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HSCT Sector Combustor Evalutations for Demonstration Engine

Stuart Greenfield, Paul Heberling, John Kastl, John Matulaitis, and Cynthia Huff
General Electric Aircraft Engines, Cincinnati, Ohio

October 2004

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Table of Contents

Table of Contents (Continued)

Summary

In LET Task 10, critical development issues of the HSCT lean-burn low emissions combustor were addressed with a range of engineering tools. Laser diagnostics and CFD analysis were applied to develop a clearer understanding of the fuel-air premixing process and premixed combustion. Subcomponent tests evaluated the emissions and operability performance of the fuel-air premixers. Sector combustor tests evaluated the performance of the integrated combustor system. A 3-cup sector was designed and procured for laser diagnostics studies at NASA-Lewis. The results of these efforts supported the earlier selection of the Cyclone Swirler as the pilot stage premixer and the IMFH (Integrated Mixer Flame Holder) tube as the main stage premixer of the LPP combustor.

In the combustor system preliminary design subtask, initial efforts to transform the sector combustor design into a practical subscale engine combustor met with significant challenges. Concerns about the durability of a stepped combustor dome and the need for a removable fuel injection system resulted in the invention and refinement of the MRA (Multistage Radial Axial) combustor system in 1994. The MRA combustor was selected for the HSR Phase II LPP subscale combustor testing in the CPC Program.

Introduction

A key issue in the development of the next generation High Speed Civil Transport (HSCT) is environmental acceptability. Of particular concern is the impact of combustion-generated NOx emissions on the stratospheric ozone layer. The most straightforward method for reducing NOx emissions is using a Lean Premixed, Prevaporized (LPP) combustor. An LPP combustor generates a uniform premixture of fuel and air and burns it within a controlled, narrow range of flame temperatures. The flame temperature is selected to not only minimize NOx emissions, but to minimize CO and unburned hydrocarbon emissions. The LPP concept was chosen for development for the HSCT by GE Aircraft Engines because the approach has been proven in stationary gas turbine applications using gaseous fuels. GE's LM6000 and LM2500 DLE (Dry Low Emissions) combustors are very successful premixed combustors used in stationary applications. The DLE combustors have in common with the HSCT application engine cycles with very severe combustor inlet conditions, mission requirements for operation at full power for long periods, economic requirements for long combustor lifetimes, and environmental requirements for low emissions. The low emissions requirements for the HSCT and DLE combustors lead to additional similarities: both use multiple fuel stages with large numbers of fuel injection sites to maintain the fuel-air ratio in the optimum range and backside convection for liner cooling to minimize CO quenching. The reliability of the LM6000 and LM2500 DLE combustors with convectively-cooled liners have been proven in thousands of hours of service.

LET Task 10 builds upon the accomplishments in Task 5 of NASA Contract NAS3-25951 (Aero-Propulsion Technology or APT) in the development of a HSCT low emissions combustor. Those accomplishments include: 1) initial lean low emissions combustor system conceptual designs, 2) fuel-air mixer design, procurement and tests, and 3) the rectangular stepped-dome sector combustor design and procurement. At the completion of APT Task 5, the lean low emissions combustor was only loosely defined and several major design challenges remained. The lean combustor tentatively utilized a Cyclone Swirler as the pilot (first) fuel stage and IMFH tubes for the main stages. The Cyclone Swirler is a radial swirler in which the fuel is partially

premixed. The IMFH is a straight tube in which fuel is injected and premixed. The flame is stabilized at the exit of the IMFH tube. These fuel-air premixers were combined into combustor systems using a series of steps in the dome to isolate the fired from the unfired stages. This was done to minimize the quenching of CO. Preliminary designs for the subscale and full scale combustors which specified the number of Cyclone Swirlers, IMFH tubes, fuel stages, steps in the dome had been defined, but the details were very tentative. At the completion of APT Task 5 there was almost no definition of the fuel injector system. Based upon the single-cup tests of the IMFH, there was also a major concern about the combustion efficiency of the IMFH at subsonic cruise conditions.

The objective of Task 10 of NASA Contract NAS3-26617 (Large Engine Technology or LET) was to complete the HSR Phase I combustor development of the LPP combustor. The principal objectives of LET Task 10 were four tests of the stepped-dome sector combustor with the goal of making initial assessments of the performance of the LPP combustor as an integrated system. Supporting efforts in LET Task 10 were the continuation of the subcomponent testing begun in APT Task 5, further analysis of the subcomponents and the combustor systems using CFD, and the continued application of laser diagnostics to study the fuel-air premixing process.

Certain lean combustor development issues were addressed in separate LET Tasks. Thermal design issues of the lean combustor, including the liners and the fuel system were addressed in LET Task 42. The MRA (Multistage Radial Axial) combustor system proposed in LET Task 10 as an alternate to the baseline stepped-dome system was designed and procured in LET Task 43. Those efforts are documented in their respective task final reports.

Task 10 culminates in preliminary definition of LPP combustor system designs, discussed in Section 6 of this report. These LPP combustor designs are the starting point for further development and testing in HSR Phase II. In the second quarter of 1998, either a lean combustor design (being developed by GE) or an RQL (Rich burn, Quick quench, Lean burn) combustor design (being developed by P&W) will be downselected for further development in the HSR Program.

Section 1

Analyses of the Combustor System and Subcomponents

Several types of analyses were performed in support of the LPP combustor development. The two most effective analyses were the CFD modeling and the spreadsheet combustor system models. The CFD models of the premixers and the integrated combustion system were used to investigate the two-phase flow in the premixers, analyze the flow fields in the combustor, and study the interactions of the premixers in the combustion system. Predictions in the trends of the various performance metrics (mainly emissions and exit profiles) with changes in design were used to identify design improvements. The spreadsheet models of the combustor systems were used to understand how the combustor's fuel stages would operate over the range of power codes, altitudes, and Mach numbers within the aircraft's flight envelope. Once the number of fuel stages is determined at a cycle point, models and data correlations were used to predict the performance of the combustor and its subcomponents at that cycle point. The spreadsheet models also were used to generate the input data for the CFD models.

Early in LET Task 10, the Mach 2.4 FLADE GE21/FLA1 C1 engine cycle was was the standard cycle for the combustor studies. Table 1.1 lists the combustor conditions at key engine cycle points of the FLADE C1 engine cycle. Later in Task 10, the A5B mixed flow turbofan engine cycle became the standard cycle for the design of both the LPP and RQL combustors. Table 1.2 lists the combustor conditions for key points of the A5B MFTF engine cycle. The significant change between the two cycles was that the T_4 increased by 200 R. This results in a similar increase in the temperature in the combustion zone, making it more difficult to meet the supersonic cruise NOx emissions goal.

Table 1.1 Combustor Conditions for FLADE GE21/FLA1 C1 Engine Cycle						
Point	**Ground Idle**	**Begin Takeoff**	**Min Subsonic Cruise**	**Max Subsonic Cruise**	**Max Supersonic Cruise**	**End Supersonic Cruise**
Power Code	22	50	31.11	31.71	-	41.59
Altitude (ft)	0	0	34000	37000	55000	65000
Mach Number	0	0	0.95	0.95	2.4	2.4
W3 (lb/sec)	109.1	421.8	160.8	142.3	238.8	147.2
W36 (lb/sec)	89.3	348.2	132.1	116.8	196.7	120.9
WF36 (lb/hr)	3896	35036	10344	9078	19248	11982
P3 (psia)	56.2	305.6	105.4	92.7	181.1	111.6
P4 (psia)	51.9	285.7	98.2	86.4	167.9	103.5
T3 (degrees R)	815	1350	1159	1141	1662	1662
T4 (degrees R)	1593	3018	2526	2502	3226	3247
FAR4	0.0121	0.0280	0.0218	0.0216	0.0272	0.0275

Table 1.2 Combustor Conditions for A5B MFTF Engine Cycle						
Point	**Ground Idle**	**Begin Takeoff**	**Begin Subsonic Cruise**	**End Subsonic Cruise**	**Begin Supersonic Cruise**	**End Supersonic Cruise**
Power Code	21	50	35.54	35.51	48.27	47.42
Altitude (ft)	0	0	32500	34300	62900	68100
Mach Number	0	0	0.9	0.9	2.4	2.4
W3 (lb/sec)	72.7	424.8	148.1	137.1	172.8	131.9
W36 (lb/sec)	60.2	356.8	123.7	114.4	144.5	110.1
WF36 (lb/hr)	2517	38011	8242	7521	161.4	12321
P3 (psia)	35.2	306.8	89.4	82.2	131.9	100.5
P4 (psia)	33.0	289.6	83.9	77.1	123.8	94.3
T3 (degrees R)	702	1385	1065	1048	1690	1686
T4 (degrees R)	1523	3130	2265	2237	3441	3441
FAR4	0.0116	0.0296	0.0185	0.0183	0.0310	0.0311

1.1 CFD Modeling

CFD combustor models were developed using CONCERT, which is GE's proprietary CFD code. The CONCERT models used in Task 10 were all 3-dimensional. CONCERT 3D is a steady-state, viscous, turbulent flow code that was developed primarily for use in modeling combustors. The grid system used by CONCERT 3D is a structured, body-fitted, curvilinear mesh.

The CFD models of the Cyclone Swirler pilot and IMFH main stage premixers were used to study the fuel-air mixing process. Since these models were only used to study the interior of the premixers, no combustion was modeled and no emissions could be projected. The results of these models were used to project the performance of the various design permutations to screen concepts and to identify design changes to improve performance. CFD models of the integrated combustor system were used to better understand how the burning fuel-air mixture interacts with air from the unfired stages and the cooling flows. The system models were developed in parallel with the preparations for the sector combustor tests documented in Section 4. The predictions of the CFD models were later compared with sector combustor data, primarily exit plane emissions and temperature profile measurements. An anchored CFD sector combustor model resulted. The anchored CFD models were used for design studies (some of which were not performed in Task 10). The MRA CFD model was derived from the anchored Stepped-Dome sector combustor CFD model and used to expedite the process of improving the MRA combustor's performance.

