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FINAL REPORT

LOX/HYDROCARBON FUEL CARBON FORMATION AND MIXING DATA ANALYSIS

CONTRACT NAS 3-22823

BY

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16 Abstract

The results of a previous high-speed single-element photographic study of LOX/Hydrocarbon propellant combustion have shown regions of dark clouds emanating from the propellant spray. The prevalence of these dark clouds was found to be dependent on chamber pressure, fuel temperature, propellant mixture ratio, and injector element design; and they have been interpreted as areas of fuel vaporization-dependent carbon formation. The present study is an attempt to verify the hypothesis of fuel-vaporization limited carbon formation through analytical effort.

By applying the Priem-Heidmann Generalized-Length vaporization correlation, the computer model developed by the present study predicts the spatial variation of propellant vaporization rate using the injector cold-flow results to define the streamtubes. The calculations show that the overall and local propellant vaporization rate and mixture ratio change drastically as the injection element type or the injector operating condition is changed. These results are compared with the regions of carbon formation observed in the photographic combustion testing. The correlation shows that the fuel vaporization rate and the local mixture ratio produced by the injector element have first order effects on the degree of carbon formation. Low fuel vaporization rates significantly increase the degree of carbon formation. Also, fuel rich zoned containing vaporizing liquid fuel, are sources of carbon formation. For similar injector operating conditions, propane produces less carbon formation than RP-1 because of its higher vaporization rate. Chamber pressure also appears to have an effect on carbon formation which is observed to decrease with increasing pressure.

As a result, the degree of carbon formation can be controlled by controlling the fuel vaporization rate and the local combustor mixture ratio distribution. These parameters, on the other hand, are a function of the injector element design and the propellant properties and operating condition.

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FOREWORD

This final report is submitted for the LOX/Hydrocarbon Fuel Carbon Formation and Mixing Data Analysis Program per the requirements of Contract NAS 3-22823. The work was performed by the Aerojet Liquid Rocket Company (ALRC) for the National Aeronautics and Space Administration-Lewis Research Center (NASA-LeRC). The objective of the program was to correlate the combustion phenomena observed under NASA/JSC Contract NAS 9-15724 with the calculated propellant combustion parameters through the use of injector cold-flow testing and analytical evaluation of propellant vaporization and mixing characteristics.

The NASA-LeRC project manager was Mr. J. P. Wanhainen. The ALRC program manager was Mr. R. W. Michel, and the project engineer was Dr. J. Fang. The following individuals also contributed to the success of the program:

Arnold R. Keller	Cold-Flow Testing
Sharon L. Munger	Word Processing
Jerry L. Pieper	Reviewing

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I INTRODUCTION

A. Background

Two key areas for limiting the cost of future space transportation systems are economical engine development and operation and optimal utilization of low-cost propellants, such as the liquid oxygen/hydrocarbons (LOX/HC). As a result,it is imperative to characterize LOX/HC combustion through the analysis and test of various injector element designs to provide a data base to rationally select the most promising propellant combination(s) and injector elements for future technology efforts and engine development programs.

High-speed single-element photography has been proven to be an economical and effective method for characterizing and evaluating hypergolic propellant combustion (Reference 1). The results have been successfully applied to several engine development programs at Aerojet Liquid Rocket Company (ALRC). Recently, the same technique was successfully used to characterize LOX/HC propellant combustion under a study contract sponsored by NASA/JSC (Reference 2) in which high-speed photographs were taken of the impingement spray field and adjacent combustion zone. A total of 127 tests were conducted using four different fuels (RP-1, propane, liquid and gaseous methane, and ammonia) and seven different injector element types (Oxidizer-Fuel-Oxidizer (OFO) Triplet, Rectangular Unlike Doublet (RUD), Platelet Transverse Like-on-Like (TLOL) Doublet, Unlike Doublet (UD), Electrode-Discharge-Machined Like-on-Like (EDM-LOL) Doublet, Pre-Atomized Triplet (PAT), and Slit Triplet). These photographs show regions of dark clouds emanating from the propellant spray. The prevalence of these dark clouds was found to be dependent on chamber pressure, fuel temperature,

propellant mixture ratio, and injector element design; and they have been interpreted as areas of fuel vaporization-dependent carbon formation. However, the interpretation has not been substantiated through experimental measurement or analytical evaluation. Since this observation is key to understanding carbon formation and hence, performance and compatibility within LOX/HC engines, it is imperative that substantiation be provided.

B. Objective

The objective of this effort is to improve the understanding and the prediction techniques of LOX/HC carbon formation and combustion performance. Analytical combustion models and supporting cold flow data were used to estimate propellant mass distributions under hot-fire conditions for correlation of carbon formation regions observed in existing photographic combustion to verify the hypothesis of fuel-vaporization limited carbon formation.

C. Scope

The analytical models which were used are limited to those with successful previous experiences or those justifiable by experimental evidences. The propellant mass distribution in the combustion chamber was assumed identical to that determined by the injector cold-flow testing. The carbon formation data was limited to those reported in Reference 2 and no additional hot-fire tests were conducted.

D. Approach

The basic approach for this study consisted of the determination of the propellant droplet spray cold-flow mass distribution and calculation of the vaporization rates of individual streamtubes to provide the basis for the prediction of spatial variation of liquid and vapor phase mixing. These predictions were subsequently used to correlate with regions of suspected

carbon formation within the spray and recirculation gas zones. The program consists of the following three technical tasks:

Task I, Selection of Data for Analysis, resulted in the selection of 40 tests from the 127 tests conducted under contract NAS 9-15724 (Reference 2) for further analytical evaluation. The selected tests included data obtained fromd four injector element types (EDM-LOL, TLOL, OFO Triplet and PAT) and two fuels (RP-1 and propane).

Task II, Data Analysis, consisted of two subtasks: (1) injector cold-flow testing to measure the liquid-phase mass distributions; and (2) vaporization analysis to predict the gas temperature,and liquid/vapor propellant mass distributions in various locations in the chamber.

During Task III, Data Correlation and Analysis Update, the calculated combustion parameters were correlated with the observed combustion phenomena to define the carbon formation mechanism.

II SUMMARY

The photographic carbon formation data of Reference 2 were reviewed. From the 127 hot-fire tests conducted, forty tests were selected for further analytical evaluation of the propellant vaporization and mixing characteristics. These tests included two hydrocarbon fuels (RP-1 and propane) and four injectors (OFO Triplet, TLOL, EDM-LOL, and PAT). Each injector exhibited its unique carbon formation characteristics and the tests selected covered wide range of injector/propellant operating conditions showing large variations of carbon formation.

All four injectors were cold-flow tested using a collection device to characterize the propellant mixing pattern. The sprays issuing from the injector or formed by the impinging jets were picked up by a 4.83 cm x 4.83 cm (1.49" x 1.49") collector head, which was evenly divided into 100 (10 x 10) flow passages. The fluids through each passage were collected by a glass tube. Since the propellant simulants (Freon for the oxidizer and water for the fuel) were immiscible, the volume of each of the two simulants collected by any given location was determined readily. This measurement was repeated for various distances between the injector and the collector head, to establish the mass and mixture ratio distributions of the two propellants at various chamber axial locations.

A vaporization computer model was written to predict spatial variation of propellant vaporization rate using the injector cold flow results to define local zones (streamtubes). This model applied the Priem-Heidmann Generalized-Length vaporization correlation to the individual streamtubes determined from the cold flow measurements. Consideration was also made to

include the off-nominal gas temperature effect on the vaporization rate caused by mixture ratio variation.

Results of this analysis show that the fuel vaporization rate and the local mixture ratio produced by the injector element have first order effects on the degree of carbon formation. Low fuel vaporization rates significantly increase the degree of carbon formation. Also, fuel rich zones containing liquid (vaporizing) fuel are sources of carbon formation. For similar injector operating conditions, propane produces less carbon formation than RP-1 because of its higher vaporization rate. Chamber pressure also appears to have an effect on carbon formation which is observed to decrease with increasing pressure.

As a result, the degree of carbon formation can be controlled by controlling the fuel vaporization rate and the local combustor mixture ratio distribution. These parameters, on the other hand, are a function of the injector element design and the propellant properties and operating condition.

The present study was limited to uni-element injectors, which inherently possess large amount of hot gases recirculating in the combustion chamber. In order to have a closer simulation of full scale engine combustion environment, further investigations using multi-element injectors a recommended.

The vaporization analysis of the present study included the effect of propellant mixing, which was characterized by injector cold-flow. This approach of integrating the mixing data into the propellant vaporization analysis was found to be practical in usage and realistic in modeling; yet, the computation was simple and straight forward. Hence, an engine combustion performance model can be readily developed using the present

model as a frame work. Such a model is useful and convenient for engine design or data analysis.

III HOT-FIRE DATA

A. Test Results Summary

The work undertaken by Reference 2 resulted in the design and testing of seven single element injectors and four fuels with the aim of photographically characterizing combustion phenomena of LOX/HC propellant combinations. The seven injectors tested were the OFO Triplet, the Platelet Transverse Like-on-Like Doublet (TLOL), the Rectangular Unlike Doublet (RUD), the Unlike Doublet (UD), the Electrode Discharge Machined Like-on-Like Doublet (EDM-LOL), the Platelet Pre-Atomized Triplet (PAT), and the EDM Slit Triplet. The fuels tested were RP-1, Propane, Methane and Ammonia. The hot firings were conducted in a specifically constructed square chamber fitted with quartz windows for photographically viewing the impingement spray field. Removable copper inserts were used for varying the nozzle configuration to provide the desired operating chamber pressures. Figure 1 shows the test chamber assembly and the nozzle insert.

Test photographic results showed that the appearance of LOX/HC combustion is markedly different from previously observed storable propellant combustion (Reference 1). In the fuel rich zone, the flame was usually yellow-brownish. However, some times the flame became reddish with visible black smoke streaks which in extreme cases filled the entire combustion chamber. Figure 2 displays two photographic results. In the top photograph, black clouds are clearly visible downstream of the impingement zone. The occurrence of these clouds was assumed to indicate the formation of free carbon during the combustion process. Under different conditions, no black clouds were observed in the flame produced by the same injector and propellants as shown in the bottom photograph.

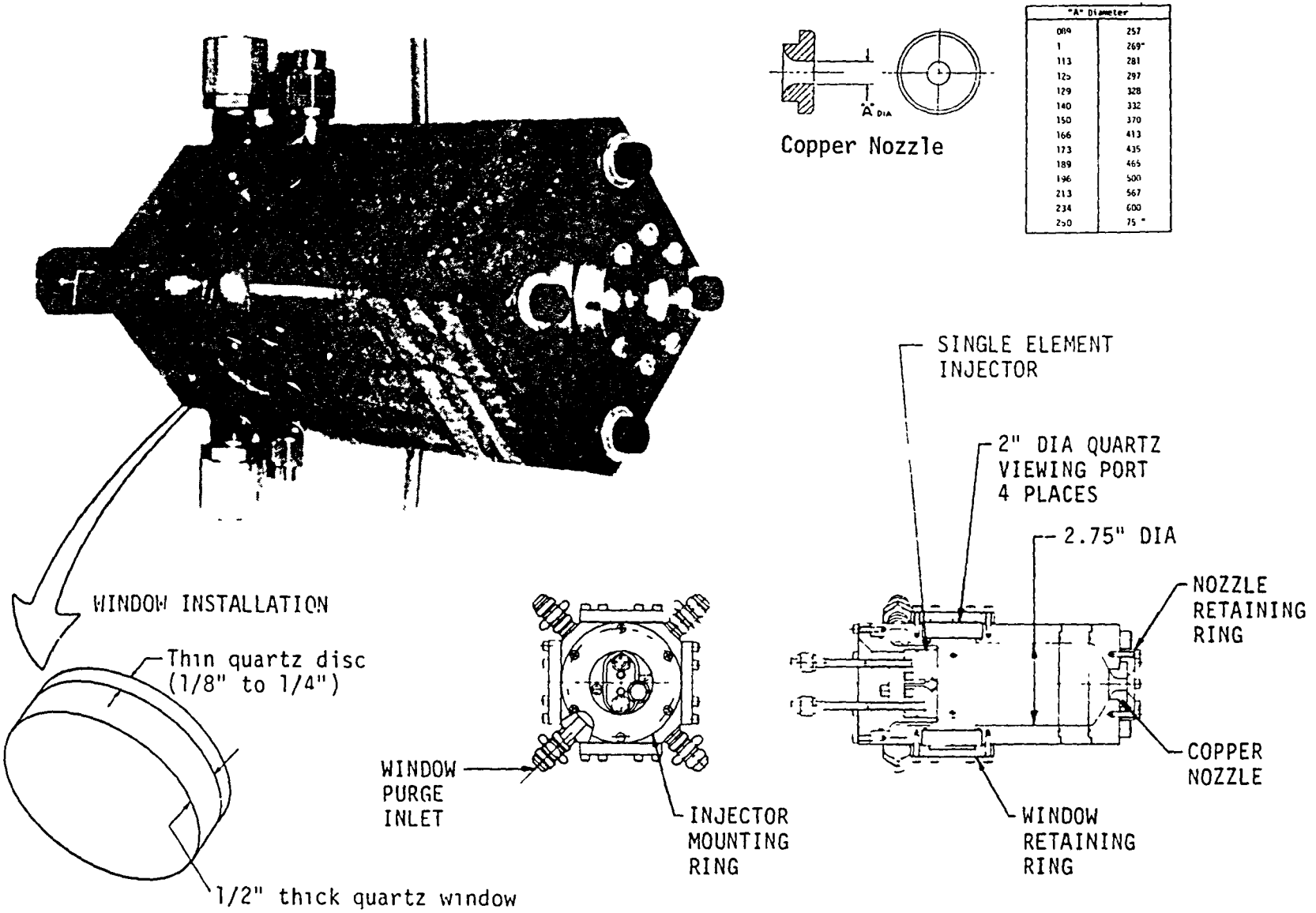
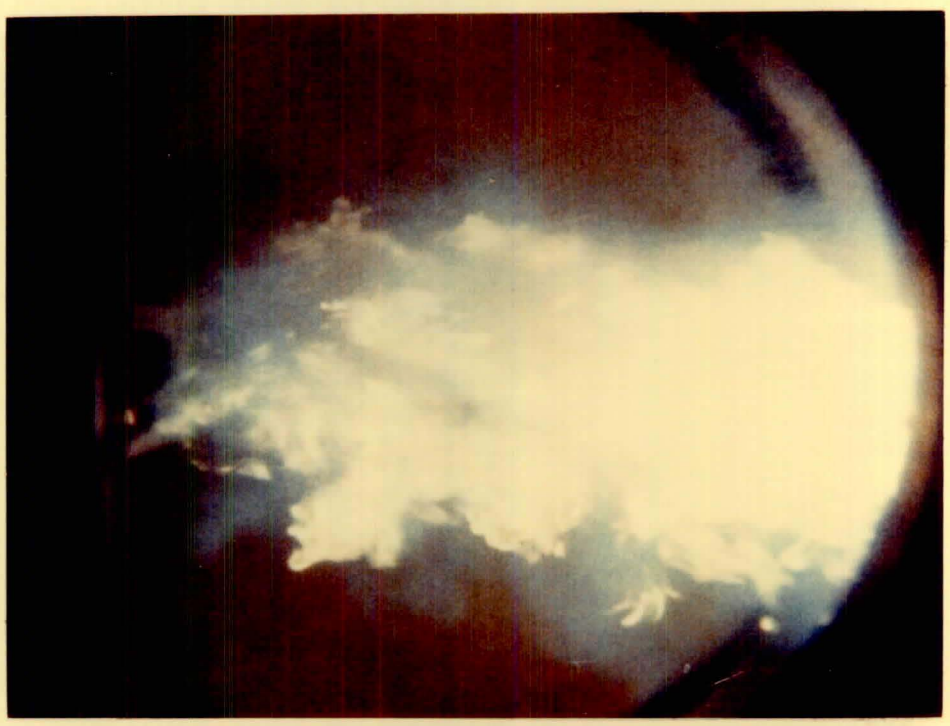


FIGURE 1. TEST CHAMBER ASSEMBLY

Pc = 4205 kPa MR = 2.95 T_f = 54 °C

Test No. = 172 Propellants = LOX/Propane



Pc = 2205 kPa MR = 3.10 T_f = 70°C

Test No. = 169 Propellants = LOX/Propane

FIGURE 2. HIGH-SPEED PHOTOGRAPHS OF CARBON FORMATION PHENOMENA EDM-LOL INJECTOR

Appendix A summarizes the test data accumulated by Reference 2. One hundred and twenty-seven (127) tests were conducted over a chamber pressure range of 860-10340 kPa (125-1500 psia), a fuel temperature range of -154 to 70 °C (-245 to 158°F), and a fuel velocity range of 15 to 213 m/sec (50-700 ft/sec). As noted in Reference 2, the data show the following carbon formation trends:

"As the fuel vaporization rate increases in the injector face near-zone, carbon formation decreases. This suggests that oxidizer/fuel mixing in liquid phase promotes carbon formation. Small drop size, high fuel temperature, and late oxidizer/fuel mixing relative to the point of atomization reduce carbon formation."

B. Data Selection

Among the 127 hot-fire tests, 40 tests were selected for further analysis during this effort. As shown in Table I, these tests include four injectors (OFO Tdriplet, TLOL, EDM-LOL, and PAT) and two fuels (RP-1 and propane).

Major considerations in the selection process, listed in order of priority, were (1) quality of existing photographic data, (2) tests comprising a wide range of operating variables, (3) previous analytical characterization of the injector element (e.g., drop size and distribution analyses), and (4) potential application to future engine systems.

The Unlike Doublet injector was tested only with ammonia, which naturally does not yield carbon formation data. The Slit Triplet injector was tested with gaseous methane, resulting in poor mixing without evidence of carbon deposits. The tests with the RUD injector did not yield good quality data for analysis. For that injector, the RP-1 tests were unsuccessful, and

TABLE I HOT-FIRE TESTS SELECTED FOR ANALYSIS

TEST NO	INJECTOR	FUEL	PC (kPa)	MR	T_f (°C)	MODE
101	OFO Triplet	RP-1	3170	2.40	10	S (Slightly Clouded)
105	OFO Triplet	RP-1	3310	2 80	10	S
106	OFO Triplet	RP-1	3345	2 75	10	S
109	OFO Triplet	RP-1	3275	2 40	13	S
110	OFO Triplet	RP-1	3310	2 70	19	S
111	OFO Triplet	RP-1	3310	2.70	19	S
116	OFO Triplet	RP-1	10340	2.60	10	C (Clear)
120	TLOL	RP-1	930	2 35	5	O (Obscure)
121	TLOL	RP-1	2135	2.80	3	M (Moderately Clouded)
122	TLOL	RP-1	5380	2.75	7	C
123	TLOL	RP-1	3275	2 65	2	S
124	TLOL	RP-1	3275	2 65	2	S
127	TLOL	RP-1	1725	2 85	1	M
128	TLOL	RP-1	2760	3.10	4	S
129	TLOL	RP-1	5515	2 80	7	C
130	TLOL	Propane	930	2 50	7	S
131	TLOL	Propane	2000	2 65	6	C
132	TLOL	Propane	3725	3 00	6	C
133	TLOL	Propane	5445	2 80	7	C
157	EDM-LOL	Propane	5515	2.80	8	M
158	EDM-LOL	Propane	3860	2 85	-2	O
159	EDM-LOL	Propane	2035	2 90	4	O
160	EDM-LOL	Propane	1035	2.80	-1	O
161	EDM-LOL	Propane	5515	2 90	16	M
162	EDM-LOL	Propane	3790	2 95	16	O
164	EDM-LOL	Propane	2000	2 90	27	O
165	EDM-LOL	Propane	5515	2 85	64	C
168	EDM-LOL	Propane	3790	2 90	68	M
169	EDM-LOL	Propane	2205	3.10	70	C
171	EDM-LOL	Propane	4415	2 80	51	S
178	PAT	Propane	3860	2 75	21	S
179	PAT	Propane	2070	2 85	19	S
182	PAT	Propane	1035	2.90	18	M
184	PAT	Propane	2070	2.85	19	S
187	PAT	Propane	5515	2 90	19	C
189	PAT	Propane	1070	2 80	17	M
190	PAT	Propane	1140	2 75	17	S
193	PAT	Propane	3860	2 80	49	S
194	PAT	Propane	2345	3 00	46	S
197	PAT	Propane	3480	3 00	6	S

the propane tests had poor visibility due to either heavy carbon formation or poor external lighting. Consequently, the remaining four injectors were considered for analysis. The reasons justifying their selection are outlined below.

The EDM-LOL injector is considered as a candidate because of its historical use with LOX/HC propellants and because of the variety of carbon formation modes it displayed at different hot-fire operating conditions.

The TLOL injector is also an interesting candidate because it is a platelet version of the EDM-LOL, having a smaller unlike impingement angle and a longer unlike impingement height. These differences between the EDM-LOL and the TLOL were found to result in entirely different mixing patterns and quantities of carbon formation.

The PAT injector, tested extensively on Contract NAS 9-15724, displayed a tendency to avoid carbon formation until lower chamber pressures were reached. The propellant streams are preatomized before impingement and have long free-stream lengths.

The OFO Triplet injector was selected because historically, it is a very high-performing element. Also, it provides an excellent design contrast to the PAT injector since it utilizes oxidizer external impingement on an internal fuel jet whereas the PAT element has the oxidizer fan contained within fuel fans.

Figures 3 through 6 show the carbon formation dependency on chamber pressure, mixture ratios and fuel temperature for the tests conducted with the OFO Triplet, TLOL, EDM-LOL, and PAT injectors. The tests selected for further analysis are identified by underlining. For each injector, the tests selected were limited to those having mixture ratios close to a specific value because the propellant mixing is affected by mixture

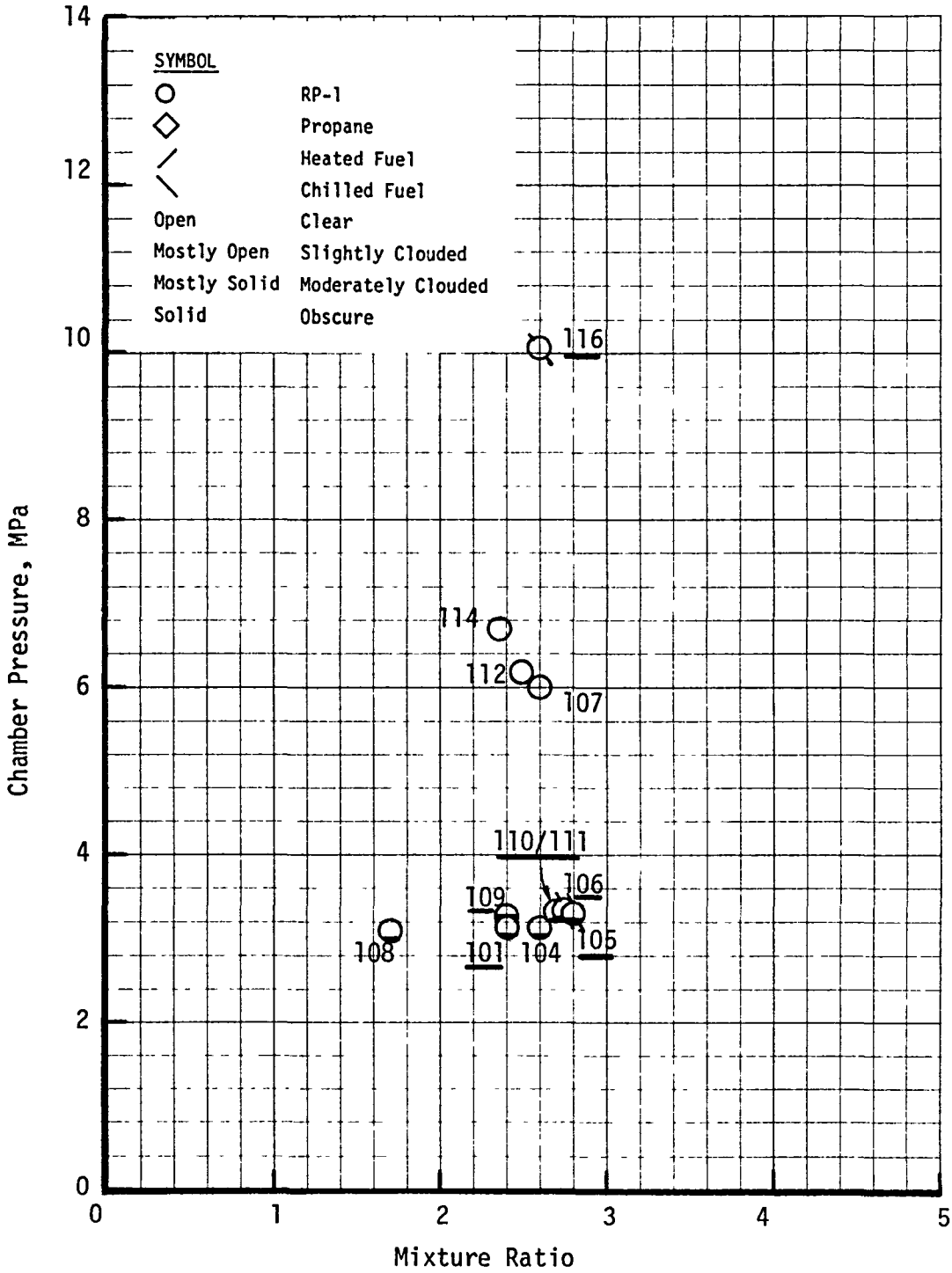


FIGURE 3. OPERATING CONDITION DEPENDENCY OF OFO TRIPLET CARBON FORMATION

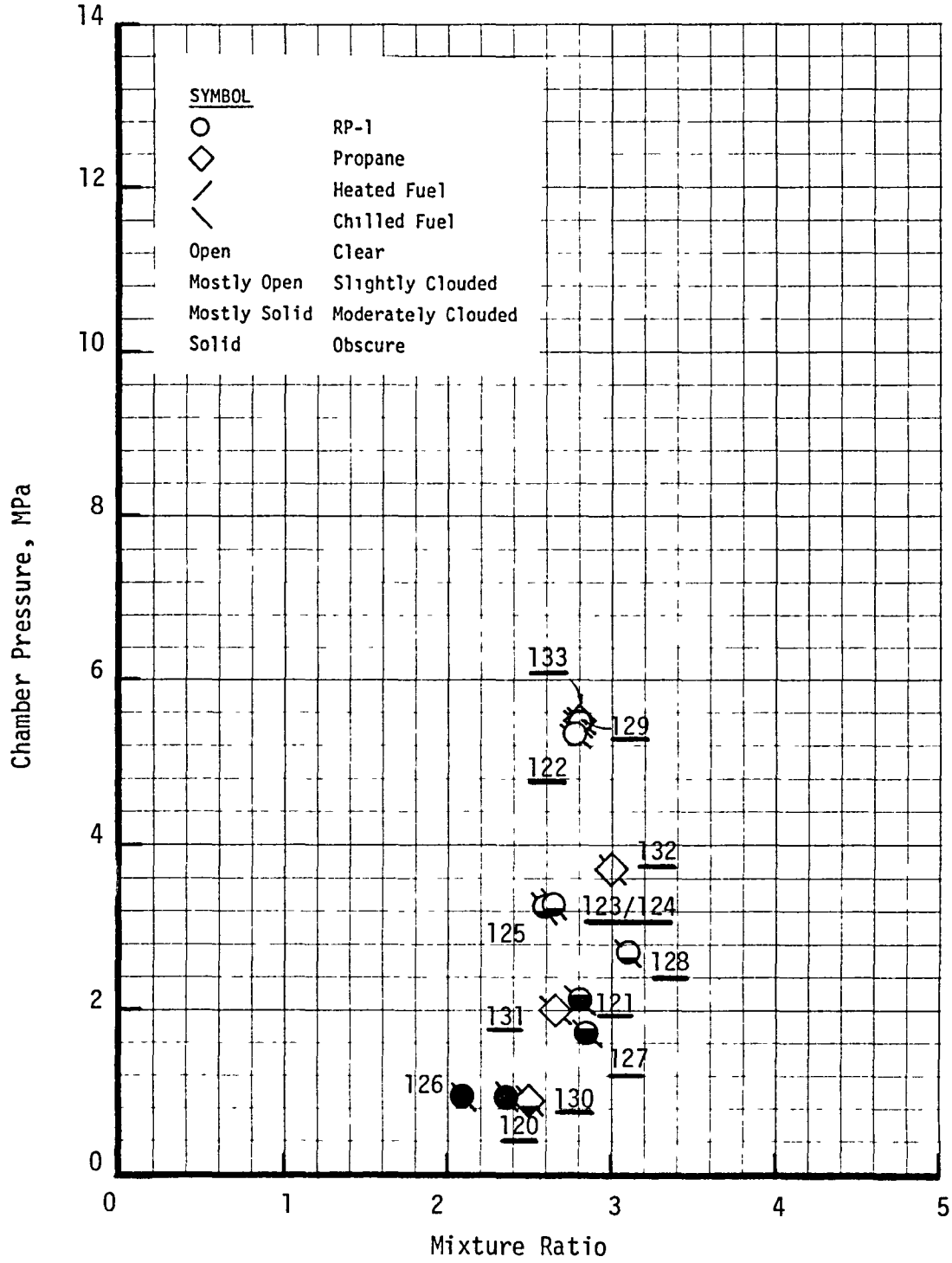


FIGURE 4. OPERATING CONDITION DEPENDENCY OF TLOL CARBON FORMATION

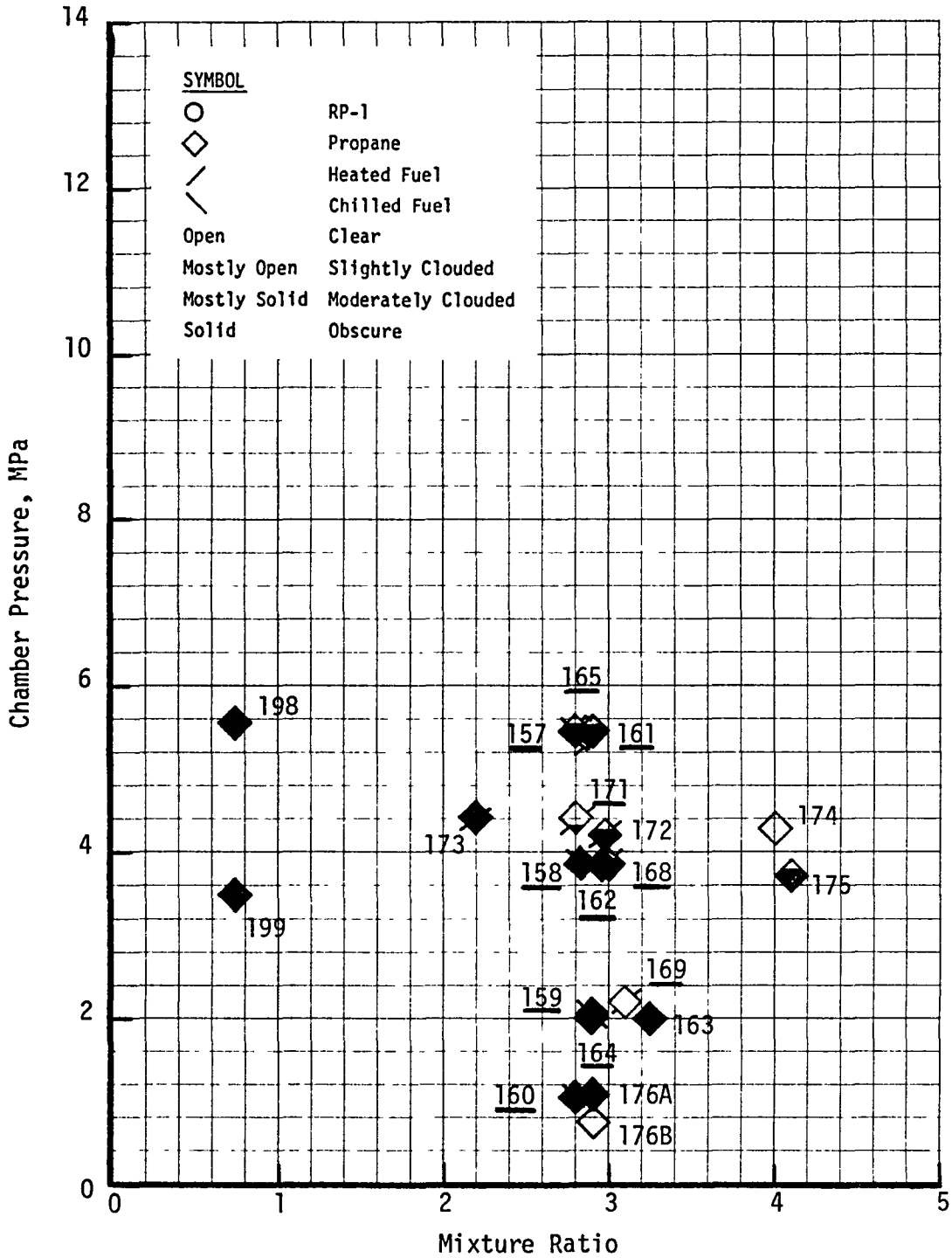


FIGURE 5. OPERATING CONDITION DEPENDENCY OF EDM-LOL CARBON FORMATION

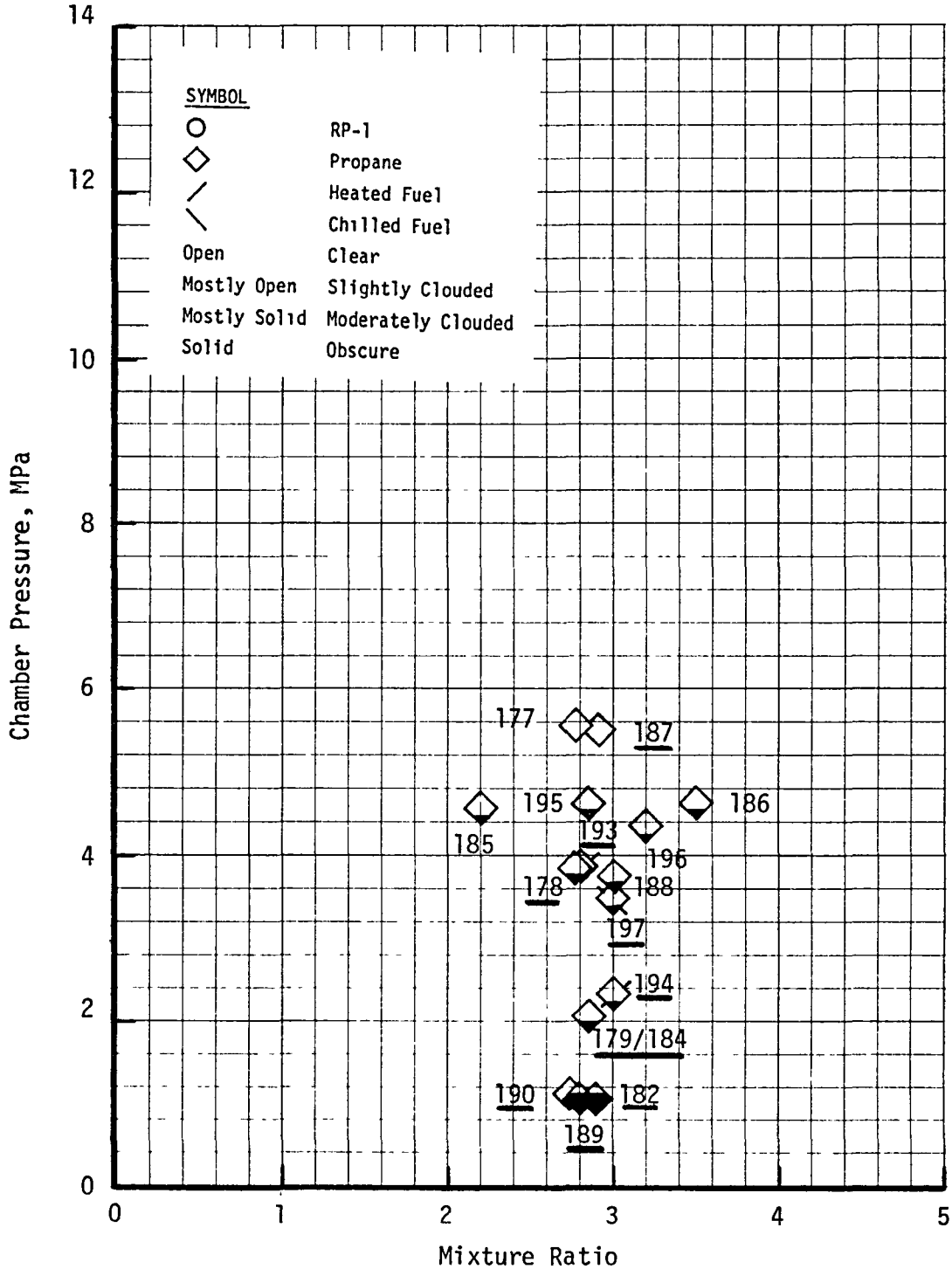


FIGURE 6. OPERATING CONDITION DEPENDENCY OF PAT CARBON FORMATION

ratio (or momentum ratio) and the cold-flow tests were limited to only one momentum ratio per injector. Figures 7 through 10 show the injection element configurations for the OFO Triplet, TLOL, EDM-LOL, and PAT injectors, respectively. The propellant atomization and mixing of the OFO Triplet injector are brought about by the unlike coherent jet streams impingement. For the TLOL and EDM-LOL injectors, the propellant atomization results from like-on-like impingement and the mixing is accomplished by canting both spray fans toward each other resulting in edge-on-edge unlike impingement. The atomization prior to the unlike impingement for the PAT injector is carried out by splashing the jet against an internal plate for the fuel or by internal jets impingement for the oxidizer. The mixing is achieved by the simultaneous broad-side impingement of the spray fans.

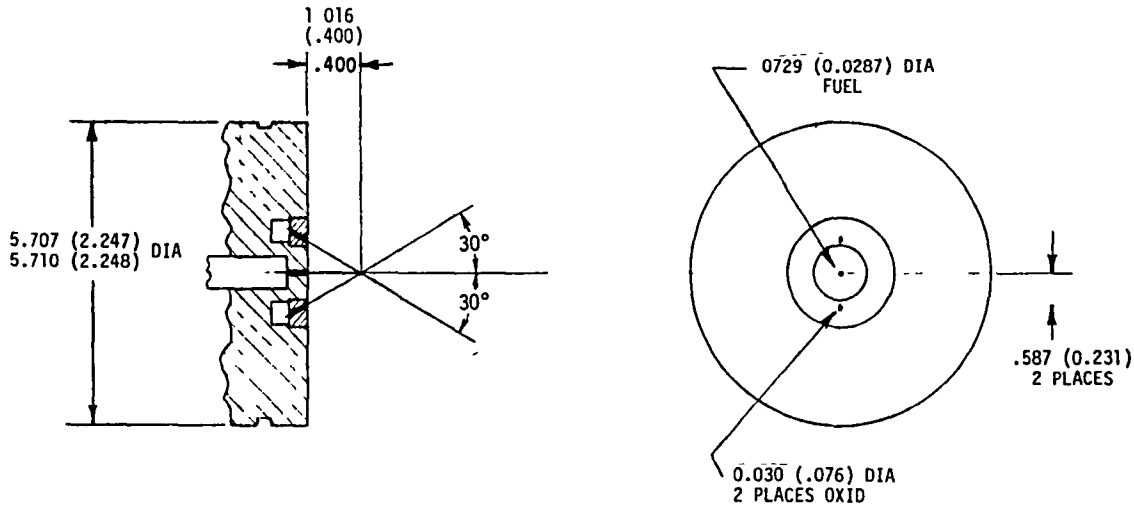


FIGURE 7. OFO TRIPLET INJECTOR CONFIGURATION

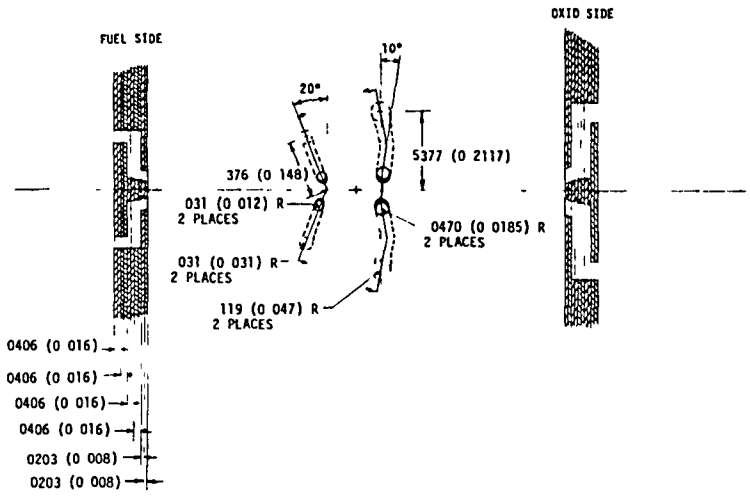


FIGURE 8. TRANSVERSE LIKE-ON-LIKE (TLOL) INJECTOR CONFIGURATION

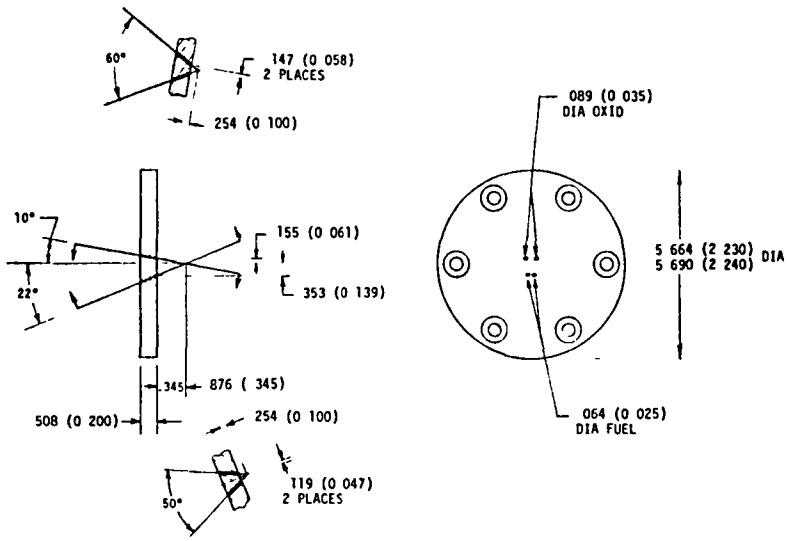


FIGURE 9. ELECTRODE DISCHARGE MACHINED LIKE-ON-LIKE (EDM-LOL) INJECTOR CONFIGURATION

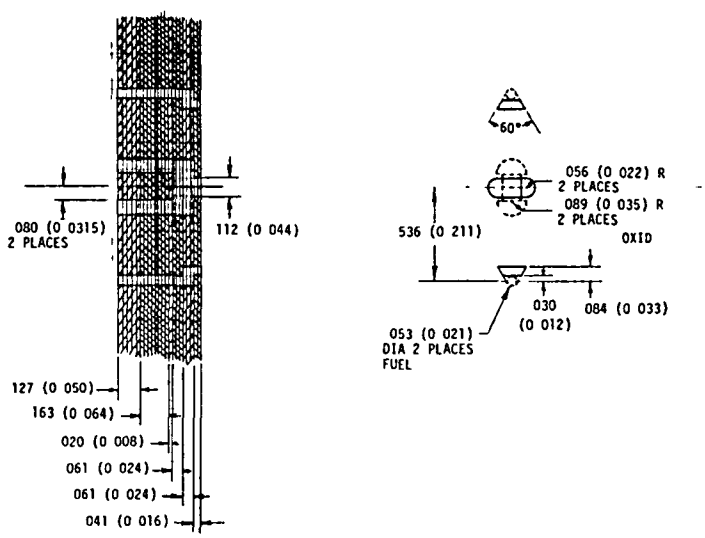


FIGURE 10. PRE-ATOMIZED TRIPLET (PAT) INJECTOR CONFIGURATION

IV INJECTOR COLD-FLOW TESTING

A. Objective

The propellant mixing of a uni-element injector is determined only by the intra-element mixing mechanism as opposed to the combination of intra- and inter-element mixing for a multi-element injector. Thus, a multi-element injector results in more uniform mixing than a uni-element injector across the entire chamber cross-section . In order to apply the vaporization correlation of Reference 3, which was based on multi-element injector data, to the present case of uni-element injector, the effect of mixing characteristics on spray combustion must be included. Moreover, the photographs of Reference 2 show localized carbon formation for some cases, indicating the strong mixing effect on carbon formation. The objective of the injector cold-flow testing was to experimentally determine the mass distributions of the oxidizer and fuel at various cross-sections of the chamber for use in the combustion analysis.

B. Method and Apparatus

The same injector bodies previously hot-fire tested in Reference 2 were used for the cold-flow testing. This experiment was conducted at the ALRC Physics Research Lab (A-Area) using the test setup shown in Figure 11. Tap water and Freon TF solvent were used as fuel and oxidizer simulants, respectively. The simulant bottles were pressurized with gaseous nitrogen. In order to maintain the injector manifold pressures at desired values, the nitrogen flows were controlled by pressure regulators. The physical properties of the Freon used are given in Figure 12.

The sprays formed by the injected liquids were intercepted by a spray collector consisting of a 10 x 10 grid of flow passages. The fluids were then collected by the glass tubes, with one tube for each grid. Since

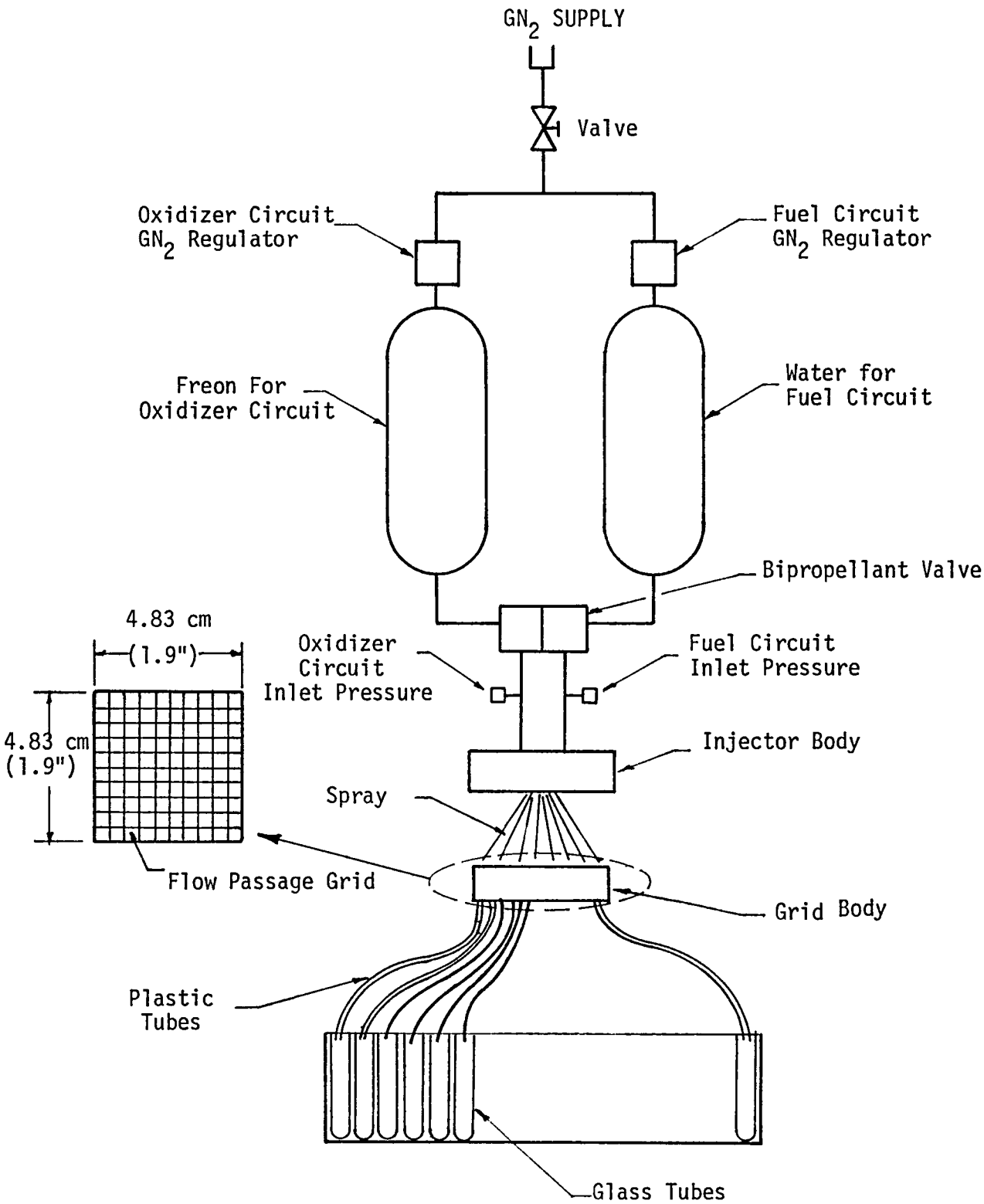
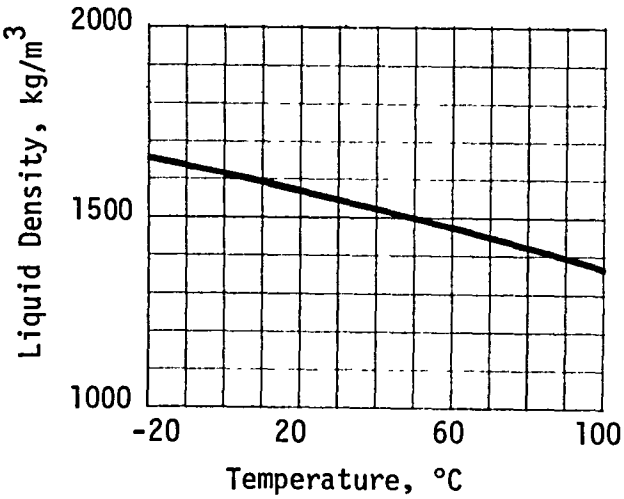
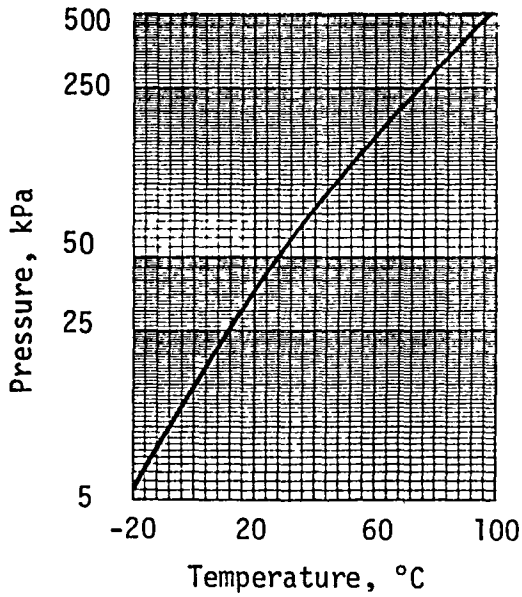


FIGURE 11. INJECTOR COLD-FLOW SETUP





Chemical Formula	$CCl_2F - CClF_2$
Molecular Weight	187.4
N.B.P.	47 °C
Freezing Point	-35 °C
Critical Temperature	214 °C
Critical Pressure	3413 kPa
Heat of Vaporization at NBP	146.82 kJ/kg
Liquid Specific Heat at 21 °C	0.892 kJ/kg °C
Liquid Viscosity at 21 °C	6.940×10^{-5} kg/m-s
Surface Tension at 25 °C	19.0 dynes/cm
Solubility of Water at 21 °C, % by Wt.	0.009

FIGURE 12. PHYSICAL PROPERTIES OF FREON TF SOLVENT

the simulants are immiscible, the mass distributions of both simulants for a given injector and test condition were readily determined from the collected fluids.

