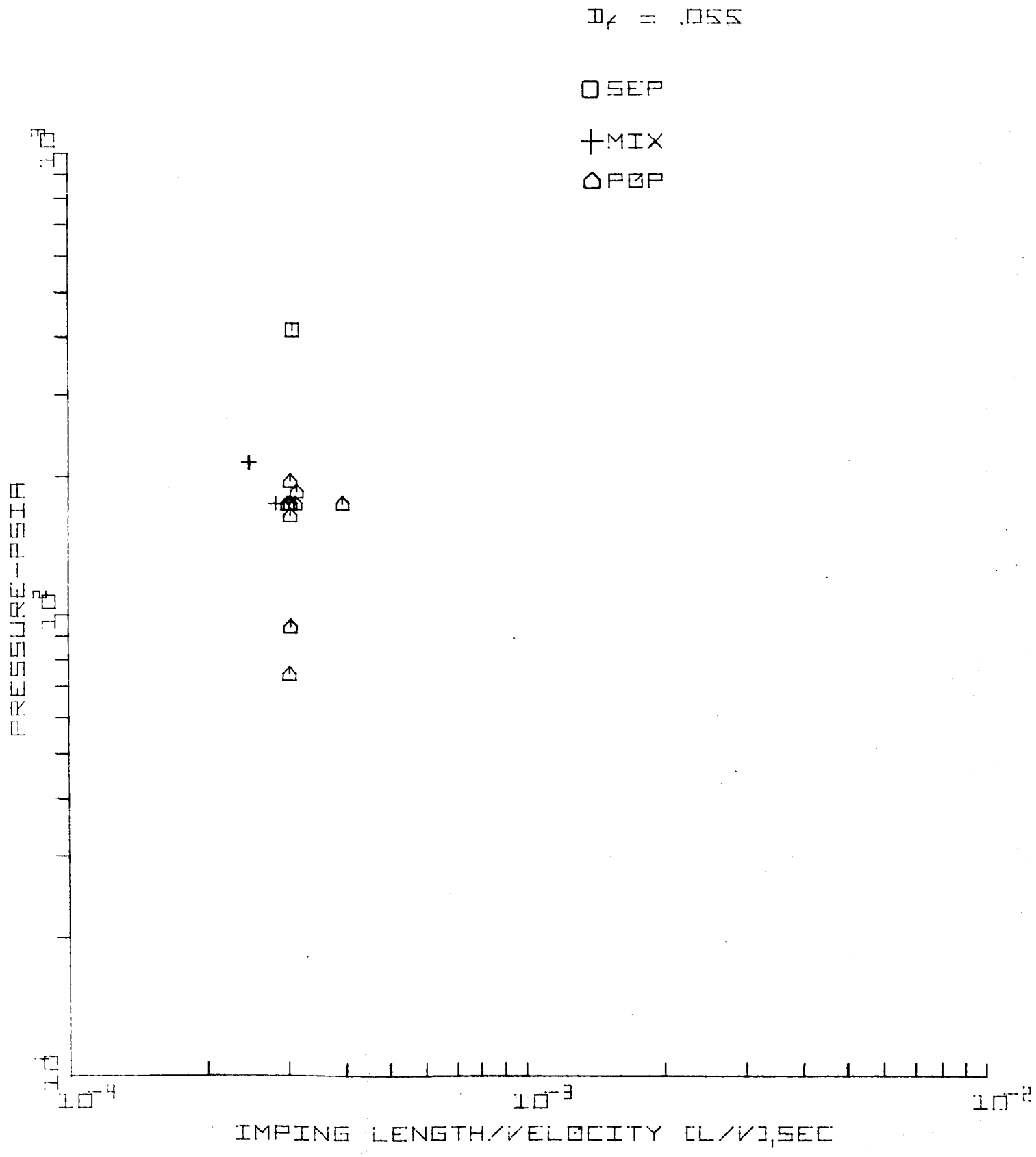

D_f = .055
SEP
MIX
POP
PRESSURE-PSIA
40.00
60.00
80.00
100.00
120.00
140.00
160.00
T_f-F

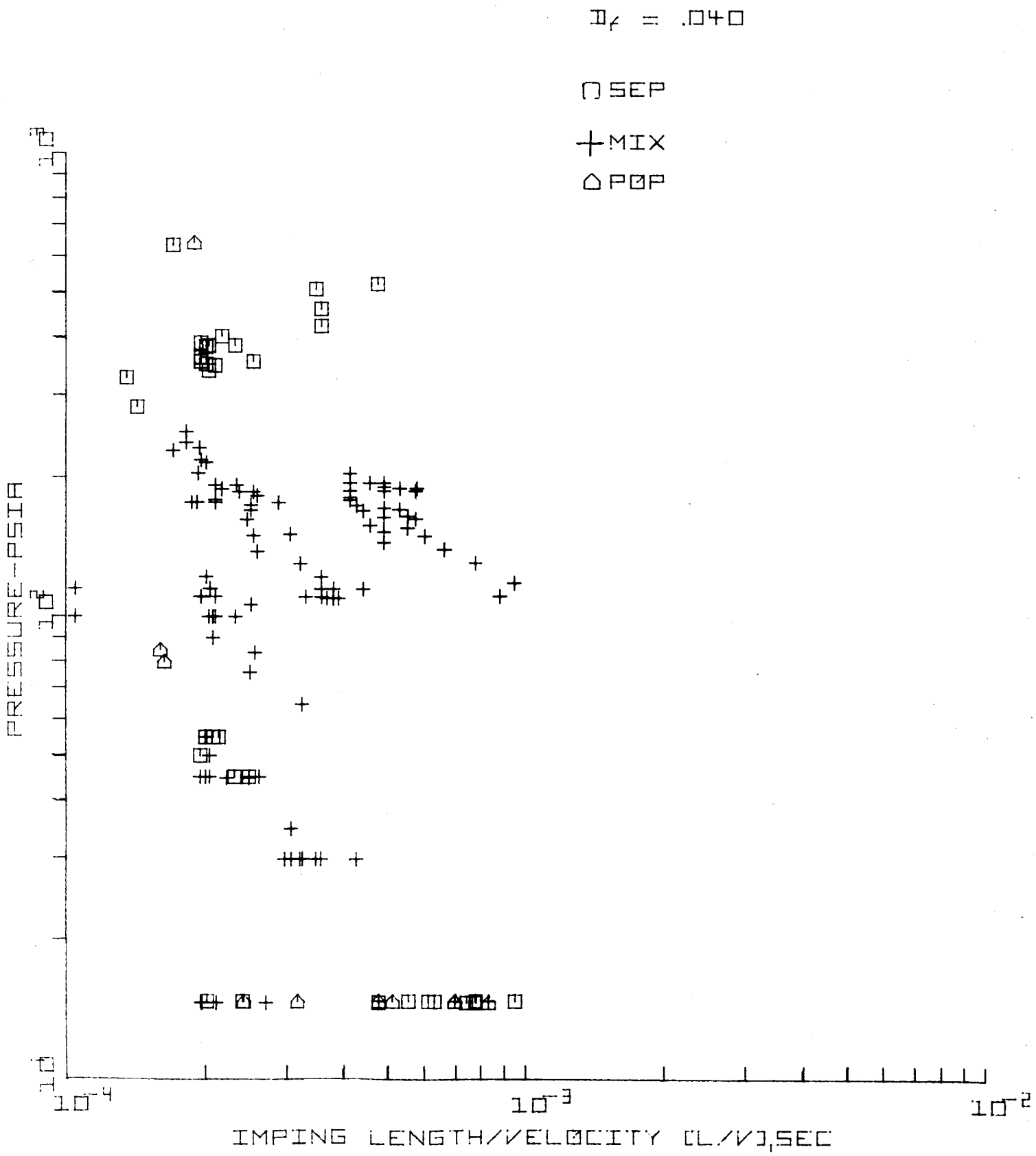

X = .060
SEP
MIX
POP
PRESSURE--PSIA
40.00
60.00
80.00
100.00
120.00
140.00
160.00
T--F

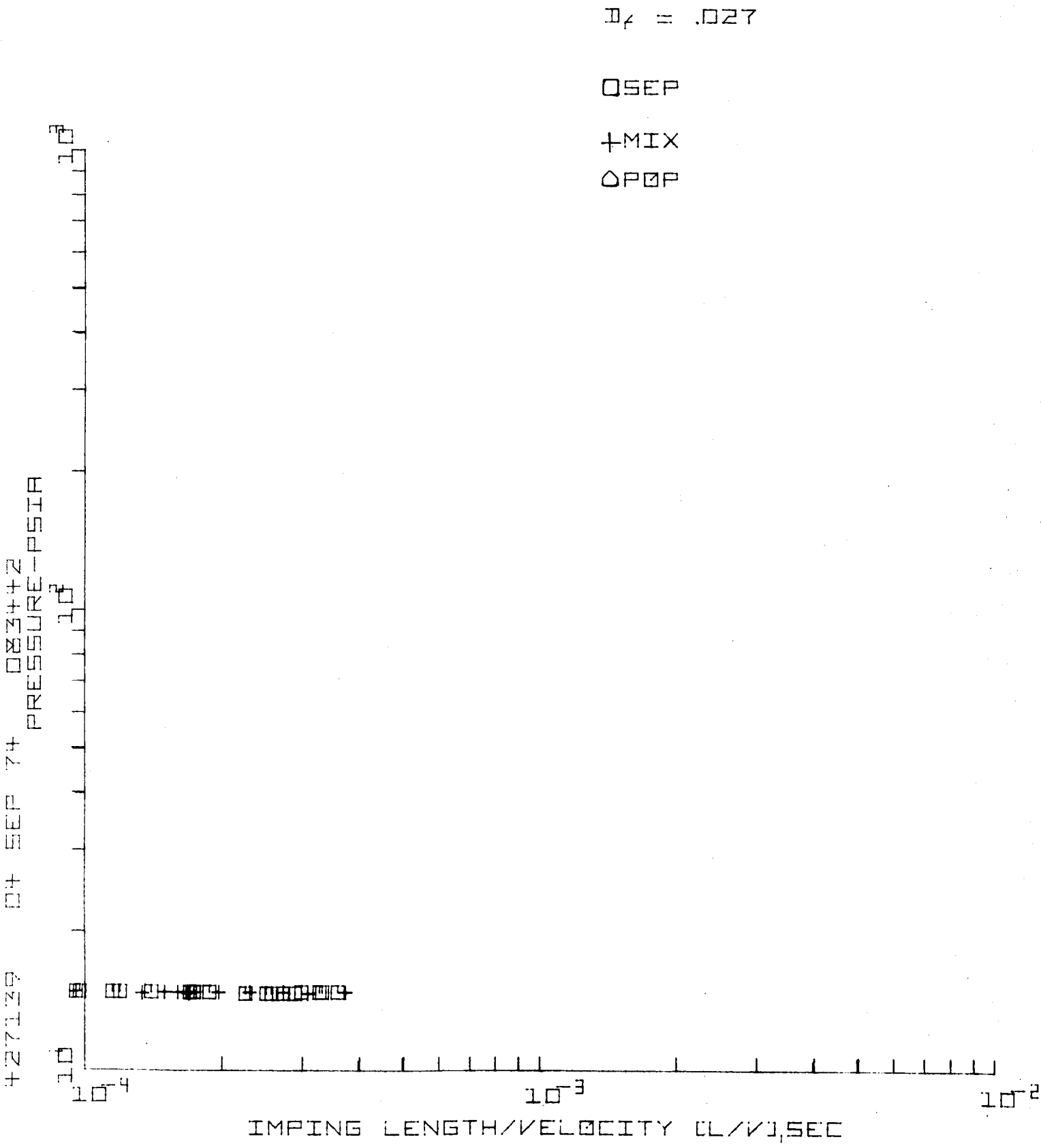

D_f = .040
SEP
MIX
POP
PRESSURE-PSIA
40.00
60.00
80.00
100.00
120.00
140.00
160.00
T_f-F


D_f = .027
SEP
MIX
POP
PRESSURE-PSIA
10^3
10^2
10^1
40.00
60.00
80.00
100.00
120.00
140.00
160.00
T_f-F


D_f = .060
SEP
MIX
POP
PRESSURE-PSIA
IMPING LENGTH/VELOCITY [L/V],SEC


D_f = .055
SEP
MIX
POP
PRESSURE-PSIA
IMPING LENGTH/VELOCITY [L/V],SEC


D_f = .040
SEP
MIX
POP
PRESSURE-PSIA
IMPING LENGTH/VELOCITY [L/V],SEC


D_f = .027
□SEP
+MIX
△POP
PRESSURE-PSIA
IMPING LENGTH/VELOCITY [L/V],SEC
10^{-4}
10^{-3}
10^{-2}

```
@FOR,IS VAPOR
FORTRAN V:  ISO VERSION 4.4S-09/03/74-09:05:38 (,0)

   MAIN PROGRAM

   STORAGE USED: CODE(1) 000326; DATA(0) 000300; BLANK COMMON(2) 000000

    COMMON BLOCKS:

    0003   LIQ     000002
    0004   VAP     000005
    0005   GAS     000004
    0006   MIX     000010


   EXTERNAL REFERENCES (BLOCK, NAME)

    0007   PROPMX
    0010   NINTR$
    0011   NRNL$
    0012   NWNL$
    0013   SIN
    0014   SQRT
    0015   CBRT
    0016   ALOG
    0017   EXP
    0020   NSTOP$

   STORAGE ASSIGNMENT  (BLOCK, TYPE, RELATIVE LOCATION, NAME)

    0001   000045 10L       0001   000236 15L       0001   000320 20L       0001   000324 30L       0001   000002 5L
    0000 R 000014 ALPHA     0005   000000 CPG       0003 R 000000 CPL       0006 R 000002 CPMX      0004 R 000000 CPV
    0006 R 000004 DMX       0000 R 000004 DO        0000 R 000032 DT        0000 R 000026 DTL       0000 R 000034 DTV
    0000 R 000031 DX        0004 R 000004 HV        0000   000042 INPUT     0000 I 000037 NS        0000 I 000007 NSTEP
    0000   000074 OUT1      0000   000134 OUT2      0000   000155 OUT3      0000   000207 OUT4      0000 R 000002 PC
    0000 R 000033 PCTV      0000 R 000016 PR        0006 R 000006 PV        0000 R 000025 QHV       0000 R 000024 QSH
    0000 R 000022 QTOT      0000 R 000023 QV        0000 R 000012 RED       0003 R 000001 RHOL      0006 R 000005 RHOMX