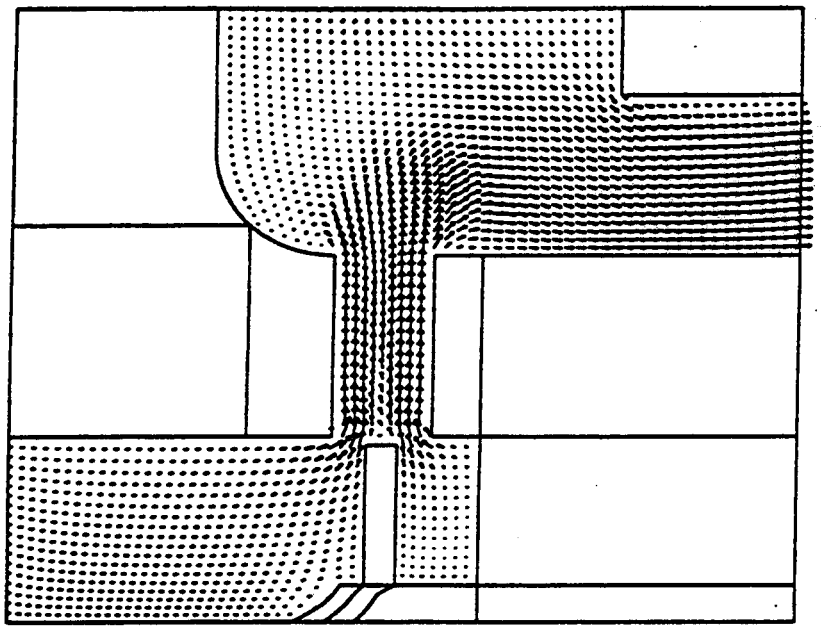
1.1.1 Cyclone Swirler Pilot CFD Modeling

Two CFD models of Configuration 3 of the Cyclone Swirler pilot were generated. Configuration 3 of the Cyclone Swirler pilot is discussed in Section 3.4. A cross-section of Configuration 3 is shown there. Configuration 3 is a slightly scaled-down version (in terms of size and effective flow area) of the Configuration 2 design tested in APT Task 5.[1-1] Both simulations were performed at the HSCT mid-supersonic cruise mission point in the Mach 2.4 FLADE GE21/FLA1 C1 engine cycle, the first engine cycle selected as a standard at GEAE for the HSCT low emissions combustor development. The combustor conditions were: T_3 = 1213°F (1673 R) P_3 =

146 psia, ΔP = 7.2%, and fuel-air ratio = 0.03444. The air flow rate was 0.521 lb/sec. The fuel flow rate was 62.48 lb/hr. The fuel was assumed to be injected with a Sauter mean diameter (SMD) of 50 μm. This assumption is based upon the results of the GE CR&D measurements, which are discussed in Section 2. The CFD model used a Rosin-Rammler drop size distribution function with droplets ranging in size from 6.9 to 131.1 μm. Figure 1.1 shows the vector flow field resulting from the first Cyclone Swirler CFD model. Figure 1.2 shows the predicted fuel droplet trajectories in the radial-circumferential plane. The Cyclone Swirler's high radial acceleration assists the vaporization and mixing of droplets because the density difference combined with the radial acceleration maintains high relative velocities between the liquid droplets and the air. In this model, it was assumed that droplets vaporized instantaneously when they reached a boundary.

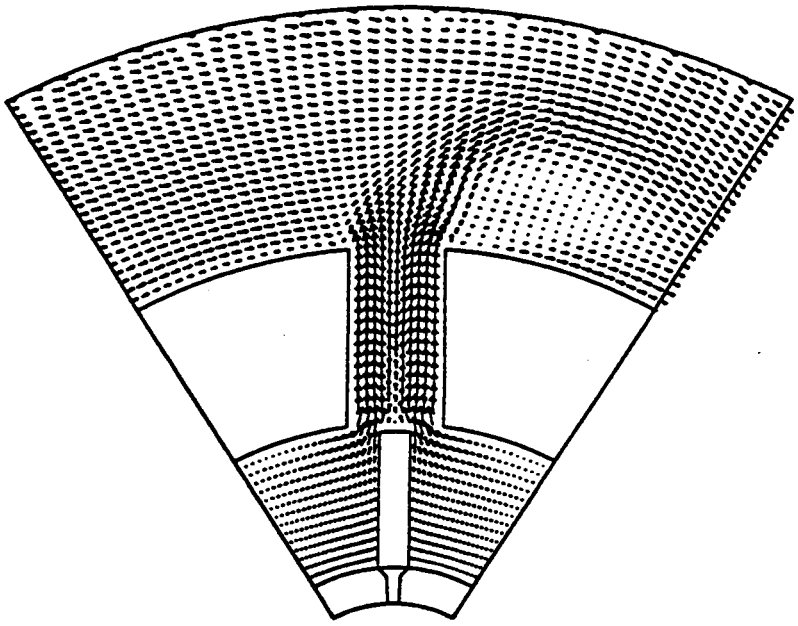
The second CFD model of the Cyclone Swirler pilot was identical to the first, except that instantaneous evaporation of fuel at the wall was not assumed. Instead, the droplets were constrained to bounce off the wall with a coefficient of restitution of unity (angle of incidence equals angle of reflection). The velocity vector field for the evaporating case and reflecting case vector are identical. The vector flow fields are shown in the radial-circumferential plane in Figure 1.4 and in the radial-axial plane in Figure 1.5. Figures 1.6 and 1.7 are contour plots comparing the fuel vapor concentrations for the two vaporization models in the two planes.

Vaporization on the wall, as assumed in the first model, is not desirable because once the fuel evaporates, there is no significant difference in the densities of the fuel and the air. The relative motion between the fuel and the air, due the high radial acceleration, ceases. This causes the rich streaks exiting the Cyclone Swirler as is shown in Figure 1.3. Re-atomized fuel in the flow field will mix more uniformly with the air because the droplets within the cyclone are in a very high acceleration field. The CFD results using the bouncing droplet model, which closely simulates re-atomized fuel, shows a less pronounced rich streak exiting the premixer. Figure 1.8 shows the difference in the droplet trajectories with the two vaporization models.



783.158

Side View



754.568

End View (ALF)

Figure 1.1 - CONCERT 3D results for plain-jet airblast atomizer of Configuration 3 of the Cyclone Swirler pilot. Velocity vector fields are shown in the radial-axial plane and the radial-circumferential plane.

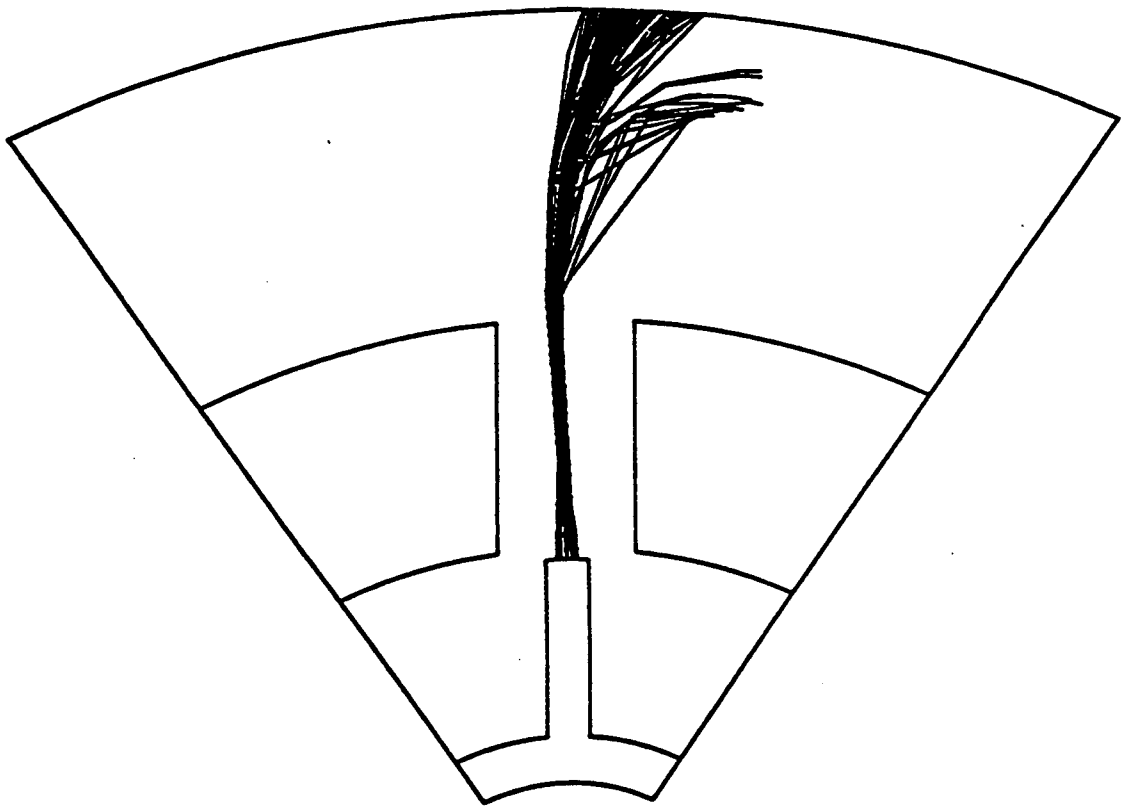
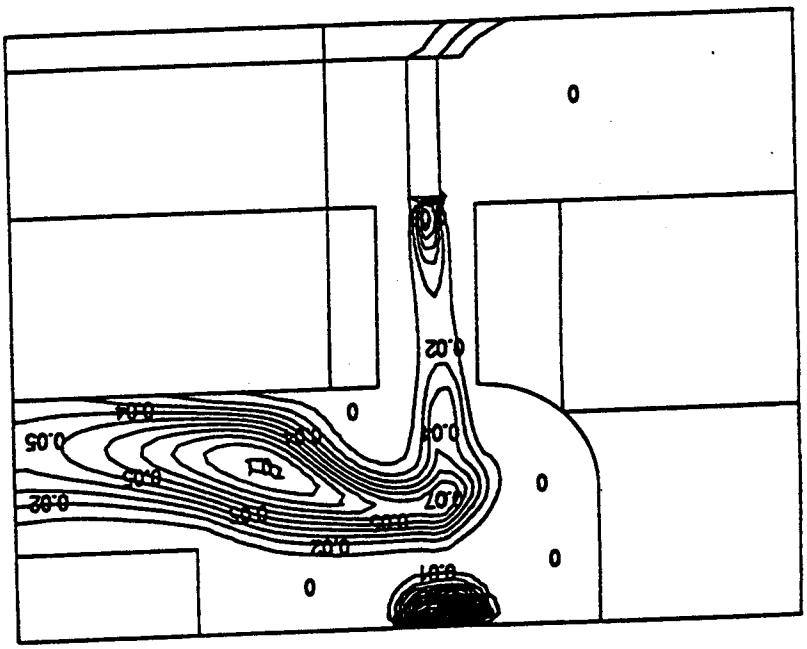
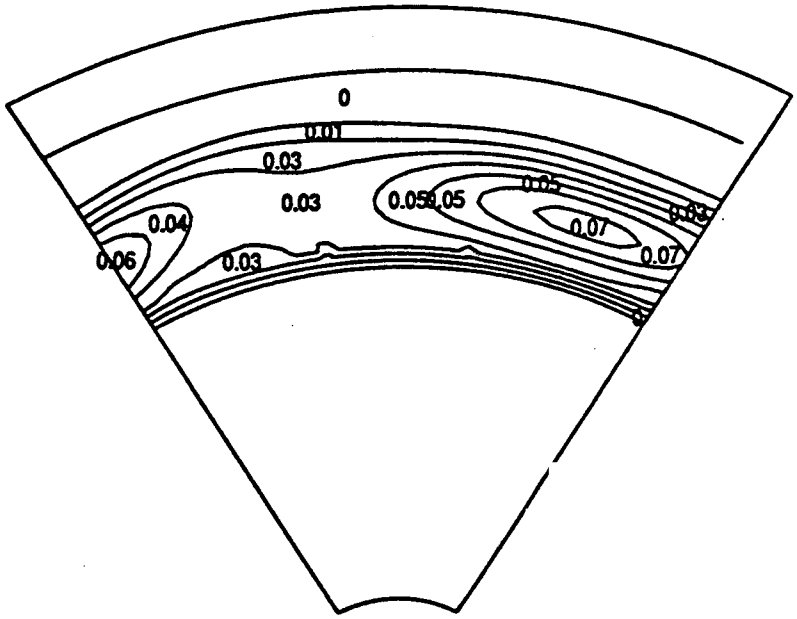


Figure 1.2 - CONCERT 3D results for plain-jet airblast atomizer of Configuration 3 of the Cyclone Swirler pilot. Droplet trajectories are shown in the radial-circumferential plane.