C. Results

For each injector, experiments were run at four different distances between the injector face and the grid face: 1.27 cm (0.5"), 2.54 cm (1.0"), 3.81 cm (1.5"), and 5.08 cm (2.0"), except for the OFO Triplet injector. For that injector, the spray exceeded the collector face area at the 5.08 cm (2.0") distance and therefore the measurements were made only at the shorter distances.

All experiments were made at oxidizer-to-fuel momentum ratios corresponding to the nominal mixture ratios of hot-fire tests. Table II summarizes the nominal injector operating conditions of both hot-fire tests and cold-flow experiments for the four injectors.

The data obtained from such cold-flow tests are summarized in Appendix B. Each grid of the collector head is represented by a block coordinate, (I, J), which contains, in order, oxidizer-to-fuel mixture ratio, oxidizer mass fraction, and fuel mass fraction. The approximate locations of the injection orifice projections on the collector head are also shown. For the case where the collector head is 3.81 cm (1.5 inches) below the injector face, the mixture ratios, oxidizer mass fractions and fuel mass fractions are shown in 3-dimensional representation in Figures 13 through 16.

The OFO Triplet injector was found to have misimpingement in a manner such that part of one oxidizer jet stream passes by the other two jets without mixing, as shown in Figure 17. This same jet stream also impinges on the fuel jet before the other oxidizer jet does. These two

TABLE II - INJECTOR HOT-FIRE AND COLD-FLOW NOMINAL OPERATING CONDITIONS

INJECTOR	EDM-LOL	OFO-TRIPLET	T-LOL	PAT
HOT-FIRE				
Oxidizer	LOX	LOX	LOX	LOX
Fuel	Propane	RP-1	RP-1	Propane
ρ_o, kg/m^3	1156	1156	1156	1156
ρ_F, kg/m^3	498	803	803	498
Nominal MR	2.9	2.6	2.8	2.9
Momentum Ratio	1.82	2.14	2.43	1.46
COLD-FLOW				
Oxidizer	Freon	Freon	Freon	Freon
Fuel	Water	Water	Water	Water
ρ_o, kg/m^3	1589	1589	1589	1589
ρ_f, kg/m^3	1002	1002	1002	1002
Momentum Ratio Sought	1.82	2.14	2.43	1.46
Reqd $\Delta P_o/\Delta P_F$	0.915	0.977	1.082	0.590
Tested ΔP_o, N/m^2	316	309	370	274
Tested ΔP_F, N/m^2	343	309	343	480

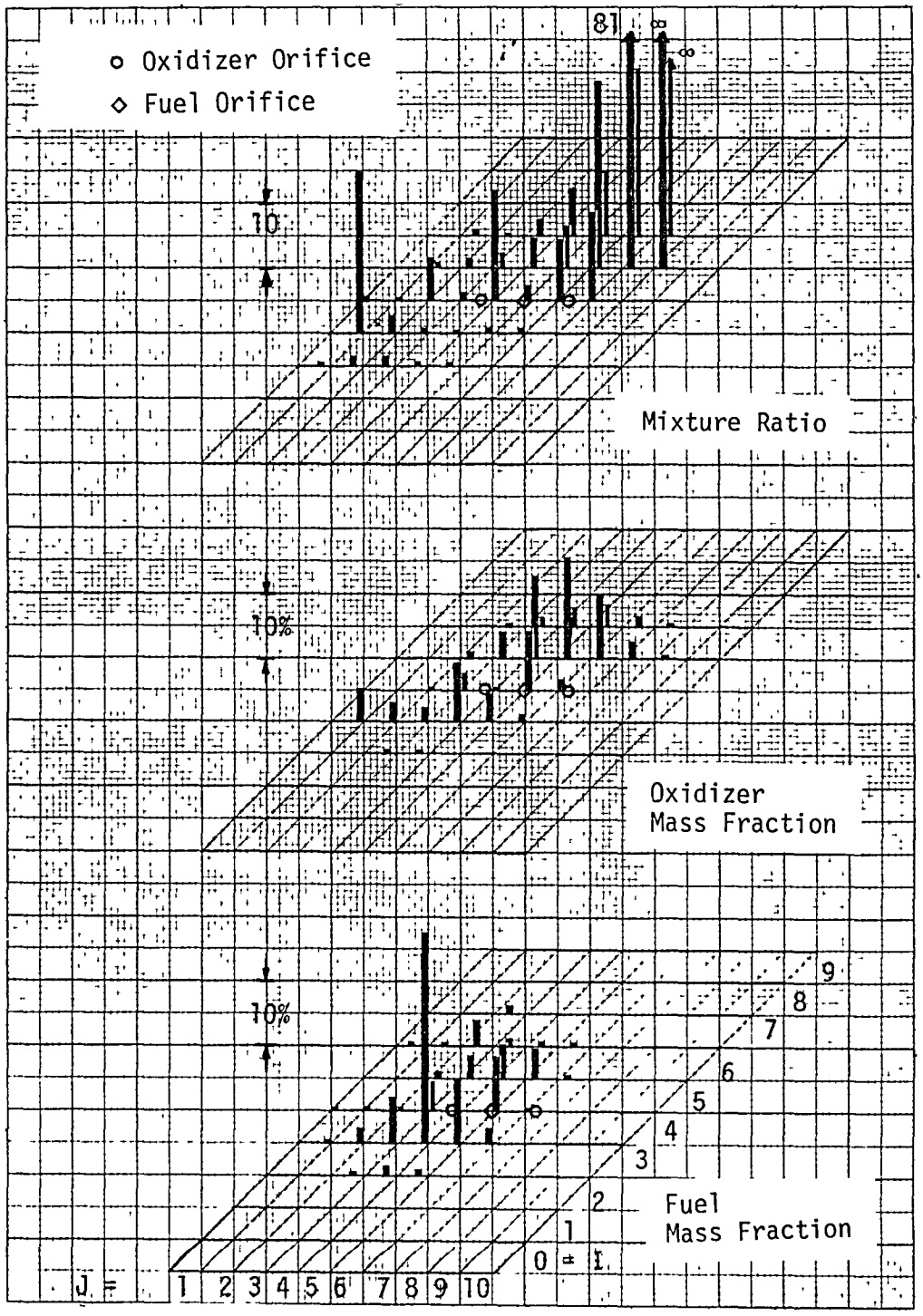


FIGURE 13. OFO TRIPLET COLD-FLOW MIXING PATTERN AT 3.81 CM AXIAL LOCATION

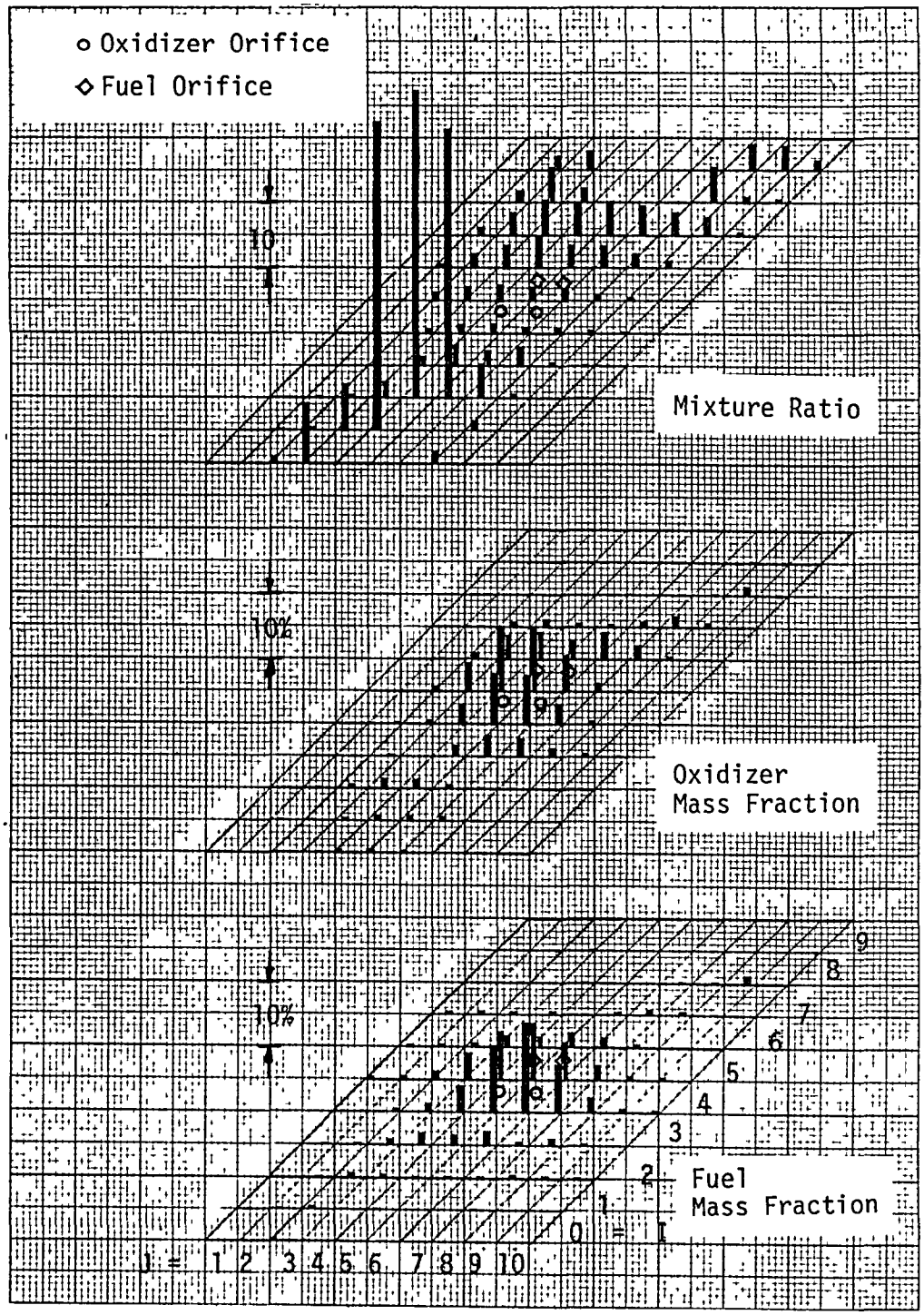


FIGURE 14. EDM-LOL INJECTOR COLD-FLOW MIXING PATTERN AT 3.81 CM AXIAL LOCATION

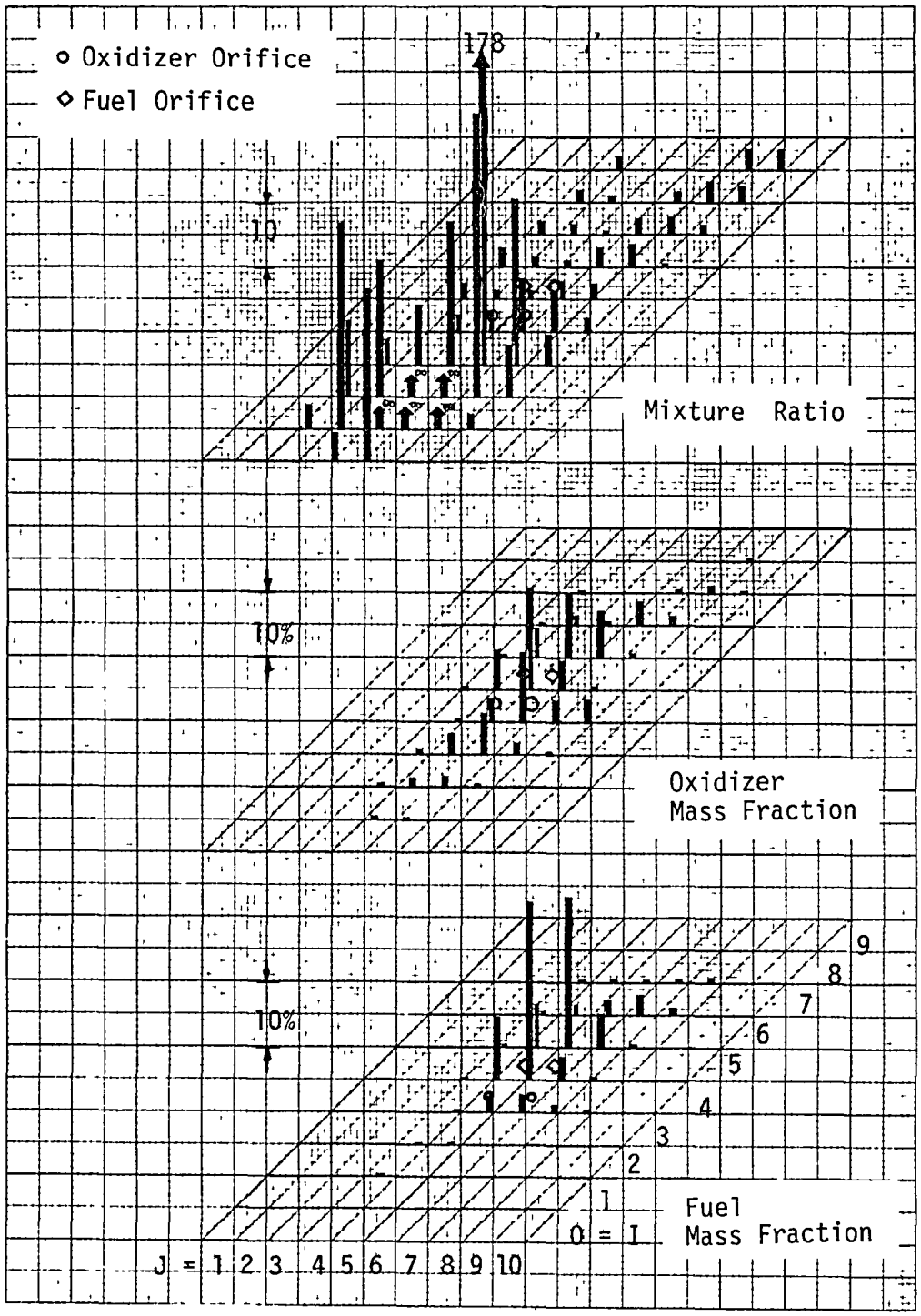


FIGURE 15. TLOL INJECTOR COLD-FLOW MIXING PATTERN AT 3.81 CM AXIAL LOCATION

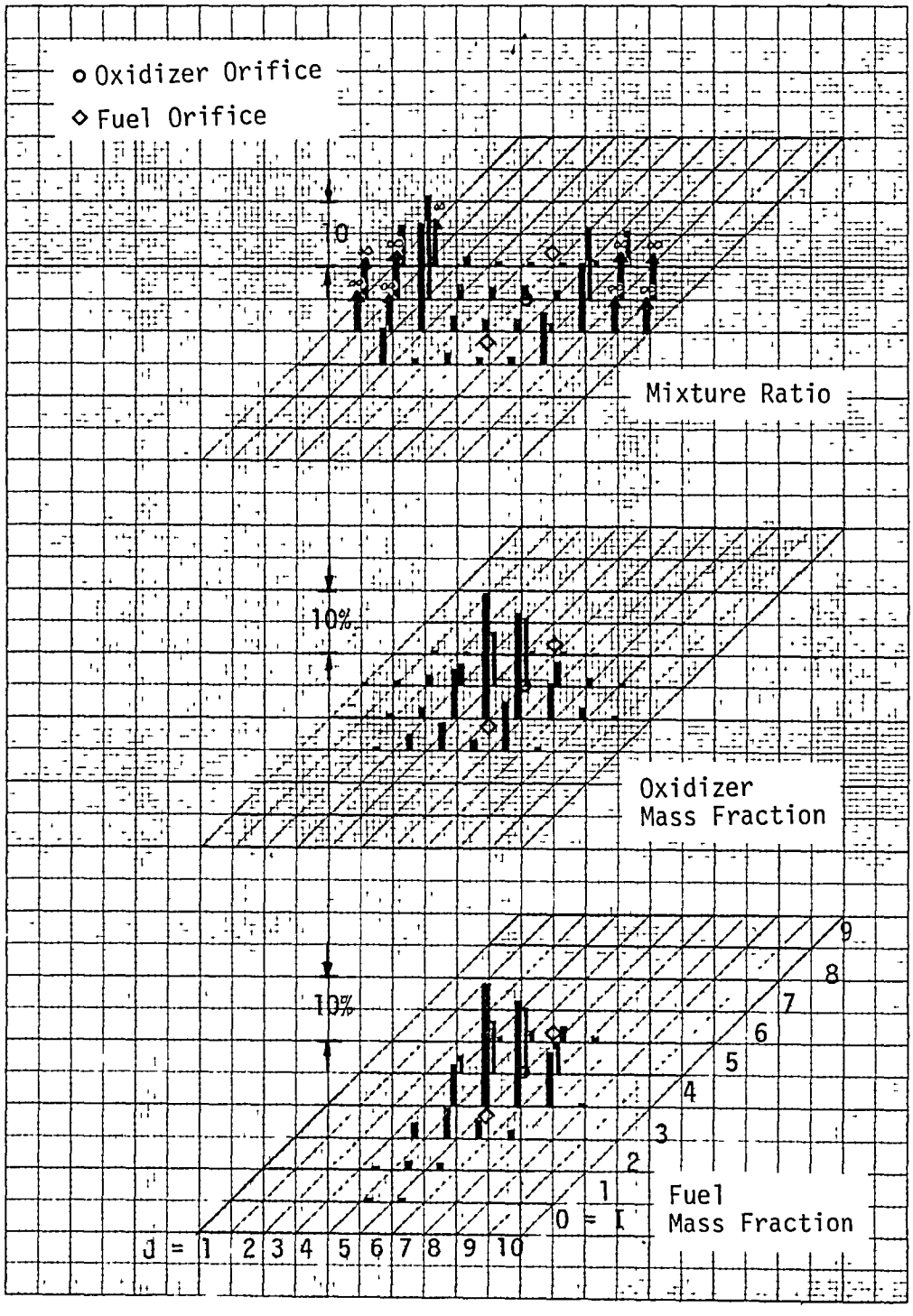


FIGURE 16. PAT INJECTOR COLD-FLOW MIXING PATTERN AT 3.81 CM AXIAL LOCATION

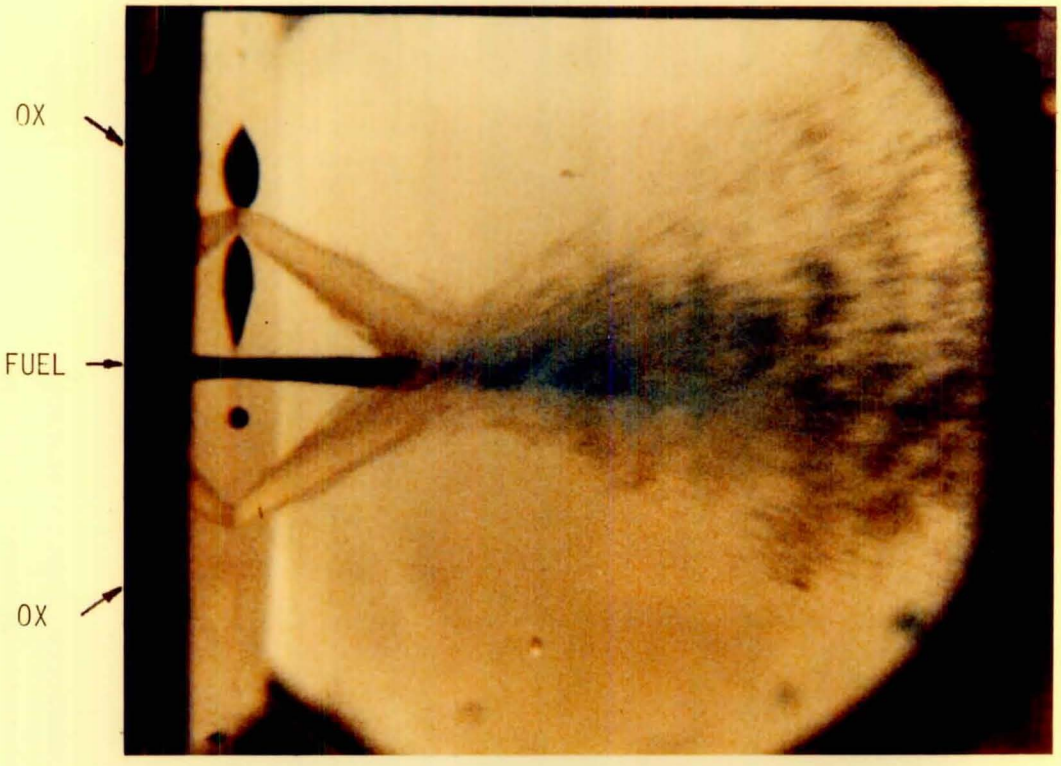


FIGURE 17. OFO TRIPLET INJECTOR COLD-FLOW SPRAY PATTERN

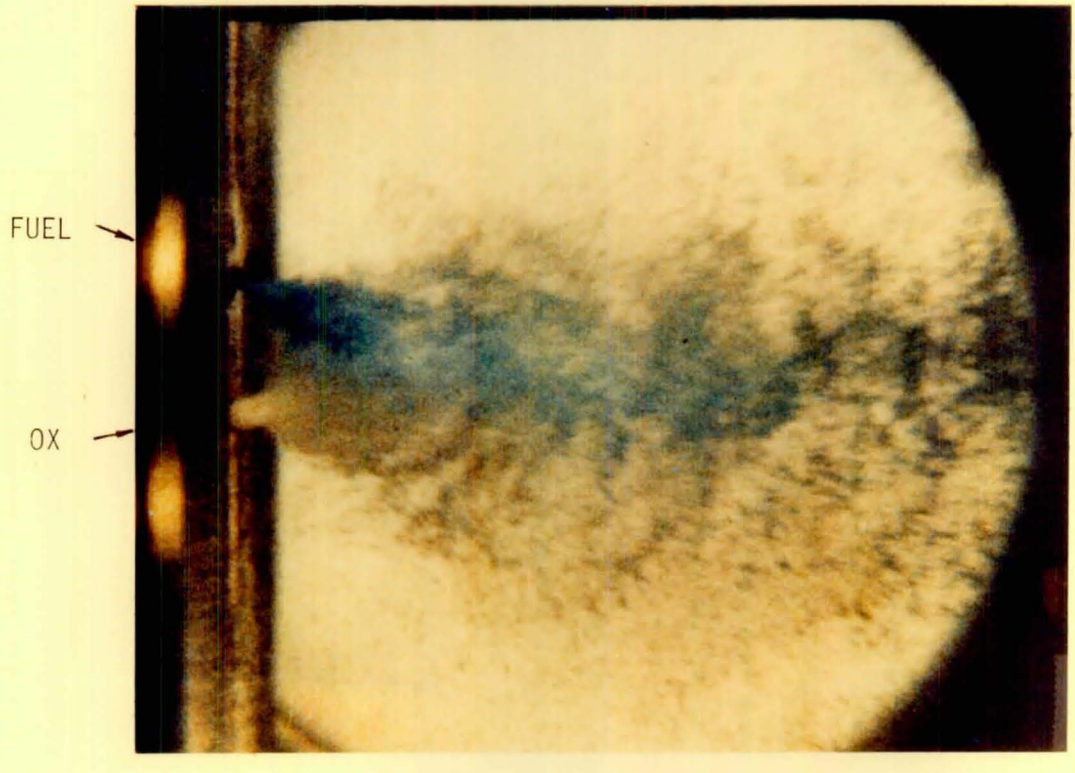


FIGURE 19. EDM-LOL INJECTOR COLD-FLOW SPRAY PATTERN

anomalies result in the uncommon cold-flow mixing pattern indicated by Figure 13. Figure 18 describes this mixing pattern and its causes.

The spray fans of the EDM-LOL element are shown in Figure 19. The unlike cant angles of the spray centerlines are 10° for the oxidizer and 22° for the fuel resulting in an unlike impingement height of 0.88 cm (.35 in.). Figure 14 shows that the fluids of both circuits are mostly concentrated in the center of the spray field so that the mass fraction decreases as it moves away from the center. Figure 20 schematically shows the mixing distribution pattern observed from Figure 14. A fuel-rich zone is sandwiched between two oxidizer-rich zones. Nominal mixture ratios appear along the oxidizer-rich and fuel-rich interfaces.

The spray fans of the TLOL element are shown in Figure 21. This element is a platelet version of the conventional LOL (EDM-LOL) element. The total included angle between the centerlines of the impinging unlike fans is 15° instead of 32° as used in EDM-LOL. This yields a long unlike impingement height approximately equal to 1.42 cm (.56 in.). Figure 15 shows that although the oxidizer spray of the TLOL element spreads much like the oxidizer spray of the EDM-LOL element due to high oxidizer momentum, the fuel is confined to a narrow area and hardly spreads and penetrates into the oxidizer-dominated zone. Figure 22 is a sketch of the mixing pattern observed from the data. This poor mixing is caused by the small unlike impingement angle.

The spray fans of the PAT element are shown in Figure 23. This element has a spray pattern different from the OFO Triplet in two ways. First, the PAT injector consists of two fuel orifices (Splash Plate elements) on the opposite sides of a single oxidizer orifice (X-Doublet element). This arrangement is just opposite to the OFO Triplet arrangement. Second, each

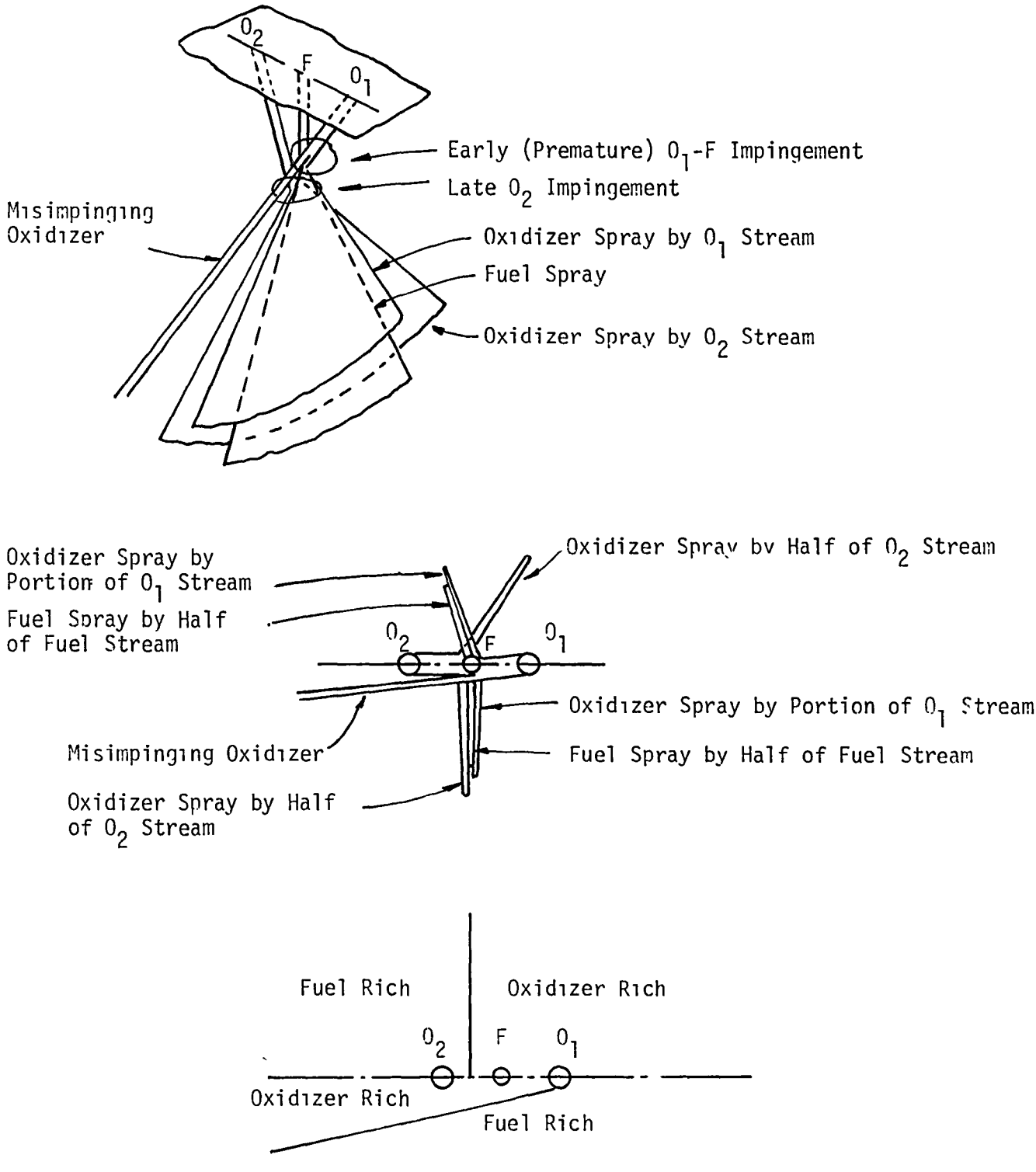


FIGURE 18. OFO INJECTOR COLD-FLOW MIXING PATTERN

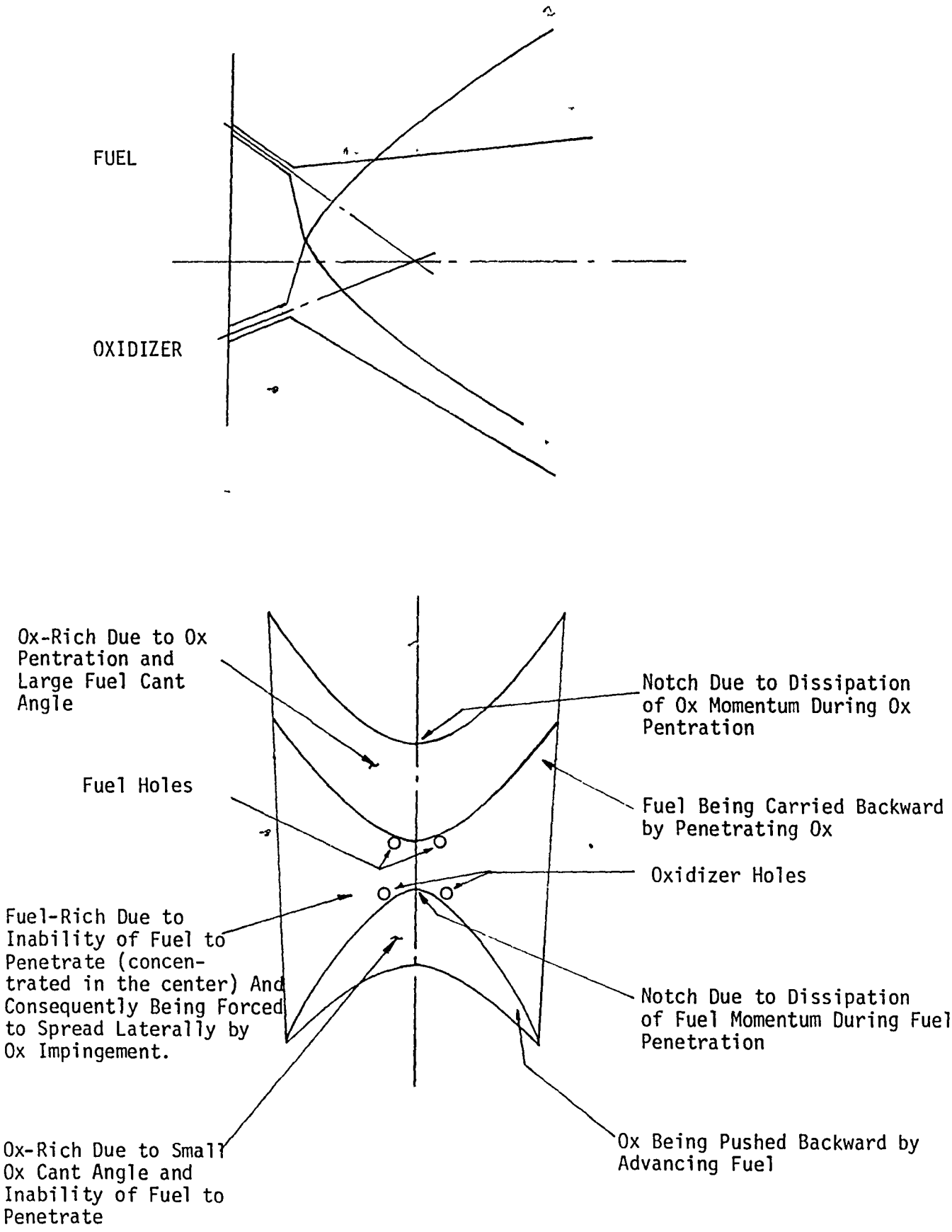


FIGURE 20. EDM-LOL INJECTOR COLD-FLOW MIXING PATTERN

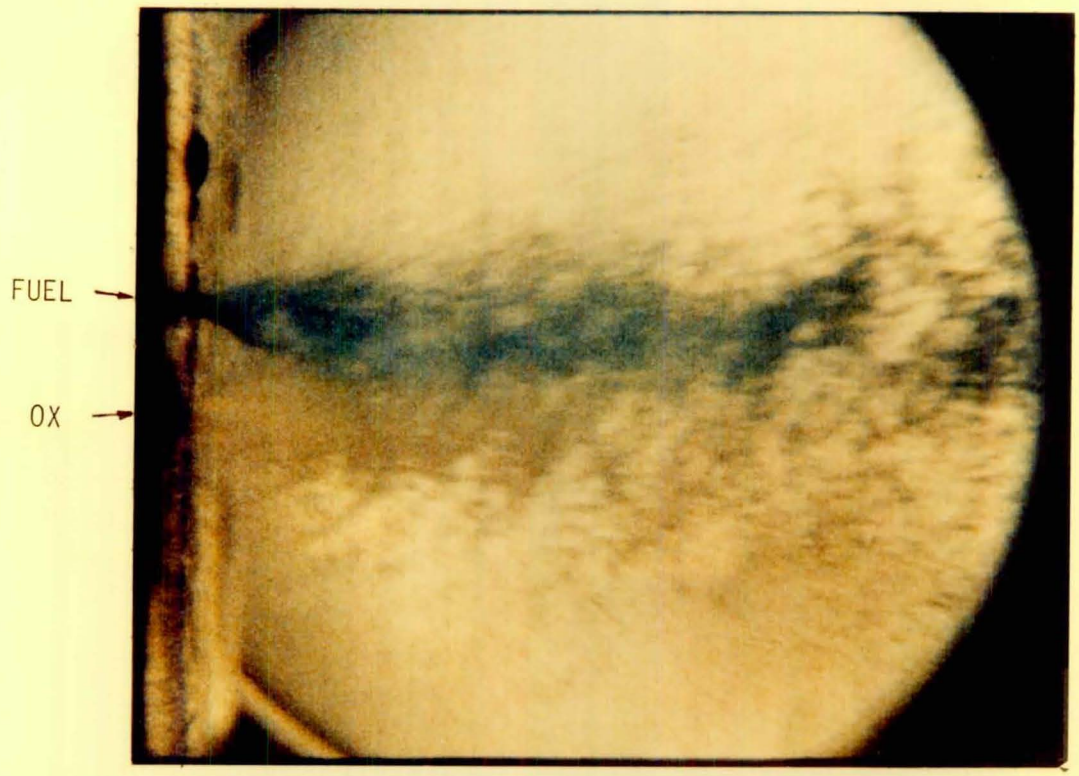


FIGURE 21. TLOL INJECTOR COLD-FLOW SPRAY PATTERN

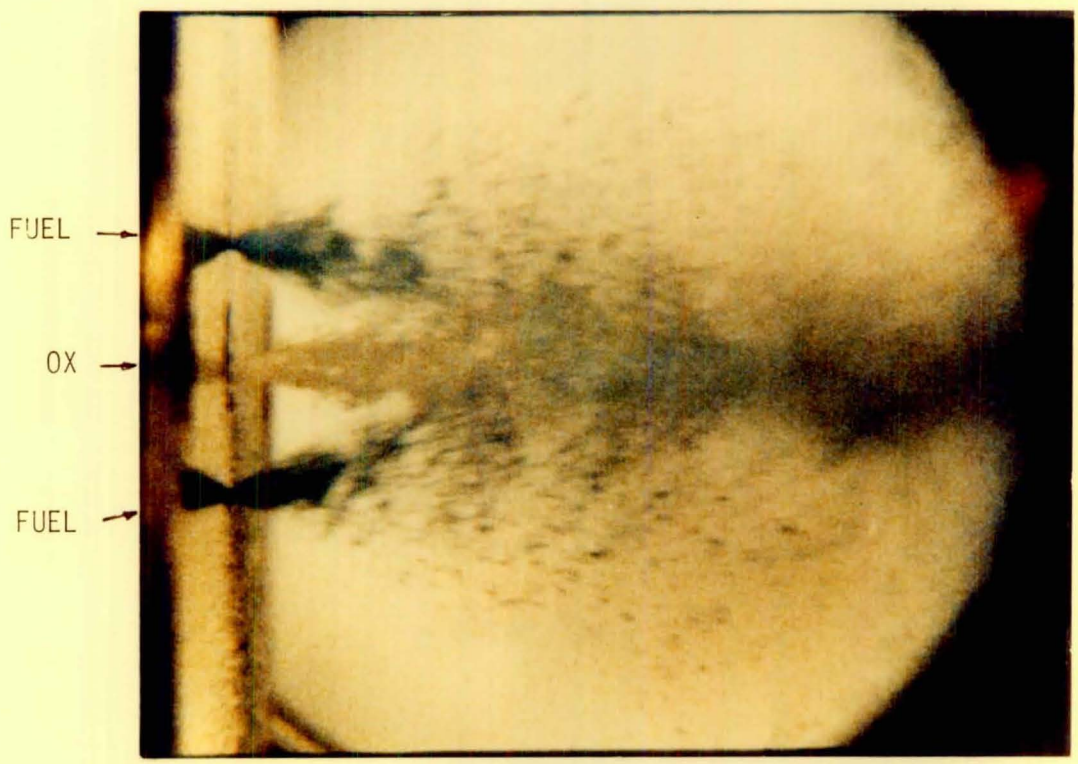


FIGURE 23. PAT INJECTOR COLD-FLOW SPRAY PATTERN

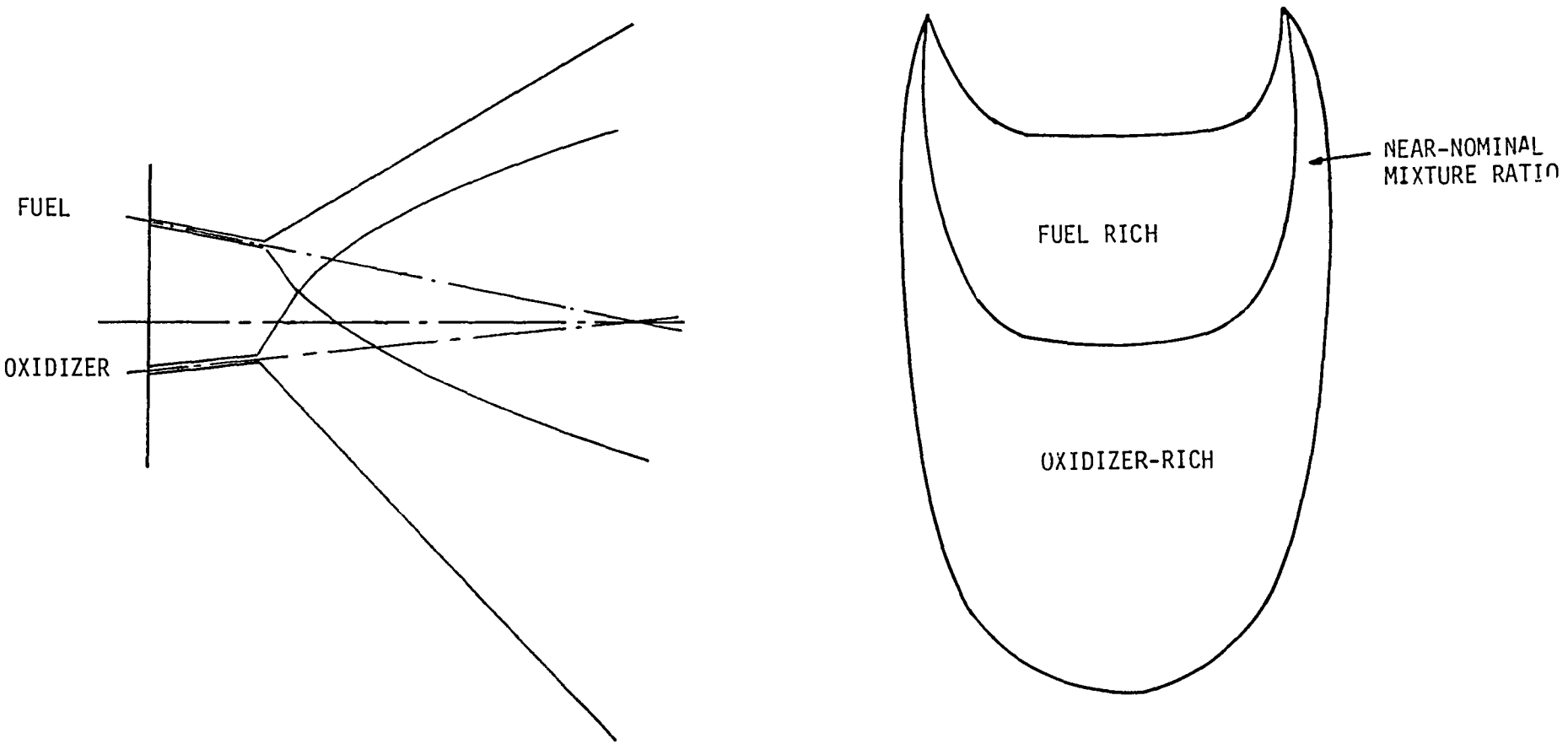


FIGURE 22. TLOL INJECTOR COLD-FLOW MIXING PATTERN

orifice of the PAT injector produces a spray fan, resulting in sheet-on-sheet impingement instead of coherent jet impingement as in the OFO Triplet. Figure 16 shows a bell-shape type of fan-span mass distribution for both the oxidizer and fuel fans. The fuel has a much smaller fan angle than the oxidizer which results in a mixing pattern consisting of a slightly fuel-rich zone along the element centerline and two oxidizer-rich zones, carrying small total mass fraction, on each side of the fuel-rich zone. The small fuel cant angle results in long unlike impingement height approximately equal to 3.38 cm (1.33 in). This causes a poor mixing pattern similar to that observed for the TLOL injector. Figure 24 qualitatively outlines the contour of the mixing pattern.

Figure 25 is a sketch of the hot-fire view window, through which the photographs of spray combustion fields were taken as described in Reference 2. Corresponding to the cold-flow testing, the entire view scope can be divided into three planes perpendicular to the chamber axis and located at 1.27 cm (0.5"), 2.54 cm (1.0"), and 3.81 cm (1.5"), respectively, downstream from the injector face. On each plane, there are as many as 100 (10 x 10) square cross-sections with dimensions at 0.48 cm x 0.48 cm (0.19" x 0.19"). Each cross-section represents a grid of cold-flow collector head and has propellant mass fractions determined by cold-flow tests. This arrangement allows a direct comparison of the vaporization analysis results with the hot-fire photographs.