    0000 R 000010 RM        0000 R 000011 SC        0000 R 000006 SPACE     0006 R 000007 TAVE      0000 R 000001 TB
    0000 R 000005 THETA     0000 R 000000 TL        0000 R 000035 TV        0000 R 000003 U         0000 R 000015 WFV
    0000 R 000027 WL        0000 R 000040 WLV       0000 R 000041 WL1       0000 R 000030 XIMP      0005   000001 XKG
    0006 R 000001 XKMX      0004   000001 XKV       0005   000002 XMUG      0006 R 000003 XMUMX     0004   000002 XMUV
    0005   000003 XMWG      0006 R 000000 XMWMX     0004 R 000003 XMWV      0000 R 000017 XNUH      0000 R 000013 XNUM
    0000 R 000036 XSTEP     0000 R 000021 Z         0000 R 000020 ZZ


00100      1*      C
00100      2*      C      PROGRAM TO CALCULATE THE HEAT UP OF A CYLINDRICAL JET
00100      3*      C      PRIOR TO IMPINGEMENT
00100      4*      C
00101      5*             NAMELIST/INPUT/TL,TB,PC,U,DO,THETA,SPACE,NSTEP
00103      6*             NAMELIST/OUT1/XMWMX,XKMX,CPMX,XMUMX,DMX,PV,TAVE,RHOMX,U,RM                    000001
00104      7*             NAMELIST/OUT2/SC,RED,XNUM,ALPHA,WFV                                           000001
00105      8*             NAMELIST/OUT3/PR,XNUH,ZZ,Z,QTOT,QV,QSH,QHV                                    000001
00106      9*             NAMELIST/OUT4/DTL,RHOL,CPL,WL,TL,XIMP,DX,DT,PCTV,DTV,TV                       000001
```

```
00107          COMMON/LIQ/CPL,RHOL                                          000002
00110          COMMON/VAP/CPV,XKV,XMUV,XMWV,HV                              000002
00111          COMMON/GAS/CPG,XKG,XMUG,XMWG                                 000002
00112          COMMON/MIX/XMWMX,XKMX,CPMX,XMUMX,DMX,RHOMX,PV,TAVE           000002
00113        5 CONTINUE                                                     000002
00114          READ (5,INPUT,END=30)                                        000002
00117          WRITE(6,INPUT)                                               000006
00122          RM=3./4.*DO                                                  000012
00123          U=U*12.                                                      000015
00124          XSTEP=NSTEP                                                  000020
00125          THETA=THETA/57.3                                             000023