Side View



End View (ALF)

Figure 1.3 - CONCERT 3D results for Configuration 3 of the Cyclone Swirler pilot. Contours of constant vaporized fuel mass fraction are shown in the radial-axial plane and the radial-circumferential plane. The axial position of this radial-circumferential plane is at the upstream end of the annular throat.

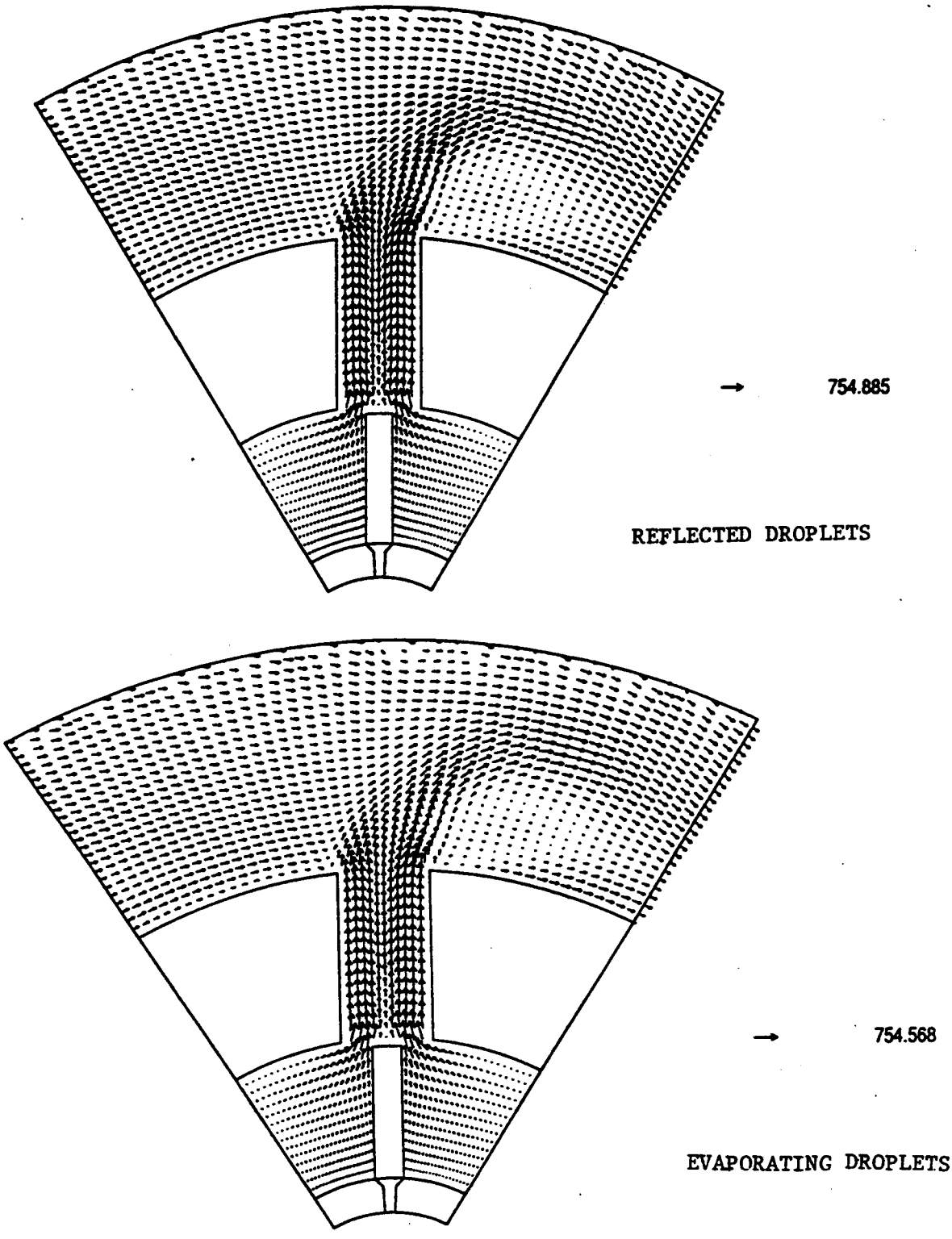


Figure 1.4 - CONCERT 3D results for plain-jet airblast atomizer of Configuration 3 of the Cyclone Swirler pilot. Velocity vector fields are shown in the radial-circumferential plane comparing the results for the reflected droplet model and the evaporating droplet model. The results are nearly identical.

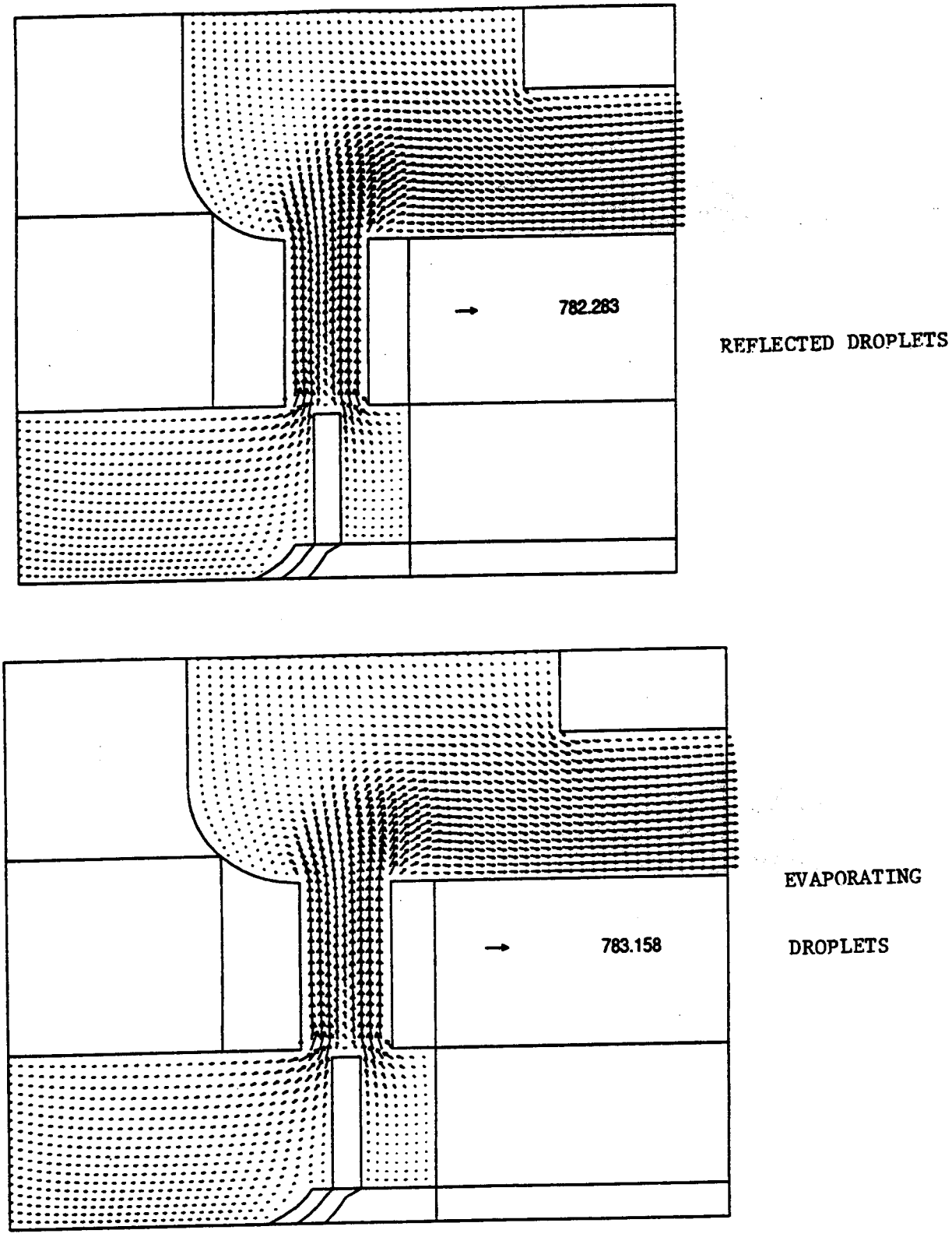


Figure 1.5 - CONCERT 3D results for plain-jet airblast atomizer of Configuration 3 of the Cyclone Swirler pilot. Velocity vector fields are shown in the radial-axial plane comparing the results for the reflected droplet model and the evaporating droplet model. The results are nearly identical.