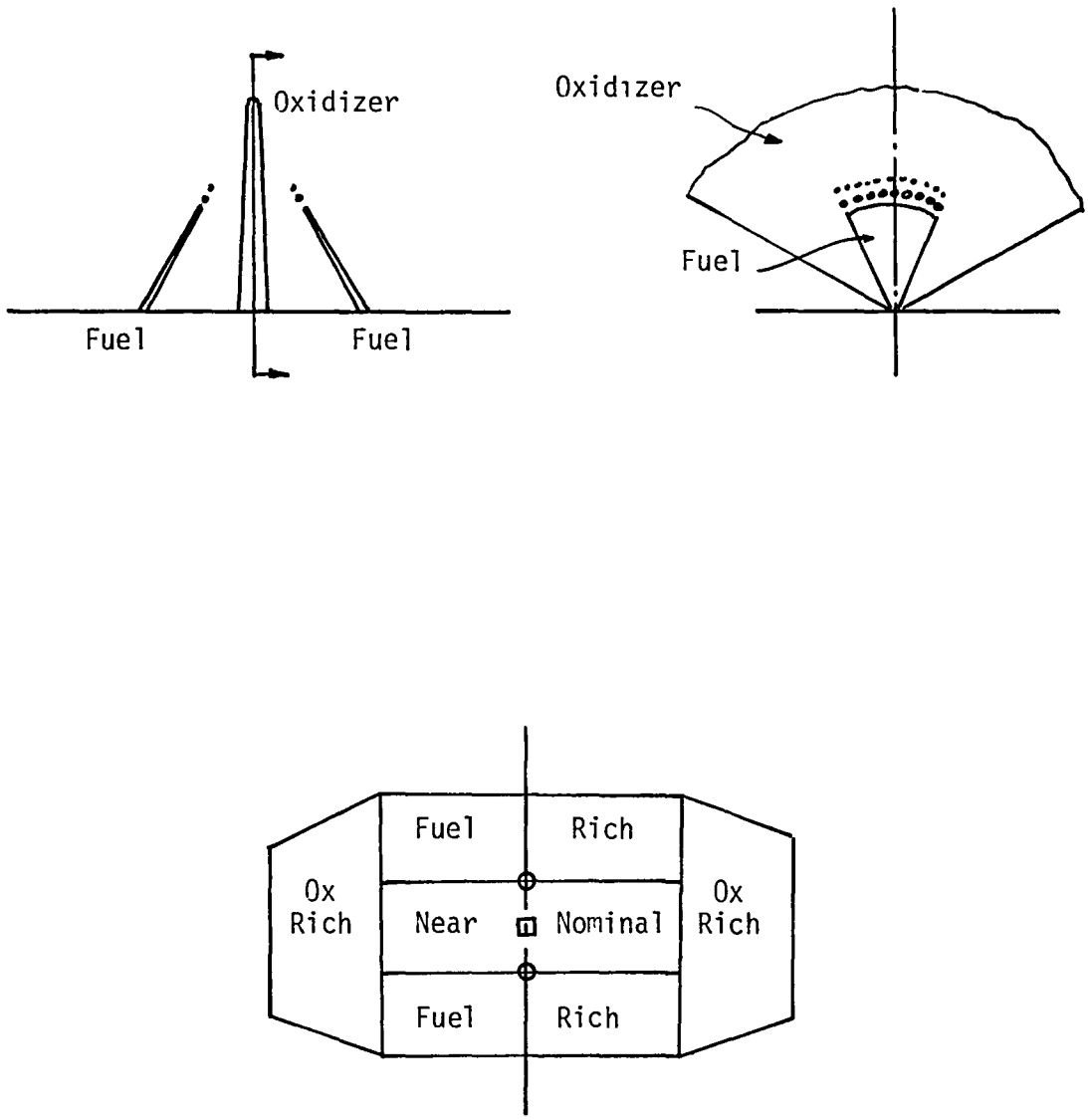


FIGURE 24. PAT INJECTOR COLD-FLOW MIXING PATTERN

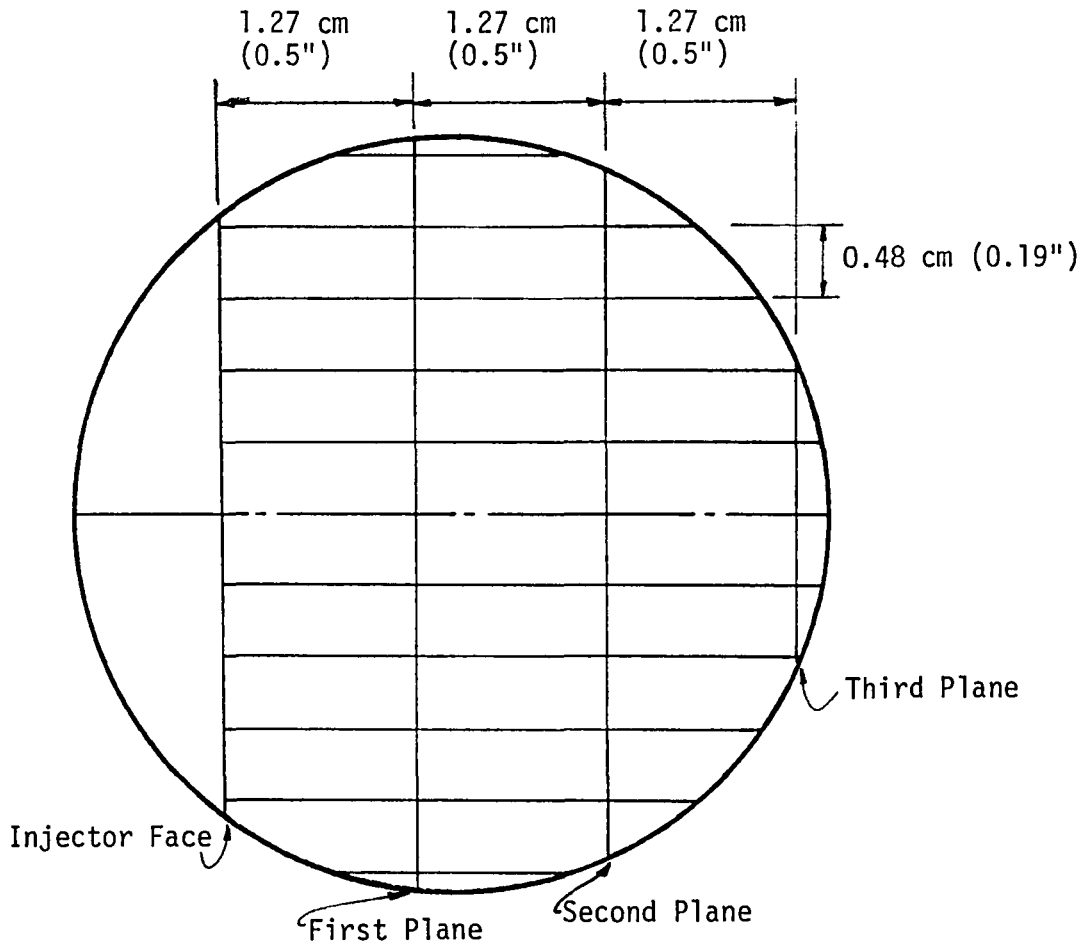


FIGURE 25. ZONING OF THE WINDOW VIEW OF THE COMBUSTION FIELD

V VAPORIZATION ANALYSIS

A. Generalized-Length Model Summary

The present vaporization analysis is based on the Priem-Heidmann Generalized-Length model reported in Reference 3. This model, correlates the propellant mass vaporized with an effective chamber length (generalized length, L_{gen}), defined by the following equation:

$$L_{gen} = (L_c/C_R^{0.44} + 0.833\ L_N/(C_R^{0.22}\ S^{0.33}))\ (Pc/2068)^{0.66}\ K_P K_J \quad (1)$$

where

$$K_P = (1 - T_r)^{0.4}\ (H_v/325.64)^{0.8}\ (M/100)^{0.35}$$

$$K_J = (r_m/76.20)^{1.45}\ (V/328)^{0.75}$$

Nomenclature is defined in Appendix F. Figure 26 shows the average value of propellant mass vaporized as a function of L_{gen}, with extrapolations from the correlation of Reference 3 for vaporization less than 1% or greater than 99%.

The correlations of the mass-median droplet radius, r_m, shown in Figure 27 were determined by Reference 3 from LOX/Heptane hot-fire performance data by assuming equal drop size for both propellants. The injection velocity is at 19.8 m/sec (65 ft/sec). The impinging jets (like-on-like) and triplet types of injector have an impingement half angles equal to 45°. In order to apply this drop size correlation to other engine operating conditions , the effects of propellant properties, injection velocity, and injector element configuration must be included.

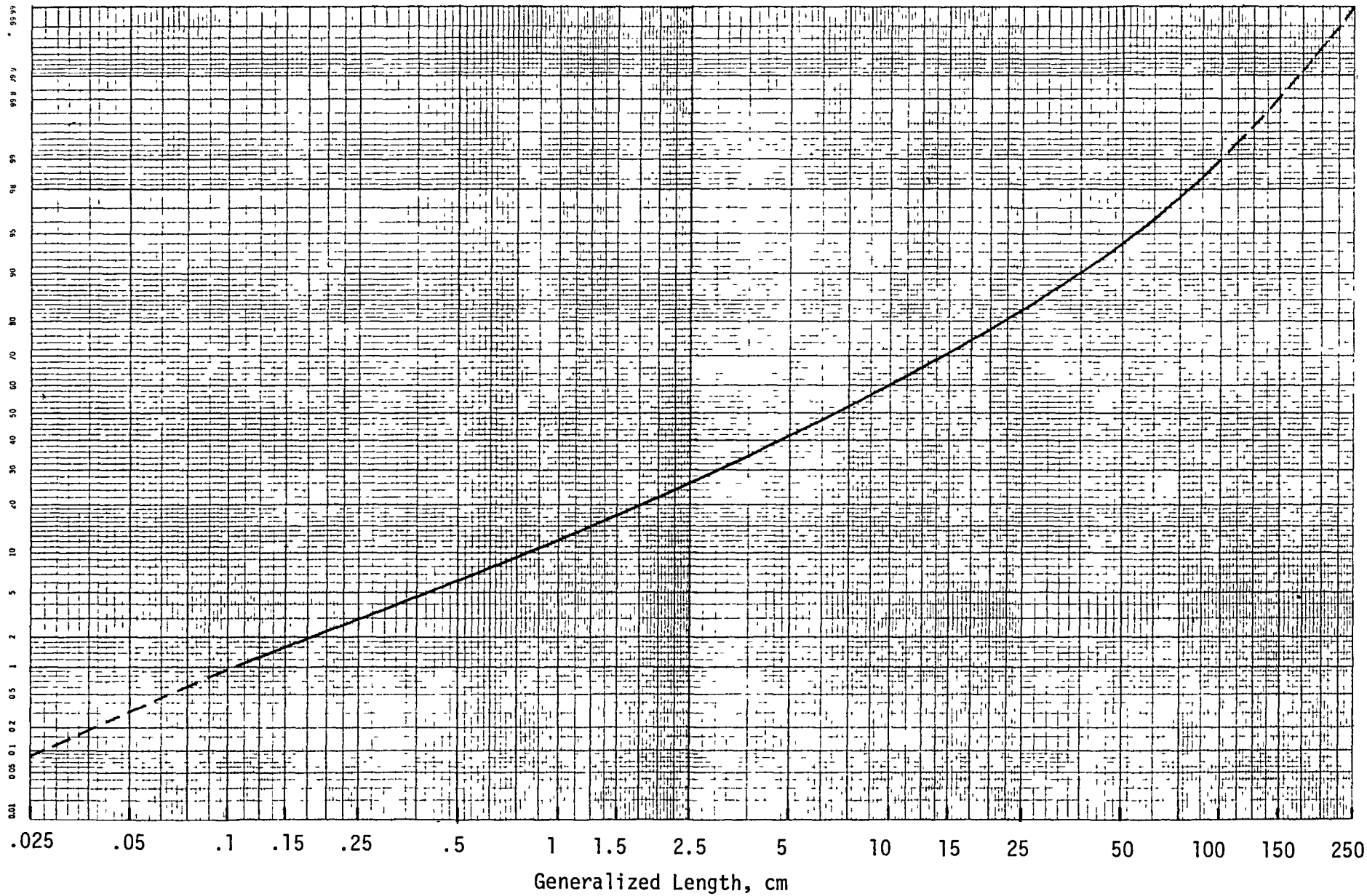


FIGURE 26. GENERALIZED LENGTH CORRELATION WITH MASS VAPORIZED (REFERENCE 3)

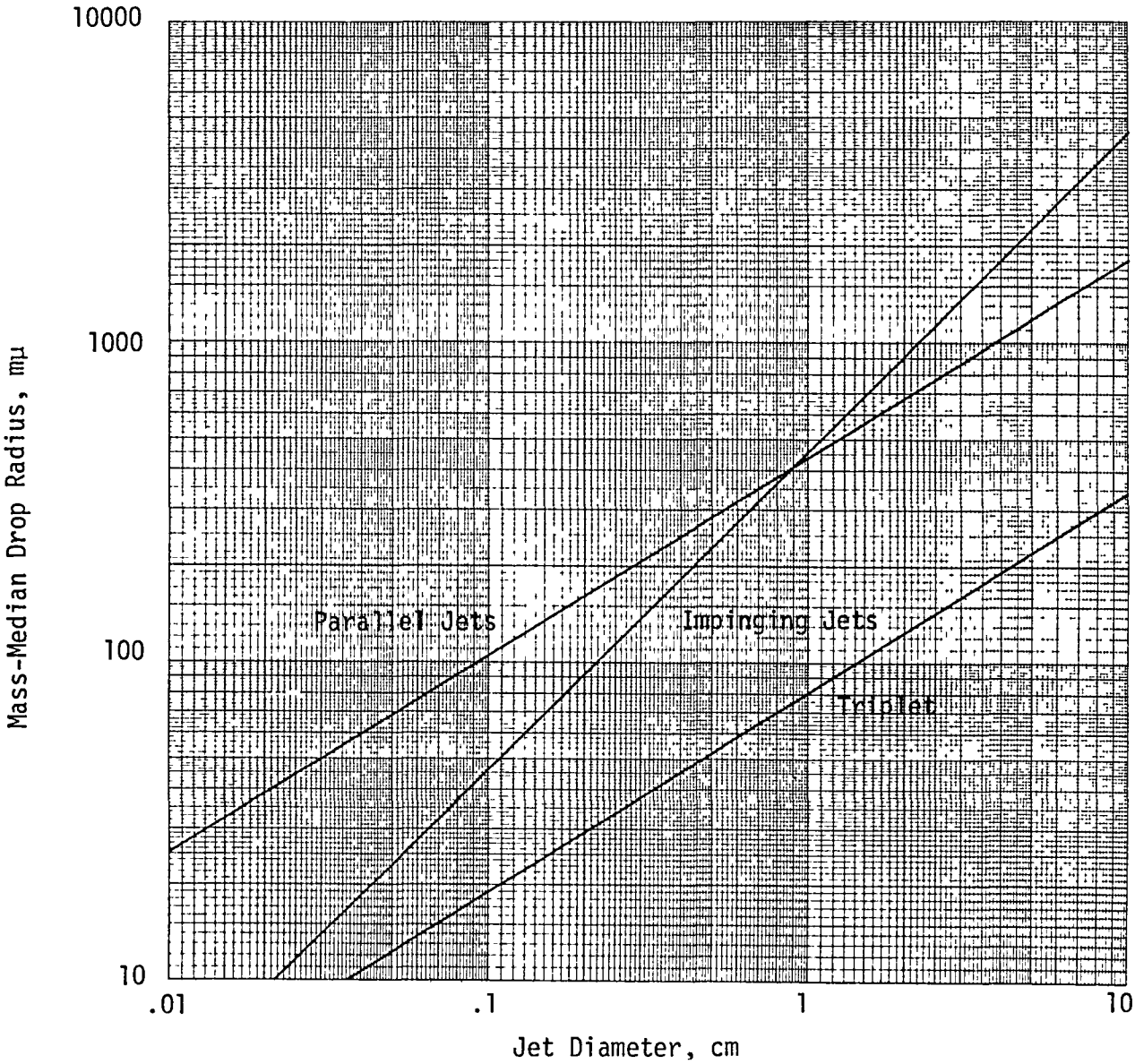


FIGURE 27. DROP SIZE DETERMINED FROM EXPERIMENTAL LOX/HEPTANE ENGINE PERFORMANCE (REFERENCE 3)

For the effects of propellant surface tension (σ), viscosity (μ), and density (ρ) on the mass median drop size (r_m), Reference 3 recommended the following relationship based on the result of Reference 4:

$$r_m = 99.29\, r_{m,\ uncor}\ (\sigma\mu/\rho)^{0.25} \qquad (2)$$

The effects of the injection velocity and injector configuration which are not included in Reference 3 are accounted for by the present investigation as discussed in the following subsection.

B. Atomization Process Considerations

Liquid droplets are formed through the disintegration of jets or sheets. All four injectors considered in the present study produce droplets by sheet disintegration. With this type of injector, a propellant sheet is either issued directly from the injection orifice such as Splash-Plate and X-Doublet, or formed by impinging jets such as OFO Triplet and Like-On-Like doublet. The self-formed sheet and the majority of the liquid mass of the impinging-jet-formed sheet exist as a forward diverging fan with attenuating fan thickness. The lateral edges of the fan break up and form drops when the declining surface tension becomes less than the propellant momentum. Due to aerodynamic instability, the leading edge of the fan breaks up into ligaments, which subsequently form droplets. This droplet formation process is affected by injector configuration, propellant physical and hydraulic properties, and the surrounding gas physical properties.

A survey of the values reported in the open literature for the exponent of the injection velocity dependency of drop size is shown in Table

111. The most reasonable value seems to be 0.66 since it was reported by most investigators and by both experimental and theoretical results. As a result, this exponent has been used to account for the injection velocity effect on drop size.

The injector configuration affects the drop size by its orifice size and the fan angle it yields. The orifice size effect has been provided by the correlation shown in Figure 27. The fan angle model and the effect of fan angle on drop size are discussed herein.

Both experimental (References 15, 16, and 17) and theoretical (Reference 18) investigations have shown that the liquid sheets formed by two like impinging jets are disk-like in shape with the thickness varying circumferentially. The sheet thickness is uniform when the total impingement angle is 180°. However, as the impingement angle decreases the mass of the liquid becomes more and more concentrated along the forward symmetrical axis and the thinner portions of the sheet break up earlier so that the sheet appears like a forward diverging fan instead of a disk-like sheet. One can use an iterative solution to arrive at the fan angle as a function of impingement angle, as shown in Figure 28. The fan angle predicted by this simplified model is shown in Figure 29 to contain no less than 88% of the mass predicted by Hasson model (Reference 18).

The sheets formed by the two outer jets of a triplet injector are identical to that formed by the like-on-like impinging jets except the fan thickness is reduced by half. The sheet formed by the middle jet stream is controlled by the impingement angle and the momentum ratio of the unlike fluids. Figure 30 shows the fan angles for a 30° half-impingement-angle

TABLE III

SURVEY OF EXPONENT OF VELOCITY DEPENDENCY OF DROP SIZE

DROP SIZE CORRELATED EXPERIMENTAL	AUTHOR	REF.	EXPONENT	INJECTION DEVICE
d_{max}	Mugele	5	-0.66	Pressure nozzle & Impinging Jet
d_{32}	Mugele	5	-0.55	Pressure nozzle & Impinging Jet
d_{32}	Dombrowski & Hooper	6	-0.79	Impinging Jet
d_{32}	Jasuja	7	-0.86	Pressure nozzle
d_{50} $(=d_m)$	Longwell	8,9	-0.66	Pressure nozzle
d_{32}	Fraser	10	-0.706	Pressure nozzle
Theoretical				
d	Hagerty & Shea	11	-1	Plane sheet
d	Fraser, et. al.	12	-2/3	Spray fan
d	Dombrowski & Hooper	13	-2/3	Spray fan, long wave length
d	Dombrowski & Hooper	13	-0.72	Spray fan, medium wave length
d	Dombrowski & Hooper	13	0	Spray fan, short wave length
d	Dombrowski & Johns	14	-2/3	Spray fan

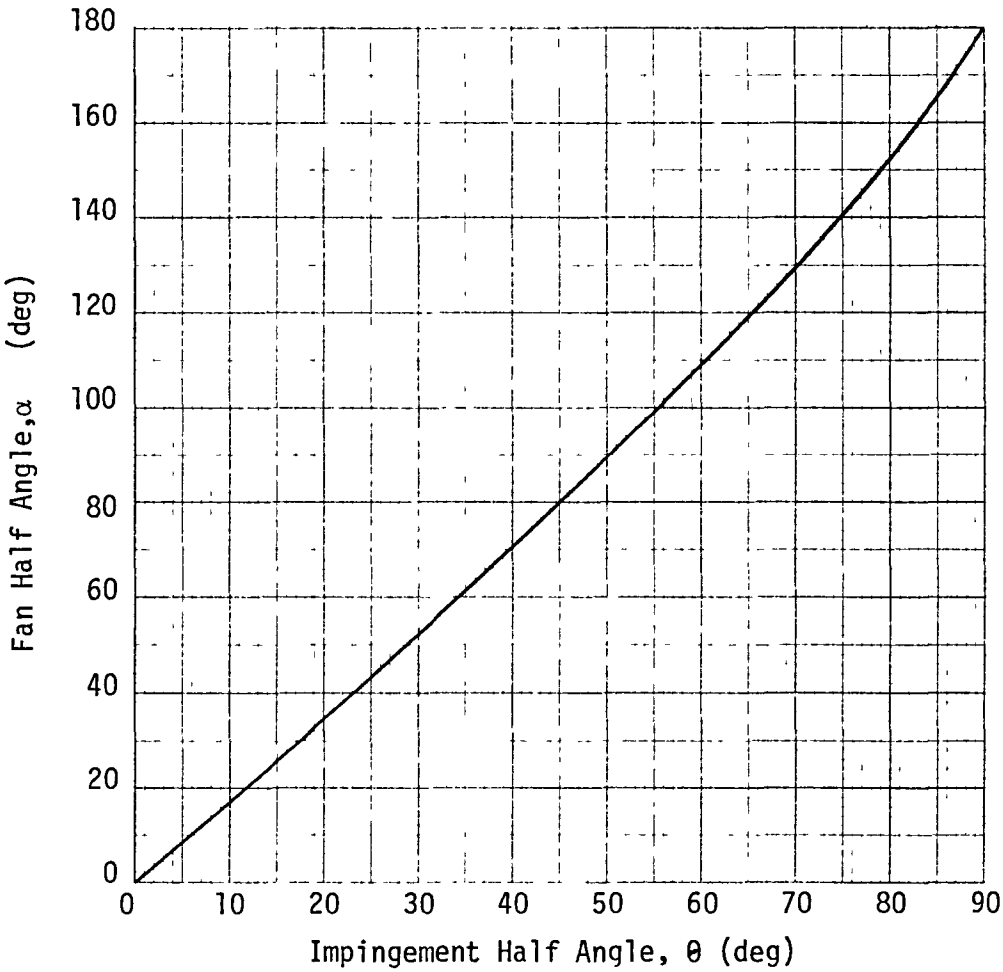


FIGURE 28. IMPINGING JET FAN ANGLE PREDICTED BY SIMPLIFIED SPRAY MODEL

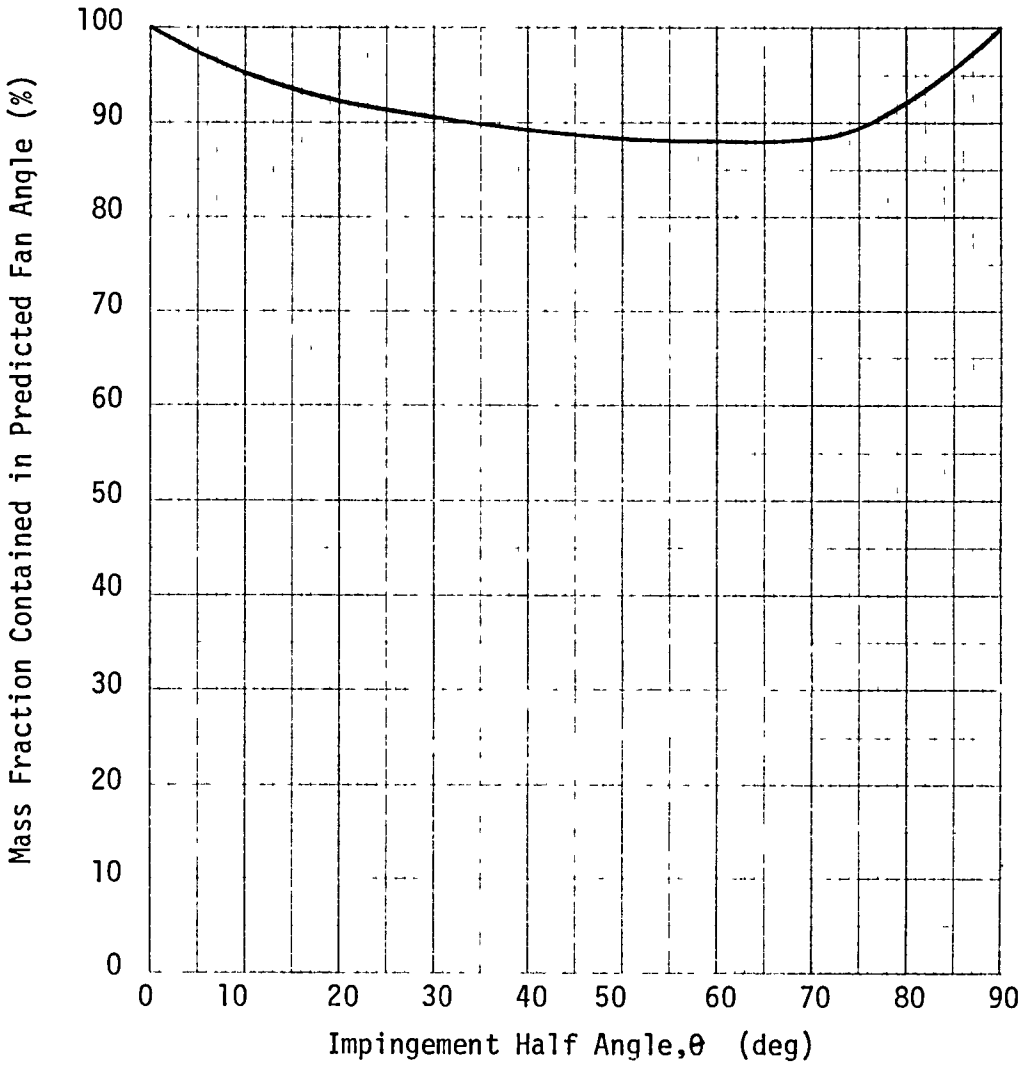


FIGURE 29. MASS FRACTION CONTAINED IN THE FAN ANGLE PREDICTED BY THE SIMPLIFIED SPRAY MODEL FOR IMPINGING JETS

triplet injector. If the maximum mixing efficiency occurs at equal fan angles, the uni-element cold-flow data of Reference 19 appear to validate the predicted middle jet fan angle.

Because of constant density and conservation of the mass, the fan angle controls the fan thickness, which in turn determines the drop size. Reference 14 implies that the exponent of the fan angle dependency of drop size is -1/3. As a result, the drop size increases or decreases as the fan angle decreases or increases.

C. Application of Generalized-Length Model

In applying the L_{gen} model to a general case, in which the propellant injection velocity and the injection element type or configuration are different from those of Reference 3, modifications to the original drop size correlation are necessary. The following calculation procedures were used by the present investigation for determining propellant vaporization efficiency.

1. Determine the uncorrected drop size from Figure 27 and the fan angle from Figure 28 or 30.

2. Calculate the corrected mass-median droplet radius using the following equation:

$$r_m = r_{m,uncor} \times 3.07\times10^3 \times \frac{\sigma\mu}{\rho}^{0.25} V^{-0.66} \alpha^{-1/3} \qquad (3)$$

3. Use equation (1) to determine the value of generalized length.

4. Use Figure 26 to determine the percentage of propellant mass vaporized at a given chamber axial location.

D. Vaporization Model

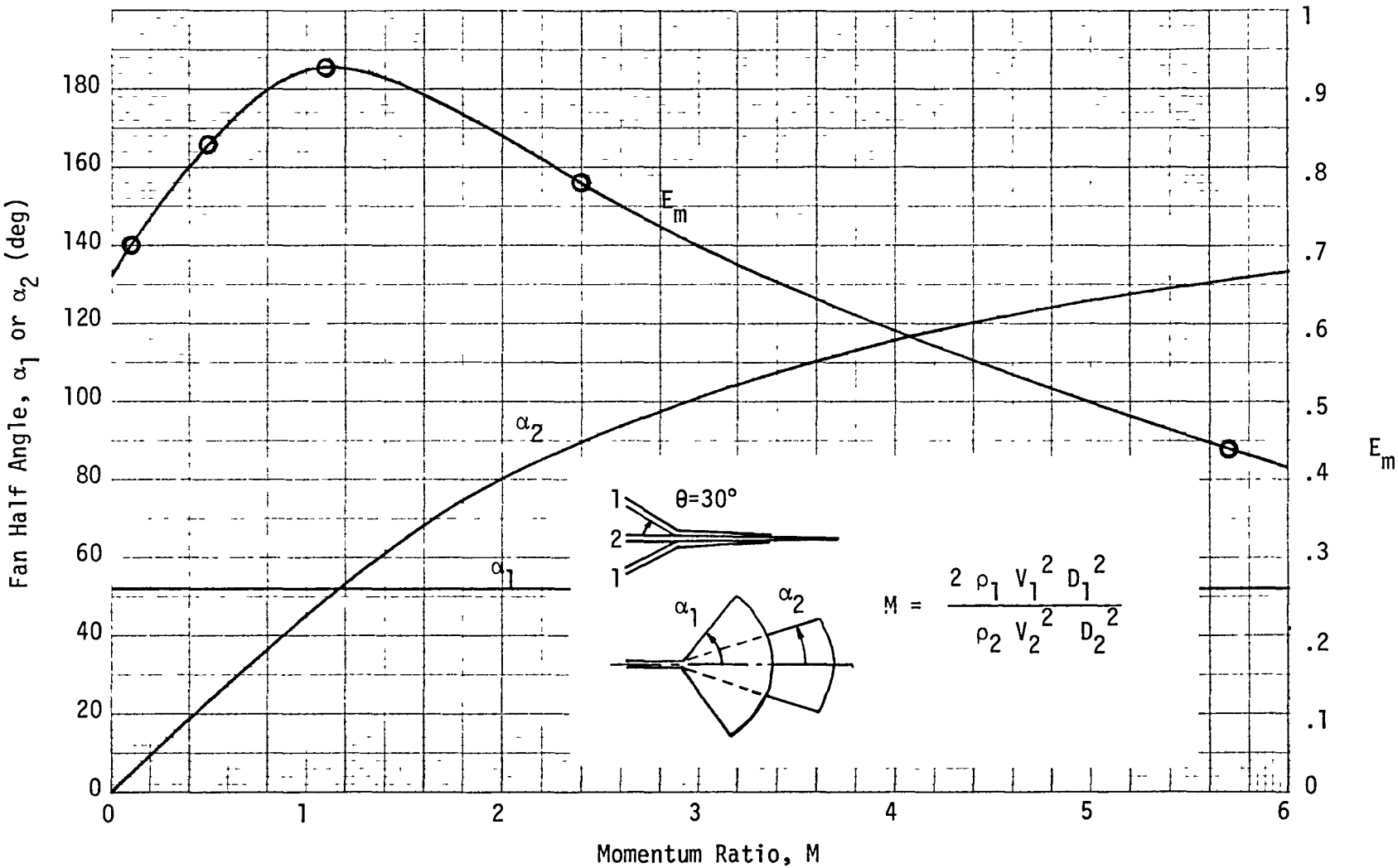


FIGURE 30. TRIPLET FAN ANGLE PREDICTED BY SIMPLIFIED SPRAY MODEL

The vaporization analysis performed by the present study is based on the L_{gen} model with the modifications described precedingly. The combustion chamber within the scope of the view window is divided axially into three equally spaced regions as shown in Figure 25. Each plane corresponds to a cold-flow collector-plane location, relative to the injector face. A three dimensional representation of the zoning is provided in Figure 31.

A vaporization computer model based on this spatial arrangement was formulated as described below.

1. Consider a chamber control volume encompassed by a right rectangular cylinder with 4.83 cm x 4.83 cm (1.9" x 1.9") cross-section and 3.81 cm (1.5") in length from the injector face.

2. The cylinder is divided axially into three sections of equal length with 1.27 cm (0.5") each. Therefore, the entire control volume contains three exit planes perpendicular to the axis.

3. Each plane is further divided into 100 (10 x 10) grids with equal dimensions at 0.48 cm x 0.48 cm (0.19" x 0.19").

4. The propellant present in a grid came solely from a specified grid in the preceding plane, thereby forming a section of a streamtube between the two grids. Oxidizer and fuel in a grid may come from different grids of the preceding plane.

5. The Priem-Heidmann Generalized-Length vaporization correlation is assumed to be applicable to individual streamtubes.

6. The off-nominal gas temperature effect on vaporization rate is accounted for by a factor of $(T-T_s)/(T_n-T_s)$, where T is the actual local gas temperature, T_n is the nominal gas temperature of 2778°K (5000°R), T_s is either the propellant saturation temperature or the critical temperature

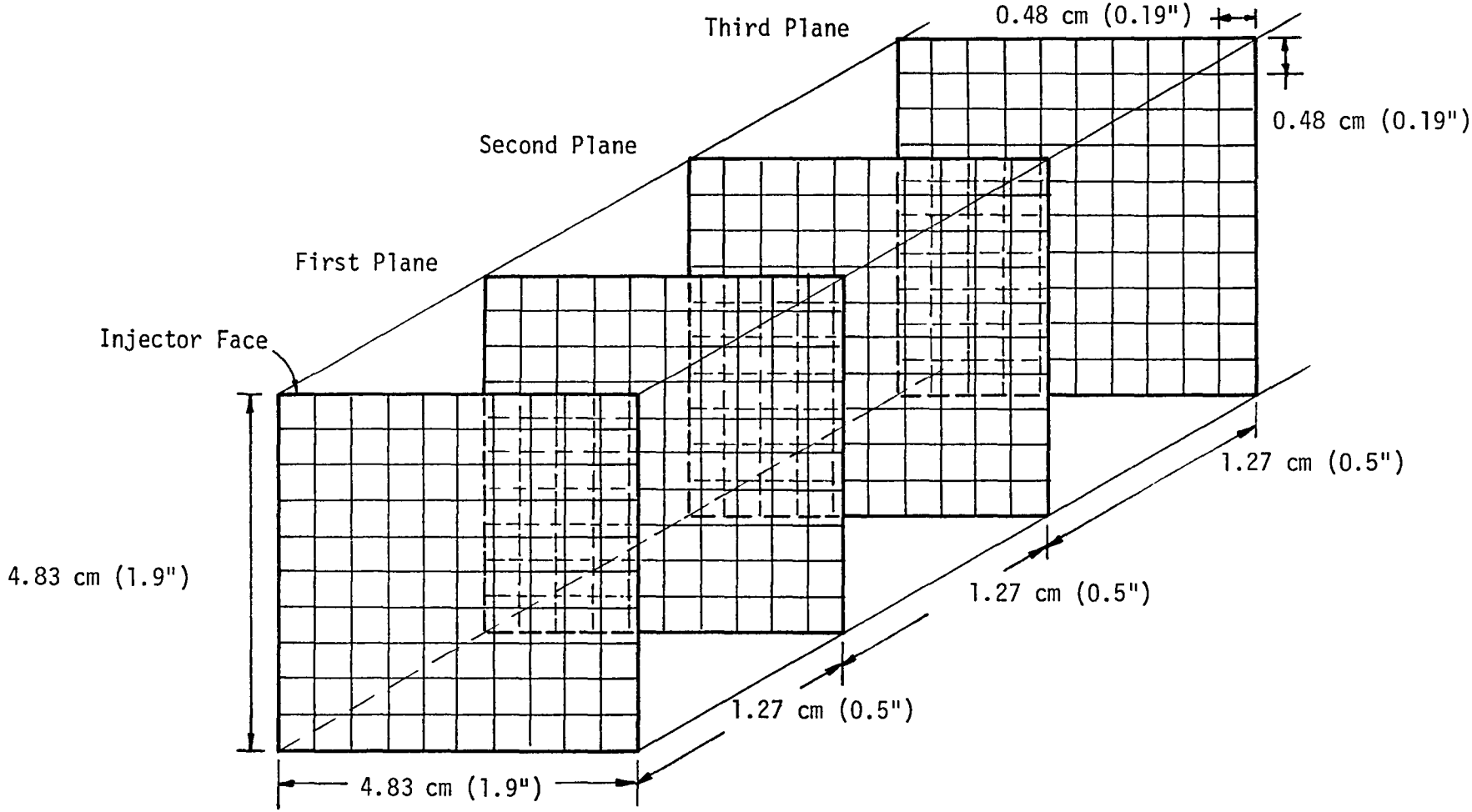


FIGURE 31. ZONING OF THE CROSS-SECTIONAL VIEW OF THE COMBUSTION FIELD

depending upon whether the chamber pressure is below or above the propellant critical pressure.

7. The vapors are assumed to travel together with the liquid droplets, from which they were evaporated.

8. The chemical reaction (propellant burning) does not take place between planes. The vapors produced in a streamtube section react instantaneously on arrival at their destined grid if the counterpart vapors are available at that location.

9. At a given propellant momentum ratio and axial location, the mass distribution of unburned propellant, including both vapor and liquid, is identical to that observed in cold flow tests.

10. The reaction of the oxidizer and fuel vapors produces equilibrium products from which the local temperature is determined. The equilibrium reaction computation is carried out by the ODE computer program of Reference 20.

11. No vaporization takes place in the preceding streamtube section, if the cold-flow mixture ratio in any grid is outside a specified range (extremely low or high).

12. The effect of the recirculating chamber gases is neglected.

The computation flowchart and program listing are provided in Appendix C. A sample run of the computer program including the input and output is also provided. The NAMELIST input includes chamber pressure (PC), operating mixture ratio (MRJ), chamber contraction ratio (CR), number of planes (NPLANE), propellant identification (IDO, IDF), propellant temperature (TO, TF), injection velocity (VO, VF), mass-median drop radius (RMO, RMF), and drop surface temperature (TSO, TSF). The propellant mass distribution is input through FORMAT input, which includes grid

number (J), mass fraction (CO, CF), and the corresponding grid number in the preceding plane (JO0, JF0). The output includes generalized length (LGO, LGF), gas temperature (TG), vaporization efficiency (EVO, EVF), vapor mixture ratio (MRV), and liquid mixture ratio (MRL).

E. Input and Results

The data input to the computer program for the 40 tests analyzed are summarized in Appendix D. The mixture ratios for the tests selected for a given injector are nearly constant and their equivalent momentum ratios are approximately equal to that of the cold-flow tests. For each injector, this results in only one mixing pattern identical to that characterized by the cold-flow tests. In preparing the mass distribution data tables, any grid containing less than 1% of the total propellant mass was neglected. This greatly reduces the size of mass distribution table and simplifies the computation without appreciable sacrifice of accuracy. The trajectories of propellants were empirically determined on the basis of measured mass distributions.

The propellant mass-median drop sizes were calculated using the method described in Section V.C. with the exception of the PAT fan angles.The fuel fan angle of the PAT injector is equal to 60°, the cup angle of the Splash Plate element. The oxidizer fan angle was determined to be 42° based on the cold-flow data. This oxidizer fan angle contains 80% of the total oxidizer flow.

Appendix E tabulates the fuel mass fraction vaporized and liquid mixture ratio at all three planes predicted by the computer program. It also provides two sets of mass average values. One is depth average, in which the mass average is taken from I = 0 to 9 at each J for the OFO Triplet injector, and from J = 1 to 10 at each I for the other three injectors. The

other is plane average, in which average is taken over the entire chamber cross section on each plane. The liquid mixture ratio represents the ratio of the liquid oxidizer to liquid fuel remaining for further vaporization and chemical reaction.

VI DATA CORRELATION

A. Fuel Vaporization Rate Effect

The photographically observed degrees of carbon formation shown in Figures 3 through 6 are compared to the average fuel vaporization efficiency at the 3.81 cm (1.5") plane in Figures 32 through 35. The degree of carbon formation is noted for each test by its location within one of four shaded bands for the four carbon formation classifications: clear, slightly clouded, moderately clouded, and obscure. The darker shading representing greater carbon formation and the lighter shading less carbon formation. The calculated vaporization rate is noted by a vertical line at the % vaporized shown on the horizontal scale.The correlations indicate that in general the carbon formation is intensified as the fuel vaporization is slowed down.

Figure 32 shows that, for the OFO Triplet injector, test 116 has the fastest RP-1 vaporization resulting in the clearest combustion flame. The TLOL injector was observed to yield much more carbon formation than the OFO Triplet injector when both injectors used RP-1 as fuel. Comparison between Figure 32 and Figure 33 indicates that this is due to the much slower RP-1 vaporization rate by the TLOL injector. Figure 33 also shows that the slower RP-1 vaporization due to its lower volatility is responsible for more carbon formation by RP-1 than by propane. Figures 34 and 35 further show the reduction in carbon formation by increasing the fuel vaporization rate for the EDM-LOL and PAT injectors.

B. Chamber Pressure Effect

In Figures 3 through 6, the chamber pressure appears to have an overwhelming effect on carbon formation. Therefore, a correlation was made to determine whether or not the pressure has direct control of the carbon

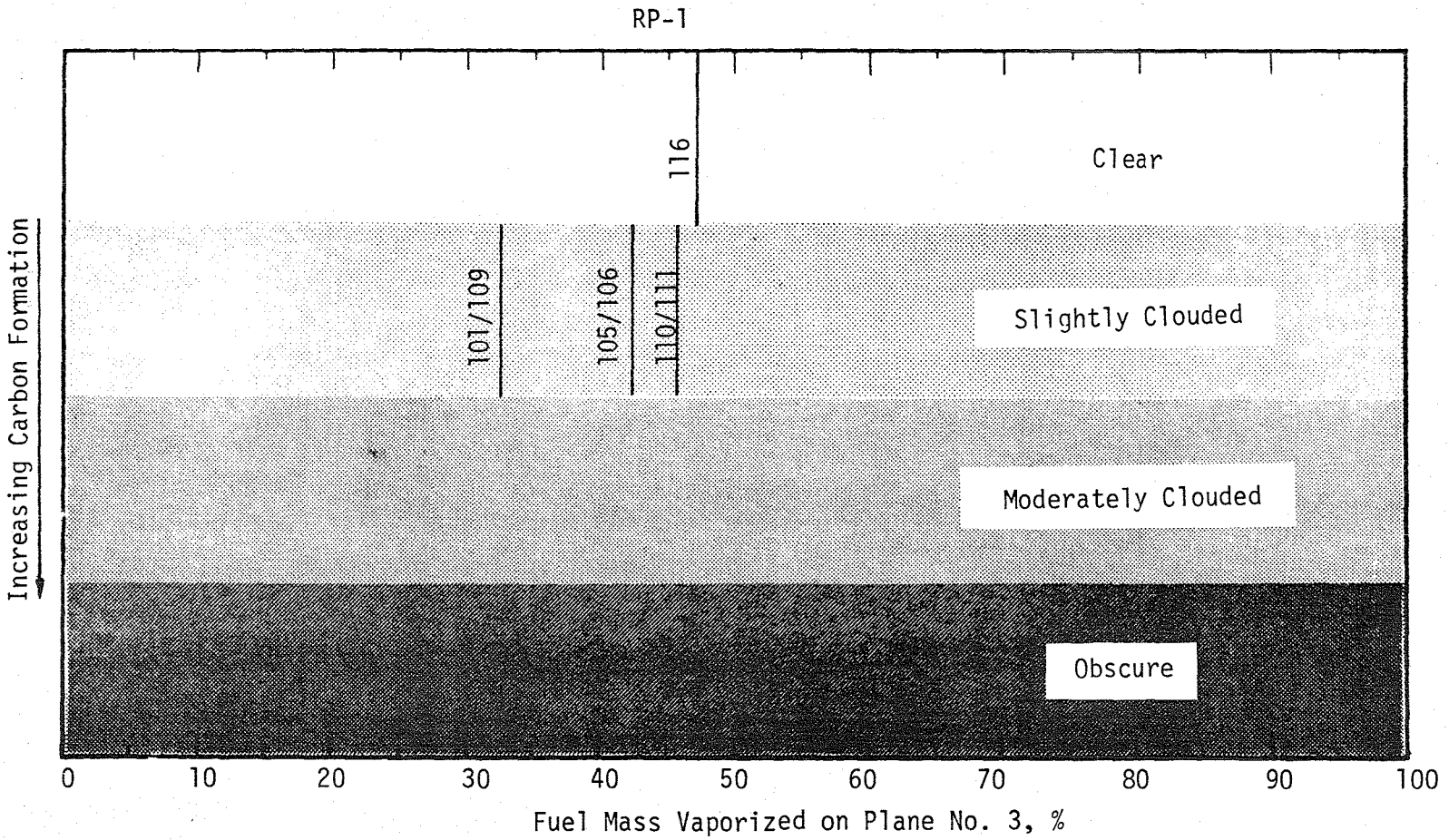


FIGURE 32. OFO TRIPLET CARBON FORMATION CORRELATION WITH FUEL VAPORIZATION RATE

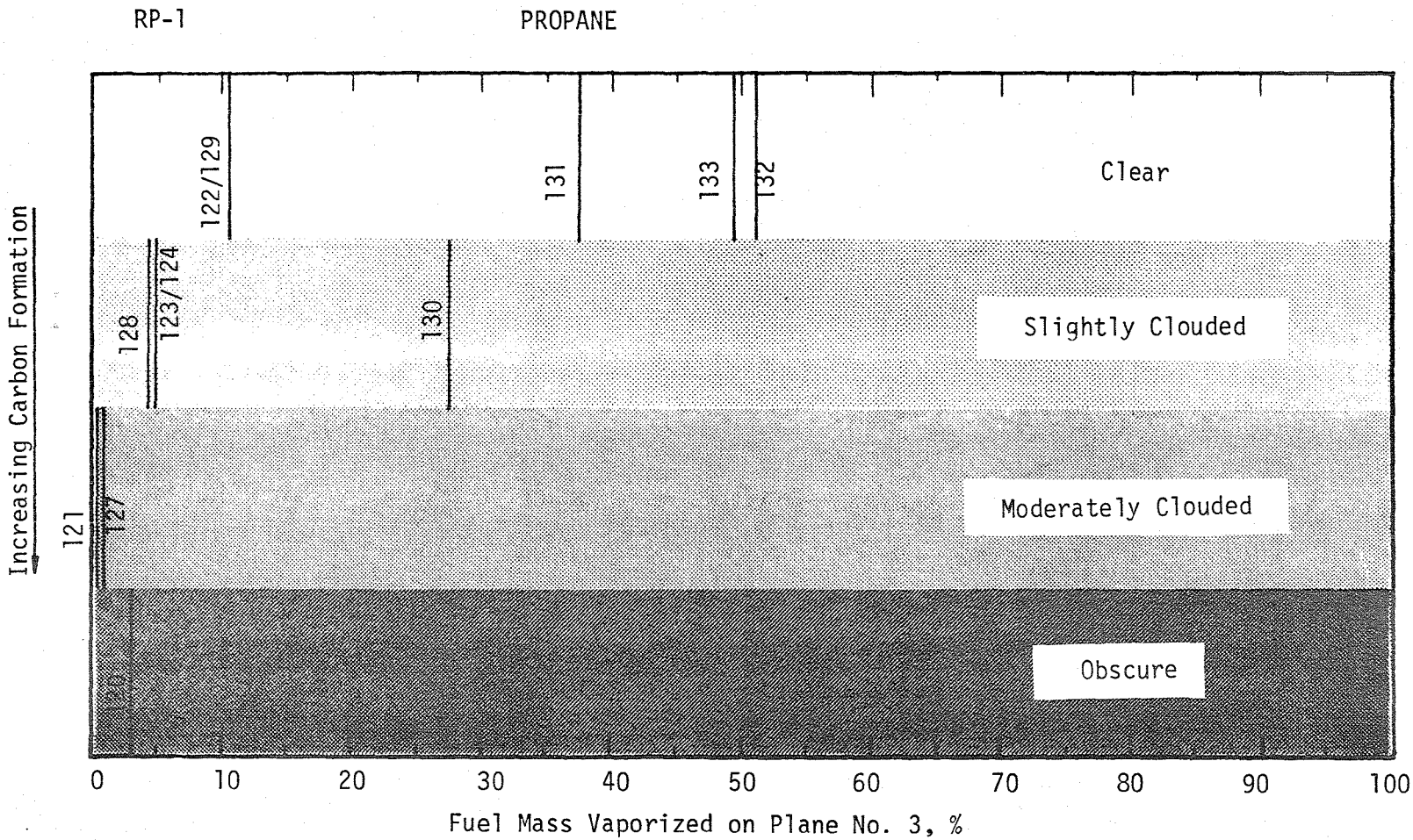


FIGURE 33. TLOL CARBON FORMATION CORRELATION WITH FUEL VAPORIZATION RATE

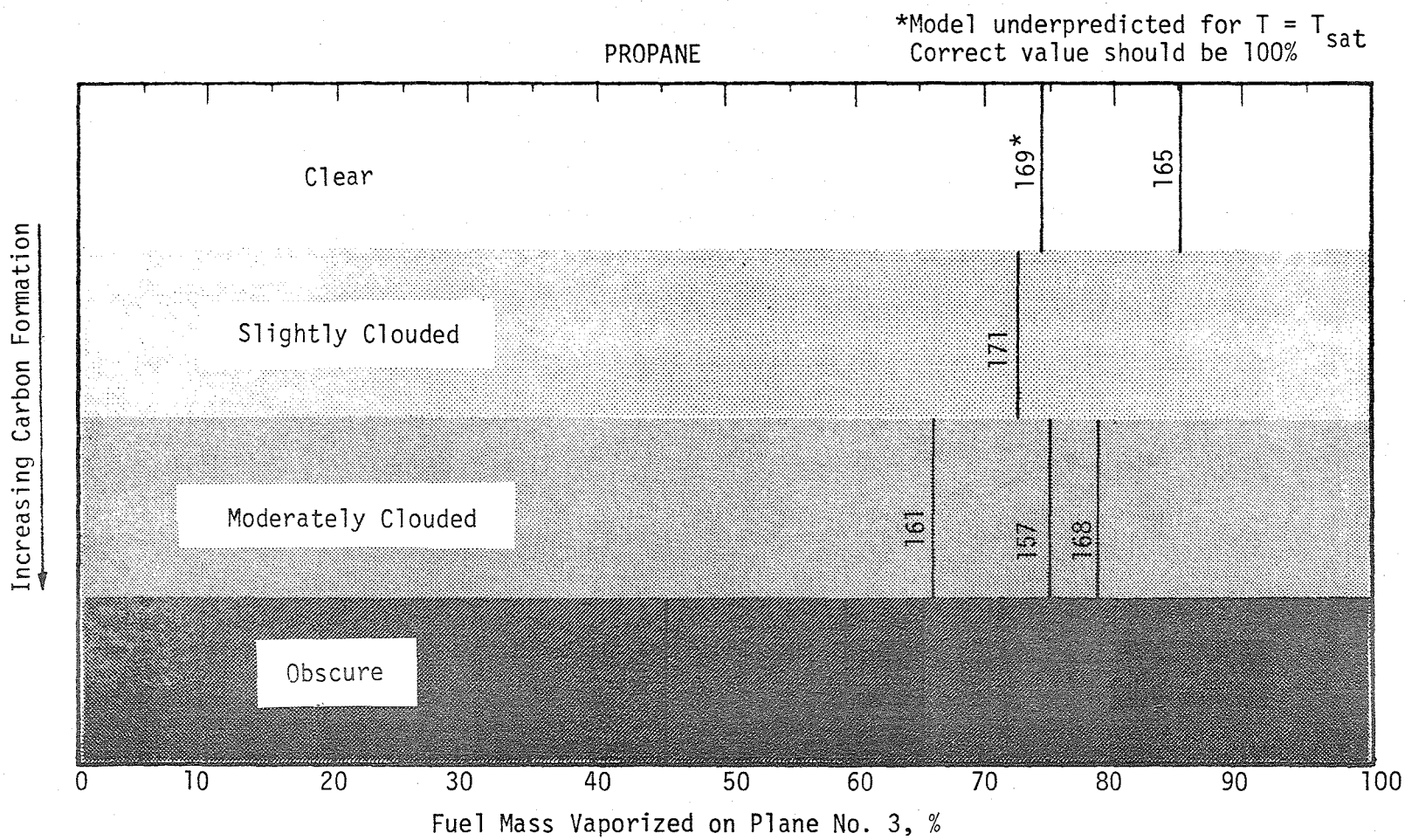


FIGURE 34. EDM-LOL CARBON FORMATION CORRELATION WITH FUEL VAPORIZATION RATE

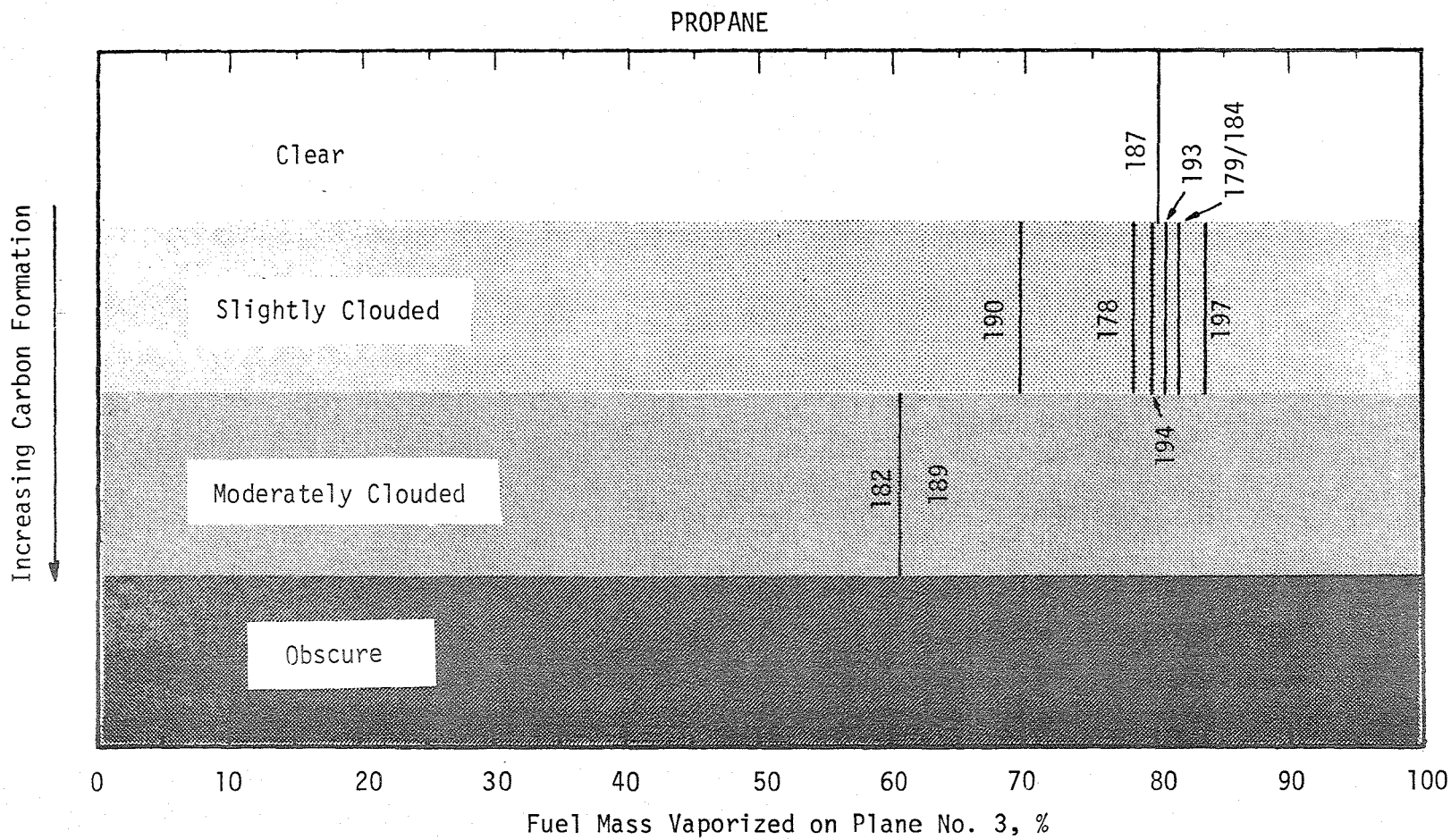


FIGURE 35. PAT CARBON FORMATION CORRELATION WITH FUEL VAPORIZATION RATE

formation in addition to its indirect effect through its influence on the vaporization rate. Figures 36 through 39 correlate the carbon formation with the chamber pressure as well as the fuel vaporization rate. The chamber pressure itself seemingly has a second order effect. High chamber pressure improves the clearness of the combustion flame at the same fuel vaporization for some cases. It explains why test 120 of the TLOL injector (Figure 37) was obscure and test 187 of the PAT injector (Figure 39) was clear. It also improves the EDM-LOL correlation (Figure 38), however, test 169 of the EDM-LOL injector does not agree well with the correlation trend because the propane was injected at the saturation temperature of the tested chamber pressure. Under that condition the propane undergoes flash vaporization upon entering the combustion chamber as shown by Figure 2. The Priem-Heidmann L_{gen} model is not valid for this case and underpredicts the vaporization rate for this case. Test 169 indeed is the most decisive evidence showing that fuel-vaporization rate controls carbon formation.