00126          XIMP=SPACE/2./SIN(THETA)                                     000026
00127          DX=XIMP/XSTEP                                                000035
00130          DT=DX/U                                                      000037
00131          PCTV=0.                                                      000041
00132          NS=0                                                         000042
00133          WLV=0.0                                                      000043
00134       10 CONTINUE                                                     000045
00135          NS=NS+1                                                      000045
00136          CALL PROPMX(TL,TB,PC)                                        000047
00136    C                                                                  000047
00136    C     CALCULATE MASS TRANSFER RATE                                 000047
00136    C                                                                  000047
00137          SC=XMUMX/DMX/RHOMX                                           000054
00140          RED=2.*RM*U*RHOMX/XMUMX                                      000060
00141          XNUM=2.+0.6*SQRT(RED)*CBRT(SC)                               000066
00142          ALPHA=PC/PV*ALOG(PC/(PC-PV))                                 000102
00143          WFV=2.*3.14159*DMX*XMWV*RM*ALPHA*XNUM*PV/18510./TAVE*1.25    000116
00143    C                                                                  000116
00143    C     CALCULATE HEAT TRANSFER RATE                                 000116
00143    C                                                                  000116
00144          PR=CPMX*XMUMX/XKMX                                           000131
00145          XNUH=2.0+0.6*CBRT(PR)*SQRT(RED)                              000135
00146          ZZ=WFV*CPV/2./3.14159/XKMX/RM/XNUH                           000144
00147          IF(ZZ.GE.80) ZZ=80.                                          000154
00151          Z=ZZ/(EXP(ZZ)-1.)                                            000163
00152          QTOT=2.*3.14159*XKMX*XNUH*RM*(TB-TL)*1.25                    000172
00153          QV=QTOT*Z                                                    000203