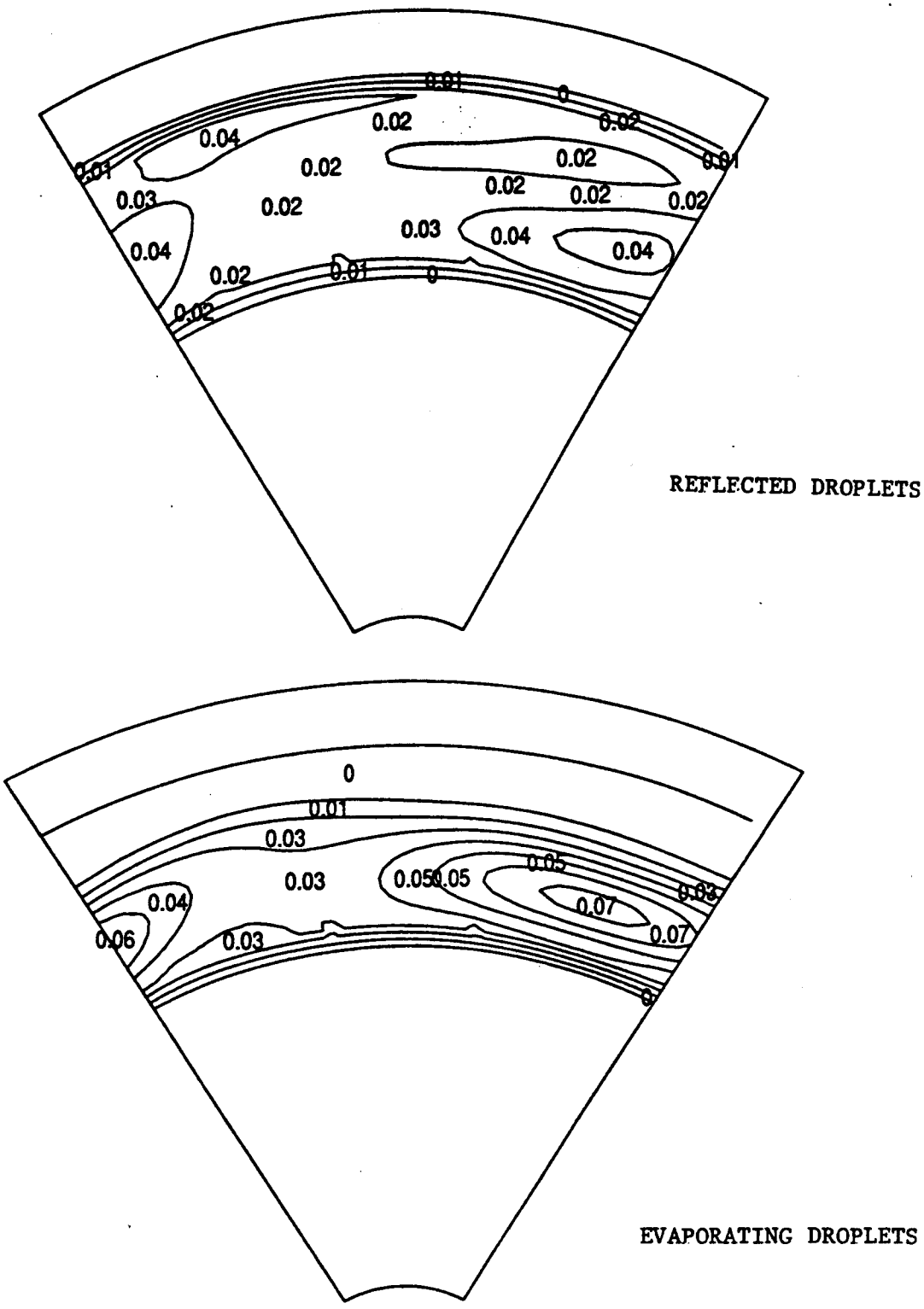
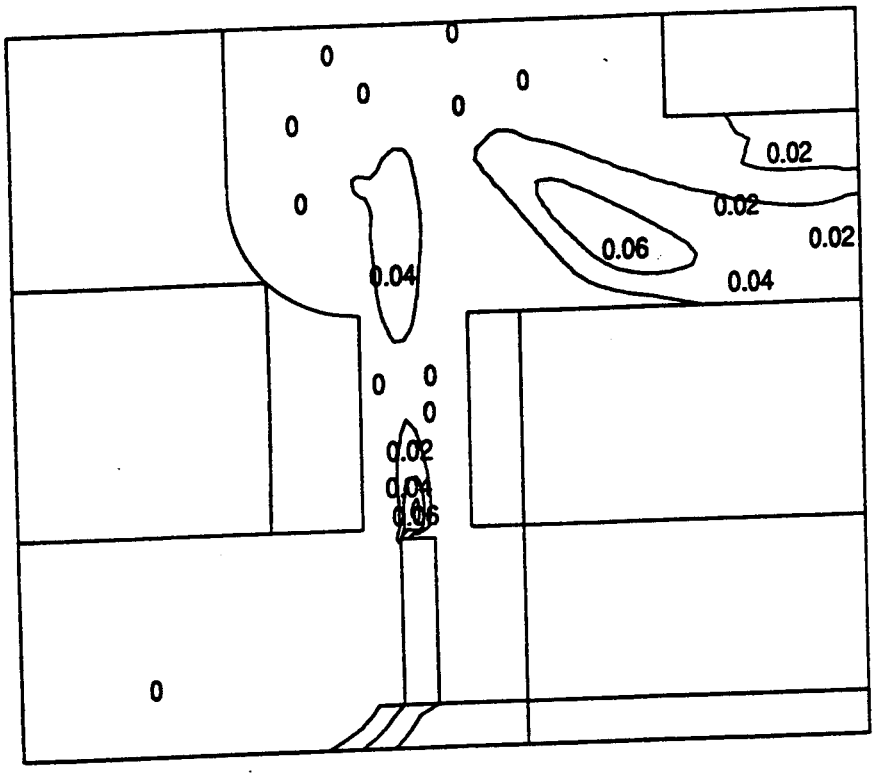
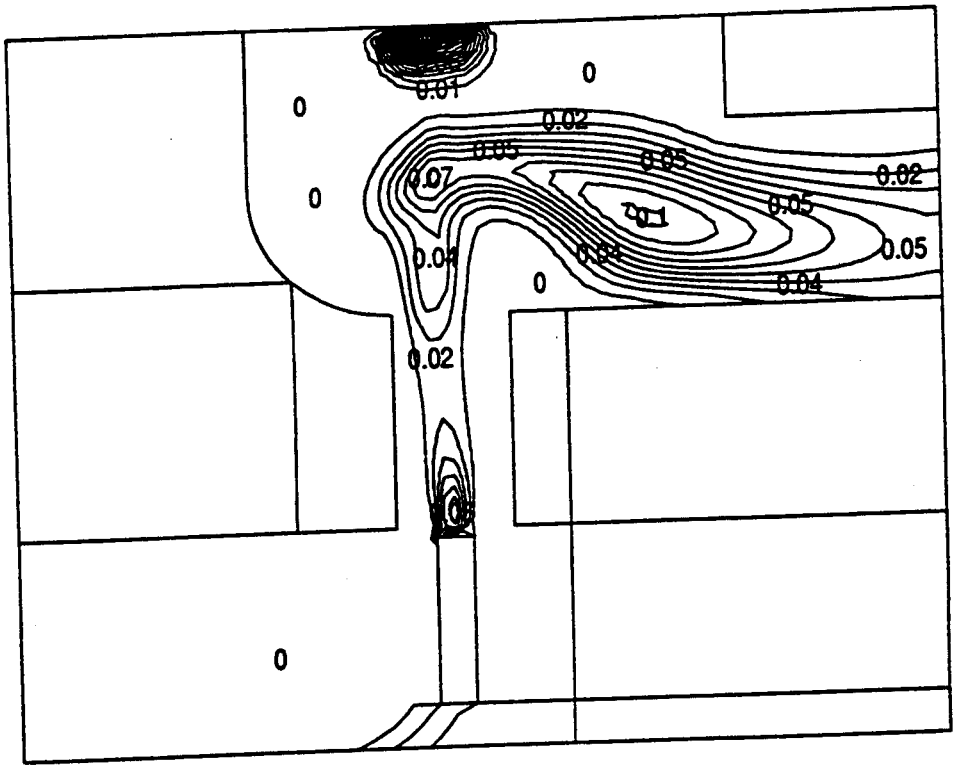


Figure 1.6 - CONCERT 3D results for plain-jet airblast atomizer of Configuration 3 of the Cyclone Swirler pilot. Contours of constant vaporized fuel mass fraction are shown in the radial-circumferential plane comparing the results for the reflected droplet model and the evaporating droplet model.

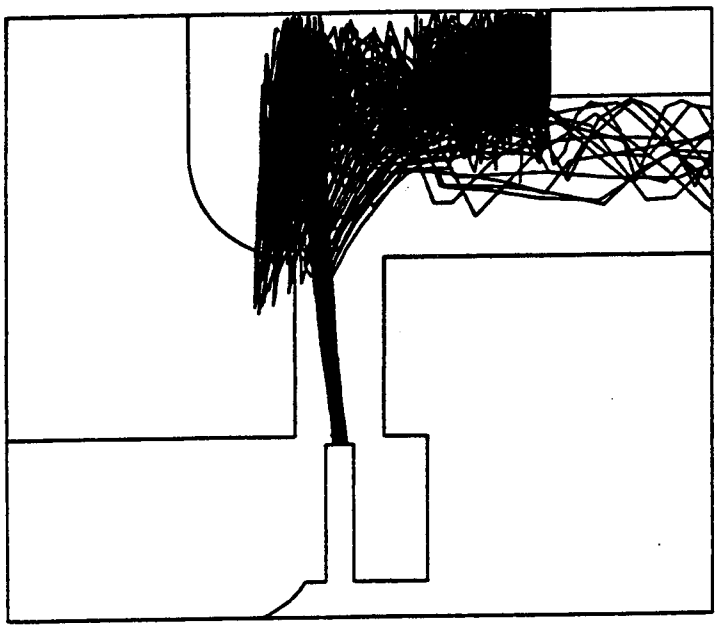


REFLECTED DROPLETS

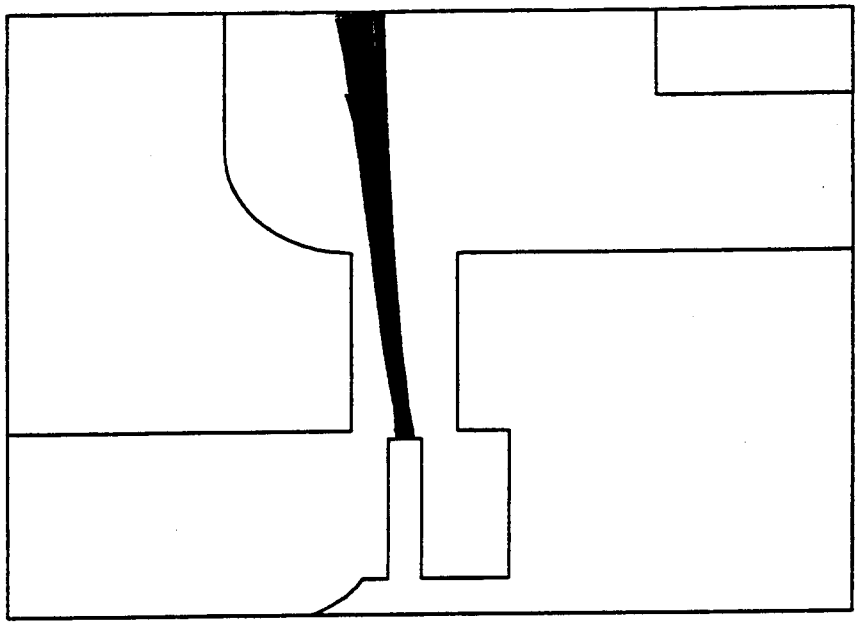


EVAPORATING DROPLETS

Figure 1.7 - CONCERT 3D results for plain jet air-blast atomizer of Configuration 3 of the Cyclone Swirler pilot. Contours of constant vaporized fuel mass fraction are shown in the radial-axial plane comparing the results for the reflected droplet model and the **evaporating droplet model.**



REFLECTED DROPLETS



EVAPORATING DROPLETS

Figure 1.8 - CONCERT 3D results for plain jet air-blast atomizer of Configuration 3 of the Cyclone Swirler pilot. Fuel droplet trajectory plots are shown in the radial-axial plane comparing the results for the reflected droplet model and the evaporating droplet model.