C. Mixing Effect

For the propane tests, the TLOL, EDM-LOL and PAT injectors exhibited different degrees of carbon formation even when they were operated at the same predicted fuel vaporization rate. This suggests that propellant mixing has a direct effect on carbon formation besides its influence on the vaporization rate.

In this study, the combustion zone of each injector was photographically viewed only from one fixed direction. Thus, the mixing characteristics discussed herein are limited to those exhibited in the plane perpendicular to that particular view. Figures 40 through 43 show the calculated depth-averaged liquid phase mixture ratios at the 3.81 cm (1.5")

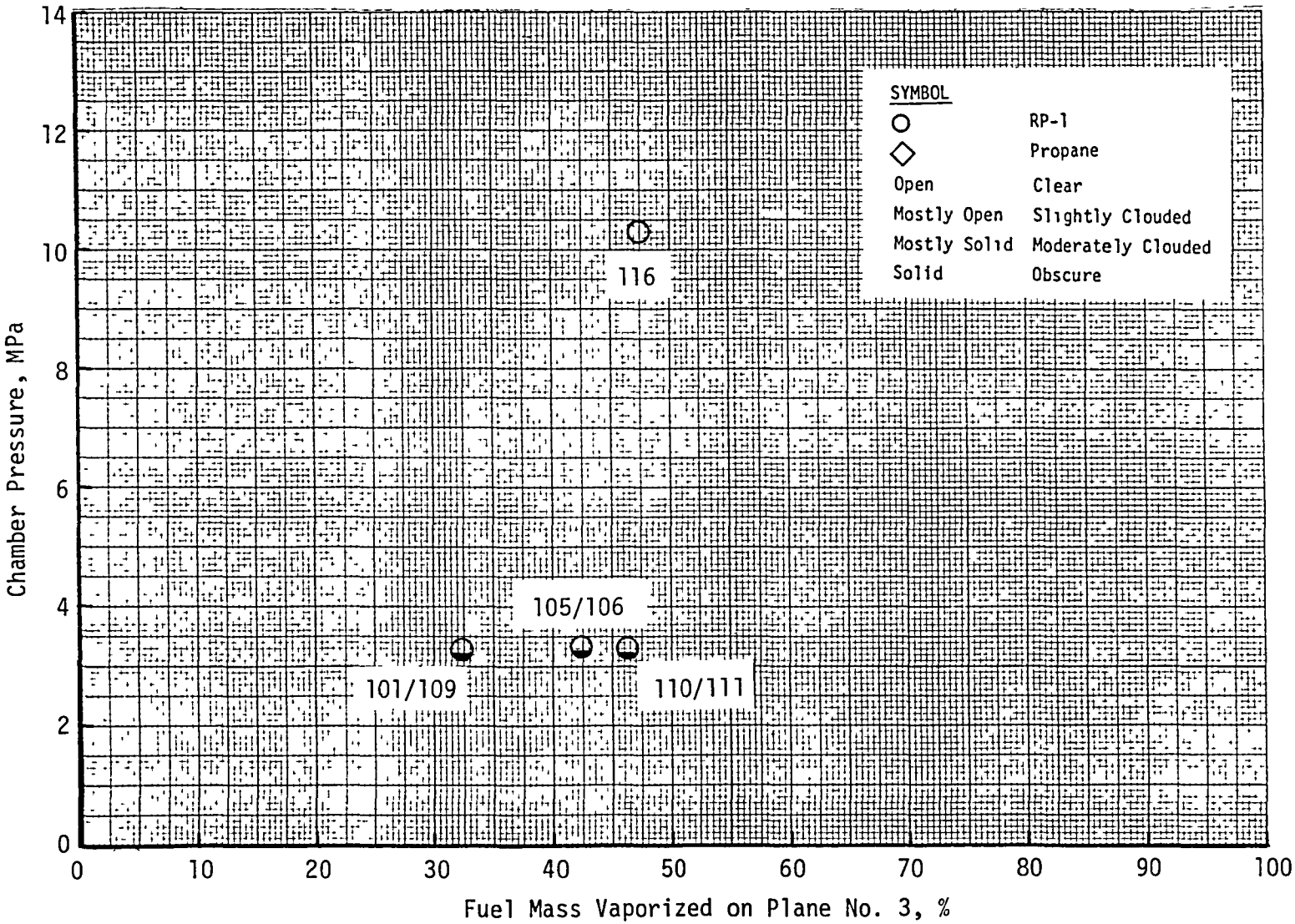


FIGURE 36. OFO TRIPLET CARBON FORMATION CORRELATION WITH CHAMBER PRESSURE AND FUEL VAPORIZATION RATE

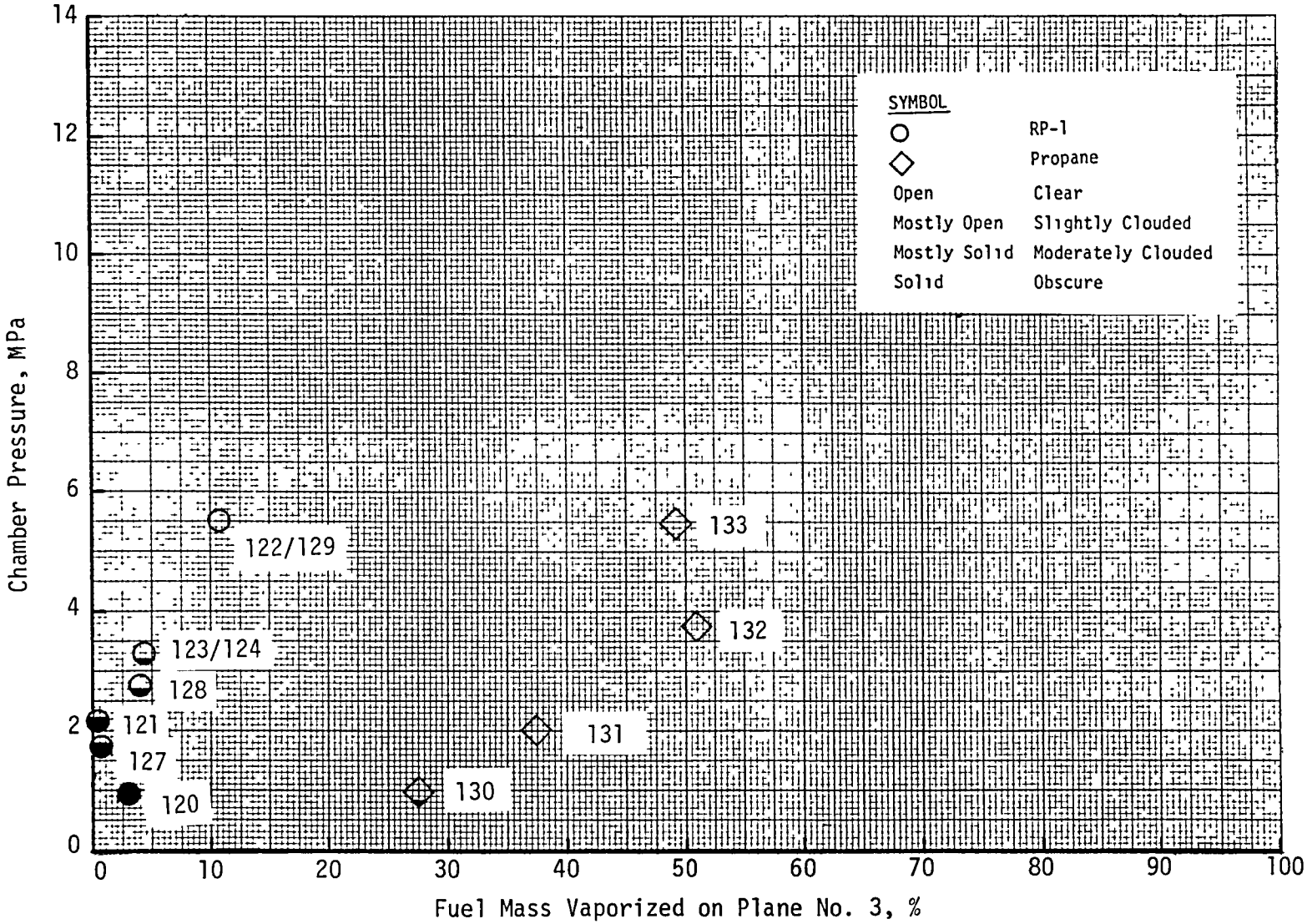


FIGURE 37. TLOL CARBON FORMATION CORRELATION WITH CHAMBER PRESSURE AND FUEL VAPORIZATION RATE

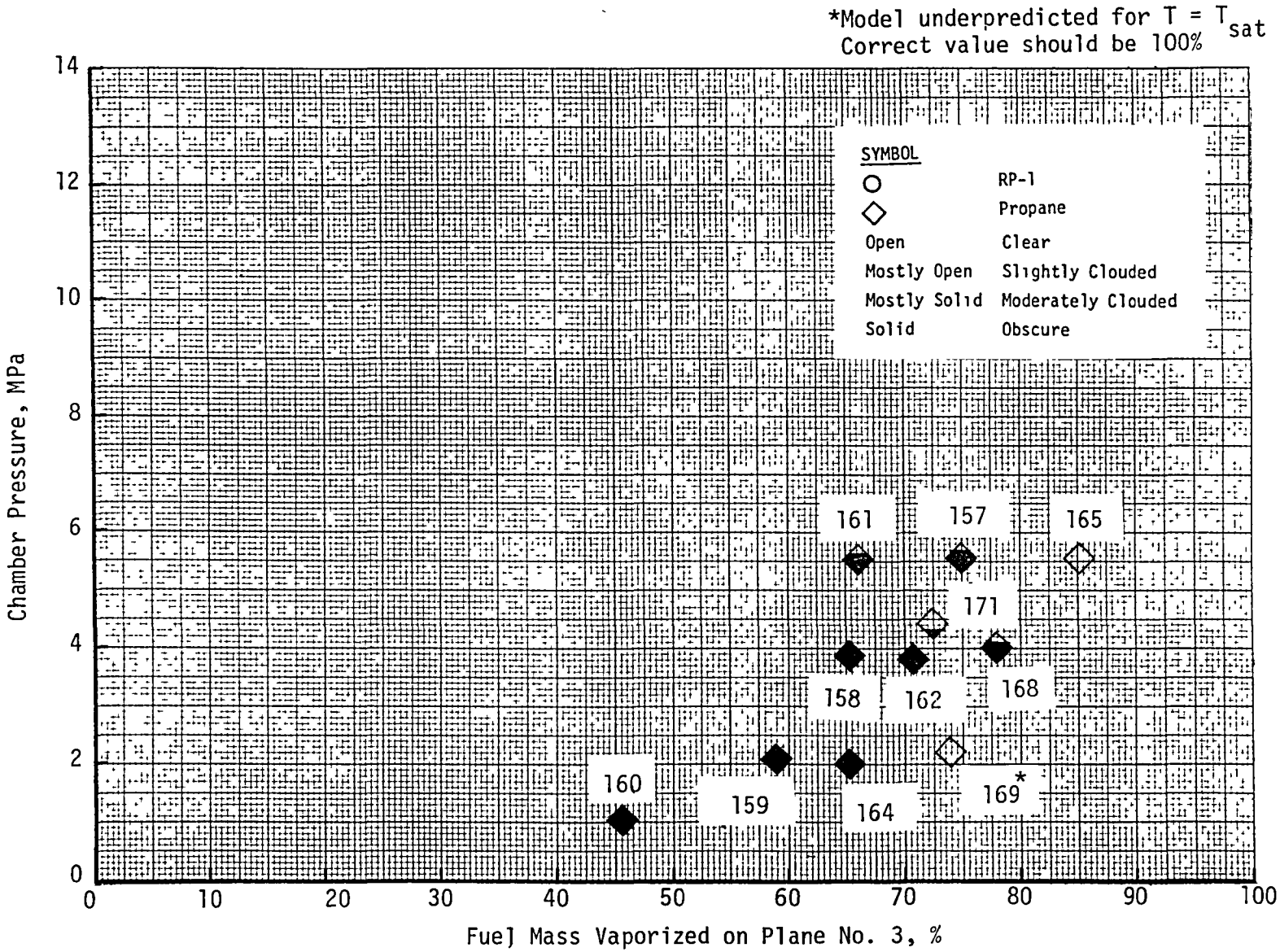


FIGURE 38. EDM-LOL CARBON FORMATION CORRELATION WITH CHAMBER PRESSURE AND FUEL VAPORIZATION RATE

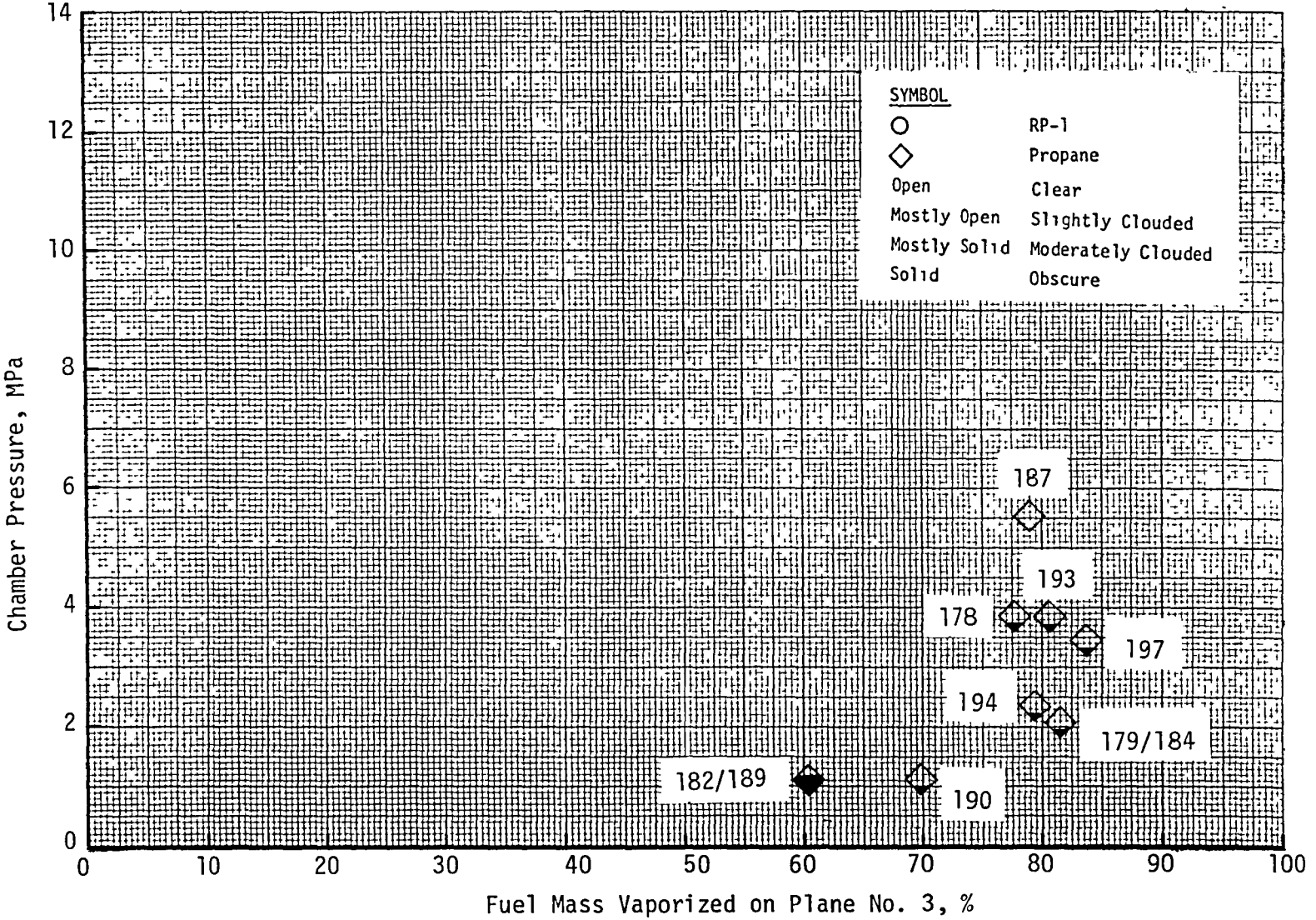


FIGURE 39. PAT CARBON FORMATION CORRELATION WITH CHAMBER PRESSURE AND FUEL VAPORIZATION RATE

plane. The distribution of this liquid mixture ratio across the chamber height is seen to vary significantly from one injector to another.

Figure 40 indicates the existence of a liquid phase fuel rich zone around the chamber center line, which is surrounded by two liquid phase oxidizer rich zones. A typical clear OFO flame is illustrated by Figure 44, which shows a small amount of dark clouds being emanated from and only existing around the center of the flame. Comparison of Figures 40 and 44 induces the direct association of the dark clouds to the unvaporized fuel. As they are migrating transversely through the oxidizer rich zone, the clouds are burned off in the oxidizer rich environment. Hence, it can be expected that the OFO Triplet element generates only a little amount of carbon that is confined at the center of the flame.

Figure 41 shows the predicted poor hot-fire liquid phase mixing for the TLOL injector. Oxidizer-rich zone exists on the oxidizer fan side, while the fuel-rich zone exists on the fuel fan side. A slightly oxidizer-rich zone appear on the back side of the fuel-rich zone but its effect on the overall flame characteristics is negligible because of its small mass fraction as shown in Figure 22. Figure 45 shows that the dark clouds of TLOL flame exists only on the fuel fan side, a liquid phase fuel rich zone.

Unlike the OFO Triplet and TLOL injectors, Figure 42 shows a much more uniform liquid phase mixture ratio distribution across the chamber for the EDM-LOL injector. Figure 46 shows that the dark clouds are emanated from everywhere throughout the entire mixed spray when they occur. This is another evidence of close relation between the carbon formation and the propellant mixing. For the EDM-LOL injector, once a carbon-laden cloud is formed, it will last indefinitely because of the lack of oxidizer-rich zone to burn it off due to the uniform mixing.

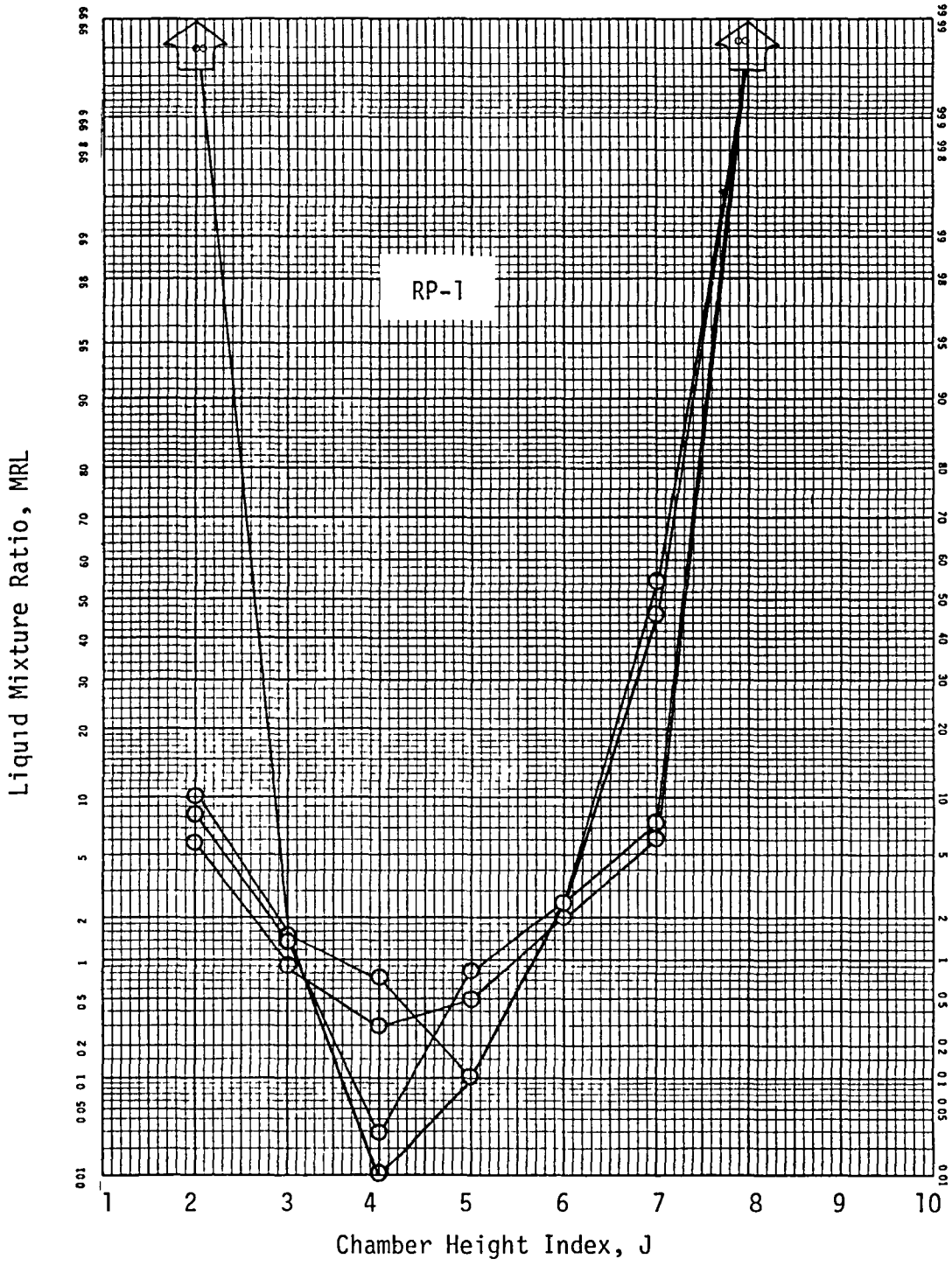


FIGURE 40. OFO TRIPLET LIQUID MIXTURE RATIO DISTRIBUTION ON PLANE NO. 3

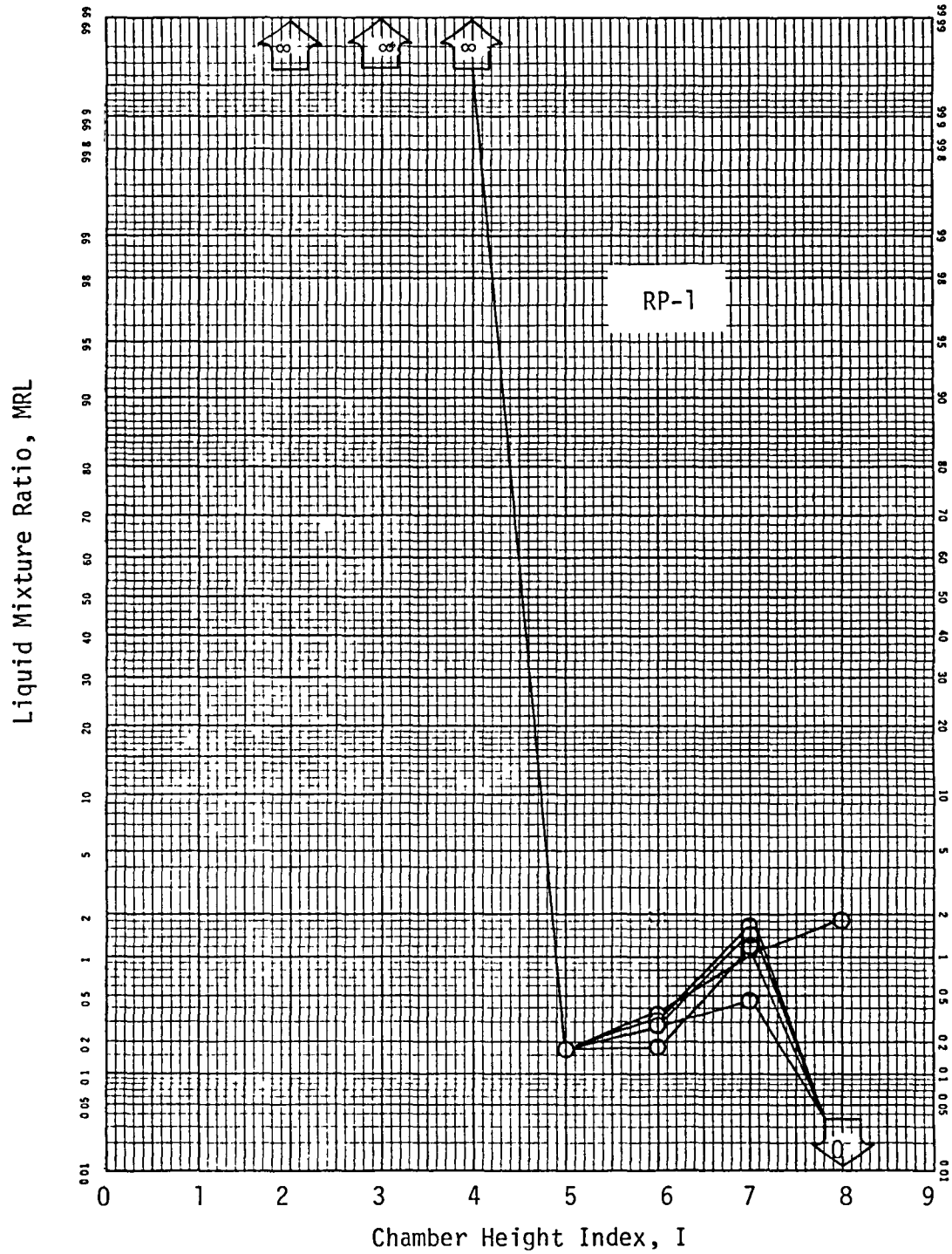


FIGURE 41. TLOL LIQUID MIXTURE RATIO DISTRIBUTION ON PLANE NO. 3 (1/2)

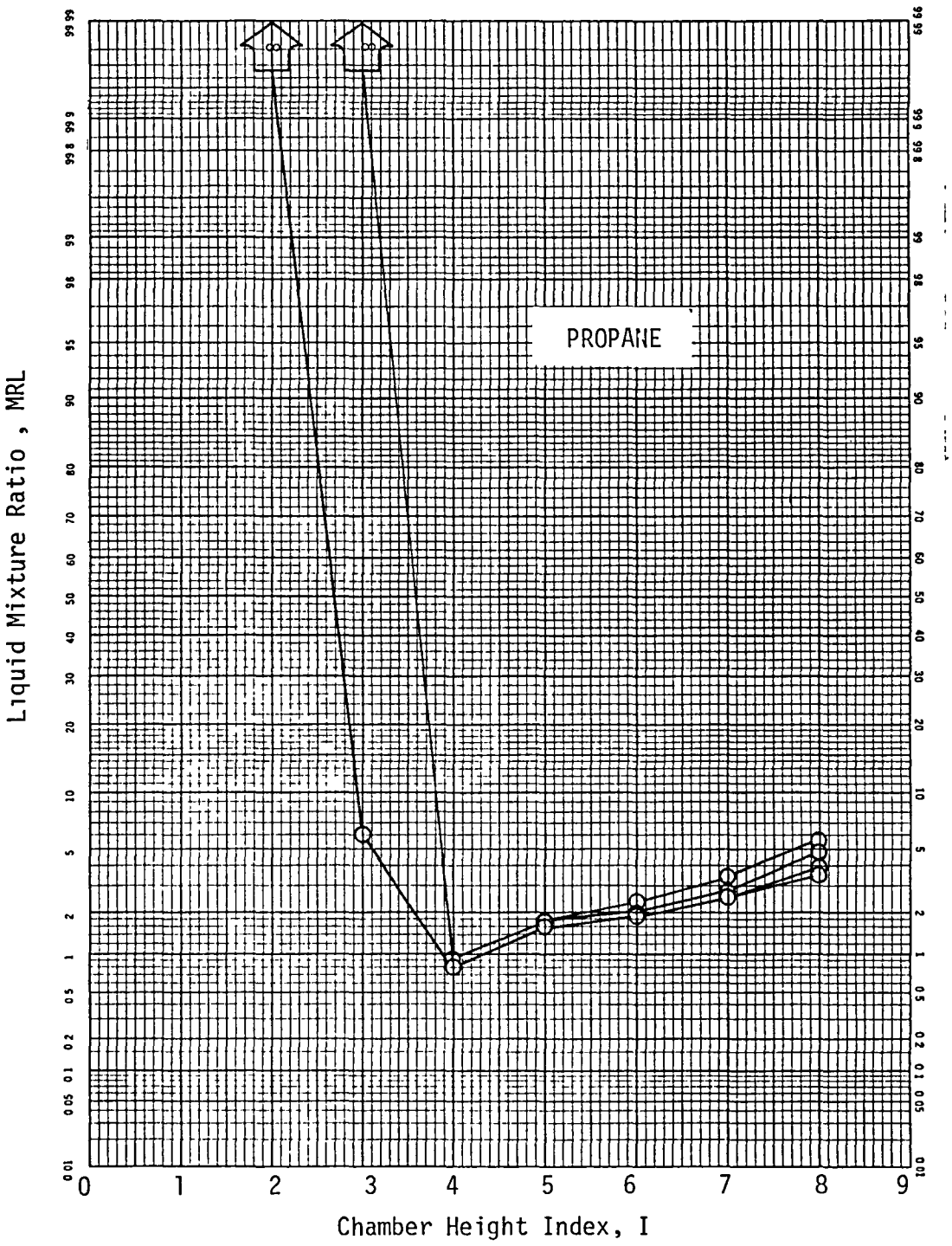


FIGURE 41. TLOL LIQUID MIXTURE RATIO DISTRIBUTION ON PLANE NO. 3 (2/2)

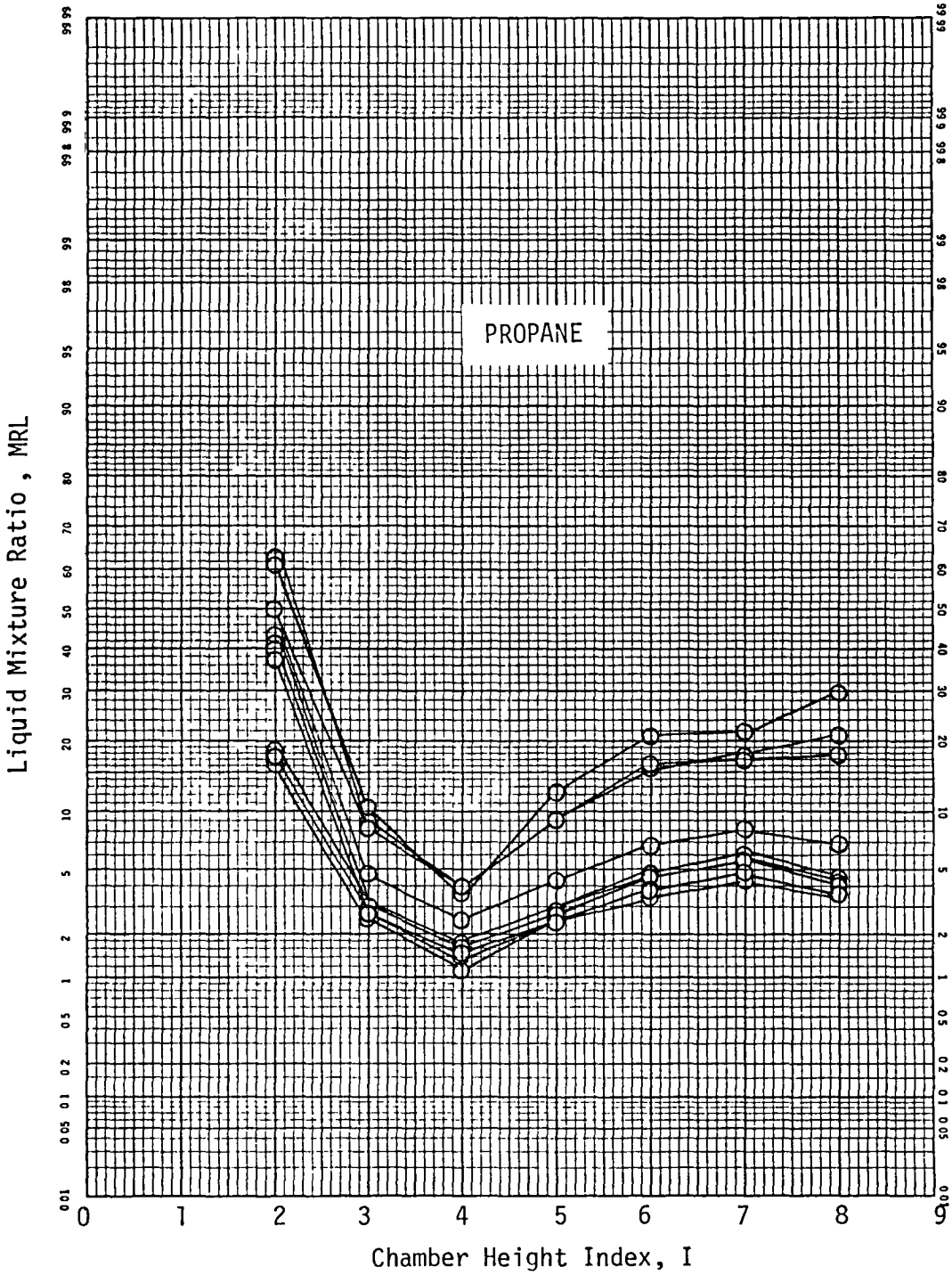


FIGURE 42. EDM-LOL LIQUID MIXTURE RATIO DISTRIBUTION ON PLANE NO. 3

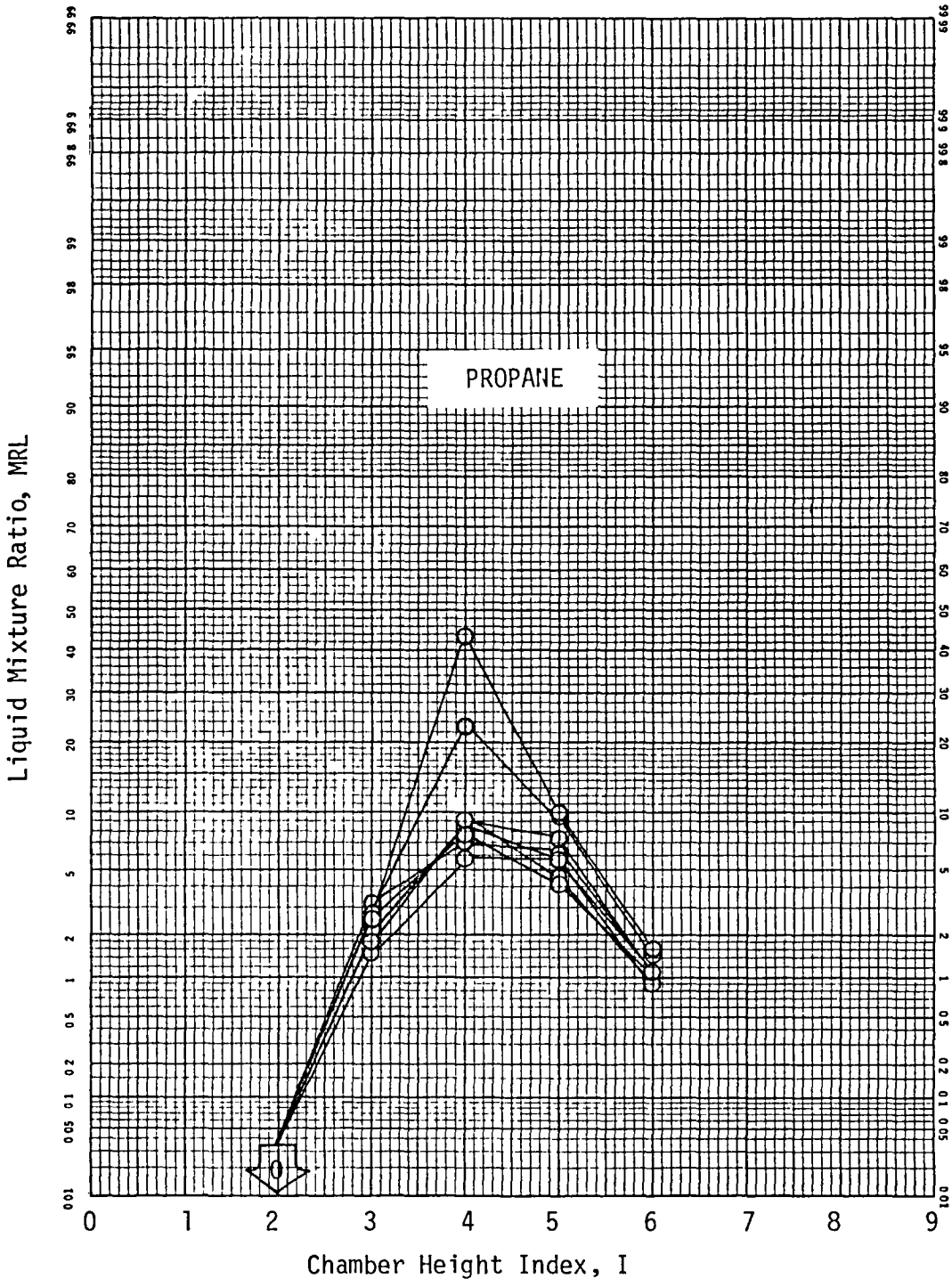


FIGURE 43. PAT LIQUID MIXTURE RATIO DISTRIBUTION ON PLANE NO. 3

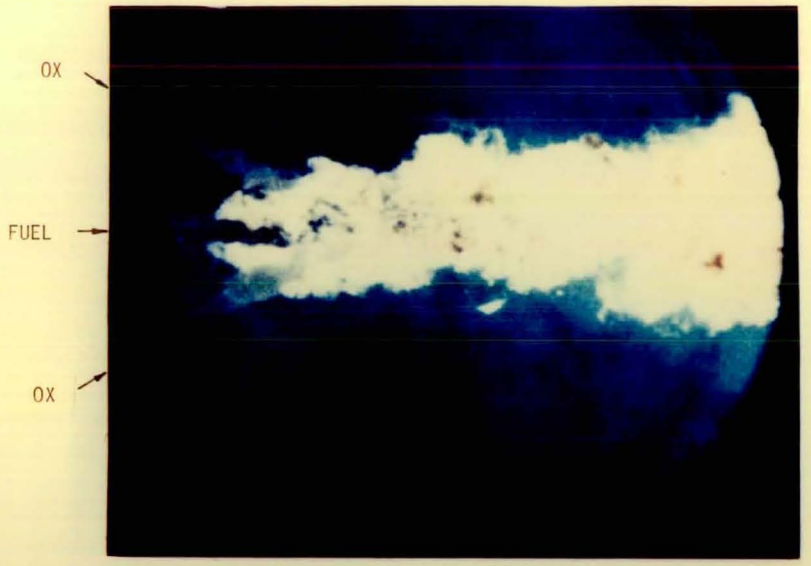


FIGURE 44. HIGH-SPEED PHOTOGRAPH OF OFO TRIPLET CARBON FORMATION PHENOMENA, TEST 116

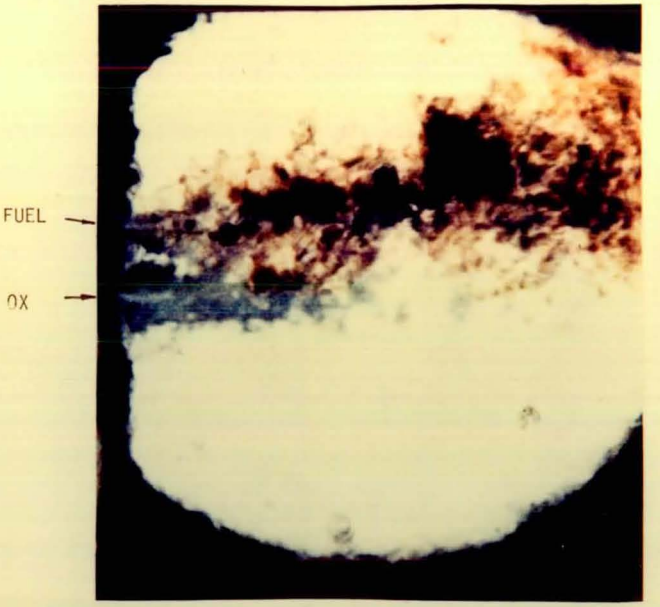


FIGURE 45. HIGH-SPEED PHOTOGRAPH OF TLOL CARBON FORMATION PHENOMENA, TEST 129

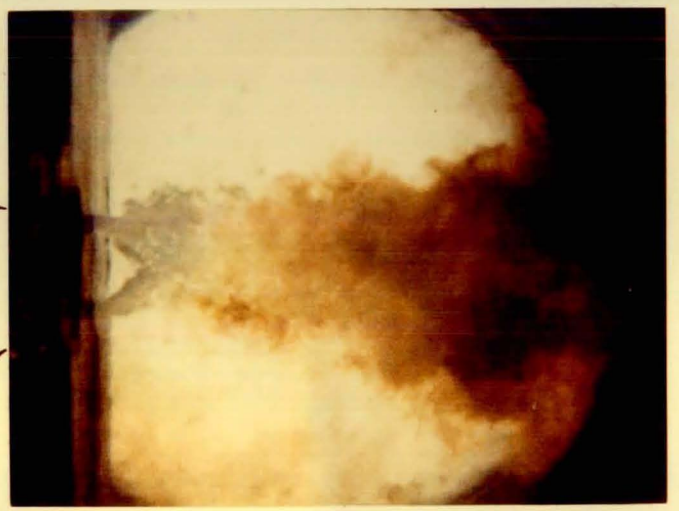


FIGURE 46. HIGH-SPEED PHOTOGRAPH OF EDM-LOL CARBON FORMATION PHENOMENA, TEST 161

FIGURE 47. HIGH-SPEED PHOTOGRAPH OF PAT CARBON FORMATION PHENOMENA, TEST 178

Comparison of Figures 33 and 34 shows that, although it has faster propane vaporization, the EDM-LOL injector produces much more carbon than the TLOL injector. The TLOL injector is a poor mixer for having a long oxidizer-fuel impingement height, therefore, the majority of the unvaporized fuel is hardly exposed to the oxidizer. The EDM-LOL injector, meanwhile, is a good mixer resulting from a much shorter oxidizer-fuel impingement height, therefore, the oxidizer is readily available to the vaporizing fuel. This difference in mixing characteristics appears to be the cause for the difference in carbon formation between these two injectors and it also leads to a conclusion that carbon formation is provoked by the exposure of liquid fuel to the oxidizer in a fuel rich environment. This also explains why the dark clouds do not occur until the fuel meets the oxidizer as shown in Figures 45 and 46.

Figure 43 shows that the unburned propellants are oxidizer-rich at the center of the flame and fuel-rich on both sides for the PAT injector. The poor mixing is due to the long unlike impingement height resulting from small impingement angle. The Splash Plate fuel element produces very fine droplets which evaporate fast. Consequently, by the time the oxidizer and fuel are mixed, there is only a small amount of unvaporized fuel left. Based on the liquid phase carbon formation mechanism, only a little carbon formation can be expected. Figures 35 and 39 uphold this conclusion. Figure 47 shows a typical PAT flame.

VII CONCLUSIONS AND RECOMMENDATIONS

A. Conclusions

Correlation of cold flow mixing data and calculated local fuel vaporization rates with photographic carbon formation data has led to the following conclusion in regard to the injector-related issues of carbon formation.