00154          QSH=QTOT-QV                                                  000205
00155          QHV=WFV*HV                                                   000207
00156          DTV=QSH/CPV/WFV                                              000212
00157          TV=TL+DTV                                                    000215
00160          IF(TV.LT.2500) GO TO 15                                      000217
00162          DTV=2500.-TL                                                 000225
00163          TV=2500.                                                     000226
00164          QSH=(2500.-TL)*CPV*WFV                                       000230
00165          QV=QTOT-QSH                                                  000233
00166       15 CONTINUE                                                     000236
00167          WL1=3.14159/4.*(DO**2.)*XIMP*RHOL                            000236
00170          WL=4./3.*3.14159*(RM**3.)*RHOL                               000243
00171          WLV=WLV+WFV*DT                                               000251
00172          PCTV=WLV/WL1*100.                                            000255
00173          DTL=(QV-WFV*HV)/CPL/WL*DT                                    000260
00174          TL=TL+DTL                                                    000267
00175          WRITE(6,OUT1)                                                000271
00200          WRITE(6,OUT2)                                                000275
00203          WRITE(6,OUT3)                                                000301
```

```
00206     67*          WRITE(6,OUT4)                                  000305
00211     68*          IF(NS.GE.NSTEP) GO TO 20                       000311
00213     69*          GO TO 10                                       000316
00214     70*       20 CONTINUE                                       000320
00215     71*          THETA=THETA*57.3                               000320
00216     72*          GO TO 5                                        000322
00217     73*       30 CONTINUE                                       000325
00220     74*          END                                            000325