In a Cyclone Swirler, the major portion of the fuel that impinges on the swirler vanes is expected to be re-atomized and entrained back into the flow field by air passing between the swirler vanes. This re-atomization process is more closely modeled by bouncing droplets of the second model than it is by the evaporating droplets of the first model. However, some of the fuel may be evaporated by contacting the hot surface. Thus, the results of the two CFD models may actually bracket the actual mixing in the Cyclone Swirler.

With the reflecting droplet model, with slower fuel evaporation, only a few of the larger droplets exit the Cyclone Swirler before being vaporized. The conclusion is that the Cyclone Swirler pilot, the primary purpose of which is to insure good combustor stability and low emissions under low engine power conditions, appears to be able to totally vaporize the fuel at supersonic cruise conditions. Although the fuel may be totally vaporized, it is not uniformly premixed. NOx emissions are dependent on the degree of mixing of the vaporized fuel and the air. However, this unfired subcomponent CFD model could not be used to make NOx emissions predictions.

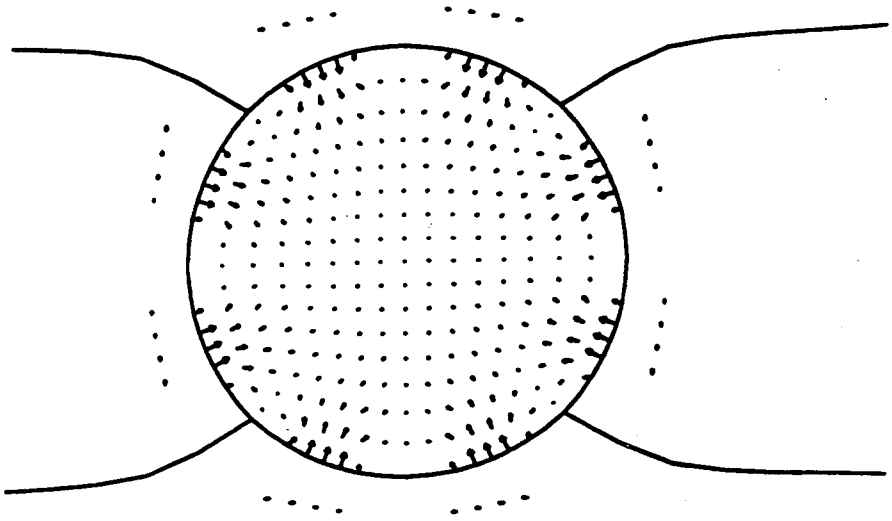
1.1.2 IMFH Tube CFD Modeling

The conditions at which the IMFH tube was modeled were based on the A5B Mixed Flow Turbofan cycle mid-supersonic cruise point. For the IMFH CFD model, the mid-supersonic cruise cycle point was de-rated to the conditions actually run in the high pressure single-cup test of IMFH Configuration 5B (configuration used in the stepped-dome rectangular sector combustor). The conditions that were modeled were P_3 = 11.47 atmospheres and T_3 = 1100°F (1560 R). The fuel flow rate was 19.17 lb/hr and the total air flow rate was 0.161 lb/sec., 11.5% of which went through the cooling circuit. The tube is 5.5 inches long with the fuel injected 1 inch from the inlet through a fuel injector tube with a 0.02 inch inner diameter. The fuel injector tube extends to the centerline of the IMFH tube and is slanted 15 degrees downstream from the radius. At the exit of the IMFH tube there are eight spent cooling air dump holes. Case 1 of the CFD model has eight dome spent cooling air dump holes centered 0.23 inch from the exit of the premixer tube of the actual hardware.

Case 2 uses four larger diameter spent cooling air dump holes in order to maintain the same total air flow and jet velocity as the first case. The flow fields in the radial-circumferential plane at the axial position of the spent cooling holes are compared for Cases 1 and 2 in Figure 1.9. The four-hole case results in better penetration of the dome cooling dump air. The baseline fuel injector tube used for Cases 1 and 2 is a wall injector with 50% immersion. Figure 1.10 provides a close-up view of the of the sidewall injector tube location. Again, this injector configuration is the one used in Configuration 5A and 5B of the single-cup IMFH and the stepped-dome sector combustor. In the CFD model, fuel is injected as a single 20 μm SMD stream at the tip of an obstacle representing the fuel injector. The droplet trajectories in the radial-axial plane are compared for Cases 1 and 2 in Figure 1.10. The vaporized fuel fraction in the radial-axial plane are compared in Figure 1.11 and the radial-circumferential plane in Figure 1.12. There is no significant differences in droplet trajectories and fuel vapor mass fractions are only slightly different. The 4-hole configuration is slightly more successful in moving fuel away from the tube wall.

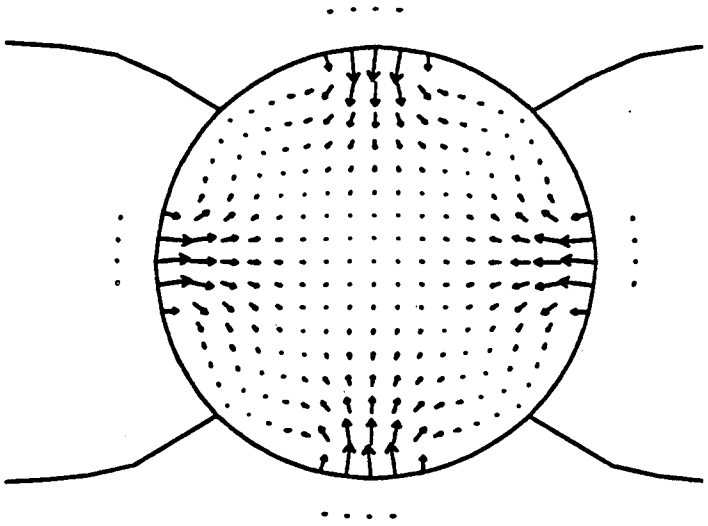
Two additional cases of the IMFH single tube mixer model were run investigating non-uniform spent cooling hole spacing. Case 3 uses four spent cooling air dump holes like Case 2. However, the holes are rearranged such that hole 1 is nearly in line with the fuel injector, hole 2 is 180° opposite hole 1, and holes 3 and 4 are 45° on each side of holes 2. Case 4 uses the same hole pattern as Case 3, but it reduces the immersion of the fuel injector from 50% to 20%.

Comparison of Case 2 in Figures 1.9 through 1.12 with Case 3 in Figures 1.13 through 1.16 leads to several conclusions. Penetration of the spent cooling air jets for Cases 2 and 3 is nearly the same. Since Case 3 dumps more dome cooling air opposite the fuel injector than Case 2, the droplet trajectories are pushed away from the mixer tube wall at this location. The fuel vapor mass fraction profiles at the exit of the mixer tube are similar for Cases 2 and 3 and the peak fuel streak is in nearly the same location for both cases. Since fuel mass fraction profiles at the exit of the mixer tube, as well as the droplet trajectories, are only slightly different between Cases 1, 2 and 3; very little difference in NOx emissions, stability, or combustion efficiency would be expected.



218.446

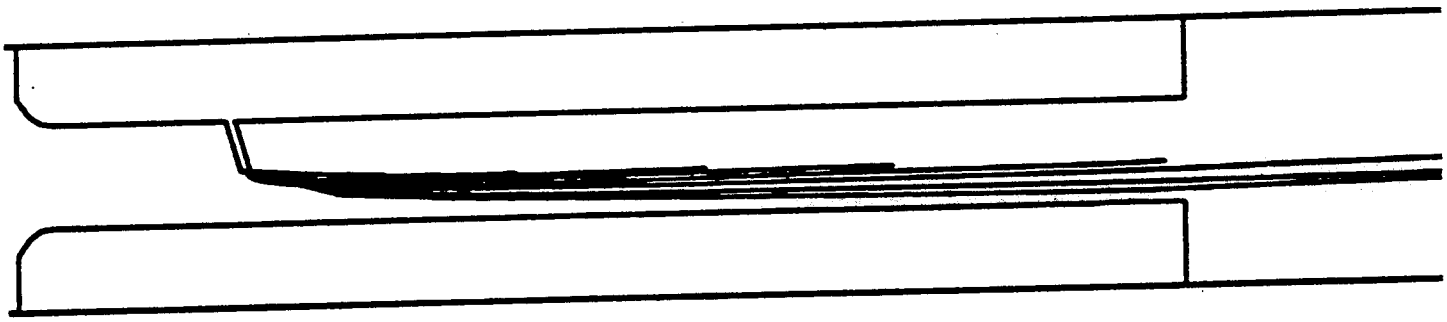
Configuration 1 - 8 Dome Cooling Dump Holes.
(End View)



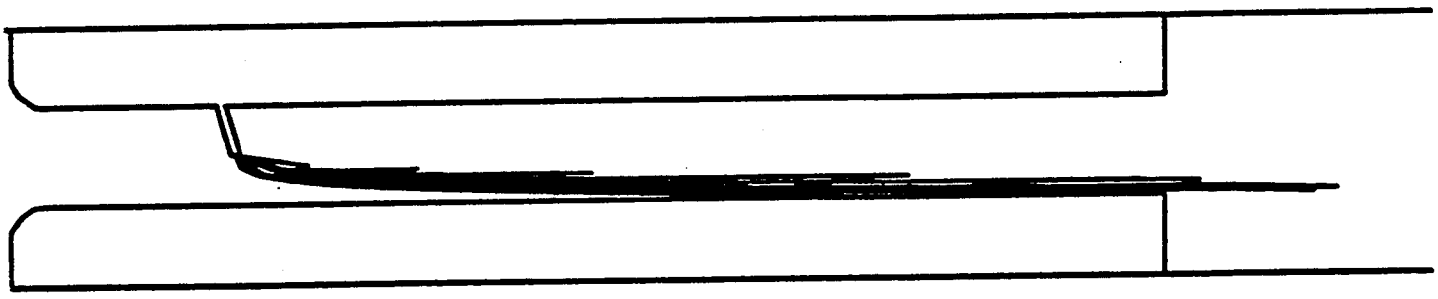
233.047

Configuration 2 - 4 Dome Cooling Dump Holes.
(End View)

Figure 1.9 - CONCERT 3D results for IMFH tube. Velocity vector plots are shown in the radial-circumferential plane passing through the spent dome cooling air injection holes. 8 cooling air holes are compared to 4 cooling air holes.