1. For all four injectors and two fuels, the carbon formation was reduced or increased when the fuel vaporization rate was increased or decreased.

2. For the TLOL injector, RP-1 formed much more carbon than propane due to the slower RP-1 vaporization rate.

3. The carbon formation originates from the areas predicted to be fuel-rich in liquid phase.

4. At a given fuel vaporization rate, early and uniform unlike mixing is conducive to carbon formation as evidenced by the EDM-LOL data.

5. The above correlation results lead to a conclusion that the carbon is formed by the liquid fuel as it is vaporizing in an oxidizer-lean environment.

6. Based on the liquid fuel carbon formation mechanism, the following injector design criteria are provided for controlling the carbon formation to meet engine design and operation requirements:

o Carbon formation can be increased or decreased by decreasing or increasing the fuel vaporization rate, whose primary controlling design parameters are injection orifice size, impingement angle, fuel temperature, and chamber pressure. High vaporization rate can result from small injection orifice, large impingement angle, high fuel temperature and high chamber pressure.

o For the slow vaporization injection elements,delaying the unlike mixing reduces carbon formation.

o Besides its effect on the vaporization rate, chamber pressure has an additional influence on carbon formation. High chamber pressure reduces carbon formation.

B. Recommendations

The following recommendations are made for future studies as a logical extension to the present work.

1. The cold-flow testing and vaporization analysis of the present study were conducted only at one mixture (or momentum) ratio for each injector. For a given injector design, the propellant mixing is strongly affected by the momentum ratio. Since the propellant mixing was found to be very influential on carbon formation, further cold-flow testing and vaporization analysis should be pursued to analytically evaluate the mixture ratio effect on carbon formation.

2. The present study was limited to uni-element injectors, which inherently possess large amount of hot gases recirculating in the combustion chamber. In order to have closer simulation of full scale engine combustion environment, further investigations using multi-element injectors are recommended.

3. The vaporization analysis of the present study included the effect of propellant mixing characteristics. This approach of integrating the mixing data into the propellant vaporization analysis was found to be practical in usage and realistic in modeling; yet, the computation was simple and straight forward. An engine combustion performance model can be readily developed using the present model as a frame work. Such a model is useful and convenient for engine design or data analysis.

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APPENDICES

A. HOT-FIRE DATA SUMMARY

FUEL TYPE	TEST NO.	INJECTOR TYPE	PC (PSIA)	MR	TF (F)	REYN	WT (LB)	CSTRE (SEC)	VF (FT/S)	MODE
RP-1	101	-F-O TRIPLET	460.	[illegible]	50.	10100.	.093	4850.	190.	SLICOK
RP-1	102	-F-O TRIPLET	0.	.00	0.	0.	.000	0.	0.	UNDEF
RP-1	103	-F-O TRIPLET	0.	.00	0.	0.	.000	0.	0.	UNDEF
RP-1	104	-F-O TRIPLET	462.	2.30	50.	11343.	.101	4250.	127.	UNDEF
RP-1	105	-F-O TRIPLET	480.	2.40	50.	10321.	.100	4600.	116.	SLICOK
RP-1	106	-F-O TRIPLET	485.	2.75	50.	10053.	.099	4650.	116.	SLICOK
RP-1	107	-F-O TRIPLET	870.	2.60	70.	20636.	.160	0.	200.	CLEAR
RP-1	108	-F-O TRIPLET	450.	1.70	70.	8039.	.047	4000.	76.	SLICOK
RP-1	109	-F-O TRIPLET	475.	2.40	55.	9382.	.053	4650.	89.	SLICOK
RP-1	110	-F-O TRIPLET	420.	2.70	67.	16826.	.137	4750.	165.	SLICOK
RP-1	111	-F-O TRIPLET	480.	2.70	67.	16826.	.137	4750.	165.	SLICOK
RP-1	112	-F-O TRIPLET	900.	2.60	72.	13840.	.097	0.	120.	CLEAR
RP-1	113	-F-O TRIPLET	0.	.00	0.	0.	.000	0.	0.	UNDEF
RP-1	114	-F-O TRIPLET	970.	2.75	66.	10315.	.075	4000.	100.	CLEAR
RP-1	115	-F-O TRIPLET	0.	.00	0.	0.	.000	0.	0.	UNDEF
RP-1	116	-F-O TRIPLET	1500.	2.50	50.	8470.	.082	4600.	100.	CLEAR
RP-1	117	R UNLIK DOUBLET	130.	2.60	15.	2498.	.000	0.	57.	OBSCUR
RP-1	118	R UNLIK DOUBLET	0.	.00	0.	0.	.000	0.	0.	UNDEF
RP-1	119	TRANSVERSE LOL	0.	.00	0.	0.	.000	0.	0.	UNDEF
RP-1	120	TRANSVERSE LOL	135.	2.35	41.	3815.	.062	4300.	58.	OBSCUR
RP-1	121	TRANSVERSE LOL	310.	2.30	38.	3140.	.064	5360.	53.	MODCOK
RP-1	122	TRANSVERSE LOL	780.	2.75	44.	6014.	.113	4750.	95.	CLEAR
RP-1	123	TRANSVERSE LOL	475.	2.65	35.	4705.	.095	4450.	82.	SLICOK
RP-1	124	TRANSVERSE LOL	475.	2.65	34.	4797.	.095	4450.	83.	SLICOK
RP-1	125	TRANSVERSE LOL	472.	2.65	33.	4776.	.094	4450.	83.	SLICOK
RP-1	126	TRANSVERSE LOL	140.	2.10	30.	2533.	.052	4000.	49.	OBSCUR
RP-1	127	TRANSVERSE LOL	250.	2.65	30.	2495.	.058	4800.	48.	MODCOK
RP-1	128	TRANSVERSE LOL	400.	3.10	39.	3426.	.077	4900.	63.	SLICOK
RP-1	129	TRANSVERSE LOL	800.	2.90	45.	5985.	.110	5100.	90.	CLEAR
C3H8	130	TRANSVERSE LOL	135.	2.50	45.	41607.	.044	4000.	63.	SLICOK
C3H8	131	TRANSVERSE LOL	290.	2.65	43.	49666.	.057	4500.	76.	CLEAR
C3H8	132	TRANSVERSE LOL	540.	3.00	43.	64458.	.079	4600.	98.	CLEAR
C3H8	133	TRANSVERSE LOL	790.	2.50	45.	78710.	.094	4650.	120.	CLEAR
C3H8	134	R UNLIK DOUBLET	0.	.00	0.	0.	.000	0.	0.	UNDEF
C3H8	135	R UNLIK DOUBLET	770.	2.60	68.	137923.	.095	4600.	166.	MODCOK
C3H8	136	R UNLIK DOUBLET	780.	2.75	58.	121770.	.095	4600.	158.	MODCOK
C3H8	137	R UNLIK DOUBLE	790.	2.70	54.	55464.	.042	4600.	73.	MODCOK
C3H8	138	R UNLIK DOUBLE	0.	.00	0.	0.	.000	0.	0.	UNDEF
C3H8	139	R UNLIK DOUBLE	540.	2.40	54.	45993.	.081	4600.	128.	MODCOK
C3H8	140	R UNLIK DOUBLE	290.	2.70	54.	74006.	.063	4150.	98.	OBSCUR
C3H8	141	R UNLIK DOUBLET	150.	2.15	52.	47125.	.043	4000.	63.	OBSCUR
C3H8	142	RUD - GAS GEN	0.	.00	0.	0.	.000	0.	0.	UNDEF
C3H8	143	RUD - GAS GEN	860.	.50	61.	128737.	.058	2900.	110.	OBSCUR
C3H8	144	RUD - GAS GEN	850.	.46	59.	133986.	.059	2850.	116.	OBSCUR
NH3	145	UNLIKE-DOUBLET	505.	1.48	65.	164142.	.117	4850.	112.	CLEAR
NH3	146	UNLIKE-DOUBLET	0.	.00	0.	0.	.000	0.	0.	UNDEF
NH3	147	UNLIKE-DOUBLET	245.	1.35	45.	129509.	.095	4650.	92.	CLEAR
NH3	148	UNLIKE-DOUBLET	350.	1.50	45.	126174.	.100	4850.	92.	CLEAR
NH3	149	UNLIKE-DOUBLET	490.	1.35	63.	145380.	.099	4750.	100.	CLEAR
NH3	150	UNLIKE-DOUBLET	250.	1.38	57.	133739.	.095	4650.	94.	CLEAR
NH3	151	UNLIKE-DOUBLET	150.	1.35	48.	137729.	.100	3900.	100.	CLEAR
NH3	152	UNLIKE-DOUBLET	505.	1.10	54.	161571.	.102	4650.	115.	CLEAR
NH3	153	UNLIKE-DOUBLET	505.	1.67	56.	154827.	.128	5100.	109.	CLEAR
NH3	154	UNLIKE-DOUBLET	505.	1.64	58.	157936.	.127	5100.	111.	CLEAR
NH3	155	UNLIKE-DOUBLET	485.	1.36	61.	105697.	.073	4500.	73.	CLEAR
NH3	156	UNLIKE-DOUBLET	500.	1.40	59.	215544.	.155	4950.	150.	CLEAR
C3H8	157	LOL - EDM	800.	2.80	47.	89923.	.106	5150.	130.	MODCOK
C3H8	158	LOL - EDM	500.	2.85	29.	65659.	.090	5000.	100.	OBSCUR
C3H8	159	LOL - EDM	295.	2.90	39.	56494.	.072	4500.	84.	OBSCUR
C3H8	160	LOL - EDM	150.	2.80	30.	39452.	.050	4100.	60.	OBSCUR
C3H8	161	LOL - EDM	800.	2.90	60.	97117.	.107	5100.	132.	MODCOK
C3H8	162	LOL - EDM	550.	2.95	61.	78565.	.088	4900.	106.	OBSCUR
C3H8	163	LOL - EDM	295.	3.25	64.	61592.	.074	4300.	81.	OBSCUR
C3H8	164	LOL - EDM	290.	2.90	80.	78058.	.075	4350.	91.	OBSCUR
C3H8	165	LOL - EDM	800.	2.85	147.	208855.	.097	4600.	144.	CLEAR
C3H8	166	LOL - EDM	0.	.00	0.	0.	.000	0.	0.	UNDEF
C3H8	167	LOL - EDM	0.	.00	0.	0.	.000	0.	0.	UNDEF
C3H8	168	LOL - EDM	550.	2.90	155.	157079.	.092	4600.	120.	MODCOK
C3H8	169	LOL - EDM	320.	3.10	158.	154762.	.088	3400.	117.	CLEAR
C3H8	170	LOL - EDM	0.	.00	0.	0.	.000	0.	0.	UNDEF
C3H8	171	LOL - EDM	640.	2.80	124.	104571.	.059	4900.	71.	SLICOK
C3H8	172	LOL - EDM	610.	2.95	130.	250770.	.123	4350.	165.	MODCOK
C3H8	173	LOL - EDM	640.	2.20	60.	8777.	.083	4300.	119.	OBSCUR
C3H8	174	LOL - EDM	625.	4.00	76.	83321.	.100	4250.	97.	SLICOK
C3H8	175	LOL - EDM	545.	4.10	79.	73611.	.090	4150.	85.	MODCOK
C3H8	176A	LOL - EDM	150.	2.90	75.	47110.	.047	4100.	56.	OBSCUR
C3H8	176B	LOL - EDM	108.	2.90	72.	75477.	.000	2000.	91.	CLEAR
C3H8	177	PRE ATOM TRIP	805.	2.75	70.	104118.	.086	5100.	155.	CLEAR
C3H8	178	PRE ATOM TRIP	560.	2.75	70.	87702.	.070	5400.	130.	SLICOK
C3H8	179	PRE ATOM TRIP	300.	2.85	66.	64553.	.055	4750.	99.	SLICOK

FUEL TYPE	TEST NO.	INJECTOR TYPE	PC (PSIA)	MR	TF (F)	REYN	WT (LB)	CSTRE (SEC)	VF (FT/S)	MODE
C3H8	180	PRE ATOM TRIP	0.	.00	0.	0.	.000	0.	0.	UNDEF
C3H8	181	PRE ATOM TRIP	0.	.00	0.	0.	.000	0.	0.	UNDEF
C3H8	182	PRE ATOM TRIP	150.	2.90	65.	44283.	.038	4400.	69.	MODCOK
C3H8	183	PRE ATOM TRIP	0.	.00	0.	0.	.000	0.	0.	UNDEF
C3H8	184	PRE ATOM TRIP	300.	2.85	66.	64553.	.055	4750.	99.	SLICOK
C3H8	185	PRE ATOM TRIP	665.	2.20	72.	122300.	.083	5400.	178.	SLICOK
C3H8	186	PRE ATOM TRIP	670.	3.50	69.	70033.	.073	5250.	105.	SLICOK
C3H8	187	PRE ATOM TRIP	800.	2.90	66.	60800.	.055	4600.	93.	CLEAR
C3H8	188	PRE ATOM TRIP	540.	3.20	64.	64092.	.060	5000.	100.	SLICOK
C3H8	189	PRE ATOM TRIP	155.	2.80	62.	58165.	.050	4700.	91.	MODCOK
C3H8	190	PRE ATOM TRIP	165.	2.75	63.	89331.	.078	4750.	140.	SLICOK
C3H8	191	PRE ATOM TRIP	700.	.00	110.	0.	.000	0.	0.	UNDEF
C3H8	192	PRE ATOM TRIP	0.	.00	0.	0.	.000	0.	0.	UNDEF
C3H8	193	PRE ATOM TRIP	560.	2.80	120.	170305.	.074	5150.	142.	SLICOK
C3H8	194	PRE ATOM TRIP	340.	3.00	115.	143277.	.068	4450.	122.	SLICOK
C3H8	195	PRE ATOM TRIP	670.	2.85	66.	95525.	.084	5400.	146.	SLICOK
C3H8	196	PRE ATOM TRIP	630.	3.20	66.	50112.	.051	4000.	78.	SLICOK
C3H8	197	PRE ATOM TRIP	505.	3.00	43.	68435.	.074	4700.	120.	SLICOK
C3H8	198	LOL-EDM GAS GE	810.	.72	79.	137519.	.079	3250.	113.	OBSCUR
C3H8	199	LOL-EDM GAS GE	510.	.73	75.	103371.	.063	3100.	88.	OBSCUR
GCH4	200	SLIT TRIPLET	770.	3.30	67.	269842.	.101	5150.	271.	CLEAR
GCH4	201	SLIT TRIPLET	760.	3.60	67.	277992.	.101	5100.	279.	CLEAR
GCH4	202	SLIT TRIPLET	540.	4.20	70.	173026.	.070	4300.	248.	CLEAR
GCH4	203	SLIT TRIPLET	535.	3.50	71.	211659.	.075	4000.	308.	CLEAR
GCH4	204	SLIT TRIPLET	290.	3.70	72.	136406.	.050	3200.	363.	CLEAR
GCH4	205	SLIT TRIPLET	125.	4.70	73.	103524.	.043	2200.	622.	CLEAR
GCH4	206	SLIT TRIPLET	630.	3.60	55.	283078.	.101	3500.	325.	CLEAR
GCH4	207	SLIT TRIPLET	620.	3.00	54.	345763.	.105	3300.	405.	CLEAR
GCH4	208	SLIT TRIPLET	0.	.00	0.	0.	.000	0.	0.	UNDEF
GCH4	209	SLIT TRIPLET	700.	4.00	56.	267785.	.105	5250.	279.	CLEAR
GCH4	210	SLIT TRIPLET	0.	.00	0.	0.	.000	0.	0.	UNDEF
GCH4	211	SLIT TRIPLET	0.	.00	0.	0.	.000	0.	0.	UNDEF
GCH4	212	SLIT TRIPLET	690.	3.35	50.	454803.	.150	5200.	471.	CLEAR
GCH4	213	SLIT TRIPLET	685.	2.80	45.	211966.	.060	4650.	216.	CLEAR
GCH4	214	SLIT TRIPLET	310.	3.45	44.	160539.	.051	4150.	363.	CLEAR
GCH4	215	SLIT TRIPLET	125.	4.50	40.	131234.	.050	2450.	707.	CLEAR
GCH4	216	SLIT TRIPLET	790.	2.75	38.	306921.	.087	5100.	260.	CLEAR
GCH4	217	SLIT TRIPLET	405.	4.70	38.	132693.	.054	4500.	225.	CLEAR
GCH4	218	SLIT TRIPLET	405.	2.75	38.	150993.	.041	4000.	257.	CLEAR
GCH4	219	SLIT TRIPLET	790.	3.20	40.	215515.	.067	4900.	183.	CLEAR
GCH4	220	SLIT TRIPLET	450.	3.00	40.	303088.	.088	4900.	468.	CLEAR
GCH4	221	SLIT TRIPLET	410.	4.00	46.	101752.	.036	4400.	174.	CLEAR
LCH4	222	LOL-EDM GAS GE	805.	.82	-220.	189924.	.082	3050.	140.	CLEAR
LCH4	223	LOL-EDM GAS GE	775.	.61	-230.	194587.	.084	2900.	157.	CLEAR
LCH4	224	LOL-EDM GAS GE	805.	.50	-206.	210361.	.068	2875.	146.	CLEAR
LCH4	225	LOL-EDM GAS GE	515.	.78	-226.	145129.	.066	3200.	113.	CLEAR
LCH4	226	LOL-EDM GAS GE	495.	.60	-245.	132636.	.066	2900.	120.	CLEAR
LCH4	227	LOL-EDM GAS GE	485.	.44	-211.	212882.	.070	2700.	150.	CLEAR

B. INJECTOR COLD-FLOW DATA SUMMARY

Injector: OFO TRIPLET

Axial Distance: 1.27 cm (0.5")

I =	J = 1	2	3	4	5	6	7	8	9	10
0										
1										
2										
3										
4					22.232 .1159 .0132	.879 .2567 .7417	2.269 .0017 .0019			
5					5.823 .0036 .0016	6.528 .6128 .2384	7.411 .0093 .0032			
6										
7										
8										
9										

○ Oxidizer Hole Projection
◇ Fuel Hole Projection

Injector: OFO TRIPLET

Axial Distance: 2.54 cm (1")

I = 0	J = 1	2	3	4	5	6	7	8	9	10
0										
1										
2										
3					0.993 .0023 .0052	0.654 .0013 .0047				
4			∞ .0338 0	18.527 .0646 .0083	2.129 .0582 .0647	.660 .1477 .5304	1.588 .0111 .0165			
5					5.293 .0092 .0041	1.915 .1393 .2342	5.898 .2401 .0964	56.374 .0656 .0028	7.622 .0044 .0014	0 0 .0019
6					5.558 .0065 .0028	9.755 .0397 .0096	13.498 .0785 .0138	32.554 .0379 .0028	∞ .0040	
7						5.293 .0009 .0004				
8										
9										

○ Oxidizer Hole Projection
◇ Fuel Hole Projection

Injector: OFO Triplet

Axial Distance: 3.31 cm (1.5")

I =	J = 1	2	3	4	5	6	7	8	9	10
0										
1										
2										
3	.0496 .0005 .0022	1.401 .0076 .0023	1.501 .0059 .0076	.794 .0066 .0163	.397 .0020 .0093		0 0 .0110			
4	24.879 .0516 .0041	2.779 .0308 .0218	.611 .0220 .0708	.555 .0934 .3268	.858 .0439 .1008	.882 .0110 .0245				
5	.794 .0015 .0038	.397 .0009 .0044	6.511 .0036 .0056	1.168 .0275 .0463	16.939 .0035 .0004	2.259 .0934 .0817	9.528 .0198 .0041	13.498 .0019 .0003		
6	.079 .0001 .0027	.794 .0010 .0025	.1687 .0093 .0109	2.321 .0417 .0354	4.889 .1285 .0517	6.443 .1560 .0477	28.584 .0989 .0068	30.988 .0280 .0007	∞ .0060 0	
7	.041 .0001 .0053	.937 .0022 .0046	.274 .0055 .0395	2.522 .0148 .0116	7.146 .0297 .0082	9.846 .0341 .0068	25.408 .0176 .0014	∞ .0049		
8		0 0 .0027	0 0 .0116	0 0 .0014						
9										

○ Oxidizer Hole Projection
◇ Fuel Hole Projection

Injector: EDM-LOL

Axial Distance: 1.27 cm (0.5")

I = 0 \ J =	1	2	3	4	5	6	7	8	9	10
0										
1										
2		0 0 .0060	0 0 .0011	1.059 .0012 .0024	7.940 .0083 .0023	1.444 .0083 .0125	.934 .0009 .0018			
3				.794 .0027 .0068	8.951 .055 .013	43.67 .049 .0023	1.286 .0015 .0024			
4				.635 .0035 .011	2.257 .239 ○ .215	1.720 .230 ○ .272	.681 .0027 .0079			
5			0 0 .0023	.977 .0071 .015	2.000 .150 ◇ .153	1.701 .199 ◇ .238	1.290 .0115 .018	0 0 .0011		
6				2.647 .0044 .0034	3.363 .0032 .0019	4.764 .0053 .0023	4.129 .0115 .0057			
7				8.999 .0015 .0003			5.955 .0027 .0009			
8							1.588 .0009 .0011			
9										

○ Oxidizer Hole Projection
◇ Fuel Hole Projection

Injector: EDM-LOL

Axial Distance: 2.54 cm (1")

I =	J = 1	2	3	4	5	6	7	8	9	10
0				4.764 .0025 .0010	3.970 .0038 .0017	3.289 .0024 .0014	.471 .0007 .0026		0 0 .0021	
1			.794 .0017 .0039	9.210 .0073 .0015	20.64 .0109 .0010	6.352 .0067 .0019	1.412 .0013 .0017			
2		0 0 .0024	.577 .0034 .0058	5.717 .015 .0049	98.46 .026 .0005	12.175 .0097 .0015	1.036 .0013 .0022			
3		0 0 .0026	.681 .0050 .0136	2.382 .038 .029	6.268 .063 .018	1.720 .022 .023	.353 .0017 .0087	0 0 .0010		
4	0 0 .0015	0 0 .0041	.669 .0067 .0184	1.588 .084 .097	1.405 .1930 ○ .252	1.006 .080 ○ .146	.489 .0067 .0252	.294 .0004 .0026		
5		.326 .0007 .0038	1.290 .0109 .0155	2.779 .0381 .058	2.117 .118 .073 ◇	2.498 .099 .073 ◇	1.450 .018 .022	.467 .0008 .0032		
6		.667 .0008 .0015	3.176 .010 .0058	4.367 .019 .0078	3.176 .0050 .0029	4.058 .019 .0037	3.298 .023 .013	1.966 .0022 .0020		
7		2.647 .0013 .0009	3.176 .0050 .0029	2.269 .0008 .0007		1.588 .0004 .0005	6.352 .010 .0029	2.925 .0029 .0018		
8		1.059 .0005 .0009	2.647 .0013 .0009		0 0 .0015		6.987 .0018 .0005	5.823 .0028 .0009	0 0 .0076	
9			0 0 .0019				1.191 .0010 .0016			

○ Oxidizer Hole Projection
◇ Fuel Hole Projection

Injector: EDM-LOL

Axial Distance: 3.31 cm (1.5")

I = 0 \ J =	1	2	3	4	5	6	7	8	9	10
0		0 0 .0017	.706 .0011 .0027	9.074 .0022 .0004	∞ .0036 0	∞ .0040 0	∞ .0023 0	1.832 .0008 .0008	0 0 .0006	0 0 .0024
1	0 0 .0007	.127 .0002 .0030	.529 .0016 .0055	7.146 .0049 .0012	47.64 .0081 .0003	∞ .0080 0	∞ .0038 0	1.588 .0011 .0012		
2		.155 .0004 .0025	.567 .0027 .0085	2.38 .0081 .0061	47.64 .0162 .0006	41.29 .0140 .0006	5.293 .0054 .0018	.529 .0011 .0036	0 0 .0018	0 0 .0010
3	0 0 .0009	.065 .0001 .0030	.418 .0027 .0097	1.489 .0162 .0195	3.176 .0324 .0182	2.454 .0275 .0201	3.032 .0113 .0067	.441 .0027 .0109	.222 .0001 .0026	0 0 .0009
4	0 0 .0015	.113 .0003 .0040	.681 .0049 .0128	1.344 .030 .040	1.355 .078 .103○	1.023 .078 .137	.728 .030 .073	.418 .0054 .023	.176 .0005 .0055	0 0 .0018
5	0 0 .0018	.218 .0005 .0044	1.191 .0081 .0122	2.077 .046 .040	2.382 .097 .073◇	2.098 .0998 ◇085	1.755 .057 .058	.998 .0119 .021	.289 .0011 .0067	0 0 .0021
6	0 0 .0012	.529 .0008 .0027	2.250 .0092 .0073	3.535 .037 .019	4.764 .041 .015	3.494 .030 .015	3.403 .041 .021	2.235 .021 .016	1.059 .0032 .0055	
7		1.323 .0013 .0018	3.630 .0086 .0043	5.293 .0108 .0036	4.764 .0049 .0018	5.029 .0021 .0007	4.764 .0081 .0030	3.516 .017 .0085	2.911 .0059 .0036	.397 .0003 .0012
8		1.985 .0013 .0012	5.558 .0038 .0012	2.117 .0011 .0009			0 0 .0006	5.558 .0076 .0024	.983 .0070 .0128	.635 .0005 .0015
9		2.117 .0011 .0009	3.000 .0009 .0005					3.970 .0013 .0006	3.705 .0038 .0018	1.588 .0011 .0012

○ Oxidizer Hole Projection
◇ Fuel Hole Projection

Injector: EDM-LOL

Axial Distance: 5.08 cm (2")

I =	J = 1	2	3	4	5	6	7	8	9	10
0	0 0 .0020	.299 .0007 .0040	.681 .0016 .0041	22.23 .0038 .0003	31.76 .0055 .0003	∞ .0055 0	∞ .0033 0	4.963 .0014 .0005	1.254 .0008 .0011	0 0 .0009
1	.079 .0001 .0023	.430 .0013 .0049	1.011 .0038 .0064	6.352 .0065 .0017	26.99 .0093 .0006	25.41 .0087 .0006	14.29 .0049 .0006	1.588 .0022 .0023	.316 .0007 .0022	0 0 .0014
2		.596 .0016 .0052	1.121 .0065 .0099	2.329 .0120 .0087	5.082 .017 .0058	3.441 .014 .0070	1.290 .0071 .0093	.561 .0033 .0099	.265 .0008 .0052	0 0 .0021
3	.176 .0003 .0026	.433 .0016 .0064	1.036 .0082 .0075	1.512 .022 .024	1.475 .035 .041	1.087 .035 .052	.761 .019 .042	.492 .0071 .042	.280 .0016 .0099	.108 .0002 .0034
4	.223 .0004 .0033	.489 .0022 .0075	1.198 .012 .017	1.720 .035 .035	1.664 .060 ○ .061	1.248 .060 .081	1.011 .038 .064	.749 .014 .031	.505 .0038 .013	.190 .0004 .0039
5	.237 .0004 .0027	.983 .0035 .0061	1.985 .016 .014	2.495 .042 .028	2.729 .060 .037 ◇	2.382 .057 .041	1.896 .044 .039	1.152 .020 .024	.970 .0060 .0104	.454 .0011 .0041
6	.741 .0008 .0017	1.390 .0038 .0046	2.779 .015 .0093	3.557 .031 .0145	3.590 .028 .013	3.427 .022 .011	3.176 .025 .013	2.529 .023 .016	1.800 .0093 .0087	.907 .0022 .0041
7	1.323 .0011 .0014	2.382 .0043 .0030	7.543 .010 .023	3.772 .010 .0046	4.764 .0065 .0023	4.083 .0039 .0016	3.176 .0055 .0029	3.609 .0136 .0064	2.779 .011 .0070	1.588 .0027 .0029
8	1.429 .0010 .0012	2.558 .0038 .0021	2.226 .0038 .0018	2.802 .0016 .0010	1.588 .0005 .0006		1.815 .0004 .0004	3.348 .0043 .0021	3.630 .0087 .0041	2.779 .0038 .0023
9	1.286 .0009 .0012	3.176 .0015 .0008	2.823 .0009 .0005					1.600 .0004 .0003	4.764 .0043 .0016	3.740 .0040 .0018

○ Oxidizer Hole Projection
◇ Fuel Hole Projection

Injector: PAT

Axial Distance: 1.27 cm (0.5")

I =	J = 1	2	3	4	5	6	7	8	9	10
0										
1										
2										
3					0 0 .044	0 0 ◇.032	0 0 .0009			
4			1.547 .0051 .0073	.027 .0009	3.606 .327 .201	2.084 .141 .150	∞ .022 0	∞ .0042 0	4.764 .0020 .0009	∞ .0020 0
5	∞ .0009 0	∞ .0040 0	∞ .012 0	10830 .046 .0009	1.832 .202 .244	1.755 .141 .178	57.17 .024 .0009	63.52 .0054 .0002	30.17 .0026 .0002	31.76 .0027 .0002
6	∞ .0078 0		∞ .0003 0	∞ .0019 0	.347 .0094 .060	.378 .0067 .039	6.881 .0017 .0006	1.588 .0003 .0004		
7					.983 .0017 .0039	0 0 .0024	0 0 .0004			
8	0 0 .0041									
9										

○ Oxidizer Hole Projection
◇ Fuel Hole Projection

Injector: PAT

Axial Distance: 2.54 cm (1")

I = 0 \ J =	1	2	3	4	5	6	7	8	9	10
0										
1										
2					0 0 .0134	0 0 .0209	0 0 .0078			
3				∞ .0083 0	1.588 .035 .0453	.658 .024 .0744	.722 .0069 .0118	34.14 .0059 .0004	28.58 .0025 .0002	∞ .0003 0
4	∞ .0010 0	27.79 .0048 .0004	∞ .0091 0	14.29 .037 .00	1.926 .204 .0054	12.17 .318 .236	1.516 .087 .161	∞ .021 0	∞ .0083 0	∞ .0021 0
5	19.06 .0017 .0002	∞ .0051 0	∞ .013 0	19.06 .0249 .0027	1.588 .040 .0526	1.642 .084 .107	1.732 .033 .040	150.9 .013 .0002	∞ .0064 0	∞ .0018 0
6		∞ .0007 0	∞ .0011 0	2.117 .0006 .0005	0 0 .0103	0 0 .0290	0 0 .0051	0 0 .0004	0 0 .0011	
7						0 0 .0040				
8										
9										

○ Oxidizer Hole Projection
◇ Fuel Hole Projection

Injector: PAT

Axial Distance: 3.31 cm (1.5")

I =	J = 1	2	3	4	5	6	7	8	9	10
0										
1					0 0 .0044	0 0 .0057				
2				.132 .0004 .0048	.053 .0004 .013	0 0 .0112	0 0 .0022			
3			5.445 .0044 .0015	.889 .026 .024	1.732 .044 .048	.934 .0182 .028	1.157 .078 .013	7.940 .0055 .0013	∞ .0027	∞ .0015
4	∞ .0009 0	∞ .0046 0	16.67 .019 .0022	2.300 .077 .063	1.971 .197 .190	1.906 .164 .164	1.254 .055 .083	10.32 .017 .0031	∞ .0069 0	∞ .0027 0
5	∞ .0036 0	∞ .0098 0	15.88 .018 .0022	2.199 .033 .028	1.974 .084 .081	2.129 .108 .103	1.516 .038 .048	11.998 .012 .0020	∞ .0053 0	∞ .0029 0
6	6.35 .0015 .0004	∞ .0036 0	1.429 .0033 .0004	.855 .0026 .0057	.425 .0055 .019	.433 .0055 .024	.907 .0036 .0077	5.399 .0031 .0011	∞ .0026 0	∞ .0013 0
7					0 0 .0061	0 0 .0066	0 0 .0039			
8										
9										

○ Oxidizer Hole Projection
◇ Fuel Hole Projection

Injector: PAT

Axial Distance: 5.08 cm (2")

I = 0 \ J =	1	2	3	4	5	6	7	8	9	10
0					0 0 .0016	0 0 .0032	0 0 .0012			
1				0 0 .0023	0 0 .0046	0 0 .0056	0 0 .0028			
2			1.475 .0028 .0032	1.207 .0081 .0116	1.134 .0106 .016	.575 .0053 .016	.265 .0013 .0083	.706 .0017 .0042	3.705 .0015 .0007	
3		4.764 .0013 .0005	7.940 .0106 .0023	1.764 .043 .042	1.684 .074 .076	1.390 .060 .051	.866 .0255 .051	1.583 .013 .014	14.29 .0057 .0007	∞ .0021 0
4	∞ .0021 0	∞ .0070 0	15.88 .021 .0023	2.382 .057 .042	1.768 .125 .123	2.779 .149 .093	1.191 .083 .120	2.722 .026 .016	15.88 .0106 .0012	∞ .0034 0
5	∞ .0043 0	∞ .0089 0	9.528 .013 .0023	1.672 .0213 .022	1.629 .043 .045	2.303 .062 .046	1.257 .040 .056	1.710 .015 .015	4.446 .0060 .0023	∞ .0017 0
6	∞ .0021 0	∞ .0028 0	7.940 .0032 .0007	.681 .0026 .0065	.893 .0057 .0111	.864 .0079 .016	.676 .0043 .013	1.038 .0036 .0060	15.88 .0021 .0002	∞ .0015 0
7					0 0 .0042	0 0 .0053	0 0 .0039	0 0 .0016		
8					0 0 .0023	0 0 .0046				
9										

○ Oxidizer Hole Projection

◇ Fuel Hole Projection

Injector: T-LOL

Axial Distance: 1.27 cm (0.5")

I =	J = 1	2	3	4	5	6	7	8	9	10
0										
1										
2			2.647 .0005 .0005	19.85 .0026 .0003	21.17 .0042 .0005	7.94 .0021 .0007				
3				14.93 .0050 .0009	34.94 .023 .0017	25.94 .010 .0010	.529 .0002 .0010			
4				9.528 .0038 .0010	57.17 .190 .0086 ○	25.81 .137 .014 ○	1.588 .0011 .0017			
5				6.352 .0017 .0007	1.380 .237 ◇ .445	2.787 .287 ◇ .266	1.059 .0008 .0021			
6				3.970 .0016 .0010	.440 .019 .112	1.089 .051 .120	6.108 .0053 .0022			
7				1.985 .0011 .0014	1.003 .0025 .0065	1.444 .0042 .0076	8.258 .0055 .0017			
8				∞ .0011 0	1.732 .0013 .0019	15.88 .0021 .0003				
9										

○ Oxidizer Hole Projection
◇ Fuel Hole Projection

Injector: T-LOL

Axial Distance: 2.54 cm (1")

I = 0 \ J =	1	2	3	4	5	6	7	8	9	10
0										
1				∞ .0018 0	∞ .0043 0	∞ .0018 0				
2				∞ .0052 0	∞ .015 0	∞ .0046 0	∞ .0029 0	∞ .0006 0		
3			2.647 .0006 .0005	23.82 .0087 .0008	49.23 .036 .0017	∞ .050 0	25.41 .0092 .0008	1.815 .0009 .0012		
4				7.058 .0046 .0013	6.785 .054 ○ .018	27.79 .162 ○ .013	5.955 .017 .0049	.397 .0002 .0013		
5				5.029 .0044 .0022	1.489 .087 ◇ .132	1.538 .248 ◇ .365	3.298 .031 .021	.318 .0002 .0016		
6				5.558 .0040 .0016	1.509 .044 .066	.962 .096 .225	4.870 .053 .025	2.779 .0024 .0020		
7				2.417 .0040 .0038	1.543 .0080 .0117	.095 .0007 .016	2.671 .021 .018	2.911 .0051 .0039		
8				3.176 .0021 .0015	.496 .0006 .0026	0 0 .0038	1.701 .0035 .0046	4.446 .0049 .0025		
9					0 0 .0008	0 0 .0008	0 0 .0008	0 0 .0008		

○ Oxidizer Hole Projection
◇ Fuel Hole Projection

Injector: T-LOL

Axial Distance: 3.81 cm (1.5")

I =	J = 1	2	3	4	5	6	7	8	9	10
0					4.537 .0023 .0011	20.64 .0015 .0002				
1			3.705 .0008 .0005	31.76 .0023 .0002	∞ .0041 0	∞ .0035 0	∞ .0017 0	2.541 .0009 .0008		
2			11.645 .0026 .0003	21.04 .0062 .0037	∞ .015 0	∞ .017 0	43.67 .0064 .0003	7.940 .0017 .0005		
3			3.705 .0008 .0005	8.999 .0079 .0028	21.84 .032 .0031	177.9 .065 .0008	25.41 .019 .0016	4.764 .0035 .0016		
4			0 0 .0008	2.565 .0049 .0041	3.176 .037 ○ .025	8.293 .109 ○ .028	6.352 .033 .011	2.071 .0035 .0036		
5				2.481 .0058 .0050	1.358 ◇ .062 .097	1.225 ◇ .157 .273	2.762 .046 .036	2.565 .0049 .0041		
6				3.006 .0062 .0044	1.477 .046 .067	.912 .099 .231	3.032 .073 .052	3.550 .0088 .0053	.397 .0002 .0012	
7				1.951 .0050 .0055	1.732 .014 .017	.424 .0046 .023	2.541 .037 .031	2.722 .014 .011	1.588 .0016 .0022	
8				1.985 .0035 .0037	.934 .0023 .0050	0 0 .0055	1.511 .0045 .0064	3.176 .012 .0078	2.382 .0028 .0025	
9				2.117 .0023 .0023	0 0 .0022	0 0 .0031	0 0 .0028	3.176 .0046 .0031	3.176 .0023 .0016	

○ Oxidizer Hole Projection

◇ Fuel Hole Projection

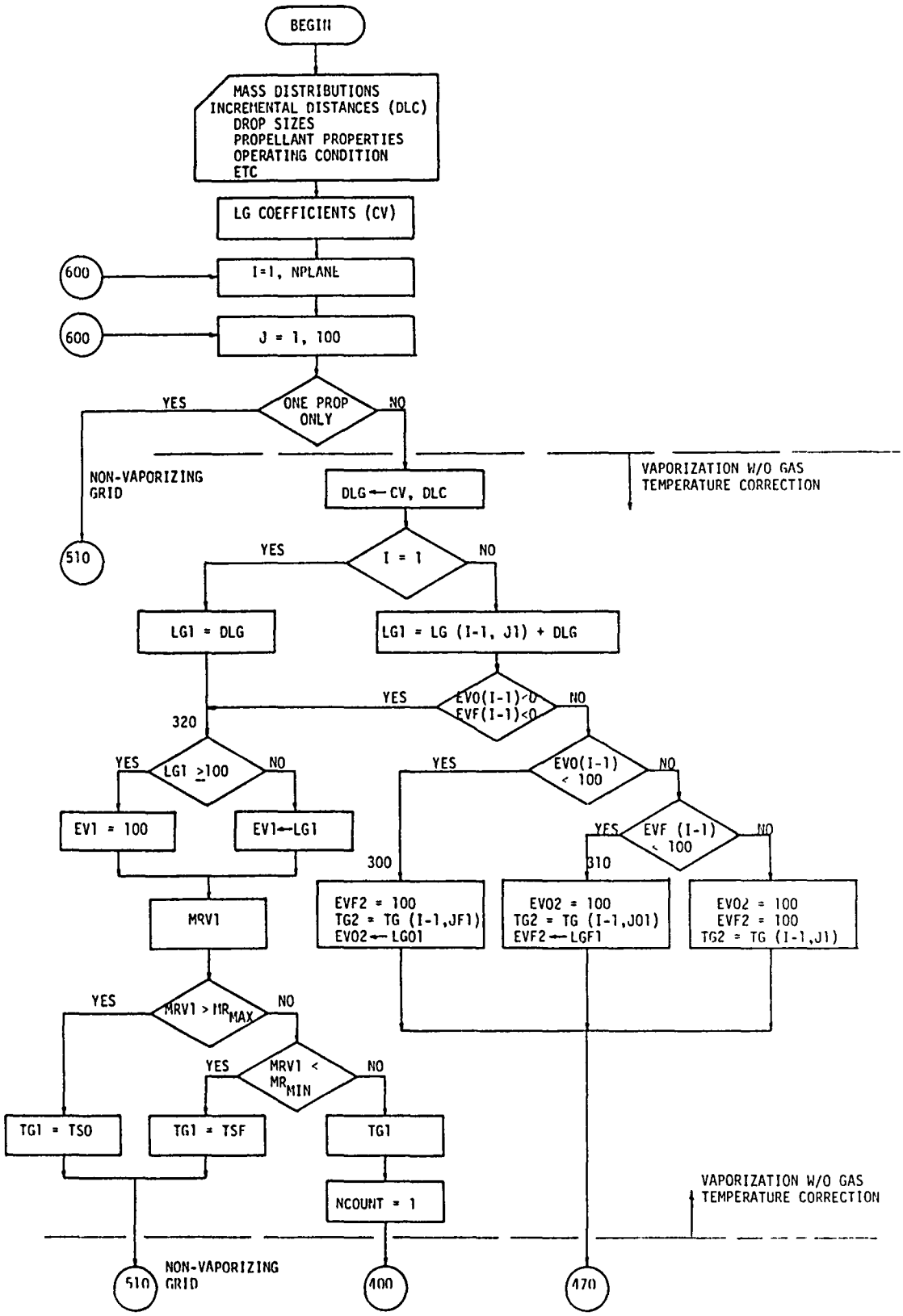
Injector: T-LOL

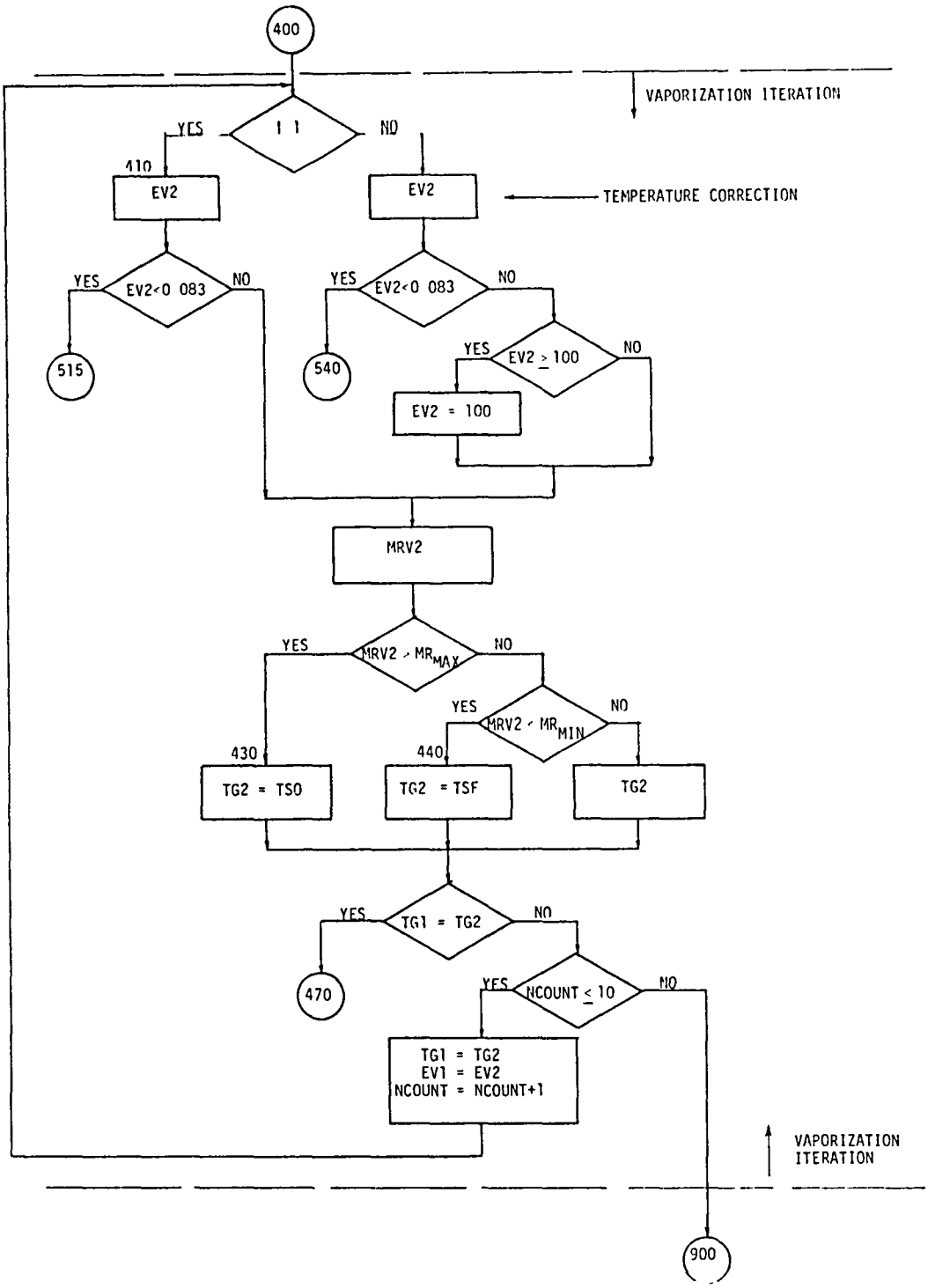
Axial Distance: 5.93 cm (2")

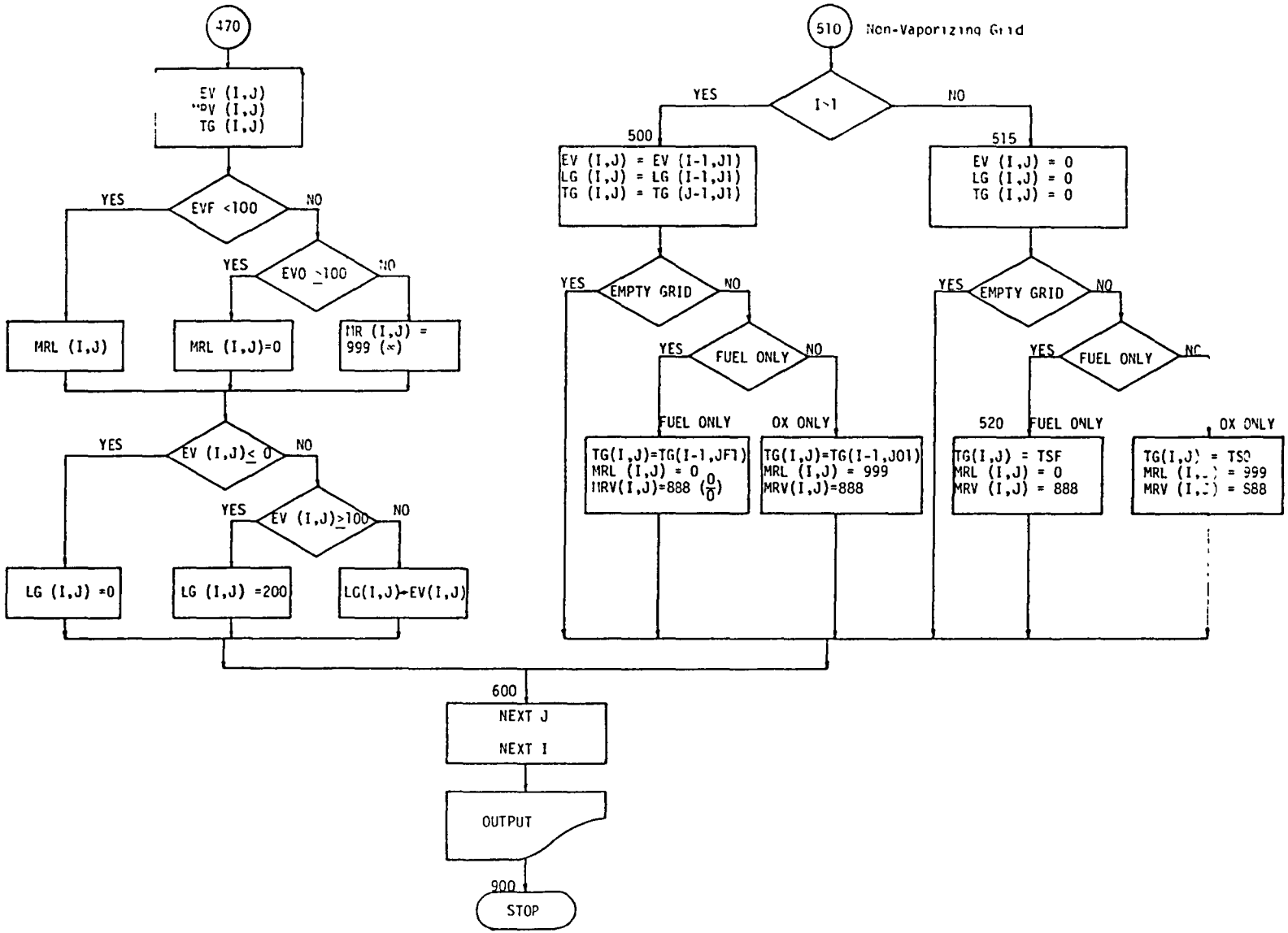
I =	J = 1	2	3	4	5	6	7	8	9	10
0				∞ .0017 0	∞ .0017 0	∞ .0012 0				
1			∞ .0017 0	∞ .0039 0	∞ .0069 0	∞ .0060 0	∞ .0022 0	∞ .0009 0		
2			26.99 .0029 .0002	17.47 .0094 .0010	∞ .022 0	∞ .022 0	∞ .0086 0	6.352 .0014 .0003		
3			3.176 .0017 .0010	5.325 .0098 .0035	22.76 .037 .0031	96.87 .052 .0010	17.87 .015 .0017	4.083 .0031 .0015	0 0 .0017	
4			0 0 .0012	1.723 .0088 .0097	3.176 .045 .027 ○	6.670 .072 .021	4.446 .024 .010	2.055 .0038 .0035		
5			.662 .0009 .0025	1.832 .013 .014	.993 .069 ◇ .133	1.344 .094 .135	2.383 .031 .025	2.382 .0051 .0041	0 0 .0021	
6			.706 .0007 .0019	1.815 .014 .015	.989 .065 .127	1.083 .103 .183	2.117 .048 .044	2.941 .0086 .0056	.529 .0003 .0012	
7			.529 .0007 .0029	2.077 .012 .011	1.191 .021 .033	1.036 .026 .048	2.558 .050 .037	2.548 .014 .010	1.444 .0017 .0023	
8			.159 .0003 .0041	1.732 .0062 .0068	.675 .0029 .0083	.069 .0003 .0095	2.193 .015 .013	3.176 .017 .010	1.800 .0029 .0031	
9			.681 .0010 .0029	1.059 .0017 .0031	.0993 .0002 .0033	0 0 .0031	.496 .0009 .0033	3.176 .0069 .0041	2.647 .0034 .0025	