      END OF COMPILATION:        NO  DIAGNOSTICS.
```

```
$FOR,IS PROPMX
FORTRAN V:  ISU VERSION 4.4S-09/03/74-09:05:42 (,0)

  SUBROUTINE PROPMX    ENTRY POINT 000167

  STORAGE USED: CODE(1) 000202; DATA(0) 000064; BLANK COMMON(2) 000000

   COMMON BLOCKS:

   0003   LIQ    000002
   0004   VAP    000005
   0005   GAS    000004
   0006   MIX    000010

  EXTERNAL REFERENCES (BLOCK, NAME)

   0007   EXP
   0010   XPRR
   0011   NERR3$

  STORAGE ASSIGNMENT  (BLOCK, TYPE, RELATIVE LOCATION, NAME)

   0005 R 000000 CPG       0003 R 000000 CPL       0006 R 000002 CPMX      0004 R 000000 CPV       0000 R 000000 C1
   0000 R 000001 C2        0006 R 000004 DMX       0004 R 000004 HV        0000   000042 INJP$     0006 R 000006 PV
   0003 R 000001 RHOL      0006 R 000005 RHOMX     0006 R 000007 TAVE      0005 R 000001 XKG       0006 R 000001 XKMX
   0004 R 000001 XKV       0005 R 000002 XMUG      0006 R 000003 XMUMX     0004 R 000002 XMUV      0005 R 000003 XMWG
   0006 R 000000 XMWMX     0004 R 000003 XMWV


00101      1*            SUBROUTINE PROPMX (TL,TB,PC)
00101      2*      C
00101      3*      C     SUBROUTINE TO CALCUATE N2H4 LIQUID AND VAPOR PROPERTIES
00101      4*      C     AND N2H4/NTO GAS PROPERTIES
00101      5*      C
00103      6*            COMMON/LIQ/CPL,RHOL
00104      7*            COMMON/VAP/CPV,XKV,XMUV,XMWV,HV
00105      8*            COMMON/GAS/CPG,XKG,XMUG,XMWG
00106      9*            COMMON/MIX/XMWMX,XKMX,CPMX,XMUMX,DMX,RHOMX,PV,TAVE
00107     10*            TAVE=(TL+TB)/2.
00107     11*      C
00107     12*      C     CALC LIQUID PROPERTIES
00107     13*      C
00110     14*            CPL=.589125+2.80708E-4*TL                                  000003
00111     15*            RHOL=3.062318E-2+4.028897E-5*TL-5.54321E-8*(TL**2.)        000007
00111     16*      C                                                                000007
00111     17*      C     CALC VAPOR PROPERTIES                                      000007
00111     18*      C                                                                000007
00112     19*            CPV=.336+1.804E-4*TAVE                                     000020
00113     20*            XKV=1.23753E-8+2.230358E-10*TAVE                           000023