Configuration 1 - 8 Dome Cooling Dump Holes.
(Side View)



Configuration 2 - 4 Dome Cooling Dump Holes.
(Side View)

Figure 1.10 - CONCERT 3D results for IMFH tube. Fuel droplet trajectory plots are shown in the radial-axial plane passing through the fuel injector tube. The effect of 8 cooling air holes on the droplet trajectories are compared to 4 cooling air holes.

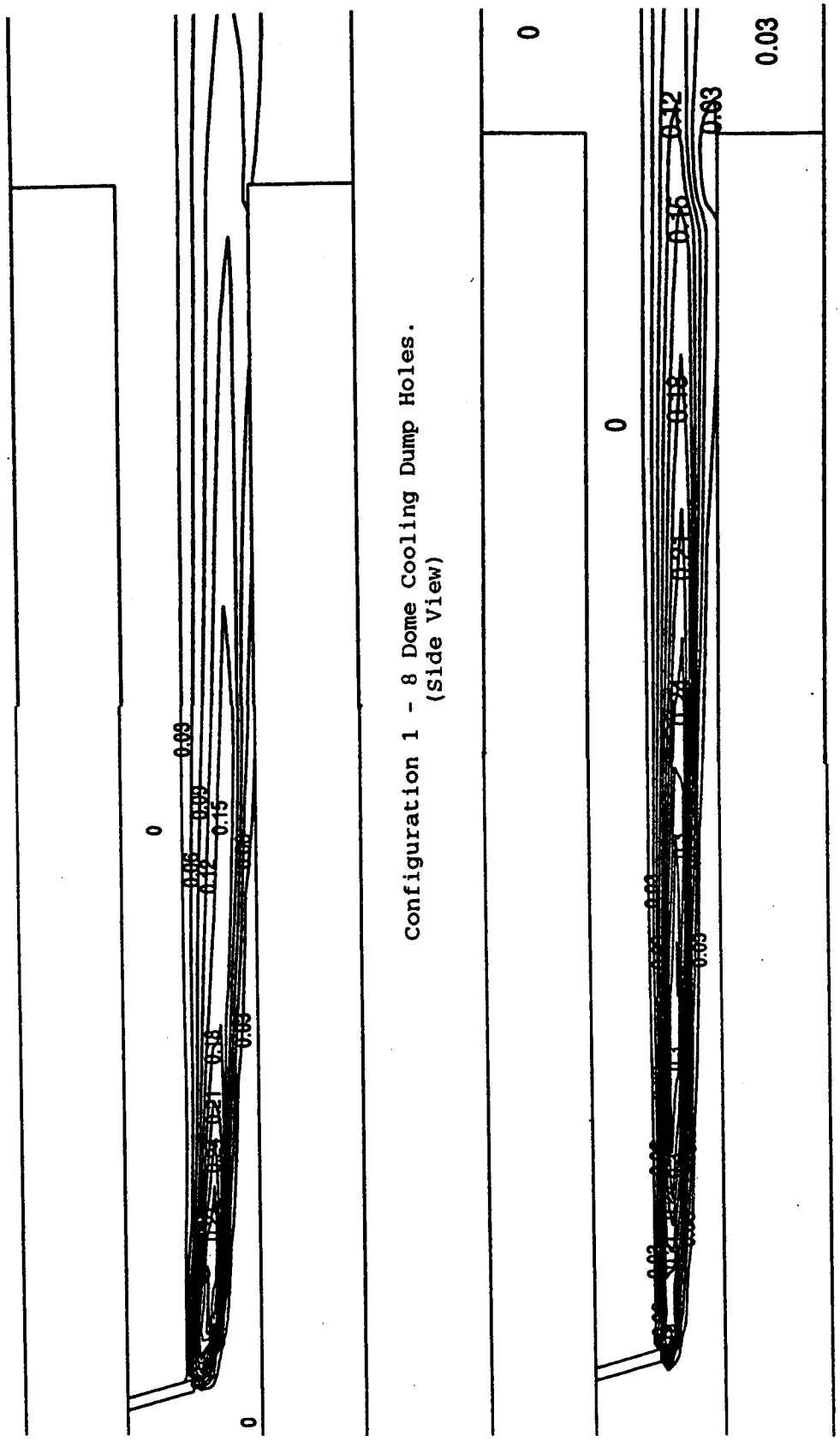
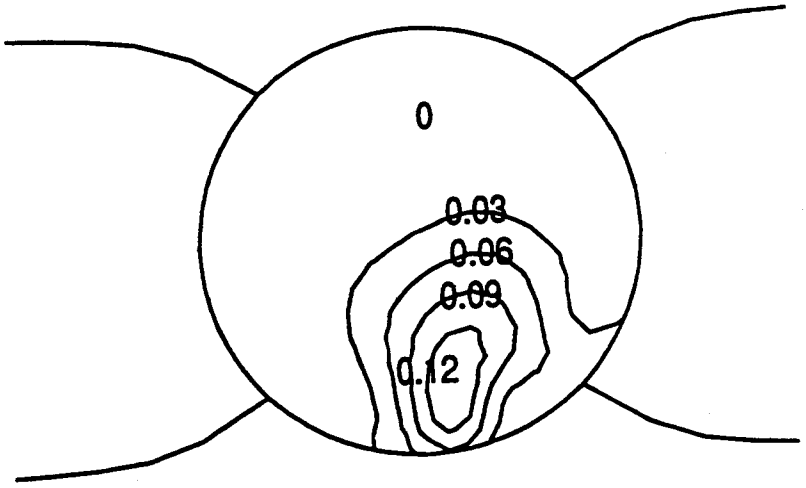
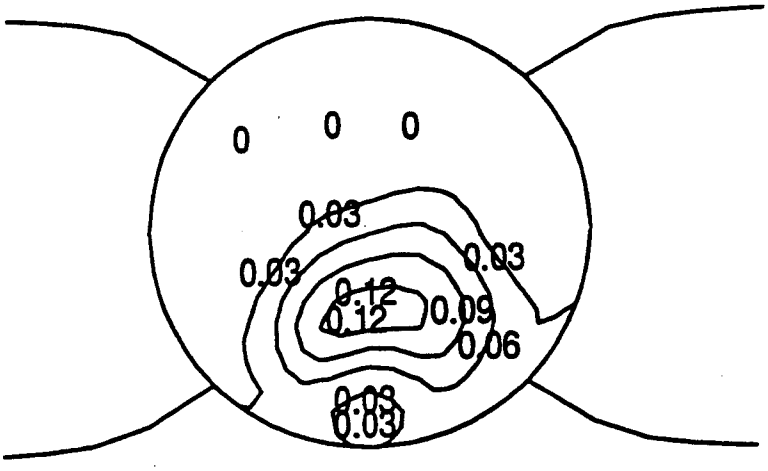


Figure 1.11 - CONCERT 3D results for IMFH tube. Plots of contours of constant vaporized fuel mass fraction are shown in the radial-axial plane passing through the fuel injector tube. The effect of 8 cooling air holes on the droplet trajectories are compared to 4 cooling air holes.



PDF-MEAN

Configuration 1 - 8 Dome Cooling Dump Holes.
(End View)



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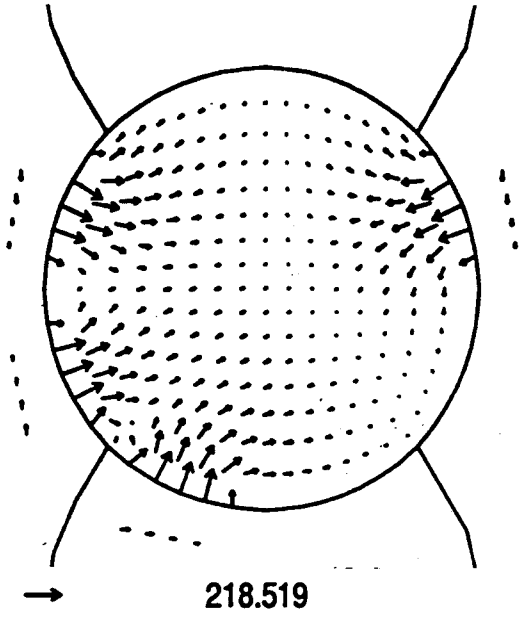
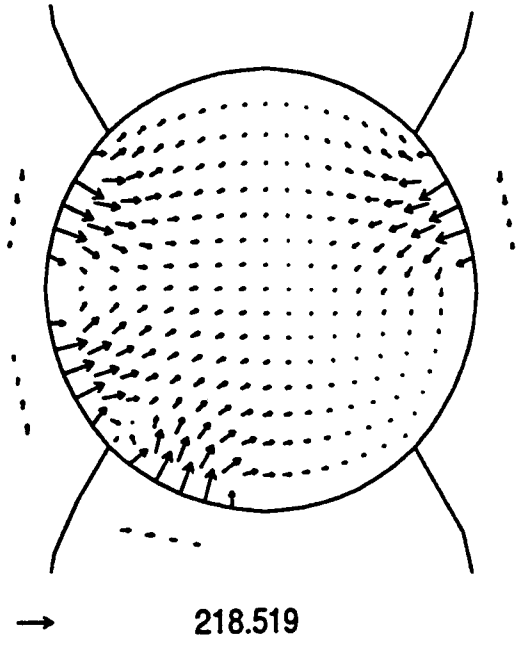
Configuration 2 - 4 Dome Cooling Dump Holes.
(End View)

Figure 1.12 - CONCERT 3D results for IMFH tube. Plots of contours of constant vaporized fuel mass fraction are shown in the radial-circumferential plane at the axial position of the of the spent dome cooling air injection holes. The effect of 8 cooling air holes on the droplet trajectories are compared to 4 cooling air holes.