○ Oxidizer Hole Projection
◇ Fuel Hole Projection

C. VAPORIZATION COMPUTATION FLOWCHART AND COMPUTER PROGRAM LISTING


BEGIN
MASS DISTRIBUTIONS
INCREMENTAL DISTANCES (DLC)
DROP SIZES
PROPELLANT PROPERTIES
OPERATING CONDITION
ETC
LG COEFFICIENTS (CV)
600
I=1, NPLANE
600
J = 1, 100
ONE PROP ONLY
YES
NO
NON-VAPORIZING GRID
510
VAPORIZATION W/O GAS TEMPERATURE CORRECTION
DLG←CV, DLC
I = 1
YES
NO
LG1 = DLG
LG1 = LG (I-1, J1) + DLG
EVO(I-1)<0 EVF(I-1)<0
YES
NO
320
LG1 ≥100
YES
NO
EV1 = 100
EV1←LG1
EVO(I-1) < 100
YES
NO
300
EVF (I-1) < 100
YES
NO
310
MRV1
EVF2 = 100
TG2 = TG (I-1,JF1)
EVO2←LGO1
EVO2 = 100
TG2 = TG (I-1,JO1)
EVF2←LGF1
EVO2 = 100
EVF2 = 100
TG2 = TG (I-1,J1)
MRV1 > MR_MAX
YES
NO
MRV1 < MR_MIN
YES
NO
TG1 = TSO
TG1 = TSF
TG1
NCOUNT = 1
VAPORIZATION W/O GAS TEMPERATURE CORRECTION
510
NON-VAPORIZING GRID
400
470


400
VAPORIZATION ITERATION
I I
YES
NO
410
EV2
EV2
TEMPERATURE CORRECTION
YES
EV2<0 083
NO
YES
EV2<0 083
NO
515
540
YES
EV2 ≥ 100
NO
EV2 = 100
MRV2
YES
MRV2 > MR_MAX
NO
YES
MRV2 < MR_MIN
NO
430
440
TG2 = TSO
TG2 = TSF
TG2
YES
TG1 = TG2
NO
470
YES
NCOUNT ≤ 10
NO
TG1 = TG2
EV1 = EV2
NCOUNT = NCOUNT+1
VAPORIZATION ITERATION
900


470
EV (I,J)
TG (I,J)
EVF <100
YES
NO
EVO ≥100
YES
NO
MRL (I,J)
MRL (I,J)=0
MR (I,J) =
999 (∞)
EV (I,J)≤ 0
YES
NO
EV (I,J)≥100
YES
NO
LG (I,J) =0
LG (I,J) =200
LG(I,J)←EV(I,J)
510
Non-Vaporizing Grid
I>1
YES
NO
500
EV (I,J) = EV (I-1,J1)
LG (I,J) = LG (I-1,J1)
TG (I,J) = TG (J-1,J1)
515
EV (I,J) = 0
LG (I,J) = 0
TG (I,J) = 0
EMPTY GRID
YES
NO
FUEL ONLY
YES
NO
FUEL ONLY
OX ONLY
TG(I,J)=TG(I-1,JF1)
MRL (I,J) = 0
MRV(I,J)=888 (0/0)
TG(I,J)=TG(I-1,JO1)
MRL (I,J) = 999
MRV(I,J)=888
520
FUEL ONLY
OX ONLY
TG(I,J) = TSF
MRL (I,J) = 0
MRV (I,J) = 888
TG(I,J) = TSO
MRL (I,J) = 999
MRV (I,J) = 888
600
NEXT J
NEXT I
OUTPUT
900
STOP

```
VV        VV      AAAAAAAA      PPPPPPPPPP        OOOOOOOO      RRRRRRRRRR
VV        VV     AAAAAAAAAA     PPPPPPPPPPP      OOOOOOOOOO     RRRRRRRRRRR
 VV      VV     AA        AA    PP        PP    OO        OO    RR        RR
 VV      VV     AA        AA    PP        PP    OO        OO    RR        RR
  VV    VV      AA        AA    PP        PP    OO        OO    RR        RR
  VV    VV      AAAAAAAAAAAA    PPPPPPPPPPP     OO        OO    RRRRRRRRRRR
   VV  VV       AAAAAAAAAAAA    PPPPPPPPPP      OO        OO    RRRRRRRRRR
   VV  VV       AA        AA    PP              OO        OO    RR    RR
    VVVV        AA        AA    PP              OO        OO    RR     RR
    VVVV        AA        AA    PP              OO        OO    RR      RR
     VV         AA        AA    PP               OOOOOOOOOO     RR       RR
     VV         AA        AA    PP                OOOOOOOO      RR        RR
```

PRINTED BY	VAPOR	CREATED BY	.APOR	STARTED PRINTING	5/14/82 07 58 20	ESTIMATED PAGES	12
USER NAME	ALRC			QUEUED	5/14/82 07 57 53	INPUT DEVICE	DG1924
ACCOUNT	0427AA133			CREATED	5/14/82 07 57 23	QUEUED TO	AJ1
ON SYSTEM	B			PART NAME	-BK1-$$-BK2-	PRINTED ON	AJ1PR1
EXEC LEVEL	37R2B-B42			PART NO	00		
EXEC DATE	05/06			FILE NAME	000427*BKFIL$VAPOR(4)		

* * * CDC / INFORMATION SYSTEMS DESIGN * 3205 CORONADO DR * SANTA CLARA, CA 95051 * (408) 727-8100 * * * 1108 1XO * * *

```
@FOR,S VAPOR
FORTRAN V:  ISD VERSION 4.9S-08/30/82-14:33:25 (26,)

   MAIN PROGRAM

   STORAGE USED: CODE(1) 002174; DATA(0) 010770; BLANK COMMON(2) 000000


   EXTERNAL REFERENCES (BLOCK, NAME)

    0003   SINTP
    0004   MINTR$
    0005   MRDU$
    0006   MIO3$
    0007   MIO2$
    0010   MRNL$
    0011   MIO1$
    0012   MWDU$
    0013   MERR2$
    0014   XERR
    0015   MSTOP$


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

    0001    000310 100L      0000    010324 1000F     0000    010325 1010F     0001    000317 110L      0001    000325 120L
    0001    000335 130L      0001    000032 135G      0001    000034 140G      0001    000344 140L      0001    000353 150L
    0001    000361 160L      0001    000612 170L      0001    000617 175L      0001    000630 180L      0001    000637 185L
    0001    000647 190L      0001    000052 20L       0000    010331 2000F     0000    010345 2010F     0000    010365 2020F
    0000    010367 2030F     0000    010373 2040F     0000    010410 2050F     0000    010432 2060F     0000    010454 2070F
    0000    010461 2080F     0000    010466 2090F     0000    010504 2100F     0000    010516 2200F     0000    010522 2210F
    0000    010524 2220F     0000    010537 2230F     0000    010545 2240F     0000    010553 2250F     0000    010560 2260F
    0000    010565 2270F     0000    010572 2280F     0000    010577 2300F     0001    000205 231G      0000    010605 2310F
    0000    010612 2320F     0000    010620 2330F     0000    010631 2340F     0000    010642 2350F     0000    010653 2360F
    0000    010664 2370F     0000    010675 2380F     0001    000223 241G      0001    000264 262G      0001    000265 265G
    0001    000076 30L       0001    000776 300L      0001    001021 310L      0001    001044 320L      0001    000577 330G
    0001    001054 330L      0001    001066 340L      0001    001106 350L      0001    000555 353G      0001    000675 356G
    0001    001110 360L      0001    001122 365L      0001    001142 368L      0001    001166 370L      0001    001171 380L
    0001    001174 390L      0001    000254 40L       0001    001176 400L      0001    001255 410L      0001    001303 420L
    0001    001315 425L      0001    001335 426L      0001    001361 430L      0001    001364 440L      0001    001366 450L
    0001    001410 460L      0001    001422 470L      0001    001443 472L      0001    001445 473L      0001    001457 474L
    0001    001504 475L      0001    001511 480L      0001    001512 485L      0001    001537 490L      0001    001541 495L
    0001    001546 510L      0001    001550 515L      0001    001603 520L      0001    001611 540L      0001    001663 550L
    0001    001673 600L      0001    001705 653G      0001    001730 665G      0001    001770 702G      0001    002003 710G
    0001    001741 710L      0001    002016 716G      0001    002031 724G      0001    002044 732G      0001    002057 740G
    0001    002072 746G      0001    002103 810L      0001    002114 820L      0001    002125 830L      0001    002136 840L
    0001    002147 850L      0001    002160 860L      0001    002170 900L      0000 R  010214 CR        0000 R  010227 CVF
    0000 R  010226 CVO       0000 R  003114 DLCF      0000 R  002440 DLCO      0000 R  002375 EV        0000 R  006524 EVF
    0000 R  010240 EVF1      0000 R  010234 EVF2      0000 R  006050 EVO       0000 R  010237 EVO1      0000 R  010233 EVO2
    0000 R  010224 HVF       0000 R  010222 HVO       0000 I  010220 I         0000 I  010204 IDF       0000 I  010203 IDO
    0000    010250 INPUT     0000 I  010236 ISITOK    0000 I  010221 J         0000 I  004244 JFC       0000 I  010232 JF1
    0000 I  010245 JJ        0000 I  010244 JJJ       0000 I  003570 JOO       0000 I  010231 JO1       0000 I  010246 J1
    0000 I  010247 J2        0000 I  010230 K         0000 R  000002 LG        0000 R  000521 LGF       0000 R  002370 LGF1
    0000 R  000045 LGG       0000 R  002371 LGO1      0000 R  002326 MR        0000 R  002325 MRJ       0000 R  001651 MRL
    0000 R  001175 MRV       0000 R  002373 MRV1      0000 R  002374 MRV2      0000 R  000001 MWF       0000 R  000000 MWO
    0000 I  010242 NCOUNT    0000 I  010217 NPLANE    0000 R  010213 PC        0000 R  010210 RMF       0000 R  010207 RMO
    0000 R  007464 T         0000 R  010225 TCF       0000 R  010223 TCO       0000 R  010243 TEST      0000 R  010206 TF
```

```
0000 R 007527 TG        0000 R 010241 TG1       0000 R 010235 TG2       0000 R 007414 TITLE1    0000 R 007440 TITLE2
0000 R 010205 TO        0000 R 007200 TP100     0000 R 007243 TP1000    0000 R 007306 TR100     0000 R 007351 TR1000
0000 R 010216 TSF       0000 R 010215 TSO       0000 R 010212 VF        0000 R 010211 VO        0000 R 005374 XCF
0000 R 004720 XCO
```

```
00101      1*
00101      2*      C DECLARATION
00101      3*
00101      4*            REAL MWO,MWF,LG,LGO,LGF,MRV,MRL,MRJ,MR,LGO1,LGF1,MRV1,MRV2
00103      5*            DIMENSION LG(35),EV(35),DLCO(3,100),DLCF(3,100),JOO(3,100),                  000001
00103      6*           1          JFO(3,100),XCO(3,100),XCF(3,100),MRV(3,100),MRL(3,100),           000001
00103      7*           2          LGO(3,100),LGF(3,100),EVO(3,100),EVF(3,100),MR(35),               000001
00103      8*           3          TP100(35),TP1000(35),TR100(35),TR1000(35),TITLE1(20),             000001
00103      9*           4          TITLE2(20),T(35),TG(3,100)                                        000001
00104     10*            NAMELIST /INPUT/IDO,IDF,TO,TF,RMO,RMF,VO,VF,PC,CR,TSO,TSF,                   000001
00104     11*           1                MRJ,NPLANE                                                  000001
00105     12*            DATA LG/0.01,0.02,0.04,0.06,0.1,0.2,0.4,0.6,0.8,1.0,1.5,2.0,                000001
00105     13*           1        3.0,4.0,5.0,6.0,7.0,8.0,9.0,10.0,13.0,15.0,17.0,                    000001
00105     14*           2        20.0,25.0,30.0,35.0,40.0,45.0,50.0,60.0,70.0,80.0,90.0,             000001
00105     15*           3        100.0/                                                              000001
00107     16*            DATA EV/0.083,0.31,0.91,1.61,3.10,6.5,12.2,17.3,21.8,25.9,34.2,             000001
00107     17*           1        41.5,52.2,60.0,66.0,70.5,74.5,77.8,80.5,82.7,87.8,90.2,             000001
00107     18*           2        92.0,94.0,96.2,97.6,98.5,99.1,99.4,99.6,99.82,99.92,                000001
00107     19*           3        99.96,99.98,99.99/                                                  000001
00111     20*            DATA MR/0.1,0.2,0.4,0.6,0.8,1.0,1.2,1.4,1.6,1.8,2.0,2.2,2.4,                000001
00111     21*           1        2.6,2.8,3.0,3.2,3.4,3.6,3.8,4.0,4.5,5.0,5.5,6.0,7.0,8.0,            000001
00111     22*           2        9.0,10.0,15.0,20.0,30.0,40.0,50.0,100.0/                            000001
00113     23*            DATA TP100/1421.0,1618.0,1844.0,1992.0,2125.0,2280.0,2712.0,                000001
00113     24*           1           3587.0,4336.0,4922.0,5347.0,5632.0,5806.0,5905.0,                000001
00113     25*           2           5959.0,5984.0,5990.0,5986.0,5974.0,5956.0,5936.0,                000001
00113     26*           3           5873.0,5801.0,5725.0,5646.0,5482.0,5313.0,5137.0,                000001
00113     27*           4           4957.0,4026.0,3257.0,2311.0,1774.0,1425.0,638.0/                 000001
00115     28*            DATA TP1000/1551.0,1817.0,2109.0,2289.0,2438.0,2586.0,2838.0,               000001
00115     29*           1            3590.0,4364.0,5027.0,5555.0,5974.0,6254.0,6429.0,               000001
00115     30*           2            6526.0,6575.0,6591.0,6589.0,6575.0,6551.0,6521.0,               000001
00115     31*           3            6433.0,6330.0,6220.0,6109.0,5876.0,5637.0,5398.0,               000001
00115     32*           4            5155.0,4055.0,3261.0,2311.0,1774.0,1425.0,673.0/                000001
00117     33*            DATA TR100/1517.0,1708.0,1934.0,2102.0,2291.0,2564.0,3090.0,               000001
00117     34*           1           4024.0,4769.0,5304.0,5651.0,5857.0,5965.0,6019.0,               000001
00117     35*           2           6040.0,6044.0,6037.0,6020.0,6001.0,5975.0,5950.0,               000001
00117     36*           3           5876.0,5797.0,5714.0,5630.0,5455.0,5275.0,5088.0,               000001
00117     37*           4           4894.0,3909.0,3133.0,2204.0,1684.0,1348.0,592.0/                000001
00121     38*            DATA TR1000/1672.0,1929.0,2213.0,2404.0,2584.0,2791.0,3131.0,               000001
00121     39*           1            4037.0,4845.0,5498.0,5988.0,6314.0,6506.0,6607.0,               000001
00121     40*           2            6652.0,6665.0,6658.0,6638.0,6611.0,6577.0,6541.0,               000001
00121     41*           3            6436.0,6325.0,6208.0,6087.0,5839.0,5587.0,5329.0,               000001
00121     42*           4            5074.0,3929.0,3135.0,2204.0,1684.0,1348.0,633.0/                000001
00123     43*                                                                                         000001
00123     44*      C INPUT DATA                                                                       000001
00123     45*                                                                                         000001
00123     46*            READ(5,1000) (TITLE1(I),I=1,20)                                             000001
00126     47*            READ(5,1000) (TITLE2(I),I=1,20)                                             000011
00131     48*            READ(5,INPUT)                                                               000021
00134     49*            DO 10 I=1,NPLANE                                                            000025
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00137     50*          DO 10 J=1,100                                                    000034
00142     51*          XCO(I,J)=0.0                                                     000034
00143     52*          XCF(I,J)=0.0                                                     000035
00144     53*          DLCO(I,J)=0.0                                                    000036
00145     54*          DLCF(I,J)=0.0                                                    000037
00146     55*          JOO(I,J)=J                                                       000040
00147     56*          JFO(I,J)=J                                                       000042
00150     57*       10 CONTINUE                                                         000052
00153     58*       20 READ(5,1010,END=30) I,J,XCO(I,J),DLCO(I,J),JOO(I,J),          000052
00153     59*         1                          XCF(I,J),DLCF(I,J),JFO(I,J)         000052
00165     60*          GO TO 20                                                         000074
00166     61*       30 WRITE(6,2000)                                                    000076
00170     62*          WRITE(6,2010)                                                    000102
00172     63*          WRITE(6,2020) (TITLE1(I),I=1,20)                                 000107
00175     64*          WRITE(6,2020) (TITLE2(I),I=1,20)                                 000122
00200     65*          WRITE(6,2030)                                                    000132
00202     66*          WRITE(6,2040) PC,MRJ,CR,NPLANE                                   000137
00210     67*          WRITE(6,2050) IDO,TO,VO,RMO,TSO                                  000150
00217     68*          WRITE(6,2060) IDF,TF,VF,RMF,TSF                                  000162
00226     69*          WRITE(6,2070)                                                    000174
00230     70*          DO 40 I=1,NPLANE                                                 000205
00233     71*          WRITE(6,2080) I                                                  000205
00236     72*          WRITE(6,2090)                                                    000213
00240     73*          DO 40 J=1,100                                                    000223
00243     74*          IF(XCO(I,J) .LE. 0.0 .AND. XCF(I,J) .LE. 0) GO TO 40             000223
00245     75*          WRITE(6,2100) J,XCO(I,J),DLCO(I,J),JOO(I,J),XCF(I,J),DLCF(I,J),  000237
00245     76*         1              JFO(I,J)                                          000237
00256     77*       40 CONTINUE                                                         000265
00261     78*                                                                          000265
00261     79*     C INITIALIZATION                                                     000265
00261     80*                                                                          000265
00261     81*          DO 50 I=1,NPLANE                                                000265.
00264     82*          DO 50 J=1,100                                                   000265
00267     83*          TG(I,J)=0.0                                                     000265
00270     84*          MRV(I,J)=0.0                                                    000265
00271     85*          MRL(I,J)=0.0                                                    000266
00272     86*          LGO(I,J)=0.0                                                    000267
00273     87*          LGF(I,J)=0.0                                                    000270
00274     88*          EVO(I,J)=0.0                                                    000271
00275     89*          EVF(I,J)=0.0                                                    000272
00276     90*       50 CONTINUE                                                        000300
00301     91*                                                                         000300
00301     92*     C PROPELLANT PROPERTY ASSIGNMENT                                    000300
00301     93*                                                                         000300
00301     94*          GO TO (100,110),IDO                                            000300
00302     95*                                                                         000310
00302     96*     C     * LO2                                                        000310
00302     97*                                                                         000310
00302     98*      100 HVO=91.6                                                       000310
00303     99*          TCO=278.0                                                      000311
00304    100*          MWO=32.0                                                       000313
00305    101*          GO TO 120                                                      000315
00306    102*      110 WRITE(6,2300)                                                  000317
00310    103*          GO TO 900                                                      000323
00311    104*      120 GO TO (130,140,150),IDF                                        000325
00312    105*                                                                         000335
00312    106*     C     * PROPANE                                                    000335
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00312    107*                                                                                  000335
00312    108*       130 HVF=183.0                                                               000335
00313    109*           TCF=670.0                                                               000336
00314    110*           MWF=44.0                                                                000340
00315    111*           GO TO 160                                                               000342
00316    112*                                                                                   000344
00316    113*     C     * RP-1                                                                  000344
00316    114*                                                                                   000344
00316    115*       140 HVF=125.0                                                               000344
00317    116*           TCF=1218.0                                                              000345
00320    117*           MWF=172.0                                                               000347
00321    118*           GO TO 160                                                               000351
00322    119*       150 WRITE(6,2310)                                                           000353
00324    120*           GO TO 900                                                               000357
00325    121*                                                                                   000361
00325    122*     C     * LG COEFFICIENT                                                        000361
00325    123*                                                                                   000361
00325    124*       160 CVO=((PC/300.0)**0.66/CR**0.44)/((1.0-TO/TCO)**0.4*(HVO/140.0)          000361
00325    125*          1    **0.8*(MWO/100.0)**0.35*(RMO/0.003)**1.45*(VO/100.0)**0.75)        000361
00326    126*           CVF=((PC/300.0)**0.66/CR**0.44)/((1.0-TF/TCF)**0.4*(HVF/140.0)          000455
00326    127*          1    **0.8*(MWF/100.0)**0.35*(RMF/0.003)**1.45*(VF/100.0)**0.75)        000455
00327    128*                                                                                   000577
00327    129*     C     * TEMPERATURE INTERPOLATION                                             000577
00327    130*                                                                                   000577
00327    131*           DO 190 K=1,35                                                           000577
00332    132*           IF(IDO .NE. 1) GO TO 110                                                000577
00334    133*           GO TO (170,180,150),IDF                                                 000601
00335    134*       170 IF(PC .LT. 1000.0) GO TO 175                                            000612
00337    135*           T(K)=TP1000(K)                                                          000613
00340    136*           GO TO 190                                                               000615
00341    137*       175 T(K)=TP100(K)+((PC-100.0)/(1000.0-100.0))*(TP1000(K)-TP100(K))          000617
00342    138*           GO TO 190                                                               000626
00343    139*       180 IF(PC .LT. 1000.0) GO TO 185                                            000630
00345    140*           T(K)=TR1000(K)                                                          000633
00346    141*           GO TO 190                                                               000635
00347    142*       185 T(K)=TR100(K)+((PC-100.0)/(1000.0-100.0))*(TR1000(K)-TR100(K))          000637
00350    143*       190 CONTINUE                                                                000655
00352    144*                                                                                   000655
00352    145*     C VAPORIZATION CALCULATION                                                    000655
00352    146*                                                                                   000655
00352    147*           DO 600 I=1,NPLANE                                                       000655
00355    148*           DO 600 J=1,100                                                          000675
00360    149*           JO1=JOO(I,J)                                                            000675
00361    150*           JF1=JFO(I,J)                                                            000677
00362    151*           IF(XCO(I,J) .LE. 0.0 .OR. XCF(I,J) .LE. 0.0) GO TO 510                  000701
00364    152*                                                                                   000715
00364    153*     C     * VAPORIZING GRIDS (BOTH OXIDIZER AND FUEL PRESENT)                     000715
00364    154*                                                                                   000715
00364    155*     C        ** FIRST TRIAL (BASED ON LC AND NOT TG CORRECTED)                    000715
00364    156*                                                                                   000715
00364    157*     C             *** FIRST PLANE LG                                             000715
00364    158*                                                                                   000715
00364    159*           LGO1=CVO*DLCO(I,J)                                                      000715
00365    160*           LGF1=CVF*DLCF(I,J)                                                      000720
00366    161*           IF(I .EQ. 1) GO TO 320                                                  000723
00370    162*                                                                                   000731
00370    163*     C             ***SECOND OR THIRD PLANE LG                                    000731
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00370    164*                                                                                                  000731
00370    165*          LGO1=LGO1+LGO(I-1,JO1)                                                                  000731
00371    166*          LGF1=LGF1+LGF(I-1,JF1)                                                                  000733
00372    167*          IF(EVO(I-1,JO1) .LT. 100.0 .AND. EVF(I-1,JF1) .LT. 100) GO TO 320                       000735
00374    168*          IF(EVO(I-1,JO1) .LT. 100.0) GO TO 300                                                   000753
00376    169*          IF(EVF(I-1,JF1) .LT. 100.0) GO TO 310                                                   000757
00400    170*          EVO2=100.0                                                                              000763
00401    171*          EVF2=100.0                                                                              000765
00402    172*          MRV2=888.0                                                                              000766
00403    173*          TG2=(TG(I-1,JO1)+TG(I-1,JF1))/2.0                                                       000770
00404    174*          GO TO 470                                                                               000774
00405    175*      300 TG2=TG(I-1,JF1)                                                                         000776
00406    176*          EVF2=100.0                                                                              001002
00407    177*          CALL SINTP(LG(1),EV(1),35,LGO1,EVO2,ISITOK)                                             001004
00410    178*          IF(ISITOK .LT. 0) GO TO 810                                                             001014
00412    179*          GO TO 470                                                                               001017
00413    180*      310 TG2=TG(I-1,JO1)                                                                         001021
00414    181*          EVO2=100.0                                                                              001025
00415    182*          CALL SINTP(LG(1),EV(1),35,LGF1,EVF2,ISITOK)                                             001027
00416    183*          IF(ISITOK .LT. 0) GO TO 820                                                             001037
00420    184*          GO TO 470                                                                               001042
00421    185*                                                                                                  001044
00421    186*      C             *** VAPORIZATION                                                            001044
00421    187*                                                                                                  001044
00421    188*      320 IF(LGO1 .GT. 100.0) GO TO 330                                                           001044
00423    189*          CALL SINTP(LG(1),EV(1),35,LGO1,EVO1,ISITOK)                                             001047
00424    190*          IF(ISITOK .LT. 0) GO TO 810                                                             001057
00426    191*          GO TO 340                                                                               001062
00427    192*      330 EVO1=100.0                                                                              001064
00430    193*      340 IF(LGF1 .GT. 100.0) GO TO 350                                                           001066
00432    194*          CALL SINTP(LG(1),EV(1),35,LGF1,EVF1,ISITOK)                                             001071
00433    195*          IF(ISITOK .LT. 0) GO TO 820                                                             001101
00435    196*          GO TO 360                                                                               001104
00436    197*      350 EVF1=100.0                                                                              001106
00437    198*      360 IF(I .GT. 1) GO TO 365                                                                  001110
00441    199*          MRV1=MRJ*(XCO(I,J)/XCF(I,J))*(EVO1/EVF1)                                                001111
00442    200*          GO TO 368                                                                               001120
00443    201*      365 MRV1=MRJ*(XCO(I,J)/XCF(I,J))*((EVO1-EVO(I-1,JO1))/                                      001122
00443    202*         1     (EVF1-EVF(I-1,JF1)))                                                               001122
00444    203*      368 IF(MRV1 .GE. MR(35)) GO TO 370                                                          001142
00446    204*          IF(MRV1 .LE. MR(1)) GO TO 380                                                           001145
00450    205*          CALL SINTP(MR(1),T(1),35,MRV1,TG1,ISITOK)                                               001151
00451    206*          IF(ISITOK .LT. 0) GO TO 830                                                             001161
00453    207*          GO TO 390                                                                               001164
00454    208*      370 TG1=TSO                                                                                 001166
00455    209*          GO TO 510                                                                               001167
00456    210*      380 TG1=TSF                                                                                 001171
00457    211*          GO TO 510                                                                               001172
00460    212*      390 NCOUNT=1                                                                                001174
00461    213*                                                                                                  001176
00461    214*      C       ** SECOND TRIAL (BASED ON TG)                                                       001176
00461    215*                                                                                                  001176
00461    216*      400 IF(I .EQ. 1) GO TO 410                                                                  001176
00463    217*                                                                                                  001177
00463    218*      C             ** SECOND OR THIRD PLANE EV                                                 001177
00463    219*                                                                                                  001177
00463    220*          EVO2=((TG1+TG(I-1,JO1)-2.0*TSO)/((5000.0-TSO)*2.0))                                     001177
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00463    221*          1     *(EVO1-EVO(I-1,J01))+EVO(I-1,J01)                    001177
00464    222*           IF(EVO2 .LT. 0.083) GO TO 540                             001213
00466    223*           IF(EVO2 .GT. 100.0) EVO2=100.0                            001222
00470    224*           EVF2=((TG1+TG(I-1,JF1)-2.0*TSF)/((5000.0-TSF)*2.0))       001230
00470    225*          1     *(EVF1-EVF(I-1,JF1))+EVF(I-1,JF1)                    001230
00471    226*           IF(EVF2 .LT. 0.083) GO TO 540                             001242
00473    227*           IF(EVF2 .GT. 100.0) EVF2=100.0                            001245
00475    228*           GO TO 420                                                 001253
00475    229*                                                                     001255
00476    230*     C             *** FIRST PLANE EV                                001255
00476    231*                                                                     001255
00476    232*       410 EVO2=((TG1-TSO)/(5000.0-TSO))*EVO1                        001255
00477    233*           EVF2=((TG1-TSF)/(5000.0-TSF))*EVF1                        001261
00500    234*           IF(EVO2 .LT. 0.083 .OR. EVF2 .LT. 0.083) GO TO 515        001266
00502    235*                                                                     001303
00502    236*     C             *** MRV2 AND TG2                                  001303
00502    237*                                                                     001303
00502    238*       420 IF(I .GT. 1) GO TO 425                                    001303
00504    239*           MRV2=MRJ*(XCO(I,J)/XCF(I,J))*(EVO2/EVF2)                  001304
00505    240*           GO TO 426                                                 001313
00506    241*       425 MRV2=MRJ*(XCO(I,J)/XCF(I,J))*((EVO2-EVO(I-1,J01))/        001315
00506    242*          1     (EVF2-EVF(I-1,JF1)))                                 001315
00507    243*       426 IF(MRV2 .GE. MR(35)) GO TO 430                            001335
00511    244*           IF(MRV2 .LE. MR(1)) GO TO 440                             001340
00513    245*           CALL SINTP(MR(1),T(1),35,MRV2,TG2,ISITOK)                 001344
00514    246*           IF(ISITOK .LT. 0) GO TO 840                               001354
00516    247*           GO TO 450                                                 001357
00517    248*       430 TG2=TSO                                                   001361
00520    249*           GO TO 450                                                 001362
00521    250*       440 TG2=TSF                                                   001364
00522    251*                                                                     001366
00522    252*     C        ** COMPARISON OF 1 AND 2                              001366
00522    253*                                                                     001366
00522    254*       450 TEST=ABS(TG2/TG1-1.0)                                     001366
00523    255*           IF(TEST .LE. 0.05) GO TO 470                              001372
00525    256*                                                                     001375
00525    257*     C             *** FURTHER ITERATION REQUIRED                    001375
00525    258*                                                                     001375
00525    259*           IF(NCOUNT .LE. 10) GO TO 460                              001375
00527    260*           WRITE(6,2320)                                             001401
00531    261*           GO TO 900                                                 001406
00532    262*       460 TG1=TG2                                                   001410
00533    263*           EVO1=EVO2                                                 001411
00534    264*           EVF1=EVF2                                                 001413
00535    265*           NCOUNT=NCOUNT+1                                           001415
00536    266*           GO TO 400                                                 001420
00537    267*                                                                     001422
00537    268*     C             *** ITERATION COMPLETED                           001422
00537    269*                                                                     001422
00537    270*       470 EVO(I,J)=EVO2                                             001422
00540    271*           EVF(I,J)=EVF2                                             001423
00541    272*           MRV(I,J)=MRV2                                             001425
00542    273*           TG(I,J)=TG2                                               001427
00543    274*           IF(EVF2 .LT. 100.0) GO TO 473                             001431
00545    275*           IF(EVO2 .GE. 100.0) GO TO 472                             001434
00547    276*           MRL(I,J)=999.0                                            001437
00550    277*           GO TO 474                                                 001441
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00551    278*        472 MRL(I,J)=0.0                                                                                001443
00552    279*            GO TO 474                                                                                   001443
00553    280*        473 MRL(I,J)=MRJ*(XCO(I,J)/XCF(I,J))*((100.-EVO(I,J))/(100.-EVF(I,J)))                          001445
00554    281*        474 IF(EVO2 .LE. 0.0) GO TO 480                                                             001457
00556    282*            IF(EVO2 .GE. 99.99) GO TO 475                                                           001461
00560    283*            CALL SINTP(EV(1),LG(1),35,EVO2,LGO(I,J),ISITOK)                                         001465
00561    284*            IF(ISITOK .LT. 0) GO TO 850                                                             001477
00563    285*            GO TO 485                                                                               001502
00564    286*        475 LGO(I,J)=200.0                                                                          001504
00565    287*            EVO2=100.0                                                                              001505
00566    288*            GO TO 485                                                                               001507
00567    289*        480 LGO(I,J)=0.0                                                                            001511
00570    290*        485 IF(EVF2 .LE. 0.0) GO TO 490                                                             001512
00572    291*            IF(EVF2 .GE. 99.99) GO TO 495                                                           001514
00574    292*            CALL SINTP(EV(1),LG(1),35,EVF2,LGF(I,J),ISITOK)                                         001520
00575    293*            IF(ISITOK .LT. 0) GO TO 860                                                             001532
00577    294*            GO TO 600                                                                               001535
00600    295*        490 LGF(I,J)=0.0                                                                            001537
00601    296*            GO TO 600                                                                               001537
00602    297*        495 LGF(I,J)=200.0                                                                          001541
00603    298*            EVF2=100.0                                                                              001542
00604    299*            GO TO 600                                                                               001544
00605    300*                                                                                                    001546
00605    301*    C       * NONVAPORIZING GRIDS (EITHER OXIDIZER OR FUEL OR BOTH ABSENT)                          001546
00605    302*                                                                                                    001546
00605    303*        510 IF(I .GT. 1) GO TO 540                                                                  001546
00607    304*                                                                                                    001550
00607    305*    C           ** FIRST PLANE                                                                      001550
00607    306*                                                                                                    001550
00607    307*        515 EVO(I,J)=0.0                                                                            001550
00610    308*            EVF(I,J)=0.0                                                                            001550
00611    309*            LGO(I,J)=0.0                                                                            001551
00612    310*            LGF(I,J)=0.0                                                                            001552
00613    311*            IF(XCO(I,J) .LE. 0.0 .AND. XCF(I,J) .LE. 0.0) GO TO 600                                 001553
00615    312*            IF(XCF(I,J) .GT. XCO(I,J)) GO TO 520                                                    001567
00617    313*                                                                                                    001573
00617    314*    C               *** OXIDIZER PRESENT ONLY                                                       001573
00617    315*                                                                                                    001573
00617    316*            TG(I,J)=TSO                                                                             001573
00620    317*            MRL(I,J)=999.0                                                                          001575
00621    318*            MRV(I,J)=888.0                                                                          001577
00622    319*            GO TO 600                                                                               001601
00623    320*                                                                                                    001603
00623    321*    C               *** FUEL PRESENT ONLY                                                           001603
00623    322*                                                                                                    001603
00623    323*        520 TG(I,J)=TSF                                                                             001603
00624    324*            MRL(I,J)=0.0                                                                            001604
00625    325*            MRV(I,J)=888.0                                                                          001605
00626    326*            GO TO 600                                                                               001607
00627    327*                                                                                                    001611
00627    328*    C           ** SECOND OR THIRD PLANE                                                            001611
00627    329*                                                                                                    001611
00627    330*        540 EVO(I,J)=EVO(I-1,JO1)                                                                   001611
00630    331*            EVF(I,J)=EVF(I-1,JF1)                                                                   001615
00631    332*            LGO(I,J)=LGO(I-1,JO1)                                                                   001623
00632    333*            LGF(I,J)=LGF(I-1,JF1)                                                                   001625
00633    334*            TG(I,J)=(TG(I-1,JO1)+TG(I-1,JF1))/2.0                                                   001627
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00634    335*          IF(XCO(I,J) .LE. 0.0 .AND. XCF(I,J) .LE. 0.0) GO TO 600                001633
00636    336*          IF(XCF(I,J) .GT. XCO(I,J)) GO TO 550                                   001647
00640    337*                                                                                 001653
00640    338*     C             *** OXIDIZER PRESENT ONLY                                     001653
00640    339*                                                                                 001653
00640    340*          TG(I,J)=TG(I-1,JO1)                                                    001653
00641    341*          MRL(I,J)=999.0                                                         001655
00642    342*          MRV(I,J)=888.0                                                         001657
00643    343*          GO TO 600                                                              001661
00644    344*                                                                                 001663
00644    345*     C             ** FUEL PRESENT ONLY                                          001663
00644    346*                                                                                 001663
00644    347*       550 TG(I,J)=TG(I-1,JF1)                                                   001663
00645    348*          MRL(I,J)=0.0                                                           001667
00646    349*          MRV(I,J)=888.0                                                         001670
00647    350*       600 CONTINUE                                                              001705
00652    351*                                                                                 001705
00652    352*     C PRINT OUTPUT                                                              001705
00652    353*                                                                                 001705
00653    354*          DO 600 I=1,NPLANE                                                      001705
00655    355*          WRITE(6,2000)                                                          001705
00657    356*          WRITE(6,2010)                                                          001712
00661    357*          WRITE(6,2200) I                                                        001717
00664    358*          DO 800 JJJ=1,10                                                        001730
00667    359*          IF(JJJ .NE. 6) GO TO 710                                               001730
00671    360*          WRITE(6,2210)                                                          001733
00673    361*       710 JJ=(JJJ-1)*10                                                         001741
00674    362*          J1=JJ+1                                                                001744
00675    363*          J2=JJ+10                                                               001750
00676    364*          WRITE(6,2220) J1,J2,(LGO(I,J),J=J1,J2)                                 001753
00706    365*          WRITE(6,2230) (LGF(I,J),J=J1,J2)                                       001773
00714    366*          WRITE(6,2240) (TG(I,J),J=J1,J2)                                        002006
00722    367*          WRITE(6,2250) (EVO(I,J),J=J1,J2)                                       002021
00730    368*          WRITE(6,2260) (EVF(I,J),J=J1,J2)                                       002034
00736    369*          WRITE(6,2270) (MRV(I,J),J=J1,J2)                                       002047
00744    370*          WRITE(6,2280) (MRL(I,J),J=J1,J2)                                       002062
00752    371*       800 CONTINUE                                                              002101
00755    372*          GO TO 900                                                              002101
00756    373*                                                                                 002103
00756    374*     C OUTSIDE TABLE RANGE                                                       002103
00756    375*                                                                                 002103
00756    376*       810 WRITE(6,2330) I,J,LGO1                                                002103
00753    377*          GO TO 900                                                              002112
00754    378*       820 WRITE(6,2340) I,J,LGF1                                                002114
00771    379*          GO TO 900                                                              002123
00772    380*       830 WRITE(6,2350) I,J,MRV1                                                002125
00777    381*          GO TO 900                                                              002134
01000    382*       840 WRITE(6,2360) I,J,MRV2                                                002136
01005    383*          GO TO 900                                                              002145
01006    384*       850 WRITE(6,2370) I,J,EVO2                                                002147
01013    385*          GO TO 900                                                              002156
01014    386*       860 WRITE(6,2380) I,J,EVF2                                                002160
01021    387*                                                                                 002170
01021    388*     C FORMATS                                                                   002170
01021    389*                                                                                 002170
01021    390*      1000 FORMAT(20A4)                                                          002170
01022    391*      1010 FORMAT(2I10,2(2F10.4,I10))                                            002170
```

```
01023     392*      2000 FORMAT(1H1,/38X,'A E R O J E T  L I Q U I D  R O C K E T  C O M P                  002170
01023     393*          1A N Y')                                                                            002170
01024     394*      2010 FORMAT(/25X,'PROPELLANT VAPORIZATION ANALYSIS BASED ON COLD-FLOW L                 002170
01024     395*          1IQUID MASS DISTRIBUTION DATA'/)                                                    002170
01025     396*      2020 FORMAT(10X,20A4)                                                                   002170
01026     397*      2030 FORMAT(/5X,'NAMELIST INPUT')                                                       002170
01027     398*      2040 FORMAT(/10X,'PC(PSIA)=',F6.1,3X,'MRJ=',F5.3,3X,'CR=',F7.3,3X,                      002170
01027     399*          1             'NPLANE=',I2)                                                       002170
01030     400*      2050 FORMAT(/10X,'IDO=',I2,3X,'TO(R)=',F6.1,3X,'VO(FT/SEC)=',F6.1,3X,                   002170
01030     401*          1             'RMO(IN)=',E10.4,3X,'TSO(R)=',F6.1)                                 002170
01031     402*      2060 FORMAT(/10X,'IDF=',I2,3X,'TF(R)=',F5.1,3X,'VF(FT/SEC)=',F6.1,3X,                   002170
01031     403*          1             'RMF(IN)=',E10.4,3X,'TSF(R)=',F6.1)                                 002170
01032     404*      2070 FORMAT(//5X,'COLD-FLOW INPUT')                                                     002170
01033     405*      2080 FORMAT(1H1,//30X,'PLANE NO.',I2)                                                   002170
01034     406*      2090 FORMAT( /10X,'J',4X,'XCO',7X,'DLCO',6X,'JOO',7X,                                   002170
01034     407*          1                    'XCF',7X,'DLCF',6X,'JFO'/)                                     002170
01035     408*      2100 FORMAT(8X,I3,T14,F6.4,T26,F5.3,T36,I3,T46,F6.4,T56,F5.3,T66,I3)                     002170
01036     409*      2200 FORMAT(10X,'PLANE NO.',I2/)                                                        002170
01037     410*      2210 FORMAT(1H1,/////)                                                                  002170
01040     411*      2220 FORMAT(/1X,'J=',I2,1X,'TO',1X,I3,2X,'LGO (IN)',3X,10(F7.3,3X))                     002170
01041     412*      2230 FORMAT(14X,'LGF (IN)',3X,10(F7.3,3X))                                              002170
01042     413*      2240 FORMAT(14X,'TG (R)',6X,10(F6.1,4X))                                                002170
01043     414*      2250 FORMAT(14X,'EVO',9X,10(F6.2,4X))                                                   002170
01044     415*      2260 FORMAT(14X,'EVF',9X,10(F6.2,4X))                                                   002170
01045     416*      2270 FORMAT(14X,'MRV',9X,10(F6.2,4X))                                                   002170
01046     417*      2280 FORMAT(14X,'MRL',9X,10(F6.2,4X))                                                   002170
01047     418*      2300 FORMAT(/10X,'UNIDENTIFIABLE OXIDIZER')                                             002170
01050     419*      2310 FORMAT(/10X,'UNIDENTIFIABLE FUEL')                                                 002170
01051     420*      2320 FORMAT(/10X,'EXCEEDS 10 ITERATIONS')                                               002170
01052     421*      2330 FORMAT(/5X,'AT I=',I2,3X,'J=',I4,3X,'LGO1=',F7.3)                                  002170
01053     422*      2340 FORMAT(/5X,'AT I=',I2,3X,'J=',I4,3X,'LGF1=',F7.3)                                  002170
01054     423*      2350 FORMAT(/5X,'AT I=',I2,3X,'J=',I4,3X,'MRV1=',F7.3)                                  002170
01055     424*      2360 FORMAT(/5X,'AT I=',I2,3X,'J=',I4,3X,'MRV2=',F7.3)                                  002170
01056     425*      2370 FORMAT(/5X,'AT I=',I2,3X,'J=',I4,3X,'EVO2=',F7.3)                                  002170
01057     426*      2380 FORMAT(/5X,'AT I=',I2,3X,'J=',I4,3X,'EVF2=',F7.3)                                  002170
01060     427*                                                                                              002170
01060     428*       900 STOP                                                                               002170
01061     429*           END                                                                                002173
END FOR
```

```
$MAP,S ,VAPOR
MAP 30R1V2-2 74R1-2 08/30/82 14:33:43

DEMAND INPUT IS ILLEGAL.  SOURCE IMAGES IGNORED.
AFCM STATUS OF OUTPUT ELEMENT=UNKNOWN
QUARTER/THIRD WORD INSENSITIVE


ADDRESS LIMITS     001000 016605       7046 IBANK WORDS DECIMAL
                   040000 055360       6897 DBANK WORDS DECIMAL
STARTING ADDRESS   014250


          SEGMENT $MAIN$          001000 016605      040000 055360

VSWTC$/FOR69                $(1)    001000 001032                                  27 JUL 76   14:02:51
VWBL($/FOR68                $(1)    001033 001221    $(0)    040000 040001         06 AUG 76   13:42:47
                                                     $(4)    040002 040053
VSILK$/FOR-E2               $(1)    001222 001337    $(0)    040054 040055         06 AUG 76   13:42:16
                                                     $(4)    040056 040130
VWEF$/FOR-E2                $(1)    001340 001573    $(2)    040131 040150         07 SEP 76   11:45:54
VR.VD$/FOR-E2               $(1)    001574 001655    $(2)    040151 040162         06 AUG 76   13:42:24
VCLOS$/FOR-E3               $(1)    001656 002121    $(2)    040163 040212         23 MAR 76   14:51:32
VLINP$/FOR-E3               $(1)    002122 003700    $(2)    040213 040402         23 MAR 76   14:52:38
VFTCH$/FOR-E2               $(1)    003701 004166    $(2)    040403 040416         27 JUL 76   13:58:56
VINPT$/FOR-E3               $(1)    004167 005575    $(2)    040417 040452         30 APR 76   16:45:16
VINIV$/FOR-E3               $(1)    005576 006035    $(2)    040453 040453         27 JUL 76   14:00:54
VIBJF$/FOR-E2               $(1)    006036 006075    $(2)    040454 040454         29 APR 74   13:47:56
VCNVT$/FOR68                $(1)    006076 006317    $(2)    040455 040552         23 MAR 76   14:51:36
VOTIN$/FOR-E3               $(1)    006320 006614    $(2)    040553 040556         16 APR 75   13:29:59
VBSBL$/FOR-E3               $(1)    006615 006667    $(0)    040557 040557         23 MAR 76   14:51:29
                                                     $(4)    040560 040615
VUPDA$/FOR68                $(1)    006670 006723                                  10 JUL 72   21:41:26
NTAB$/ISD                                            $(2)    040616 040655         23 MAR 76   14:53:06
VFCHK$/FOR-E3               $(1)    006724 007714    $(2)    040656 041027         24 MAY 76   15:30:02
                            $(3)    007715 007715    $(4)    041030 041101
VIDER$/FOR-E3               $(1)    007716 010145    $(2)    041102 041251         24 MAY 76   19:57:04
VJF00$/ISD                                           $(2)    041252 043457         23 MAR 76   14:51:07
VBDCV$/FOR-E3               $(1)    010146 010276    $(2)    043460 043535         23 MAR 76   14:51:25
VFTV$/FOR-E2                $(1)    010277 010321                                  29 APR 74   13:47:54
VFMT$/FOR-E3                $(1)    010322 011204    $(2)    043536 043611         23 MAR 76   14:52:00
VOUT$/FOR-E3                $(1)    011205 013002    $(2)    043612 043655         14 SEP 77   20:51:42
VOBUF$/FOR68                $(1)    013003 013043                                  10 JUL 72   21:41:08
FORCOM$/FORFTN                                       $(2)    043657 043664         24 MAY 76   15:28:58
VINTR$/FOR-E3               $(1)    013044 013203    $(2)    043665 043715         17 JAN 77   17:26:16
VERCOM$/FOR-TE3             $(1)    013204 013263    $(2)    043716 043731         11 MAR 75   15:33:59
ERU$/SYS74-ISD                                                                     14 DEC 79   09:57:06
VERR$/FOR-E3                $(1)    013264 013627    $(2)    043732 044122         16 APR 75   13:17:20
FORVCOM$/FOR-TE3                                     $(2)    044123 044132         24 MAY 76   15:29:07
VSTOP$/FOR-TE3              $(1)    013630 013673    $(2)    044133 044141         17 JAN 77   13:40:51
VEXP$/FOR-E3                $(1)    013674 014071    $(2)    044142 044213         17 MAR 77   09:01:41
VIER$/FOR-E3                $(1)    014072 014247    $(2)    044214 044334         24 MAY 76   15:30:15
BLANK$COMMON(COMMONBLOCK)
VAPOR                       $(1)    014250 016443    $(0)    044335 055324         30 AUG 82   14:33:36
                                                     $(2)    BLANK$COMMON
```

```
      SUBROUTINE SINTP(U,V,N,X,Y,ISITOK)
      DIMENSION U(N),V(N)
      DO 1 I=2,N
      J=I
      IF (X.LT.U(1))GO TO 3
      IF(X.GT.U(N))GO TO 3
      IF((X-U(I))/(U(N)-U(1)))2,2,1
    1 CONTINUE
    2 Y=V(J-1)+(V(J)-V(J-1)) *((X-U(J-1))/(U(J)-U(J-1)))
      ISITOK=1
      GO TO 10
    3 WRITE(6,4)X,Y
    4 FORMAT(2X,15HTABLE TOO SMALL,5X,3HX= ,F13.5,5X,3HY= ,F13.5)
      ISITOK=-1
   10 RETURN
      END
```