00114     21*            XMUV=4.19981E-8+9.581164E-10*TAVE                          000027
00115     22*            XMWV=32.084                                                000033
```

```
00116    23*          PV=EXP(14.328787-(7363.22/(TL-63.1713)))                    000035
00117    24*          HV=730.747-0.3591305*TL+1.214E-4*(TL**2.)                   000047
00117    25*     C                                                                000047
00117    26*     C    CALC GAS PROPERTIES                                         000047
00120    27*          CPG=0.517                                                   000056
00121    28*          XKG=4.0E-6                                                  000060
00122    29*          XMUG=4.74E-6                                                000062
00123    30*          XMWG=20.82                                                  000064
00123    31*     C                                                                000064
00123    32*     C    CALC VAPOR MIX MEAN PROPERTIES                              000064
00123    33*     C                                                                000064
00124    34*          C1=(1.-PV/2./PC)                                            000066
00125    35*          C2=PV/2./PC                                                 000073
00126    36*          XMWMX=C1*XMWG+C2*XMWV                                       000075
00127    37*          CPMX=C1*XMWG/XMWMX*CPG+C2*XMWV/XMWMX*CPV                    000102
00130    38*          XKMX=C1*XKG+C2*XKV                                          000111
00131    39*          XMUMX=C1*XMUG+C2*XMUV                                       000115
00132    40*          DMX=(.63+.001*(TAVE-2000.))*(300./PC)/(XMWMX**(.83-.06*(((TAVE-300  000122
00132    41*         *0.)/1000.)**2.)))                                           000122
00133    42*          RHOMX=PC*XMWMX/TAVE/18510.                                  000146
00134    43*          RETURN                                                      000152
00135    44*          END                                                         000201
```

END OF COMPILATION: NO DIAGNOSTICS.

@FIN