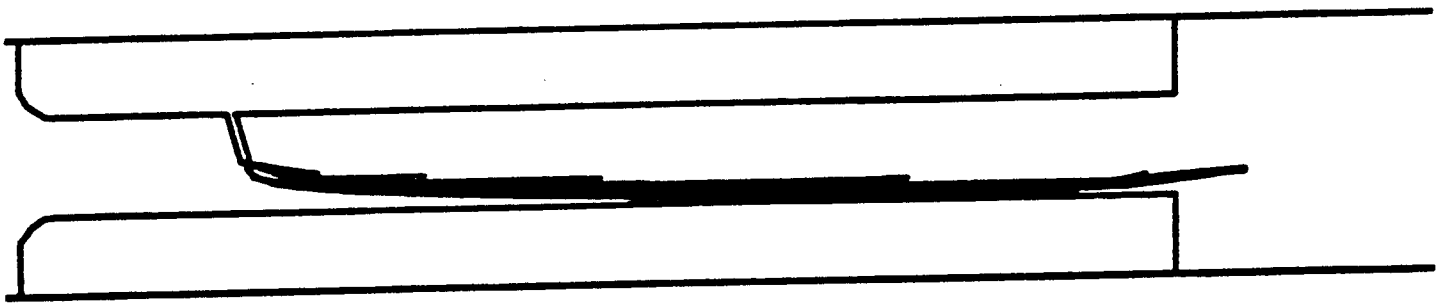


Configuration 3 - 4 Dome Cooling Dump Holes,
Unequally Spaced, 50% Hypo Fuel Tube Immersion.
(End View)

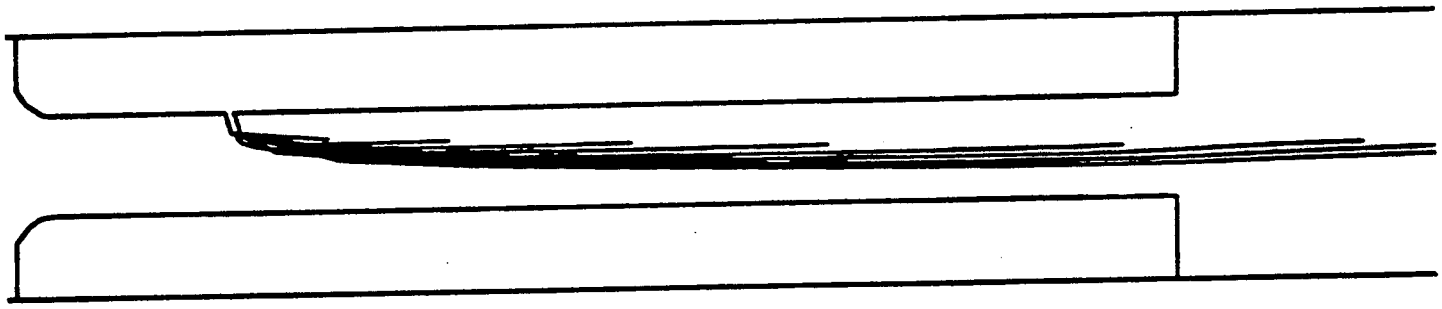


Configuration 4 - 4 Dome Cooling Dump Holes,
Unequally Spaced, 20% Hypo Fuel Tube Immersion.
(End View)

Figure 1.13 - CONCERT 3D results for IMFH tube. Plots of velocity vectors are shown in the radial-circumferential plane in the plane of 4 spent cooling air holes unequally spaced around the tube wall. Results are shown for 50% immersions of the fuel injector tube and 20% immersion. There is no difference for this particular result.



Configuration 3 - 4 Dome Cooling Dump Holes,
Unequally Spaced, 50% Hypo Fuel Tube Immersion.
(Side View)



Configuration 4 - 4 Dome Cooling Dump Holes,
Unequally Spaced, 20% Hypo Fuel Tube Immersion.
(Side View)

Figure 1.14 - CONCERT 3D results for IMFH tube. Plots of fuel droplet trajectories are shown in the radial-axial plane through the fuel injector tube. The 4 spent cooling air holes are unequally spaced around the tube wall. Results are shown for 50% immersions of the fuel injector tube and 20% immersion.

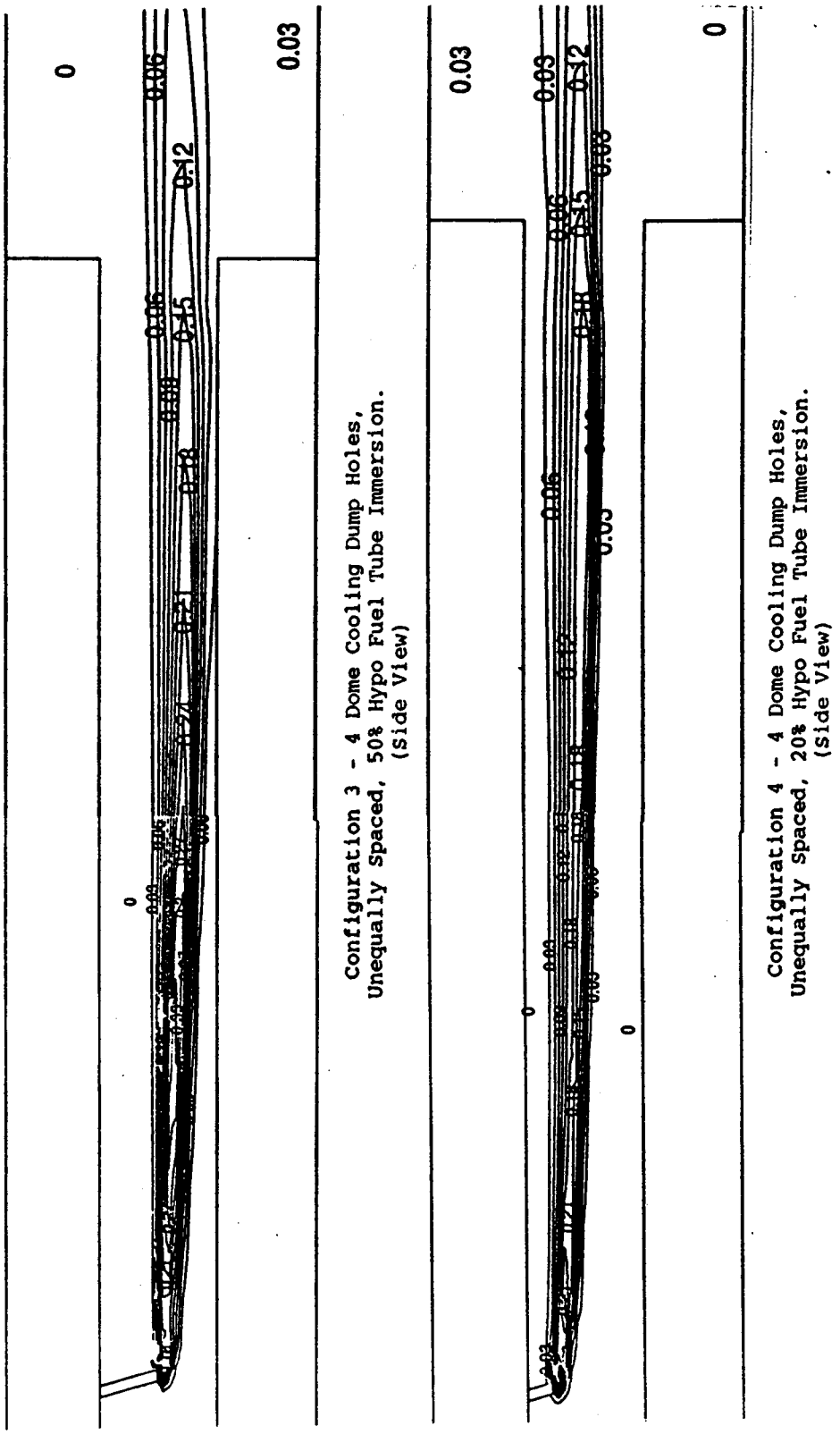
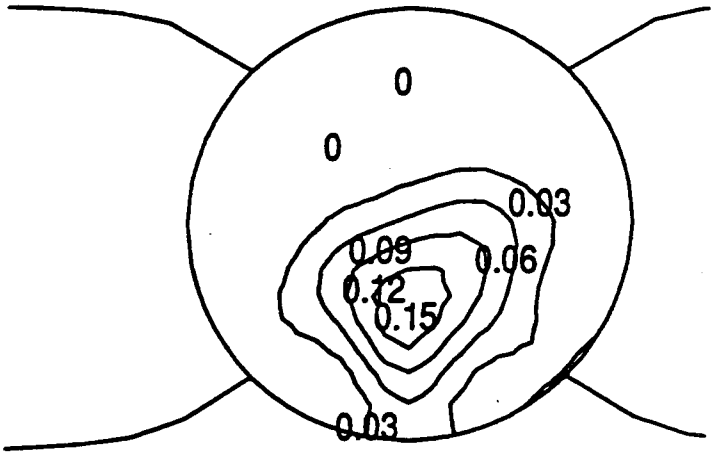
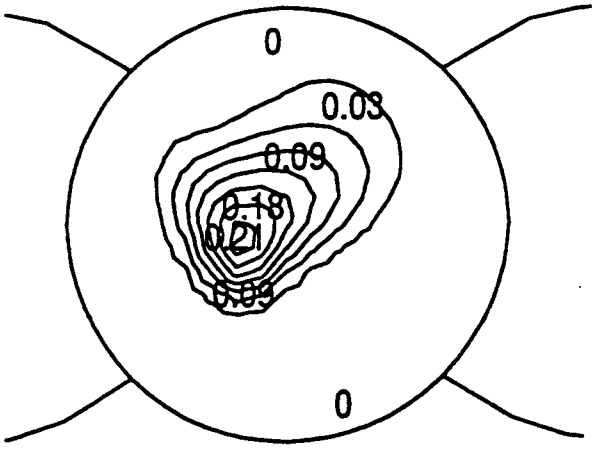


Figure 1.15 - CONCERT 3D results for IMFH tube. Plots of constant contours of vaporized fuel mass fraction are shown in the radial-axial plane through the fuel injector tube. The 4 spent cooling air holes are unequally spaced around the tube wall. Results are shown for 50% immersions of the fuel injector tube and 20% immersion.



PDF-MEAN
Configuration 3 - 4 Dome Cooling Dump Holes,
Unequally Spaced, 50% Hypo Fuel Tube Immersion.
(End View)



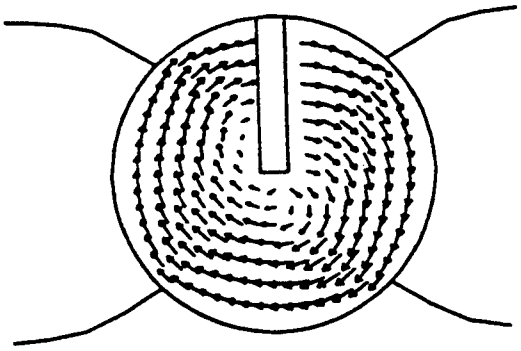
PDF-MEAN
Configuration 4 - 4 Dome Cooling Dump Holes,
Unequally Spaced, 20% Hypo Fuel Tube Immersion.
(End View)

Figure 1.16 - CONCERT 3D results for IMFH tube. Plots of contours of constant vaporized fuel mass fraction are shown in the a radial-circumferential plane in the plane of 4 spent cooling air holes unequally spaced around the tube wall. Results are shown for 50% immersions of the fuel injector tube and 20% immersion. The injectors are centered at the top (not shown).

Comparison of the results for Cases 3 and 4 in Figures 1.15 through 1.16 reveals that the peak fuel mass fraction for Case 3 is 0.15, whereas the peak mass fraction for Case 4 is 0.21. The peak mass fraction findings for Case 4 support the conclusions drawn about the mixer tube exit fuel/air distribution regarding the single-cup test of Swirl-IMFH with 20% injector immersion in Section 3.3.1. The measured data for the 50% immersion case has lower NOx emissions and better combustion efficiency, because the 50% injector immersion results in a more uniform mixture. The better mixing of the 50% injector immersion is consistent with the fuel being nearer the wall, as shown in Figures 1.1.4 through 1.16, where the mixture is subjected to more shear within the tube.