A E R O J E T L I Q U I D R O C K E T C O M P A N Y

PROPELLANT VAPORIZATION ANALYSIS BASED ON COLD-FLOW LIQUID MASS DISTRIBUTION DATA

EDM LOL INJECTOR
TEST 171

NAMELIST INPUT

PC(PSIA)= 640 0 MRJ=2 800 CR=616 000 NPLANE= 3

IDO= 1 TO(R)= 200 0 VO(FT/SEC)= 44 0 RMO(IN)= 1186-02 TSO(R)= 270 0

IDF= 1 TF(R)= 584 0 VF(FT/SEC)= 71 0 RMF(IN)= 6430-03 TSF(R)= 665 0

COLD-FLOW INPUT

PLANE NO 1

J	XCO	DLCO	JOO	XCF	DLCF	JFO
25	0088	300	25	0023	300	25
26	0088	300	26	0125	300	26
35	0550	300	35	0130	300	35
36	0490	300	36	0023	300	36
44	0035	300	44	0110	300	44
45	2390	300	45	2150	300	45
46	2300	300	46	2720	300	46
47	0027	300	47	0079	300	47
54	0071	300	54	0150	300	54
55	1500	300	55	1530	300	55
56	1990	300	56	2380	300	56
57	0115	300	57	0180	300	57
67	0115	300	67	0057	300	67

PLANE NO 2

J	XCO	DLCO	JOO	XCF	DLCF	JFO
15	0109	800	25	0010	800	26
24	0150	800	35	0049	800	25
25	0260	800	35	0005	800	36
26	0097	800	26	0015	800	26
33	0050	800	44	0136	800	35
34	0380	800	44	0290	800	45
35	0630	800	45	0180	800	45
36	0220	800	36	0230	800	46
37	0017	800	47	0087	800	47
43	0067	800	54	0184	800	44
44	0840	800	45	0970	800	45
45	1930	800	45	2520	800	46
46	0800	800	46	1460	800	56
47	0067	800	46	0252	800	57
53	0109	800	55	0155	800	54
54	0881	800	55	0580	800	55
55	1180	800	56	0730	800	55
56	0990	800	56	0730	800	56
57	0180	800	46	0220	800	56
63	0100	800	55	0058	800	54
64	0190	800	55	0078	800	55
66	0190	800	56	0087	800	56
67	0230	800	57	0130	800	56
77	0100	800	56	0029	800	67

PLANE NO 3

J	XCO	DLCO	JOO	XCF	DLCF	JFO
23	0027	1 300	24	0085	1 300	33
24	0081	1 300	24	0061	1 300	24
25	0162	1 300	25	0006	1 300	25
26	0140	1 300	26	0006	1 300	26
33	0027	1 300	24	0097	1 300	33
34	0162	1 300	34	0195	1 300	34
35	0324	1 300	35	0182	1 300	35
36	0275	1 300	35	0201	1 300	36
37	0113	1 300	26	0067	1 300	26
38	0027	1 300	37	0109	1 300	37
43	0049	1 300	33	0128	1 300	43
44	0300	1 300	44	0400	1 300	44
45	0780	1 300	45	1030	1 300	45
46	0780	1 300	46	1370	1 300	45
47	0300	1 300	36	0730	1 300	46
48	0054	1 300	37	0230	1 300	46
53	0081	1 300	43	0122	1 300	53
54	0460	1 300	54	0400	1 300	44
55	0970	1 300	45	0730	1 300	55
56	0998	1 300	56	0850	1 300	56
57	0570	1 300	46	0580	1 300	46
58	0119	1 300	47	0210	1 300	46
63	0092	1 300	53	0073	1 300	53
64	0370	1 300	54	0190	1 300	54
65	0410	1 300	55	0150	1 300	55
66	0300	1 300	55	0150	1 300	66
67	0410	1 300	56	0210	1 300	57
68	0210	1 300	57	0160	1 300	47
73	0086	1 300	63	0043	1 300	63
74	0108	1 300	64	0036	1 300	64
77	0081	1 300	66	0030	1 300	67
78	0170	1 300	67	0085	1 300	57
88	0076	1 300	66	0024	1 300	77
89	0070	1 300	77	0128	1 300	67

AEROJET LIQUID ROCKET COMPANY

PROPELLANT VAPORIZATION ANALYSIS BASED ON COLD-FLOW LIQUID MASS DISTRIBUTION DATA

PLANE NO 1

J= 1 TO	10	LGO (IN)	000	000	000	000	000	000	000	000	000	000
		LGF (IN)	000	000	000	000	000	000	000	000	000	000
		TG (R)	0	0	0	0	0	0	0	0	0	0
		EVO	00	00	00	00	00	00	00	00	00	00
		EVF	00	00	00	00	00	00	00	00	00	00
		MRV	00	00	00	00	00	00	00	00	00	00
		MRL	00	00	00	00	00	00	00	00	00	00
J=11 TO	20	LGO (IN)	000	000	000	000	000	000	000	000	000	000
		LGF (IN)	000	000	000	000	000	000	000	000	000	000
		TG (R)	0	0	0	0	0	0	0	0	0	0
		EVO	00	00	00	00	00	00	00	00	00	00
		EVF	00	00	00	00	00	00	00	00	00	00
		MRV	00	00	00	00	00	00	00	00	00	00
		MRL	00	00	00	00	00	00	00	00	00	00
J=21 TO	30	LGO (IN)	000	000	000	000	767	670	000	000	000	000
		LGF (IN)	000	000	000	000	923	791	000	000	000	000
		TG (R)	0	0	0	0	5233 5	4744 8	0	0	0	0
		EVO	00	00	00	00	21 06	18 88	00	00	00	00
		EVF	00	00	00	00	24 32	21 59	00	00	00	00
		MRV	00	00	00	00	9 28	1 72	00	00	00	00
		MRL	00	00	00	00	11 17	2 04	00	00	00	00
J=31 TO	40	LGO (IN)	000	000	000	000	727	000	000	000	000	000
		LGF (IN)	000	000	000	000	868	000	000	000	000	000
		TG (R)	0	0	0	0	5014 5	270 0	0	0	0	0
		EVO	00	00	00	00	20 16	00	00	00	00	00
		EVF	00	00	00	00	23 19	00	00	00	00	00
		MRV	00	00	00	00	10 30	888 00	00	00	00	00
		MRL	00	00	00	00	12 31	999 00	00	00	00	00
J=41 TO	50	LGO (IN)	000	000	000	274	979	838	280	000	000	000
		LGF (IN)	000	000	000	277	1 238	1 020	285	000	000	000
		TG (R)	0	0	0	2374 6	6241 4	5546 4	2420 4	0	0	0
		EVO	00	00	00	8 60	25 46	22 58	8 78	00	00	00
		EVF	00	00	00	8 69	29 85	26 23	8 92	00	00	00
		MRV	00	00	00	88	2 66	2 04	94	00	00	00
		MRL	00	00	00	89	3 31	2 48	96	00	00	00

J=51 TO 60	LGO (IN)	000	000	000	074	937	829	574	000	000	000
	LGF (IN)	000	000	000	067	1 173	1 007	665	000	000	000
	TG (R)	0	0	0	4020 1	6012 5	5507 7	4297.6	0	0	.0
	EVO	00	00	00	2 15	24 60	22 40	16 63	00	00	00
	EVF	00	00	00	1 88	28 77	26 01	18 76	00	00	00
	MRV	00	00	00	1 51	2 35	2 02	1 59	00	00	00
	MRL	00	00	00	1 32	2 91	2 46	1 84	00	00	00
J=61 TO 70	LGO (IN)	000	000	000	000	000	000	952	000	000	000
	LGF (IN)	000	000	000	000	000	000	1 197	000	000	000
	TG (R)	0	0	0	0	0	0	6149 8	0	0	0
	EVO	00	00	00	00	00	00	24 92	00	00	00
	EVF	00	00	00	00	00	00	29 17	00	00	00
	MRV	00	00	00	00	00	00	4 83	00	00	00
	MRL	00	00	00	00	00	00	5 99	00	00	00
J=71 TO 80	LGO (IN)	000	000	000	000	000	000	000	000	000	000
	LGF (IN)	000	000	000	000	000	000	000	000	000	000
	TG (R)	0	0	0	0	0	0	0	.0	0	0
	EVO	00	00	00	00	00	00	.00	00	00	00
	EVF	00	00	00	00	00	00	00	00	00	00
	MRV	00	00	00	00	00	00	00	00	00	00
	MRL	00	00	00	00	00	00	00	00	00	00
J=81 TO 90	LGO (IN)	000	000	.000	000	.000	000	000	000	000	000
	LGF (IN)	000	000	000	000	000	000	000	000	000	000
	TG (R)	0	0	0	0	0	0	0	0	0	0
	EVO	00	00	00	00	00	00	00	00	00	00
	EVF	00	00	00	00	00	00	00	00	00	00
	MRV	00	00	00	00	00	00	00	00	00	00
	MRL	00	00	00	00	00	00	00	00	00	00
J=91 TO 100	LGO (IN)	000	000	000	000	000	000	000	000	000	000
	LGF (IN)	000	000	000	000	000	000	000	000	000	000
	TG (R)	0	0	0	0	0	0	0	0	0	0
	EVO	00	00	00	00	00	00	00	00	00	00
	EVF	00	00	00	00	00	00	00	00	00	00
	MRV	00	00	00	00	00	00	00	00	00	00
	MRL	00	00	00	00	00	00	00	00	00	00

AEROJET LIQUID ROCKET COMPANY

PROPELLANT VAPORIZATION ANALYSIS BASED ON COLD-FLOW LIQUID MASS DISTRIBUTION DATA

PLANE NO 2

J= 1 TO 10	LGO (IN)	000	000	000	000	000	000	000	000	000	000
	LGF (IN)	000	000	000	000	000	000	000	000	000	000
	TG (R)	0	0	0	0	0	0	0	0	0	0
	EVO	00	00	00	00	00	00	00	00	00	00
	EVF	00	00	00	00	00	00	00	00	00	00
	MRV	00	00	00	00	00	00	00	00	00	00
	MRL	00	00	00	00	00	00	00	00	00	00
J=11 TO 20	LGO (IN)	000	000	000	000	1 673	000	000	000	000	000
	LGF (IN)	000	000	000	000	1 600	000	000	000	000	000
	TG (R)	0	0	0	0	2234 0	0	0	0	0	0
	EVO	00	00	00	00	36 73	00	00	00	00	00
	EVF	00	00	00	00	35 66	00	00	00	00	00
	MRV	00	00	00	00	31 43	00	00	00	00	00
	MRL	00	00	00	00	30 01	00	00	00	00	00
J=21 TO 30	LGO (IN)	000	000	000	2 823	727	2 192	000	000	000	000
	LGF (IN)	000	000	000	3 580	000	2 586	000	000	000	000
	TG (R)	0	0	0	5591 5	5014 5	3807 2	0	0	0	0
	EVO	00	00	00	50 30	20 16	43 55	00	00	00	00
	EVF	00	00	00	56 72	00	47 77	00	00	00	00
	MRV	00	00	00	7 60	888 00	16 51	00	00	00	00
	MRL	00	00	00	9 84	999 00	19 57	00	00	00	00
J=31 TO 40	LGO (IN)	000	000	367	329	3 422	000	881	000	000	000
	LGF (IN)	000	000	1 398	3 841	4 202	1 020	867	000	000	000
	TG (R)	0	0	1945 0	2195 3	5318 4	5546 4	2131 6	0	0	0
	EVO	00	00	11 25	10 17	55 49	00	23 46	00	00	00
	EVF	00	00	32 51	58 76	61 21	26 23	23 17	00	00	00
	MRV	00	00	36	64	8 88	888 00	55	00	00	00
	MRL	00	00	1 35	7 99	11 25	00	55	00	00	00
J=41 TO 50	LGO (IN)	000	000	631	3 605	3 483	2 535	2 179	000	000	000
	LGF (IN)	000	000	521	4 469	3 763	2 945	1 808	000	000	000
	TG (R)	0	0	2791 8	5831 8	5593 0	3603 5	2339 4	0	0	0
	EVO	00	00	18 01	56 92	55 97	47 22	43 42	00	00	00
	EVF	00	00	15 29	62 82	58 15	51 61	38 70	00	00	00
	MRV	00	00	1 20	2 20	2 06	1 40	84	00	00	00
	MRL	00	00	99	2 81	2 26	1 67	69	00	00	00

J=51 TO 60	LGO (IN)	000	000	3 476	3 643	3 335	3 357	3 118	000	000	000
	LGF (IN)	000	000	2 304	4 531	4 520	4 124	3 794	000	000	000
	TG (R)	0	0	6118 0	6306 4	6296 1	6345 4	5629 0	0	0	0
	EVO	00	00	55 91	57 21	54 81	54 98	53 12	00	00	00
	EVF	00	00	44 76	63 19	63 12	60 75	58 39	00	00	00
	MRV	00	00	2 46	3 85	3 93	3 44	2 08	00	00	00
	MRL	00	00	1 57	4 94	5 55	4 35	2 58	00	00	00
J=61 TO 70	LGO (IN)	000	000	3 550	3 493	000	3 234	2 669	000	000	000
	LGF (IN)	000	000	2 402	4 311	000	3 954	4 071	000	000	000
	TG (R)	0	0	5932 9	5887 1	0	6014 4	6288 4	0	0	0
	EVO	00	00	56 49	56 05	00	54 02	48. 66	00	00	00
	EVF	00	00	45 80	61 87	00	59 64	60 43	00	.00	00
	MRV	00	00	5 95	6 18	00	5 54	3 99	00	00	00
	MRL	00	00	3 88	7 86	00	6 97	6 43	00	00	00
J=71 TO 80	LGO (IN)	000	000	000	000	000	000	3 005	000	000	000
	LGF (IN)	000	000	000	000	000	000	4 151	000	000	000
	TG (R)	0	0	0	0	0	0	5447 3	0	0	0
	EVO	00	00	00	00	00	00	52 24	00	00	00
	EVF	00	00	00	00	00	00	60 91	00	00	00
	MRV	00	00	00	00	00	00	8 28	00	00	00
	MRL	00	00	00	00	00	00	11 80	00	00	00
J=81 TO 90	LGO (IN)	000	000	000	000	000	000	000	000	000	000
	LGF (IN)	000	000	000	000	000	000	000	000	000	000
	TG (R)	0	0	0	0	0	0	0	0	0	0
	EVO	00	00	00	00	00	00	00	00	00	00
	EVF	00	00	00	00	00	00	00	00	00	00
	MRV	00	00	00	00	00	00	00	00	00	00
	MRL	00	00	00	00	00	00	00	00	00	00
J=91 TO 100	LGO (IN)	000	000	000	000	000	000	000	000	000	000
	LGF (IN)	000	000	000	000	000	000	000	000	000	000
	TG (R)	0	0	0	0	0	0	0	0	0	0
	EVO	00	00	00	00	00	00	00	00	00	00
	EVF	00	00	00	00	00	00	00	00	00	00
	MRV	00	00	00	00	00	00	00	00	00	00
	MRL	00	00	00	00	00	00	00	00	00	00

AEROJET LIQUID ROCKET COMPANY

PROPELLANT VAPORIZATION ANALYSIS BASED ON COLD-FLOW LIQUID MASS DISTRIBUTION DATA

PLANE NO 3

J= 1 TO	10	LGO (IN)	000	000	000	000	000	000	000	000	000	000
		LGF (IN)	000	000	000	000	000	000	000	000	000	000
		TG (R)	0	0	0	0	0	0	0	0	0	0
		EVO	00	00	00	00	00	00	00	00	00	00
		EVF	00	00	00	00	00	00	00	00	00	00
		MRV	00	00	00	00	00	00	00	00	00	00
		MRL	00	00	00	00	00	00	00	00	00	00
J=11 TO	20	LGO (IN)	000	000	000	000	1 673	000	000	000	000	000
		LGF (IN)	000	000	000	000	1 600	000	000	000	000	000
		TG (R)	0	0	0	0	2234 0	0	0	0	0	0
		EVO	00	00	00	00	36 73	00	00	00	00	00
		EVF	00	00	00	00	35 66	00	00	00	00	00
		MRV	00	00	00	00	00	00	00	00	00	00
		MRL	00	00	00	00	00	00	00	00	00	00
J=21 TO	30	LGO (IN)	000	000	4 592	6 982	1 334	3 357	000	000	000	000
		LGF (IN)	000	000	1 497	8 734	484	3 758	000	000	000	000
		TG (R)	0	0	4527 4	6343 3	270 0	1244 0	0	0	0	0
		EVO	00	00	63 55	74 43	31 45	54 98	00	00	00	00
		EVF	00	00	34 15	79 78	14 34	58 11	00	00	00	00
		MRV	00	00	1 66	3 47	165 80	61 81	00	00	00	00
		MRL	00	00	49	4 70	60 50	70 22	00	00	00	00
J=31 TO	40	LGO (IN)	000	000	4 107	369	7 295	7 329	5 346	1 773	000	000
		LGF (IN)	000	000	1 457	3 874	8 985	6 497	6 350	1 708	000	000
		TG (R)	0	0	3632 4	2041 5	6177 1	6287 7	6218 8	2249 5	0	0
		EVO	00	00	60 64	11 32	75 47	75 58	67 56	38 19	00	00
		EVF	00	00	33 49	59 02	80 46	72 49	71 90	37 24	00	00
		MRV	00	00	1 41	45	4 68	3 99	4 44	71	00	00
		MRL	00	00	46	5 03	6 26	3 40	5 45	68	00	00
=41 TO	50	LGO (IN)	000	000	1 219	7 344	7 158	2 940	1 992	1 182	000	000
		LGF (IN)	000	000	1 634	9 042	8 268	5 522	4 522	3 617	000	000
		TG (R)	0	0	2369 6	5405 8	5524 2	2798 3	2280 2	1914 6	0	0
		EVO	00	00	29 53	75 63	75 02	51 56	41 39	28 92	00	00
		EVF	00	00	36 16	80 59	78 52	68 35	63 13	57 02	00	00
		MRV	00	00	88	1 97	2 03	1 20	75	33	00	00
		MRL	00	00	1 18	2 64	2 47	2 44	1 83	1 09	00	00

J=51 TO 60	LGO (IN)	000	000	954	8 156	7 599	7 897	5 581	2.577	000	000
	LGF (IN)	000	000	4 636	9 809	10 298	9 922	6 577	3 750	000	000
	TG (R)	0	0	2260 9	6342 3	6346 5	6343 7	6214 5	3200 3	0	0
	EVO	00	00	24 96	78 22	76 48	77 46	68 61	47 68	00	00
	EVF	00	00	63 82	82 28	83 21	82 53	72 81	58 05	00	00
	MRV	00	00	73	3 06	3 42	3 09	2 59	1 30	00	00
	MRL	00	00	3 86	3 96	5 21	4 24	3 18	1.98	00	00
J=61 TO 70	LGO (IN)	000	000	7 871	8 000	7 491	7 693	7 750	7 243	000	000
	LGF (IN)	000	000	8 084	10 062	9 716	9 194	8 744	4 641	000	000
	TG (R)	0	0	6341 2	6094 7	5697 7	6058 0	6065 9	6234 8	0	0
	EVO	00	00	77 38	77 80	76 12	76 79	76 97	75 30	00	00
	EVF	00	00	78 03	82 81	82 08	80 93	79 81	63 84	.00	00
	MRV	00	00	3 50	5 12	7 10	5 31	5 27	4 33	00	00
	MRL	00	00	3 63	7 04	10 20	6 82	6 23	2.51	00	00
J=71 TO 80	LGO (IN)	000	000	7.645	7 329	000	000	7 232	7 130	000	000
	LGF (IN)	000	000	7 648	9 042	000	000	9 253	8 756	000	000
	TG (R)	0	0	6002 5	5533 1	0	0	5714 2	6069 2	0	0
	EVO	00	00	76 63	75 58	00	00	75 26	74.93	00	00
	EVF	00	00	76 64	80 59	00	00	81 06	79 84	00	00
	MRV	00	00	5 60	7 88	00	00	7 02	5 26	00	00
	MRL	00	00	5 60	10 57	00	00	9 87	6 97	00	00
J=81 TO 90	LGO (IN)	000	000	000	000	000	000	000	7 087	5 719	000
	LGF (IN)	000	000	000	000	000	000	000	8 513	7 767	000
	TG (R)	0	0	0	0	0	0	0	5427 4	3493 7	0
	EVO	00	00	00	00	00	00	00	74 79	69 23	00
	EVF	00	00	00	00	00	00	00	79 18	77 03	00
	MRV	00	00	00	00	00	00	00	8 37	1 38	00
	MRL	00	00	00	00	00	00	00	10 74	2 05	00
J=91 TO 100	LGO (IN)	000	000	000	000	000	000	000	000	000	000
	LGF (IN)	000	000	000	000	000	000	000	000	000	000
	TG (R)	0	0	0	0	0	0	0	0	0	0
	EVO	00	00	00	00	00	00	00	00	00	00
	EVF	00	00	00	00	00	00	00	00	00	00
	MRV	00	00	00	00	00	00	00	00	00	00
	MRL	00	00	00	00	00	00	00	00	00	00

^·QT VAPOR

D. VAPORIZATION ANALYSIS INPUT DATA

PLANE NO 1 OFO TRIPLET

J	XCO	DLCO	JOO	XCF	DLCF	JFO
45	1159	300	45	0132	300	45
46	2567	300	46	.7417	300	46
56	6123	300	56	2384	300	56

PLANE NO 2 OFO TRIPLET

J	XCO	DLCO	JOO	XCF	DLCF	JFO
43	0388	800	45	0000	800	43
44	0646	800	45	0083	800	45
45	0582	800	46	0647	800	46
46	1477	800	46	5304	800	46
47	0111	800	46	0165	800	46
55	0092	800	45	0041	800	45
56	1893	800	56	2342	800	56
57	2401	800	56	0964	800	46
58	0656	800	56	0028	800	46
62	0377	800	45	0096	800	56
63	0785	800	56	013d	800	46
63	0379	800	56	0028	800	46

PLANE NO 3 OFO TRIPLET

J	XCO	DLCO	JOO	XCF	DLCF	JFO
34	0066	1 300	45	0163	1.300	46
37	0000	1 300	37	0110	1 300	47
41	0516	1 300	42	0041	1 300	44
42	0308	1 300	43	.0218	1 300	45
43	0220	1 300	44	0705	1 300	46
44	0934	1 300	45	3266	1 300	46
45	0439	1 300	45	1008	1 300	46
46	0110	1 300	46	0245	1 300	46
53	0036	1 300	54	0056	1 300	55
54	[illegible]	1 300	55	0463	1 300	46
55	0035	1 300	56	0004	1 300	46
56	0934	1 300	56	.0817	1.300	57
57	0163	1 300	57	0041	1 300	58
63	0093	1 300	54	0109	1 300	56
64	0417	1 300	55	.0354	1.300	56
65	1285	1 300	55	0517	1 300	56
66	1560	1 300	56	0417	1 300	56
67	0939	1 300	57	.0068	1 300	56
68	0280	1 300	57	0007	1 300	68
73	0035	1 300	65	0395	1 300	56
74	0148	1 300	65	0116	1 300	56
75	0297	1 300	66	0082	1 300	66
76	0341	1 300	66	0068	1 300	67
77	0176	1 300	67	0014	1 300	68
83	0000	1 300	83	0110	1 300	56

PLANE NO. 1 TLOL

J	XCO	DLCO	JOO	XCF	DLCF	JFO
35	.0230	.300	35	.0017	.300	35
36	.0100	.300	36	.0010	.300	36
45	.1900	.300	45	.0086	.300	45
46	.1370	.300	46	.0140	.300	46
55	.2370	.300	55	.4450	.300	55
56	.2870	.300	56	.2660	.300	56
65	.0190	.300	65	.1120	.300	65
66	.0510	.300	66	.1200	.300	66
76	.0042	.300	76	.0076	.300	76

PLANE NO. 2 TLOL

J	XCO	DLCO	JOO	XCF	DLCF	JFO
25	.0150	.800	35	.0000	.800	35
35	.0360	.800	45	.0017	.800	35
36	.0500	.800	36	.0000	.800	36
37	.0092	.800	36	.0008	.800	36
45	.0540	.800	45	.0160	.800	45
46	.1620	.800	46	.0130	.800	46
47	.0170	.800	46	.0049	.800	46
55	.0870	.800	55	.1320	.800	55
56	.2460	.800	56	.3650	.800	56
57	.0310	.800	56	.0210	.800	56
65	.0440	.800	55	.0660	.800	55
66	.0960	.800	66	.2250	.800	66
67	.0530	.800	66	.0250	.800	66
75	.0060	.800	65	.0117	.800	65
76	.0007	.800	76	.0160	.800	76
77	.0210	.800	76	.0180	.800	76

PLANE NO. 3 TLOL

J	XCO	DLCO	JOC	XCF	DLCF	JFO
25	.0150	1.300	25	.0000	1.300	25
26	.0170	1.300	36	.0000	1.300	26
35	.0320	1.300	35	.0031	1.300	35
36	.0650	1.300	46	.0008	1.300	46
37	.0190	1.300	36	.0016	1.300	47
45	.0370	1.300	45	.0250	1.300	45
46	.1090	1.300	46	.0280	1.300	56
47	.0330	1.300	46	.0110	1.300	56
54	.0058	1.300	55	.0050	1.300	55
55	.0620	1.300	55	.0970	1.300	55
56	.1570	1.300	56	.2730	1.300	56
57	.0460	1.300	56	.0360	1.300	56
64	.0062	1.300	65	.0044	1.300	65
65	.0460	1.300	65	.0670	1.300	65
66	.0990	1.300	66	.2310	1.300	66
67	.0730	1.300	56	.0520	1.300	57
68	.0088	1.300	66	.0053	1.300	57
74	.0050	1.300	75	.0055	1.300	75
75	.0140	1.300	75	.0170	1.300	75
76	.0046	1.300	76	.0230	1.300	76
77	.0370	1.300	66	.0310	1.300	67
78	.0140	1.300	66	.0110	1.300	67
87	.0045	1.300	76	.0064	1.300	77
88	.0120	1.300	76	.0078	1.300	77

PLANE NO 1 EDM-LOL

J	XCO	DLCO	JOO	XCF	DLCF	JFO
25	0058	300	25	0023	300	25
26	0088	300	26	.0125	.300	26
35	0150	300	35	0130	300	35
36	0450	300	36	0023	300	36
44	0035	300	44	.0110	300	44
45	2390	300	45	.2150	300	45
46	2300	300	46	2720	.300	46
47	0027	300	47	0079	300	47
54	0071	300	54	0150	300	54
55	1500	300	55	1530	.300	55
56	1470	300	56	2380	300	56
57	0115	300	57	.0180	300	57
67	0115	300	67	0057	300	67

PLANE NO 2

EDM-LOL

J	XCO	DLCO	JDO	XCF	DLCF	JFO
15	0109	800	25	.0010	.800	26
24	0150	800	35	.0049	.800	25
25	0260	800	35	.0005	.800	36
26	0097	800	26	.0015	.800	26
33	0050	800	44	0136	800	35
34	0380	800	44	0290	.800	45
35	0630	800	45	0180	.800	45
36	0220	800	36	0230	.800	46
37	0017	800	47	0087	800	47
43	0067	800	54	0184	800	44
44	0840	800	45	0970	800	45
45	1930	800	45	2520	.800	46
46	0800	800	46	1460	.800	56
47	0067	800	46	0252	800	57
53	0109	800	55	0155	800	54
54	0881	800	55	0580	.800	55
55	1120	800	56	0730	800	55
56	0940	800	56	0730	800	56
57	0180	800	46	0220	.800	56
63	0100	800	55	0058	800	54
64	0190	800	55	0078	800	55
66	0190	800	56	0087	800	56
67	0230	800	57	0130	800	56
77	0100	800	56	0029	800	67

PLANE NO 3

EDM-LOL

J	XCO	DLCO	JJO	XCF	DLCF	JFO
23	0027	1 300	24	0085	1.300	33
24	0061	1 300	24	0061	1.300	24
25	0162	1 300	25	0006	1 300	25
26	0140	1 300	26	0006	1 300	26
33	0027	1 300	24	0097	1.300	33
34	0162	1 300	34	0195	1 300	34
35	0364	1 300	35	0182	1.300	35
36	0275	1 300	35	0201	1 300	36
37	0110	1 300	26	0067	1 300	26
36	0027	1 300	37	0109	1 300	37
43	0049	1 300	33	0123	1 300	43
44	0400	1 300	44	0400	1 300	44
45	0763	1 300	45	1030	1 300	45
46	0760	1 300	46	1370	1 300	45
47	0300	1 300	36	0730	1 300	46
48	0054	1 300	37	0230	1 300	46
53	0061	1 300	43	0122	1.300	53
54	0460	1 300	54	0400	1 300	44
55	0470	1 300	45	0730	1 300	55
56	0492	1 300	56	0850	1 300	56
57	0570	1 300	46	0580	1 300	46
58	0119	1 300	47	0210	1.300	46
63	0092	1 300	53	0073	1 300	53
64	0370	1 300	54	0190	1 300	54
65	0410	1 300	55	0150	1 300	55
66	0300	1 300	55	0150	1.300	66
67	0410	1 300	56	0210	1.300	57
68	0210	. 300	57	0160	1.300	47
73	0086	1 300	63	0043	1.300	63
74	0106	1 300	64	0036	1 300	64
77	0081	1 300	66	0030	1.300	67
78	0170	1 300	67	0085	1 300	57
83	0076	1 300	66	0024	1 300	77
87	0070	1 300	77	0128	1.300	67

PLANE NO. 1 PAT

J	XCO	DLCO	JOO	XCF	DLCF	JFO
35	.0000	.300	35	.0690	.300	35
36	.0000	.300	36	.0320	.300	36
44	.0270	.300	44	.0000	.300	44
45	.3270	.300	45	.2010	.300	45
46	.1410	.300	46	.1500	.300	46
47	.0220	.300	47	.0000	.300	47
53	.0120	.300	53	.0000	.300	53
54	.0460	.300	54	.0000	.300	54
55	.2020	.300	55	.2440	.300	55
56	.1410	.300	56	.1780	.300	56
57	.0240	.300	57	.0000	.300	57
65	.0094	.300	65	.0600	.300	65
66	.0674	.300	66	.0390	.300	66

PLANE NO. 2 PAT

J	XCO	DLCO	JOO	XCF	DLCF	JFO
25	.0000	.800	35	.0134	.800	35
26	.0000	.800	36	.0210	.800	36
35	.0350	.800	45	.0450	.800	35
36	.0240	.800	46	.0740	.800	36
37	.0070	.800	47	.0120	.800	36
44	.0370	.800	44	.0054	.800	45
45	.2040	.800	45	.2213	.800	45
46	.3180	.800	46	.2358	.800	46
47	.0870	.800	47	.1161	.800	46
48	.0210	.800	47	.0000	.800	48
53	.0130	.800	53	.0000	.800	53
54	.0250	.800	54	.0027	.800	55
55	.0400	.800	55	.0530	.800	55
56	.0840	.800	56	.1070	.800	56
57	.0330	.800	57	.0400	.800	56
58	.0130	.800	57	.0000	.800	58
65	.0094	.800	65	.0103	.800	65
66	.0067	.800	66	.0290	.800	66

PLANE NO. 3 PAT

J	XCO	DLCO	JOO	XCF	DLCF	JFO
25	.0000	1.300	25	.0130	1.300	25
26	.0000	1.300	26	.0110	1.300	26
34	.0260	1.300	35	.0240	1.300	35
35	.0440	1.300	35	.0480	1.300	35
36	.0182	1.300	36	.0280	1.300	36
37	.0078	1.300	37	.0130	1.300	37
43	.0190	1.300	44	.0022	1.300	44
44	.0770	1.300	45	.0632	1.300	45
45	.1970	1.300	45	.1902	1.300	45
46	.1640	1.300	46	.1640	1.300	46
47	.0550	1.300	47	.0830	1.300	47
48	.0170	1.300	48	.0031	1.300	47
53	.0180	1.300	53	.0022	1.300	54
54	.0330	1.300	54	.0280	1.300	55
55	.0840	1.300	55	.0810	1.300	55
56	.1080	1.300	56	.1030	1.300	56
57	.0380	1.300	57	.0480	1.300	57
58	.0120	1.300	58	.0020	1.300	57
65	.0055	1.300	65	.0190	1.300	65
66	.0055	1.300	66	.0240	1.300	66

INJECTOR	TEST NO	PC	MRJ	CR	NPLANE	IDO	IDF	TO	TF	VO	VF	RMO	RMF	TSO	TSF
OFO	101	475	2.40	490	3	1	2	208	520	80	91	2.924×10^{-4}	6.797×10^{-4}	255	1218
OFO	105	480	2.80	251	3	1	2	185	510	112	116	$2\ 716 \times 10^{-4}$	5.714×10^{-4}	256	1218
OFO	106	480	2 80	251	3	1	2	185	510	112	116	$2\ 716 \times 10^{-4}$	$5\ 714 \times 10^{-4}$	256	1218
OFO	109	475	2.40	490	3	1	2	208	520	80	91	$2\ 924 \times 10^{-4}$	6.797×10^{-4}	255	1218
OFO	110	480	2 70	176	3	1	2	205	525	162	164	1.892×10^{-4}	4.316×10^{-4}	256	1218
OFO	111	480	2.70	176	3	1	2	205	525	162	164	1.892×10^{-4}	4.316×10^{-4}	256	1218
OFO	116	1500	2.60	963	3	1	2	205	510	95	100	2.925×10^{-4}	6.416×10^{-4}	278	1218
TLOL	120	135	2.35	122	3	1	2	199	505	46	58	$1\ 495 \times 10^{-3}$	2.889×10^{-3}	212	1100
TLOL	121	310	2 80	212	3	1	2	227	491	55	51	1.108×10^{-3}	3.347×10^{-3}	245	1210
TLOL	122	800	2 75	349	3	1	2	188	503	82	92	$1\ 090 \times 10^{-3}$	2.131×10^{-3}	278	1218
TLOL	123	475	2 65	270	3	1	2	209	498	78	83	9.920×10^{-4}	2.354×10^{-3}	255	1218
TLOL	124	475	2 65	270	3	1	2	209	498	78	83	9.920×10^{-4}	2.354×10^{-3}	255	1218
TLOL	127	250	2.85	212	3	1	2	189	489	45	48	1.621×10^{-3}	3.484×10^{-3}	222	1180
TLOL	128	400	3 00	251	3	1	2	188	493	62	62	1.311×10^{-3}	2.900×10^{-3}	250	1218
TLOL	129	800	2 75	349	3	1	2	188	503	82	92	$1\ 090 \times 10^{-3}$	2.131×10^{-3}	278	1218
TLOL	130	135	2 50	176	3	1	1	192	505	24	64	2.444×10^{-3}	1.164×10^{-3}	212	530
TLOL	131	290	2 65	270	3	1	1	185	502	44	80	1.693×10^{-3}	1.009×10^{-3}	238	595
TLOL	132	540	3 00	349	3	1	1	186	504	61	99	1.365×10^{-3}	8.730×10^{-4}	260	655
TLOL	133	790	2.80	428	3	1	1	186	505	40	122	$1\ 803 \times 10^{-3}$	7.600×10^{-4}	278	666
EDM-LOL	157	800	2.80	349	3	1	1	190	506	89	131	8.380×10^{-4}	5.660×10^{-4}	278	666
EDM-LOL	158	560	2.85	322	3	1	1	180	488	72	101	9.640×10^{-4}	7.110×10^{-4}	263	645
EDM-LOL	159	295	2.90	212	3	1	1	185	500	61	85	1.075×10^{-3}	7.570×10^{-4}	237	595
EDM-LOL	160	150	2 80	176	3	1	1	210	490	52	68	$1\ 000 \times 10^{-3}$	$9\ 230 \times 10^{-4}$	215	540
EDM-LOL	161	800	2 90	349	3	1	1	185	520	93	133	$8\ 140 \times 10^{-4}$	$5\ 370 \times 10^{-4}$	278	666
EDM-LOL	162	550	2 95	322	3	1	1	195	521	76	104	$8\ 560 \times 10^{-4}$	$6\ 310 \times 10^{-4}$	263	640
EDM-LOL	164	290	2 90	212	3	1	1	195	538	64	92	$9\ 570 \times 10^{-4}$	6.500×10^{-4}	238	595
EDM-LOL	165	800	2 85	428	3	1	1	194	607	84	144	$7\ 950 \times 10^{-4}$	$3\ 530 \times 10^{-4}$	278	666
EDM-LOL	168	550	2 90	349	3	1	1	184	617	67	122	$1\ 011 \times 10^{-3}$	$3\ 680 \times 10^{-4}$	263	640
EDM-LOL	169	320	3 10	270	3	1	1	190	616	70	119	$9\ 820 \times 10^{-4}$	$3\ 740 \times 10^{-4}$	240	605
EDM-LOL	171	640	2 80	616	3	1	1	200	584	44	71	$1\ 186 \times 10^{-3}$	$6\ 430 \times 10^{-4}$	270	665

INJECTOR	TEST NO.	PC	MRJ	CR	NPLANE	IDO	IDF	TO	TF	VO	VF	RMO	RMF	TSO	TSF
PAT	178	560	2 75	349	3	1	1	180	530	60	132	7.820×10^{-4}	$2\ 580 \times 10^{-4}$	264	660
PAT	179	300	2 85	279	3	1	1	190	526	42	95	$6\ 300 \times 10^{-4}$	$2\ 400 \times 10^{-4}$	230	600
PAT	182	150	2.90	212	3	1	1	180	525	31	65	$1\ 210 \times 10^{-3}$	$4\ 120 \times 10^{-4}$	215	540
PAT	184	300	2 85	279	3	1	1	190	526	42	95	6.300×10^{-4}	$2\ 400 \times 10^{-4}$	230	600
PAT	187	800	2 90	754	3	1	1	190	527	45	94	9.480×10^{-4}	$3\ 230 \times 10^{-4}$	278	666
PAT	189	150	2 90	212	3	1	1	180	525	31	65	$1\ 210 \times 10^{-3}$	$4\ 120 \times 10^{-4}$	215	540
PAT	190	165	2.75	109	3	1	1	180	525	65	143	7.420×10^{-4}	$2\ 450 \times 10^{-4}$	220	550
PAT	193	560	2 80	349	3	1	1	185	580	60	161	7.820×10^{-4}	$1\ 920 \times 10^{-4}$	264	660
PAT	194	340	3 00	270	3	1	1	190	578	57	136	8.090×10^{-4}	2.140×10^{-4}	243	610
PAT	197	505	3 00	349	3	1	1	180	504	62	122	7.660×10^{-4}	2.920×10^{-4}	260	640

E. PREDICTED FUEL VAPORIZATION AND LIQUID PHASE MIXTURE RATIO

TEST NO 105 INJECTOR OFO

GRID NO.	PLANE NO. 1		PLANE NO. 2		PLANE NO. 3	
	EVF	MRL	EVF	MRL	EVF	MRL
34					65.46	0.03
37					41.73	0
41					0	∞
42					52.16	8.26
43			0	∞	56.98	2 01
44			0	∞	58.81	0 05
45	0	∞	40.89	0.24	66.00	0 03
46	15.85	0 35	55.78	0	66.25	0.00
47			41.73	0.16	41.73	0
53					19.74	1.04
54					55 78	0
55			0	∞	61.03	59 05
56	0	∞	0	0	29.27	2 17
57			15.85	∞	15.90	15.64
58			15.85	∞	15.85	0
63					18.41	1.43
64					0	∞
65					0	∞
66			0	∞	0	∞
67			15.85	∞	0	∞
68			15.85	∞	15.85	∞
73					1.06	0.35
74					0	∞
75					0	∞
76					15.88	16 26
77					15.64	41.20
83					0	0
DEPTH AVG						
J=1					0	∞
2					52.16	8 26
3			0	∞	31.70	1 41
4			0	∞	52 40	0 03
5	0	∞	38.45	0 21	41.45	0.83
6	11.99	0 15	38.21	0	26.65	2 46
7			5.43	0 01	23.44	7.46
8			0	∞	15.85	∞
9						
10						
PLANE AVG.	11 84	0 14	33 47	0 02	42 26	2 00

TEST NO 109 INJECTOR: OFO

GRID NO	PLANE NO. 1		PLANE NO. 2		PLANE NO. 3	
	EVF	MRL	EVF	MRL	EVF	MRL
34					50.72	0.02
37					31.91	0
41					0	∞
42					40.84	5.73
43			0	∞	36.19	1 17
44			0	∞	47.18	1.42
45	0	∞	31.14	0.22	51.12	0 02
46	10.98	0.32	91.95	0.06	51.28	0.02
47			31.91	0.15	31.91	0
53					15.07	0 86
54					38.03	2 30
55			0	∞	47.27	37 87
56	0	∞	0	∞	21.94	1 74
57			10.98	∞	10.99	12.74
58			10.98	∞	10.98	0
63					13.90	1.20
64					0	∞
65					0	∞
66			0	∞	0	∞
67			10.98	∞	0	∞
68			10.98	∞	10.98	∞
73					1.10	0.30
74					0	∞
75					0	∞
76					10.98	13.24
77					10.92	33.56
83					0	0

DEPTH AVG						
J=1						
2					40.84	5.73
3			0	∞	20.53	0 90
4			0	∞	41.26	0 31
5	0	∞	29.28	0.20	32.10	0.52
6	8.31	0.14	21.89	0 03	20.19	1.98
7			4.16	0.01	17.65	6 06
8			0	∞	0	∞
9						
10						
PLANE AVG.	8.20	0.13	19.81	0.03	32.37	1 59

TEST NO. 110/111 INJECTOR· OFO

GRID NO	PLANE NO. 1		PLANE NO. 2		PLANE NO. 3	
	EVF	MRL	EVF	MRL	EVF	MRL
34					65.84	0
37					51.22	0
41					0	∞
42					50.47	∞
43			0	∞	54.49	1.83
44			0	∞	55.83	0
45	0	∞	50.47	0 03	66.56	0
46	20.99	0.16	52.64	0	66.88	0
47			51.22	0.02	51.22	0
53					24.47	0.96
54					52.64	0
55			0	∞	60.15	33.76
56	0	∞	16.25	1 22	21.60	0.03
57			20.99	∞	21.16	15.91
58			20.99	∞	20.99	0
63					59.53	2.44
64					16.25	∞
65					16.25	∞
66			0	∞	46.20	1.53
67			20.99	∞	42.93	67 07
68			20.99	∞	20.99	∞
73					25.73	0.51
74					16.25	∞
75					0	∞
76					21.13	16.54
77					20.67	42.01
83					16.25	0
DEPTH AVG.						
J=1						
2					50.47	∞
3			0	∞	42.26	1 49
4			0	∞	51.60	0
5	0	∞	47.46	0.03	47 01	0.11
6	15.88	0.07	40.98	0.51	35.38	2.48
7			24.93	0	41.68	54.53
8			20.99	∞	20.99	∞
9						
10						
PLANE AVG	15.67	0.06	38.91	0 25	46.25	6.78

TEST NO. 116 INJECTOR: OFO

GRID NO.	PLANE NO. 1		PLANE NO. 2		PLANE NO. 3	
	EVF	MRL	EVF	MRL	EVF	MRL
34					63.06	0
37					47 44	0
41					0	∞
42					64.43	10 32
43			0	∞	56.59	1.85
44			0	∞	57.87	1.28
45	0	∞	46.55	0.06	65.66	0
46	18.57	0.18	55.70	0	65.85	0
47			47.44	0.04	47.44	0
53					23.55	0.88
54			0	∞	55.70	0
55			14.80	1.17	60.85	8.47
56	0	∞	18.57	∞	18.69	0.11
57			18.57	∞	18.72	14 85
58					18.57	0
63					23.55	0.88
64					55.70	0
65					60.85	8 47
66			0	∞	18.69	0.11
67			18.57	∞	18.72	14 85
68			18.57	∞	18.57	0
73					55.00	2.05
74					34.22	4.65
75					14.80	∞
76					41.32	1 65
77					41.57	63.08
83					18.57	∞

DEPTH AVG.

J=1						
2					64.43	0 01
3			0	0	42.49	0 61
4			0	0	54.77	0.86
5	0	0	43.78	4.38	45.92	0.97
6	14.05	1.76	42.64	3.77	32 26	16.12
7			22.33	0.17	30.94	1 99
8			18 57	0	18.57	0
9						
10						
PLANE AVG	13.87	1 60	39 60	2.22	47.31	4 96

TEST NO. 120 INJECTOR· TLOL

GRID NO	PLANE NO 1		PLANE NO 2		PLANE NO 3	
	EVF	MRL	EVF	MRL	EVF	MRL
25			0	∞	0	∞
26					0	∞
35	0	∞	0	∞	0	∞
36	0	∞	0	∞	0	∞
37			0	∞	0	∞
45	0	∞	0	∞	0	∞
46	0	∞	0	∞	0	∞
47			0	∞	0	∞
54					0	∞
55	0	0	0	0	0	0
56	0	∞	0	0	0	0
57			0	∞	0	∞
64					0	∞
65	1.03	0.35	0	0	0	0
66	0.70	0.91	4.11	0.74	9.97	0.53
67			0.75	4.49	0	∞
68					0	∞
74					9.37	1.15
75			4.84	1.12	9.51	1.04
76	0	0	0.09	0.10	7.15	0.28
77			0	∞	0.75	1.82
78					0.76	1.95
87					0	0
88					0	∞

DEPTH AVG.						
I=0						
1						
2			0	∞	0	∞
3	0	∞	0	∞	0	∞
4	0	∞	0	∞	0	∞
5	0	0	0	0	0	0
6	0.86	0.69	2.99	1.31	6.40	0.27
7	0	0	1.27	0.31	4.68	1.45
8					0	
9						
PLANE AVG.	0 20	0.07	1 09	0.33	2.88	0.20

TEST NO. 121 INJECTOR· TLOL

GRID NO.	PLANE NO. 1		PLANE NO. 2		PLANE NO 3	
	EVF	MRL	EVF	MRL	EVF	MRL
25			0	∞	0	∞
26					0	∞
35	0	∞	0	∞	0	∞
36	0	∞	0	∞	0	∞
37			0	∞	0	∞
45	0	∞	0	∞	0	∞
46	0	∞	0	∞	0	∞
47			0	∞	0	∞
54					0	∞
55	0	0	0	0	0	0
56	0	∞	0	0	0	0
57			0	∞	0	∞
64					0	∞
65	1.13	0.37	0	0	0	0
66	0	0	0	0	0	0
67			0	∞	0	∞
68					0	∞
74					1.41	1 90
75			1 40	1.45	1.42	1.72
76	0	0	0.47	0.11	9.03	0.19
77			0	∞	0	∞
78					0	∞
87					0	
88					0	∞

DEPTH AVG.						
I=0						
1						
2			0	∞	0	∞
3	0	∞	0	∞	0	∞
4	0	∞	0	∞	0	∞
5	0		0		0	
6	0.55	0.14	0	0	0	-
7	0	0	0.52	0.40	2.74	0 47
8					0	-
9						
PLANE AVG.	0.13	0.01	0.03	0 01	0.25	0 04

TEST NO 123/124 INJECTOR· TLOL

GRID NO	PLANE NO 1		PLANE NO 2		PLANE NO. 3	
	EVF	MRL	EVF	MRL	EVF	MRL
25			0	∞	0	∞
26					0	∞
35	0	∞	0	∞	0	∞
36	0	∞	0	∞	0	∞
37			0	∞	0	∞
45	0	∞	0	∞	0	∞
46	0	∞	0	∞	0	∞
47		∞	0	∞	0	∞
54					0	∞
55	0	0	0	0	0	0
56	0	∞	0	0	0	0
57			0	∞	0	∞
64					0	∞
65	2.16	0.34	0	0	0	0
66	1.37	0 94	6.77	0.65	15.69	0.37
67			1.51	4.59	0	∞
68					0	∞
74					14.80	0.83
75			8.09	0.92	15.01	0.74
76	0	0	0.31	0.11	12.02	0.19
77			0	∞	1.52	1.50
78					1.52	1 60
87					0	0
88					0	∞

DEPTH AVG.

I=0						
1						
2			0	∞	0	∞
3	0	∞	0	∞	0	∞
4	0	∞	0	∞	0	∞
5	0	-	4 77	0.45	0	-
6	1.75	0.71	4.94	1.29	10.18	0.19
7	0	0	3.18	0.26	7.74	1.17
8					0	-
9						
PLANE AVG.	0.42	0.07	4.50	0 52	4 61	0.15

TEST NO: 127 INJECTOR: TLOL

GRID NO.	PLANE NO. 1		PLANE NO. 2		PLANE NO. 3	
	EVF	MRL	EVF	MRL	EVF	MRL
25			0	∞	0	∞
26					0	∞
35	0	∞	0	∞	0	∞
36	0	∞	0	∞	0	∞
37			0	∞	0	∞
45	0	∞	0	∞	0	∞
46	0	∞	0	∞	0	∞
47			0	∞	0	∞
54					0	∞
55	0	0	0	0	0	0
56	0	∞	0	0	0	0
57			0	∞	0	∞
64					0	∞
65	1.04	0.43	0	0	0	0
66	0	0			0	0
67					0	∞
68					0	∞
74					8.72	1 45
75			4.69	1.38	8.09	1.30
76	0	0	0.20	0 12	7.62	0.34
77			0	∞	0	∞
78					0	∞
87					0	0
88					0	∞

DEPTH AVG.						
I=0						
1						
2			0	∞	0	∞
3	0	∞	0	∞	0	∞
4	0	∞	0	∞	0	∞
5	0	-	0	-	0	-
6	0.50	0.17	0	-	0	-
7	0	0	1.27	0.38	6.80	1.24
8					0	-
9						
PLANE AVG.	0.12	0.02	0.06	0.01	0.63	0.10

TEST NO. 128 INJECTOR: TLOL

GRID NO	PLANE NO. 1		PLANE NO. 2		PLANE NO. 3	
	EVF	MRL	EVF	MRL	EVF	MRL
25			0	∞	0	∞
26					0	∞
35	0	∞	0	∞	0	∞
36	0	∞	0	∞	0	∞
37			0	∞	0	∞
45	0	∞	0	∞	0	∞
46	0	∞	0	∞	0	∞
47			0	∞	0	∞
54					0	∞
55	0	0	0	0	0	0
56	0	∞	0	0	0	0
57			0	∞	0	∞
64					0	∞
65	1.71	0.43	0	0	0	0
66	1.09	1 13	5.72	0.87	13.43	0.58
67			1.20	5.54	0	∞
68					0	∞
74					12.42	1 29
75			6.88	1.29	12.63	1 15
76	0	0	0.26	0.13	10.28	0.30
77			0	∞	1.22	2.10
78					1.22	2.25
87					0	0
88					0	∞

DEPTH AVG.						
I=0						
1						
2			0	∞	0	∞
3	0	∞	0	∞	0	∞
4	0	∞	0	∞	0	∞
5	0	-	0	-	0	-
6	1.39	0.86	4.17	1.64	8.62	0 29
7	0	0	1.85	0.36	6.52	1.68
8					0	-
9						
PLANE AVG.	0.33	0 08	1.53	0.41	3 90	0 22

TEST NO· 129 INJECTOR· TLOL

GRID NO	PLANE NO. 1		PLANE NO 2		PLANE NO 3	
	EVF	MRL	EVF	MRL	EVF	MRL
25			0	∞	0	∞
26					0	∞
35	0	∞	0	∞	0	∞
36	0	∞	0	∞	0	∞
37			0	∞	0	∞
45	0	∞	0	∞	0	∞
46	0	∞	0	∞	0	∞
47			0	∞	0	∞
54					18.91	1.22
55	2.36	1.22	9.50	1.05	20.44	0.62
56	0	∞	0	0	0	0
57			0	∞	0	∞
64					18.16	1.53
65	3.55	0.36	9.48	1.06	20.25	0.68
66	2 72	0 95	11.06	0.62	23.21	0.37
67			3.41	4.48	0	∞
68					0	∞
74					21.86	0 82
75			12.09	0.94	22.09	0.74
76	2.29	1.27	6.55	0.08	14.71	0.25
77			7.91	2.01	3.41	1.35
78					3.41	1.46
87					16.83	0.93
88					14.37	2.25

DEPTH AVG.						
I=0						
1						
2			0	∞	0	∞
3	0	∞	0	∞	0	∞
4	0	∞	0	∞	0	∞
5	1.48	0.62	2 42	0.26	5.05	0 17
6	3.12	0 72	10.12	1.50	18.90	0 35
7	2.29	1 27	8.50	1.46	11.14	1.08
8					15.48	1.83
9						
PLANE AVG.	1.84	0.38	5.27	0.53	10 69	0.28

TEST NO. 130 INJECTOR: TLOL

GRID NO.	PLANE NO. 1		PLANE NO 2		PLANE NO. 3	
	EVF	MRL	EVF	MRL	EVF	MRL
25			0	∞	0	∞
26					0	∞
35	0	∞	0	∞	0	∞
36	0	∞	0	∞	0	∞
37			0	∞	18.45	35.97
45	0	∞	7.10	7.32	28.61	3.44
46	0	∞	0	∞	22.46	∞
47			6.66	8.48	22.46	∞
54					36.00	2.64
55	5.44	1.31	18.62	1.57	34.13	1.46
56	7 52	2.65	22.46	1.60	35.98	1.30
57			23.24	3.48	38.50	2.88
64					36.04	3.20
65	1 95	0.42	18.69	1.59	34.76	1.57
66	1.72	1.06	4.87	1.05	7.39	1.04
67			15.54	5 09	39.86	3 24
68					39.14	4 91
74					32.36	2 08
75			12.36	1.65	32.07	1 89
76	5.69	1.36	13.39	0.11	17.97	0 47
77			20.18	2.77	34.49	3.23
78					34.42	3.45
87					24.39	1 94
88					37.91	4.31

DEPTH AVG.						
I=0						
1						
2			0	∞	0	∞
3	0	∞	0	∞	5.37	5.98
4	0	∞	4.47	2 46	24.86	0.79
5	6.22	1.96	21.51	1.72	35.76	1 58
6	1.83	0 81	8.60	1.97	18.00	1.85
7	5 69	1.36	15.80	2.08	29.53	2.59
8					31.82	3 56
9						
PLANE AVG.	5.01	1.05	16.06	1.79	27.42	2 01

TEST NO 131 INJECTOR: TLOL

GRID NO.	PLANE NO. 1		PLANE NO 2		PLANE NO. 3	
	EVF	MRL	EVF	MRL	EVF	MRL
25			0	∞	0	∞
26					0	∞
35	0	∞	0	∞	0	∞
36	0	∞	0	∞	0	∞
37			0	∞	8.62	∞
45	0	∞	9.28	7.69	36.01	3.52
46	0	∞	0	∞	29.80	∞
47			8.62	8.90	29.80	∞
54					46.21	2.70
55	8.17	1.38	25.89	1.64	44.22	1.50
56	10.56	2.78	29.80	1.67	45.84	1.34
57			30.74	3.63	48.54	2.94
64					46.17	3.28
65	8.74	0.44	25.96	1.65	44.93	1.60
66	5.83	1.11	11.68	1.09	18.87	1.06
67			22.66	5.28	49.97	3 33
68					52.65	5.72
74					41.92	2 14
75			16.91	1.72	41.61	1.94
76	8.50	1.43	18.89	0.11	24.34	0.49
77			27.79	2.89	45.07	3.40
78					44.97	3 63
87					33.53	2 15
88					48.14	4.78

DEPTH AVG.						
I=0						
1						
2			0	∞	0	∞
3	0	∞	0	∞	2.51	∞
4	0	∞	5.83	2.58	32.23	0.80
5	9 06	2.06	28 84	1 80	45.70	1.63
6	4.34	0.85	15.53	2.05	29.05	1.92
7	8.50	1.43	21.89	2.18	38.74	2.72
8					41.56	3.95
9						
PLANE AVG.	7.70	1.10	22 94	1.87	37.46	1.52

TEST NO 132 INJECTOR: TLOL

GRID NO	PLANE NO 1		PLANE NO. 2		PLANE NO 3	
	EVF	MRL	EVF	MRL	EVF	MRL
25			0	∞	0	∞
26					0	∞
35	0	∞	0	∞	0	∞
36	0	∞	0	∞	0	∞
37			0	∞	0	∞
45	0	∞	11.60	8 62	44.45	3 89
46	0	∞	0		39.53	∞
47			0		39.53	∞
54					59.07	2 89
55	12.93	1 54	36.44	1.77	57.26	1.60
56	14.93	3.10	39 53	1.81	57.88	1.42
57			39.66	3.92	60.40	3.14
64					58.94	3.51
65	4.06	0.50	36.51	1.79	57.91	1.72
66	9.95	1.24	27.43	1.17	38.98	1.13
67			31.58	5.78	60.56	3.47
68					59.61	5.40
74					53.58	2.28
75			23.46	1.90	53.38	2.06
76	13.28	1 60	26.93	0.12	33.26	0.53
77			37.67	3.12	56.42	3 49
78					56.32	3.72
87					45.76	2.60
88					47.33	5.87

DEPTH AVG.						
I=0						
1						
2			0	∞	0	∞
3	0	∞	0	∞	0	∞
4	0	∞	5.82	2 11	41.45	0 88
5	13.68	2.31	38.75	1.95	57.97	1.73
6	7.11	0.96	29 65	2.25	46.17	2 02
7	13.28	1 60	30.27	2.39	49.55	2 83
8					46.62	4.85
PLANE AVG.	11.76	1.21	33.80	1.90	51.05	1.61

TEST NO. 133 INJECTOR. TLOL

GRID NO.	PLANE NO 1		PLANE NO. 2		PLANE NO 3	
	EVF	MRL	EVF	MRL	EVF	MRL
25			0	∞	0	∞
26					0	∞
35	0	∞	0	∞	0	∞
36	0	∞	0	∞	0	∞
37			0	∞	13.60	∞
45	0	∞	14.70	8.12	52.61	3.79
46	0	∞	0		45.18	
47			13.60	9.40	45.18	∞
54					62.51	2.96
55	12.63	1.46	36.98	1.74	59.03	1.64
56	18.65	2.95	45.18	1.80	62.25	1.47
57			47.12	3.91	66.02	3.25
64					62.54	3 60
65	4.82	0.47	37.13	1.76	60.04	1.76
66	4.20	1.18	13.48	1.15	18.04	1.14
67			31.96	5.65	68.39	3.86
68					77.09	11 32
74					58.56	2.34
75			25.66	1.82	57.87	2.12
76	13.28	1.52	27.20	0.12	34.61	0.52
77			40.47	3.08	61.07	4 23
78					60.89	4.51
87					50.60	2.75
88					56.91	6 91

DEPTH AVG.						
I=0						
1						
2			0	∞	0	∞
3	0	∞	0	∞	3.96	∞
4	0	∞	9.23	2.71	48.08	0.86
5	14.88	2.19	43.17	1.93	61.82	1.79
6	4.50	0.91	19 88	2.20	24.56	2.30
7	13.28	1.52	32.03	2.33	53.31	3.30
8					34.07	5 60
9						
PLANE AVG.	12.02	1.16	33.15	1.99	49.23	1 77

TEST NO 157 INJECTOR EDM-LOL

GRID NO	PLANE NO. 1		PLANE NO 2		PLANE NO. 3	
	EVF	MRL	EVF	MRL	EVF	MRL
15			40.51	36.11	40.51	
23					30.66	0.39
24			46.59	7.61	73.48	2.85
25	17.89	10.10	0	∞	7.49	57.93
26	26.55	1.81	50.66	15 22	57.54	51.94
33			27.89	1.13	30 35	0.39
34			61.53	4.62	80.44	2.18
35	16.45	11.21	56.80	8 06	75.91	3.64
36	0	∞	27.66	0	72.80	2.46
37			25.25	0.50	69.47	3.58
38					39.06	0.59
43			22.16	0.68	48.23	1.43
44	1.39	0.88	61.35	1.95	80.18	1.47
45	27.54	2.85	60.83	1.73	79.65	1 49
46	27.66	2.17	56.89	1.26	77.29	1 41
47	2.03	0.95	46.84	0.59	68.68	1.66
48					64.16	1 14
53			51.40	1.27	75.13	1.67
54	18.54	1.25	61.07	3.43	80.94	2 28
55	27.76	2.51	60 89	3 67	80.35	2.61
56	27.63	2.14	61.19	3.06	80.83	2.28
57	25.29	1.65	61.16	1 84	76.48	2.00
58					68.95	1.88
63			50.66	3.14	77.48	2.12
64			59.22	5.55	79.90	3.83
65					78.81	5.45
66			59.58	4.96	78.45	3 74
67	24.52	5.22	60 48	4.27	80.00	3.81
68					66.29	1.48
73					75.25	3.41
74					76.79	6.10
77			53.64	7.40	78.56	5 67
78					79.99	4.28
88					71.99	5.30
89					76.70	1.36
DEPTH AVG.						
I=0						
1			40 51	36.11		
2	25 20	5 30	44.10	5.33	47.33	36.89
3	13.98	6 11	43 79	4 90	65.79	2.70
4	26.64	2.47	57 88	1 61	74.86	1.47
5	27.26	2.25	60.44	3.22	78.75	2.29
6	24 52	5.22	58.37	4.62	76.99	3 77
7			53.43	7 40	78 12	4.78
8					71.99	3 52
9						
PLANE AVG	26.67	2.76	57 02	3.23	75.05	3 77

TEST NO: 158 INJECTOR: EDM-LOL

GRID NO.	PLANE NO. 1		PLANE NO. 2		PLANE NO. 3	
	EVF	MRL	EVF	MRL	EVF	MRL
15			31.89	35.67	31.89	
23					30.06	0.57
24			34.88	7.68	61.32	2.88
25	11.95	10.32	0	∞	0	∞
26	19.47	1.84	40.23	15.38	42.16	54 26
33			27 01	1.01	28.91	0.53
34			48.74	4.10	70.09	2.04
35	11.07	11 45	44.32	8.17	64.14	3.73
36	0	∞	19.72		60.03	2 56
37			21.33	0.50	58.42	3.65
38					33.03	0 60
43			22.35	0.64	41.35	1.23
44	2.34	0.89	48.81	1.97	70 08	1 51
45	19.34	2.91	48 97	1.76	69.98	1.53
46	19.72	2.21	46.59	1.26	67.99	1.30
47	4.48	0.95	38.02	0.63	59.54	1.54
48					55.15	0 98
53			43 68	1.45	66.94	1 42
54	15.44	1.26	48.33	3.46	70 46	2.36
55	19.60	2.56	48.15	3.68	69.38	2.61
56	19.73	2.19	48.72	3.08	70.10	2.35
57	19.01	1.68	49.12	1.86	67.42	2.01
58					60.19	1.93
63			42.60	3.59	67.93	2.35
64			46.63	5.61	68.86	3.94
65					67.62	5.56
66			47.24	5 01	67.34	3 89
67	16.99	5.34	48.03	4.13	69 68	4.00
68					56.35	1.79
73					65.34	3.77
74					65.31	6.21
77			41.21	7.56	67.47	5.72
78					69 64	4.29
88					59.73	5.60
89					66.45	1.33
DEPTH AVG.						
I=0						
1			31.89	35.67		
2	18.30	5.41	33.52	5.38	41.45	17 27
3	9.41	6.24	34.86	4.79	56.08	2.75
4	18.94	2.52	46 87	1.63	65.51	1.42
5	19.12	2.30	48.29	3.25	68.58	2.32
6	16.99	5.34	46.63	4.67	66.38	3.94
7			41.21	7.56	67.55	4 89
8					59.73	3 66
9						
PLANE AVG.	18.85	2.82	45.89	3.24	65.30	3 06

TEST NO. 159 INJECTOR EDM-LOL

GRID NO.	PLANE NO. 1		PLANE NO. 2		PLANE NO. 3	
	EVF	MRL	EVF	MRL	EVF	MRL
15			26.20	34.83	26.20	0
23					19.95	0.48
24			31.53	8 10	56.25	3.18
25	10.61	10.68	0	∞	0	∞
26	16.16	1.93	35.05	16.66	37.11	58.97
33			12 37	1.13	17.04	0 42
34			42.53	4.23	63.90	2.25
35	9.84	11.84	38.89	8.91	58.48	4.15
36	0	∞	16.43	0	52.87	2.80
37			17.81	0 53	52.91	4.05
38					28.37	0.64
43			18.78	0.77	28 48	1.43
44	1.60	0.91	42.57	2.18	63.91	1.73
45	16.19	3.05	42.66	1.93	63.81	1.75
46	16.43	2.32	40.59	1.39	62.01	1.43
47	3.23	0.98	32.66	0.68	53.41	1.55
48					48.86	0.96
53			37.64	1.63	60.66	1.66
54	12.68	1.31	42.20	3.82	64.21	2.70
55	16.36	2.69	42.06	4.06	63.16	3.01
56	16.42	2.30	42.47	3.41	63.86	2 71
57	15.76	1.76	42.78	2.05	61.20	2.27
58					53.13	1.96
63			36.80	4.00	61.62	2.73
64			40.82	6.16	62.70	4.50
65					61.55	6 34
66			41.28	5 51	61.22	4.48
67	14.49	5.57	41.92	4 54	63 48	4.57
68					50.22	2 19
73					59.31	4.35
74					59.43	6.98
77			36.45	8.41	61.37	6 42
78					63 45	4.82
88					54.80	6.59
89					60.58	1 42
DEPTH AVG.						
I=0						
1		26 20	22.55			
2	15.30	5.63	30.01	5.75	33.86	18.79
3	8.36	6.44	28.54	5.16	49.38	3 03
4	15.80	2.64	40.80	1.79	59.19	1.57
5	16.24	2.41	42.00	3.59	62.28	2.65
6	14.49	5.57	40.57	5.14	60.23	4.53
7			36.45	8.41	61.46	5.52
8					54.80	4.24
9						
PLANE AVG.	15.86	2.95	39.76	3.51	58.95	3.44

TEST NO 160 INJECTOR· EDM-LOL

GRID NO	PLANE NO 1		PLANE NO. 2		PLANE NO. 3	
	EVF	MRL	EVF	MRL	EVF	MRL
15			17.12	32.37	17.12	0
23					30.89	0.79
24			16.88	7.30	36.87	2 54
25	4.75	10.11	0	∞	0	∞
26	10.07	1.75	23.13	14.16	23.72	50 44
33			16.20	0.67	28.43	0.69
34			28.33	2.86	47.67	1 41
35	4.35	11.23	24.86	7 54	40.84	3.23
36	0	∞	9.87	∞	36.94	2.33
37			20.58	0.44	36.84	3.22
38					23 90	0.54
43			24.74	0 72	41.66	0.62
44	8.12	0.81	28.87	1 78	48.42	1 21
45	9.43	2.79	29.62	1.59	48.94	1 23
46	9.87	2.11	29.49	1.12	48.52	0.93
47	8.66	0.87	24.39	0 58	38.07	1.37
48					39.12	0.64
53			29.86	1.45	49 98	1.16
54	10.04	1.18	28.32	3.14	48.15	1.94
55	9.65	2.45	28.16	3.32	46.48	2.10
56	9.88	2.09	28.90	2.78	47.53	1.93
57	10.13	1.59	29.59	1.67	48.55	1.59
58					51.09	1.80
63			28.59	3.61	48 71	2.05
64			26.87	5.13	45.97	3.26
65					44.59	4.64
66			27.64	4.55	44.41	3.28
67	7.72	5.16	28.27	3 62	47.66	3.31
68					39.46	1 82
73					45.83	3.40
74					42.06	5.32
77			10 68	7.38	40.53	4.78
78					47.60	3.49
88					11.02	4 97
89					40.50	1 68

DEPTH AVG.

I=0						
1			17 12	32.37		
2	9.24	5.26	17.02	5.03	31.75	16.03
3	3.70	6 12	20.54	4.12	37.58	2.36
4	9.63	2.41	29.04	1.47	45.88	1 14
5	9.81	.19	28.66	2.94	48.90	2.35
6	7.72	5.16	27.86	4.26	44.98	3 33
7			10.68	7.38	45.70	4.13
8					11.02	3.48
9						
PLANE AVG.	9.60	2.71	27.88	2.91	45 62	2.76

TEST NO. 161 INJECTOR· EDM-LOL

GRID NO	PLANE NO 1		PLANE NO 2		PLANE NO 3	
	EVF	MRL	EVF	MRL	EVF	MRL
15			40.93	37.15	40.93	0
23					25 89	0.31
24			50.75	8.38	76.53	3.30
25	20.16	10.67	0	∞	8.82	59.72
26	28.04	1.94	52.60	16.81	59.66	57.84
33			19.05	1.29	23.06	0.26
34			60.53	5.22	82.87	2.62
35	18.68	11.82	59.88	9.00	78.48	4.24
36	0	∞	29.78	0	75.72	2.86
37			25.80	0.53	71.72	4.09
38					40.18	0.64
43			21.19	0.78	28.05	1.51
44	0.84	0.92	64.26	2.21	82.59	1.77
45	29.96	3.06	63.40	1.94	82.02	1.79
46	29.78	2.33	59.12	1 41	79.66	1.69
47	1.64	0.98	48.05	0.64	70.69	1.86
48					66.12	1.27
53			52.81	1.38	76.93	2.14
54	18.49	1.32	64.02	3.87	83.34	2.74
55	30.08	2.70	63.85	4.17	82.90	3.18
56	29.71	2.30	63.89	3.45	83.25	2.77
57	26.32	1.77	63.73	2.08	78.47	2.34
58					70.76	2.10
63			52.21	3.38	79.66	2.48
64			62.19	6 24	82.43	4.61
65					81.04	6.56
66			62.30	5.58	81 05	4.49
67	26.98	5.58	63.23	4.95	82 32	4.56
68					68.14	1.67
73					77.28	1 67
74					79.09	7.23
77			56.87	8.34	81.15	6.80
78					82.31	5 15
88					75.14	6.28
89					79.29	1.59
DEPTH AVG.						
I=0						
1			40.93	37.15		
2	26.82	5.63	47.47	5 87	46.08	39 55
3	15.87	6.43	44.61	5.50	67.08	3 14
4	28.79	2.65	60.23	1 81	51.74	1.74
5	29.30	2.42	63.18	3.64	81.04	2.76
6	26.98	5.58	60 96	5.23	79.35	4.52
7			56.87	8 34	80.49	5.71
8					75.14	4.15
9						
PLANE AVG.	28.77	2.96	59.34	3.61	66 15	4.33

TEST NO. 162 INJECTOR: EDM-LOL

GRID NO	PLANE NO. 1		PLANE NO 2		PLANE NO 3	
	EVF	MRL	EVF	MRL	EVF	MRL
15			36.26	37.94	36.26	0
23					34.36	0.57
24			40.05	7.89	67.13	2.94
25	14.46	10.64	0	∞	0	∞
26	23.39	1.89	45.58	15.76	47 54	55.51
33			31.32	1.07	33.19	0.53
34			54.70	4 42	75 42	2.10
35	13.39	11.81	49.98	8.35	69.66	3 76
36	0	∞	23.72	0	66.39	2.59
37			24.53	0.52	64.16	3 73
38					37.10	0 62
43			25.21	0.62	45.90	1.32
44	2.72	0.92	54.80	2.01	75.40	1.49
45	23.27	2.99	55.01	1.79	75.33	1.52
46	23.72	2.27	52.51	1.29	73.50	1.32
47	5.26	0.98	43.17	0.64	65.27	1.68
48					60.92	1.10
53			49.24	1.45	72.67	1.44
54	18.49	1.30	54.30	3.53	75.72	2.36
55	23.57	2.64	54.11	3.75	74.66	2.58
56	23.72	2.25	54.73	3.14	75.36	2 34
57	22.82	1.72	55.17	1.89	72.79	2 00
58					66 81	2.12
63			48.05	3.58	73.56	2.33
64			52.48	5.73	74.15	3.93
65					72.93	5 56
66			53.14	5.11	72.63	3 85
67	20.47	5.49	53.99	4.24	74.94	3.99
68					61.91	1.67
73					71.09	3.77
74					70.59	6 22
77			46.58	7 63	72.79	5 77
78					74 91	4 33
88					65.53	5.54
89					72.03	1 37
DEPTH AVG.						
I=0						
1			26.26	37.94		
2	22.00	5.60	38.35	5.51	46.21	17.72
3	11.38	6.43	39.77	4.98	61.45	2.79
4	22.78	2.59	52 72	1.66	70.98	1.45
5	23.44	2.36	54.13	3.31	73.98	2.31
6	20.47	5.49	52.47	4.76	71.74	3 91
7			46.58	7.63	72.93	4 92
8					65.53	3.65
9						
PLANE AVG.	22.87	2.91	51 64	3.33	70.71	3.10

TEST NO. 164 INJECTOR EDM-LOL

GRID NO	PLANE NO. 1		PLANE NO 2		PLANE NO 3	
	EVF	MRL	EVF	MRL	EVF	MRL
15			30.28	35.07	30.28	0
23					20.58	0.42
24			39 09	8.36	64.36	3.33
25	14.02	10.73	0	∞	6.64	64.50
26	19.64	1 96	41.02	17.06	48.31	59.18
33			13.89	1.20	19.40	0.38
34			49.79	4.56	70.71	2.43
35	13.02	11.89	46.09	9.14	66.34	4.41
36	0	∞	20.32	0	60.84	2.90
37			19.81	0 53	59.94	4.19
38					31.67	0.65
43			17.52	0 80	28.17	1.49
44	0.90	0.92	49.71	2.24	70.60	1.83
45	20.26	3.09	49.40	1.99	70.28	1 85
46	20.32	2 35	46.55	1.43	68.11	1.57
47	1.35	0.98	37.46	0 68	59.33	1.66
48					54.36	1.05
53			42.30	1.60	66 16	1.86
54	14.15	1.33	49.41	3.93	71.11	2.84
55	20.39	2,72	49 27	4.20	70.48	3 23
56	20.30	2.32	49.51	3.51	70.91	2.86
57	18.86	1.78	49.60	2.12	67.47	2.43
58					57.28	2.00
63			41.72	3.92	67 86	2.79
64			48.00	6.33	70.01	4.76
65					68.99	6.71
66			48.28	5.67	68.83	4.75
67	18.00	5.62	48.97	4.77	70.25	4.77
68					56.32	2 14
73					65.74	4.43
74					67.25	7.43
77			43.87	8 65	68.83	6 84
78					70.24	5.16
88					63.01	6.92
89					67.32	1.52
DEPTH AVG.						
I=0						
1			30.28	35 07		
2	18.77	5.67	36 68	5.91	38.81	41.67
3	11.06	6 47	33.61	5.36	55.75	3.19
4	9.36	1.99	47.04	1 85	65.16	1 68
5	20.25	2.44	48.96	3.70	68.94	2.82
6	18.40	5.62	47.39	5.29	67.19	4.75
7			43 87	8.65	68.47	5 85
8					63.01	4.47
9						
PLANE AVG.	14.28	2.64	46.10	3.62	65.29	4 47

TEST NO. 165 INJECTOR· EDM-LOL

GRID NO.	PLANE NO. 1		PLANE NO 2		PLANE NO 3	
	EVF	MRL	EVF	MRL	EVF	MRL
15			13.57	23.55	13.57	0
23					60.05	0.55
24			81.10	16.35	95.15	11.56
25	46.03	13.99	0	∞	14.58	55.25
26	12 86	2.08	56.43	23.33	70.18	89.44
33			56.49	2 07	59.80	0 48
34			69.87	10.79	70.26	6 79
35	44.44	15.24	80.50	17.98	94.56	14.40
36	0	∞	34.58		86.91	4.55
37			33.66	0.60	87.13	9.15
38					50.31	0 78
43			35.09	1.09	42.71	1.49
44	14.31	0.94	80.66	4.40	92.91	5 31
45	46.78	4.09	71.15	2.08	92.51	3.91
46	34.58	2.81	61.07	2.06	83.23	4.49
47	14.61	1.01	11.81	0.60	61.11	2 95
48					72.29	1.34
53			42.70	1.06	79.10	5.64
54	16.32	1.41	80.80	7.88	94.55	8 22
55	41.70	3.45	80.78	9.40	95.96	11.69
56	34.04	2.77	76.43	6.43	95.59	11.07
57	6.03	1.84	70.67	3 47	84.10	4 78
58					69.54	2.10
63			61.79	4.54	96.55	13 01
64			79.48	12.22	95.67	17 93
65					95 16	25.37
66			75.44	10.14	94 78	16.41
67	52.44	7.89	76.40	9.88	92.11	10.59
68					93.60	10.68
73					93.48	12.83
74					94.24	23.56
77			84.13	25.89	94.62	23 55
78					92.13	11.90
88					94.85	29 60
89					90.54	3.79
DEPTH AVG						
I=0						
1			13.57	23 55		
2	18.01	7.10	69.86	9 62	72.26	49 40
3	37.76	8.30	57.76	11.04	76.97	8 19
4	39.01	3.39	66.01	2.50	80.55	3.98
5	34.99	2 97	76.10	7.43	90.65	9 12
6	52.44	7.89	74.44	9.79	94.36	16 44
7			84.13	25.89	93.21	16.90
8					94.85	17.90
9						
PLANE AVG.	36.98	3.75	68.19	6.30	85.08	10 73

TEST NO 168 INJECTOR· EDM-LOL

GRID NO	PLANE NO. 1		PLANE NO. 2		PLANE NO 3	
	EVF	MRL	EVF	MRL	EVF	MRL
15			4.83	22 69	4.83	0
23					57.63	0.73
24			81.92	22.15	94.96	18.10
25	47.29	16.02	0	∞	11.15	61.86
26	1.34	2.05	55.87	27.46	71.94	115.12
33			54.78	2.17	57.47	0.64
34			47.56	6.56	49.18	4 15
35	46.25	17.48	73.41	19.74	93.46	20.71
36	0	∞	6.52	0	80.19	5.24
37			30.14	0.64	88.18	13.65
38					46.22	0.87
43			31.44	1.19	33.63	1.51
44	12.47	0.98	68 07	4.37	86.02	5 39
45	34.61	4.05	45.08	2.34	85.07	4.72
46	6.52	2.52	41.43	1 96	69.11	3.44
47	12.73	1.05	36.07	0.89	57.95	1.93
48					56.97	1 03
53			26 26	1.80	64.52	3.96
54	14.05	1.47	71.65	8.27	89 71	8.32
55	28.30	3 37	71.56	9 45	94.26	19 08
56	6.15	2.49	66.56	6.81	93.32	13.96
57	0.59	1.85	52.01	3.27	73.98	4.94
58					60.59	2.41
63			58.75	6.44	95.65	23 87
64			71.06	13.09	94.13	24 68
65					93.51	33.62
66			67.51	11.18	93.74	24.85
67	50.36	8.80	67.92	9.30	85.23	10.51
68					73.19	5.00
73					92.94	21.17
74					92.92	33.23
77			83.60	35.60	93.26	32.03
78					85.17	10 55
88					94.91	50 41
89					86.01	4 14
DEPTH AVG.						
I=0						
1			4.83	22 69		
2	8 48	7.95	70.32	12.25	70.82	61.15
3	39.30	9 51	41.80	10 56	69.61	10.41
4	18.68	3.23	47.34	2 61	71.10	3.71
5	14 19	2 79	65.38	7.68	85.59	12.17
6	50.36	8.80	67.01	10.37	88 49	20.91
7			83.60	35.68	89.58	21 81
8					94.91	29 42
9						
PLANE AVG.	10.07	3.72	52 53	6.59	77.92	13.49

TEST NO. 169 INJECTOR: EDM-LOL

GRID NO	PLANE NO. 1		PLANE NO. 2		PLANE NO 3	
	EVF	MRL	EVF	MRL	EVF	MRL
15			3.25	26.74	3.25	0
23			73.55	18.80	49.74	0.83
24			0	∞	90.57	13.04
25	38.22	15.46	48.93	27.35	14.88	71.22
26	2.17	2.20			65.55	112.67
33			48.68	2.05	51.49	0.73
34		45.43	6.87	45.86	45.86	4.35
35	37.35	16.94	68.39	19.19	88.68	15.53
36	0	∞	10.40		72.83	4 96
37			26.28	0 67	82.22	11 69
38					41.40	0.91
43			27.42	1.25	29.44	1.53
44	10.34	1.03	65.00	4.47	83.20	5.24
45	31.80	5.22	45.58	2.52	82.42	4.61
46	10.40	2.75	39.81	2.09	67.87	3 66
47	10 55	1.11	31.81	0.91	55.04	2.04
48					54.19	1.10
53			28.02	1.91	60.47	3.99
54	11.66	1.55	66.86	8 08	86.03	7 94
55	26.89	3.57	66.79	9.39	89.49	12.66
56	9.89	2.71	60.36	6.63	88.41	10.42
57	0.93	1.99	50.17	3.47	70.33	5.06
58					48.44	2.35
63			51.70	6.30	87.36	10.21
64			66.09	12.79	89.30	17.63
65					88 67	25.27
66			60.44	10.69	88.27	17.51
67	41.18	8.41	60.93	9.03	81.52	10 93
68					67.09	4 88
73					87.10	15 21
74					87.85	25 14
77			75.52	27.65	87.86	23 45
78					81.49	11.27
88					90.50	35.42
89					80.83	3.70
DEPTH AVG						
I=0						
1			3.25	26.74		
2	7.77	7.86	62.87	11.15	64.78	62.97
3	31.74	9.20	39.85	10.46	64.32	8.55
4	19.50	3.43	46.25	2.74	68.82	3.76
5	15.71	3.00	60.86	7.58	80.65	9.19
6	41.18	8.41	60.43	10.06	83.32	15.75
7			75 52	27.65	84.90	17.49
8					90.50	20 98
9						
PLANE AVG.	17.97	3.88	50.16	6.52	74.07	11 23

TEST NO. 171 INJECTOR· EDM-LOL

GRID NO	PLANE NO 1		PLANE NO 2		PLANE NO 3	
	EVF	MRL	EVF	MRL	EVF	MRL
15			35.66	30.01	35.66	0
23					34.15	0.49
24			56.72	9.84	78.78	4.70
25	24.32	11.17	0	∞	14.34	60 50
26	21.59	2 04	47.77	19.57	58.11	70 22
33			32.51	1.35	33.49	0.46
34			58.76	7.99	59.02	5 03
35	23.19	12.31	61.21	11.25	80.46	6 26
36	0	∞	26.23		72.49	3.40
37			23.17	0.55	71.90	5.45
38					37.24	0 68
43			15.19	0.99	36.16	1.18
44	8.69	0.89	62.82	2.81	80.59	2 64
45	29.85	3 31	58.15	2.26	78.52	2.47
46	26.23	2.48	51.61	1.67	68.35	2.44
47	8.92	0.96	38.70	0 69	63.13	1.83
48					57.02	1.09
53			44.76	1.57	63 82	3 86
54	1.88	1.32	63.19	4.94	82.28	3.96
55	28.77	2.91	63.12	5.55	83.21	5.21
56	26.01	2.46	60.75	4.35	82.53	4.24
57	18.76	1.84	58.39	2.58	72.81	3.18
58					58.05	1.98
63			45.80	3.88	78.03	3.63
64			61.87	7.86	82.81	7.04
65					82.08	10.20
66			59 64	6 97	80.93	6.82
67	29.17	5.99	60.43	6.43	79.81	6 23
68					63.84	2.51
73					76.64	5.60
74					80.59	10.57
77			60.91	11 80	81.06	9.87
78					79.84	6.97
88					79.18	10.74
89					77.03	2 05
DEPTH AVG.						
I=0						
1			35.66	30 01		
2	22.01	5.88	50.66	6.87	51.92	43.79
3	19.70	6.71	43.91	7.28	62.10	4.54
4	27.12	2.85	54.84	2.16	69.59	2.30
5	25 84	2.59	60.81	4 70	78.15	4.17
6	29 17	5.99	58.15	6.58	78 09	6 75
7			60.19	11 80	79.46	8 06
8					79.18	6.80
9						
PLANE AVG.	26.37	3.15	55.41	4.41	72.46	5.79

TEST NO 178 INJECTOR: PAT

GRID NO	PLANE NO. 1		PLANE NO 2		PLANE NO. 3	
	EVF	MRL	EVF	MRL	EVF	MRL
25			0	0	0	0
26			0	0	0	0
34					50.74	2 40
35	0	0	0	0	31.20	1.77
36	0	0	0	0	20.94	1.35
37			0.69	1.60	40.94	1.79
43				55.99		49 94
44	0	∞	53.34	∞	95.63	10 44
45	53.34	6.17	84.27	5.00	95.52	8.70
46	39.73	3.12	79.66	6.46	95.55	8.52
47	0	∞	39.73	0	40.17	3.01
48			0	∞	39.73	∞
53	0	∞	0	∞	64.63	∞
54	0	∞	64.63	67.36	90.46	6.75
55	33.18	2.62	67.98	2.94	90.61	6.08
56	30.77	2.47	67.09	3.03	90.99	6.29
57	0	∞	3.077		75.30	3.78
58			0	∞	74.31	57.41
65	11.19	0.44	51.30	2.99	76 46	1.13
66	53.41	6.56	74.14	1.01	79.55	1.02

DEPTH AVG.						
I=0						
1						
2			0	0	0	0
3	0	0	0 06	0.16	33.94	1 84
4	47.65	4.78	73.17	4.59	85.95	9.13
5	32.16	2 20	60.12	8.15	87.62	7.29
6	27.82	2.89	68.15	1.87	78.18	1.07
7						
8						
9						
PLANE AVG	34.11	3.44	58.02	4.87	77.71	7.55

TEST NO 179/184 INJECTOR: PAT

GRID NO	PLANE NO 1		PLANE NO 2		PLANE NO 3	
	EVF	MRL	EVF	MRL	EVF	MRL
25			0	0	0	0
26			0	0	0	0
34					3.28	1.76
35	0	0	0	0	0.95	1.49
36	0	0	0	0	0.18	1.11
37			25.51	1.71	71.76	1.98
43					52 08	∞
44	0	∞	52.08	∞	96.20	6.97
45	52.08	5.55	85.50	4 01	96.30	5.98
46	48.78	3.13	83.95	5.70	96.07	5.69
47	0	∞	83.75	8.32	94.86	6.01
48			0	∞	83.75	∞
53	0	∞	0	∞	68.42	∞
54	0	∞	68.42	81.66	91.05	11.94
55	44.73	2.69	80.36	2.97	94.90	5.28
56	42.92	2 55	79.56	3.05	44.96	5.37
57	0	∞	80 60	7.66	94.20	6.21
58			0	∞	80.60	∞
65	12.05	0.45	54.88	2.83	79.44	0.98
66	51.81	5.88	73.25	0.84	79.36	0.83

DEPTH AVG						
I=0						
1						
2			0	0	0	0
3	0	0	2.34	0.17	9.40	1.52
4	50.70	4.40	84.21	5.15	95.21	5.71
5	43.97	2.26	79.83	10.33	94.06	5.75
6	27.71	2.63	68 44	1.71	79.40	0.90
7						
8						
9						
PLANE AVG.	40.28	3.27	68.86	5.81	81.56	5 14

TEST NO 182 INJECTOR: PAT

GRID NO.	PLANE NO 1		PLANE NO 2		PLANE NO 3	
	EVF	MRL	EVF	MRL	EVF	MRL
25			0	0	0	0
26			0	0	0	0
34					35.58	2.98
35	0	0	0	0	34.13	2.50
36	0	0	0	0	14.36	1.67
37			0.34	1.69	18.67	1.81
43					79.35	64.28
44	0	∞	64.52	51.08	79.85	6.00
45	28.72	5.41	60.27	3.71	79.58	5.07
46	22.34	3.00	56.35	5.24	79.46	4 93
47	0	∞	22.34	0	22.65	2.47
48			0	∞	64.56	39 41
53	0	∞	0	∞	44.67	∞
54	0	∞	44.67	44.60	71.53	5.85
55	18.88	2.59	46.92	2.71	72.25	4.51
56	17.57	2.46	46.11	2.80	72.56	4.58
57	0	∞	17.57	0	17.73	2.78
58			0	∞	17.57	∞
65	6.27	0.46	33 47	2.98	57.32	1.06
66	28.74	5.75	49.88	0.85	57.12	0.86

DEPTH AVG.						
I=0						
1						
2			0	0	0	0
3	0	0	0.03	0.17	27.76	2.39
4	26.05	4.27	51.10	5.91	70.14	7.39
5	18.33	2.17	40 67	6.13	61.75	4 07
6	15.12	2.58	45.58	1.78	57.21	0.95
7						
8						
9						
PLANE AVG.	18.95	3 17	40 17	5 31	60 41	5 66

TEST NO 187 INJECTOR: PAT

GRID NO	PLANE NO 1		PLANE NO 2		PLANE NO 3	
	EVF	MRL	EVF	MRL	EVF	MRL
25			0	0	0	0
26			0	0	0	0
34					49.77	2.59
35	0	0	0	0	47.90	2.16
36	0	0	0	0	22.78	1.42
37			2.23	1.70	55.83	2.06
43					51.20	47.77
44	0	∞	48.49	∞	94.40	9.15
45	48.49	6.07	81.59	4.74	94.28	7.70
46	39.31	3.24	78.05	6.42	94.32	7.54
47	0	∞	39.31	0	52.43	3.15
48			0	∞	39.31	∞
53	0	∞	0	∞	68.07	∞
54	0	∞	68.07	78.89	89.69	7 47
55	33.82	2.75	68.46	3.09	89.96	6.06
56	31.83	2.60	67.80	3.19	90.23	6.21
57	0	∞	31.83		76.47	4.03
58			0	∞	31.83	∞
65	10.70	0.46	50.64	3.13	75.89	1.19
66	38.40	6.44	70.44	0.98	76.59	0.99

DEPTH AVG.						
I=0						
1						
2			0	0	0	0
3	0	0	0.20	0.17	42.99	2.11
4	44.65	4.75	71.35	4.49	86.85	8.24
5	32.98	2.30	60.88	9.40	86 95	5 49
6	25.55	2.86	62.25	1 92	76.28	1.08
7						
8						
9						
PLANE AVG	33.13	3 47	57.02	5.07	78.99	6.54

TEST NO 190 INJECTOR. PAT

GRID NO	PLANE NO. 1		PLANE NO 2		PLANE NO. 3	
	EVF	MRL	EVF	MRL	EVF	MRL
25			0	0	0	0
26			0	0	0	0
34					43.83	2.58
35	0	0	0	0	25.75	1 96
36	0	0	0	0	17.64	1.44
37			0.45	1.60	23.75	1 71
43					89.60	91 58
44	0	∞	78.47	77.13	90.44	7.37
45	41.53	5.52	74 62	4 07	90.22	6 20
46	32.17	2 98	70.63	5.62	90.12	5.96
47	0	∞	32.17	0	32.51	2 68
48			0	∞	77.41	56.25
53	0	∞	0	∞	56.58	∞
54	0	∞	56.58	55.51	83.70	6.41
55	27.15	2.54	60.01	2.76	84.02	5 01
56	25.25	2.40	59.03	2.84	89.38	5.13
57	0	∞	25.25	0	25.43	2.91
58			0	∞	25.25	∞
65	9.01	0.44	43.61	2 92	68.84	1 07
66	41.57	5.87	63.67	0.88	70.19	0.89

DEPTH AVG.						
I-0						
1						
2			0	0	0	0
3	0	0	0.04	0.16	27.35	1.99
4	13.46	1.13	64.51	7.33	80.66	9.51
5	26.35	2.13	52.59	6.94	72 81	4 50
6	21.84	2.62	58.41	1.76	69.59	0.97
7						
8						
9						
PLANE AVG.	18.45	1.60	51.00	6.43	69.60	6.93

TEST NO 193 INJECTOR PAT

GRID NO	PLANE NO. 1		PLANE NO 2		PLANE NO 3	
	EVF	MRL	EVF	MRL	EVF	MRL
25			0	0	0	0
26			0	0	0	0
34					55.38	2 74
35	0	0	0	0	32.83	1.90
36	0	0	8.78	0.59	91.11	5 10
37			0.15	1 63	19.63	1.73
43					98.85	662 16
44	0	0	95 88	394 88	98.56	34.08
45	66.08	8.76	91.14	9 56	98 43	27.07
46	26.42	3.04	82.43	9 12	98.72	33 57
47	0	∞	26.42	0	26.74	2 52
48			0	∞	26.42	∞
53	0	∞	0	∞	57 61	∞
54	0	∞	57.61	57.22	92 03	7.69
55	8.43	2.39	60.81	3.10	91.87	9 20
56	5.05	2.25	62.04	3.30	92.82	10 15
57	0	∞	5 05	0	74.88	3 88
58			0	∞	76 36	63.33
65	13 52	0.46	54 54	3.43	79.84	1 47
66	67.36	9 58	84 06	1.69	87.87	1.77

DEPTH AVG.						
I=0						
1						
2			0	0	0	0
3	0	0	4 97	0 43	50.54	2.76
4	49.49	6.37	74 65	24.89	86.33	44.18
5	7.00	2.00	50.41	7.39	88 77	9.96
6	34.73	4 12	76 32	2.45	84.32	1.63
7						
8						
9						
PLANE AVG.	24.68	4 18	57.87	18 29	80.48	28.09

TEST NO 194 INJECTOR PAT

GRID NO	PLANE NO. 1		PLANE NO 2		PLANE NO 3	
	EVF	MRL	EVF	MRL	EVF	MRL
25			0	0	0	0
26			0	0	0	0
34					51.74	3.08
35	0	0	0	0	30.74	2.17
36	0	0	8.02	0.62	87.48	4.38
37			0.16	1.75	27.90	1.94
43					96.50	279 04
44	0	∞	91.01	199.00	96.67	20.35
45	56.90	7.92	86.59	7.86	96.56	16.92
46	35.58	3.52	79.07	8.77	96.61	17 43
47	0	∞	35.58	0	35.87	3 08
48			0	∞	35.58	∞
53	0	∞	0	∞	53.66	∞
54	0	∞	53.66	56.67	89.71	9.12
55	13.68	2.64	60.08	3 36	89.77	8.89
56	8.17	2.45	59.74	3.50	90.40	9 42
57	0	∞	8.17	0	72.28	4 13
58			0	∞	67.84	50.79
65	11.76	0 49	51.41	3.63	76.88	1.52
66	57.45	8.49	77.30	1.45	82.24	1.52

DEPTH AVG.						
I=0						
1						
2			0	0	0	0
3	0	0	4 55	0 45	48 93	2 84
4	47.98	5.99	73 33	15 56	86.25	22 90
5	11.36	2 19	44.82	7.55	86.36	9.39
6	29.76	3 70	70.51	2 41	79.87	1.52
7						
8						
9						
PLANE AVG.	25.49	4.07	55.66	12.12	79.38	16 03

TEST NO 197 INJECTOR PAT

GRID NO	PLANE NO 1		PLANE NO 2		PLANE NO 3	
	EVF	MRL	EVF	MRL	EVF	MRL
25			0	0	0	0
26			0	0	0	0
34					90.14	4 42
35	0	0	37.09	1 17	90.03	3.71
36	0	0	0	0	23.98	1.40
37			21.92	1.82	65.32	2.16
43					46.72	45.66
44	0	∞	44.32	∞	93.15	7.28
45	44.32	5.80	78.84	4.14	93.11	6.18
46	40.70	3 27	77.34	5.89	93.01	5.91
47	0	∞	40.70	0	79.51	3.51
48			0	∞	40.70	∞
53	0	∞	0	∞	38.42	38 36
54	0	∞	36.79	∞	71.56	∞
55	36.79	2.81	71.56	3.05	90.47	5.48
56	35.21	2.67	71.06	3 16	90.61	5 59
57	0	∞	35 21		80.00	4.06
58			0	∞	35.21	∞
65	10.15	0.47	49.97	3.09	75.09	1.11
66	44.08	6.15	66.45	0.89	73.01	0 88

DEPTH AVG.						
I=0						
1						
2			0	0	0	0
3	0	0	14.75	0.72	70.84	3.27
4	42.81	4.59	70.25	4.05	90 32	6.89
5	36.12	2.35	63.66	2.01	85.77	6.15
6	23.52	2 75	62.13	1 86	73.93	0.99
7						
8						
9						
PLANE AVG	33.60	3.42	58.75	3.25	83.71	6.11

F. NOMENCLATURE

C_R	Chamber Contraction Ratio
H_v	Heat of Vaporization, J/kg
L_c	Length of Straight Chamber Section, cm
K_J	Constant Containing Drop Size and Velocity
K_P	Constant Containing Propellant Properties
L_{gen}	Generalized Length, cm
L_N	Length of Converging Chamber Section, cm
M	Molecular Weight
Pc	Chamber Pressure, kPa
r_m	Mass-Median Droplet Radius, μm
$r_{m,\ uncor}$	Uncorrected Mass-Median Droplet Radius, μm, Figure 27
S	Converging Nozzle Shape Factor $(1 + 1/\sqrt{C_R} + 1/C_R)/3$
T	Propellant Temperature, °K
T_c	Propellant Critical Temperature, °K
T_r	Reduced Temperature, T/T_c
V	Propellant Injection Velocity, m/s
α	Spray Fan Half Angle, degree
μ	Dynamic viscosity, kg/m-sec
ρ	Density, kg/m^3
σ	Surface Tension, N/m

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