Both immersions yield a fuel rich steak near the tube centerline (although the beneficial effect of the mixing of the spent cooling air ejection is not included in these results). For a given level of non-uniformity at the exit of the tube, it preferable for the richer gases to be nearer the centerline, because that mixture will not enter the mixing boundary layer till later (where they would be slowed down and ignited) and be unlikely to enter the recirculation zone. Thus once ignited, the hotter centerline gases will tend to have a much lower residence time to produce NOx than the cooler regions. For a given a level of mixture non-uniformity at the exit of the tube, having the leaner gases near the wall is expected to be less detrimental to combustion efficiency. Entering the combustor near the tube wall, they will enter the mixing boundary layer first where they are ignited, slowed down, and also be more likely to recirculate. The leaner gases would therefore tend to have the longer residence time they need to burn efficiently. These arguments would indicate the emissions performance of the IMFH has some tolerance to fuel-air mixing non-uniformity of the type seen in Figure 1.16 (richer gases in the center).

In order to investigate the effect of swirl added at the inlet of the IMFH tube (swirl angle = 11.5°), CFD Cases 5A and 6 were run. Case 5A used the four equally spaced cooling dump holes with a 50% fuel injector tube immersion. Case 6 adds 11.5° swirl to the Case 4 parameters (unequal spacing of the spent cooling air dump holes and the 20% fuel injector tube immersion). Figure 1.17 shows the flow field vector plots of Case 5A in the radial-circumferential plane at the axial positions of the fuel injector and the spent cooling air injection holes. The swirling flow field of Case 5A and its interactions with the injector and the spent cooling air are readily evident.



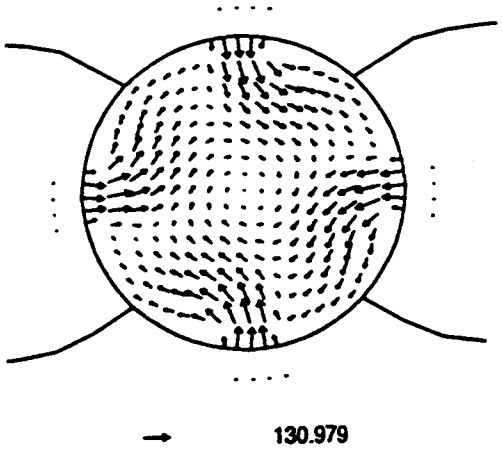


Figure 1.17 - CONCERT 3D results for IMFH tube. 50% fuel injector tube immersion. Plots of velocity vectors are shown in the radial-circumferential plane in the plane of the fuel injector and the 4 spent cooling air holes equally spaced around the tube wall. The flow into the tube has an 11.5 degree swirl angle.

Figure 1.18 shows the fuel vapor mass fraction for Case 5A. It is seen that the Case 5A peak fuel mass fraction decreased to 0.09 from 0.12 in Case 2 when swirl was added to the mixer tube. This is lower than any of the previous cases. Figure 1.19 compares the fuel vapor mass fraction for Case 5A to Case 2. The cross-sectional area over which the fuel spreads is very similar, although the area in the swirling case appears slightly larger. Figure 1.20 shows the fuel droplet trajectories for Case 5A. Figure 1.21 compares the droplet trajectories for Cases 2 and 5A. The swirling flow pushed a significant amount of fuel to the mixer tube walls where it would be instantly vaporized (the model's boundary condition). This vaporization may have increased the peak fuel mass fraction for Case 5A over what it would have been without the vaporization at the wall boundary condition.

Figure 1.22 shows the flow field vector plot for Case 6 in the radial-circumferential plane at the axial positions of the fuel injector and the spent cooling air injection holes. Again the swirl and its interactions are clearly seen. Figure 1.23 shows the fuel droplet trajectories in the radial-circumferential plane and the radial axial plane. Figure 1.24 shows the fuel vapor mass fraction contours in the radial-axial plane. It can be seen that by reducing the fuel injector tube immersion to 20%, the fuel contacting the mixer tube wall has actually increased. This can be explained by considering the flow field relative to the tip of the fuel injector. In the 50% immersion case, the fuel is injected at the center of the swirling stream. Thus as the fuel travels away from the injector tip, the angular velocity of the air increases from zero, slowly increasing the radial acceleration. In the 20% immersion case, the local flow field is highly swirling at the injector tip. The radial acceleration the droplets see is high right from the time it is injected, so the fuel is centrifuged to the mixer tube wall. Based upon these results and their interpretation, it appears that for swirling flow within an IMFH tube, a 50% fuel injector immersion is optimum.

1.1.3 Combustor System CFD Modeling

CONCERT 3D CFD modeling was used to investigate design variations of the Multistage Radial Axial (MRA) combustor. A mechanical layout of the original MRA was never performed before the design evolved to a significantly different design (the "inverted MRA" still being

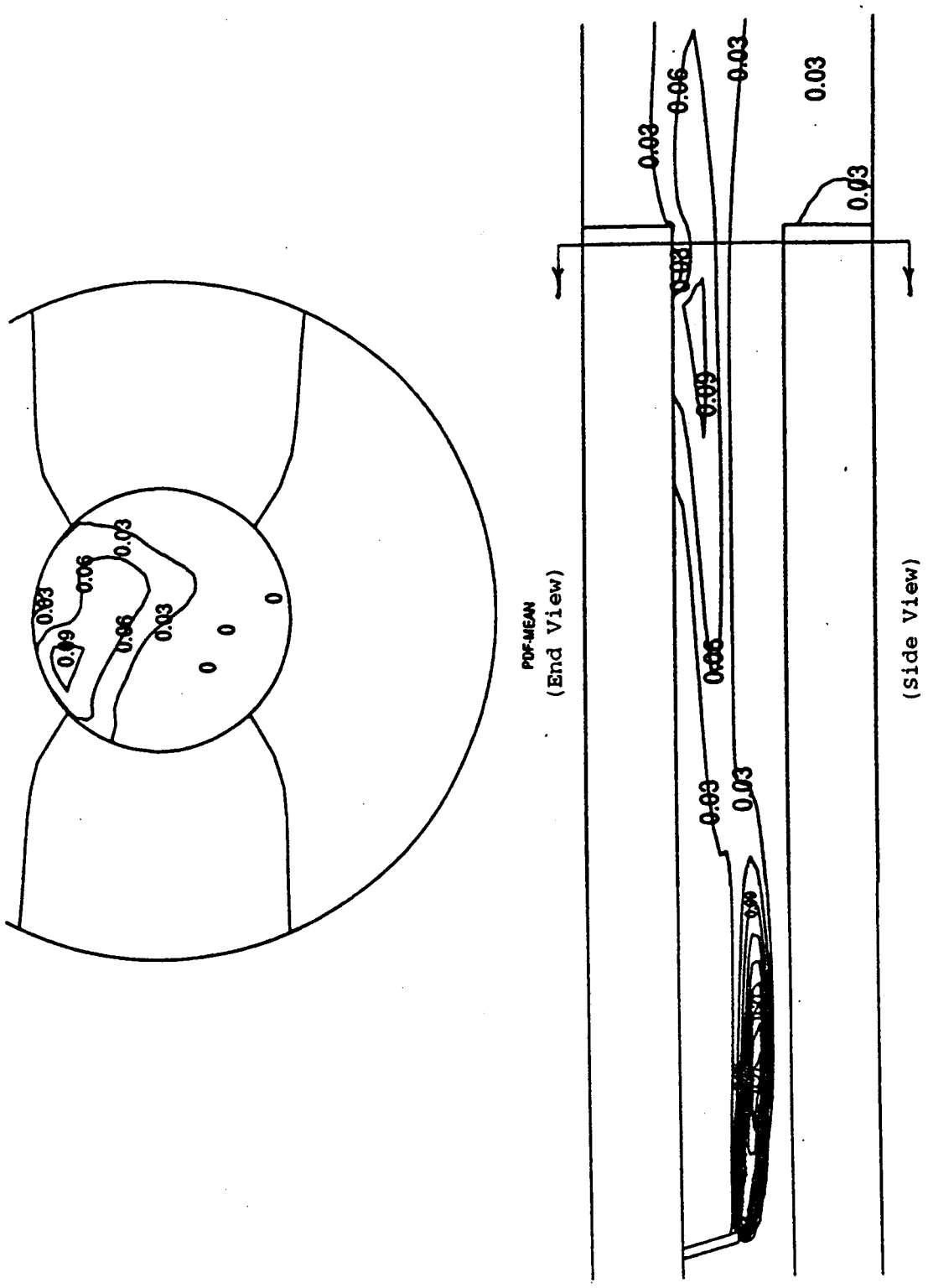
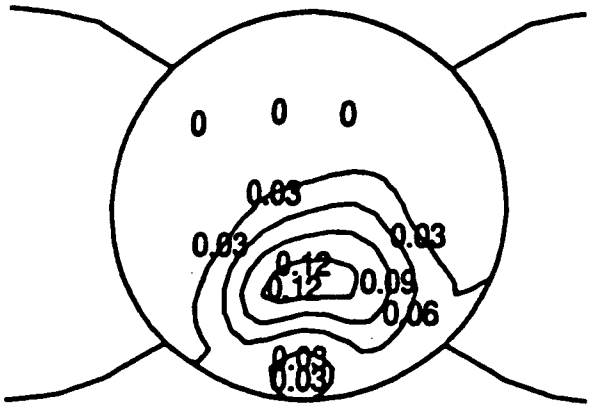
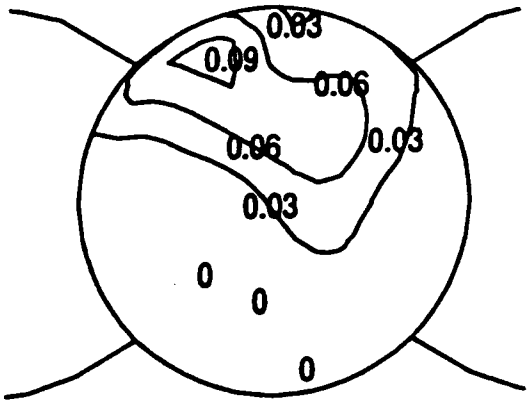


Figure 1.18 - CONCERT 3D results for IMFH tube. Plots of contours of constant vaporized fuel mass fraction are shown in the radial-circumferential plane and the radial-axial plane. The flow in the tube has an 11.5-degree swirl angle. There are 4 spent cooling air holes.



Configuration 2, Non-swirling



Configuration 5A, 11.5-degree swirl

Figure 1.19 - CONCERT 3D results for IMFH tube. Plots of contours of constant vaporized fuel mass fraction are shown in the a radial-circumferential plane in the plane of 4 spent cooling air holes equally spaced around the tube wall. 50% immersion of the fuel injector tube. Results with no swirl (Configuration 2) are compared with 11.5-degree swirl angle (Configuration 5A).

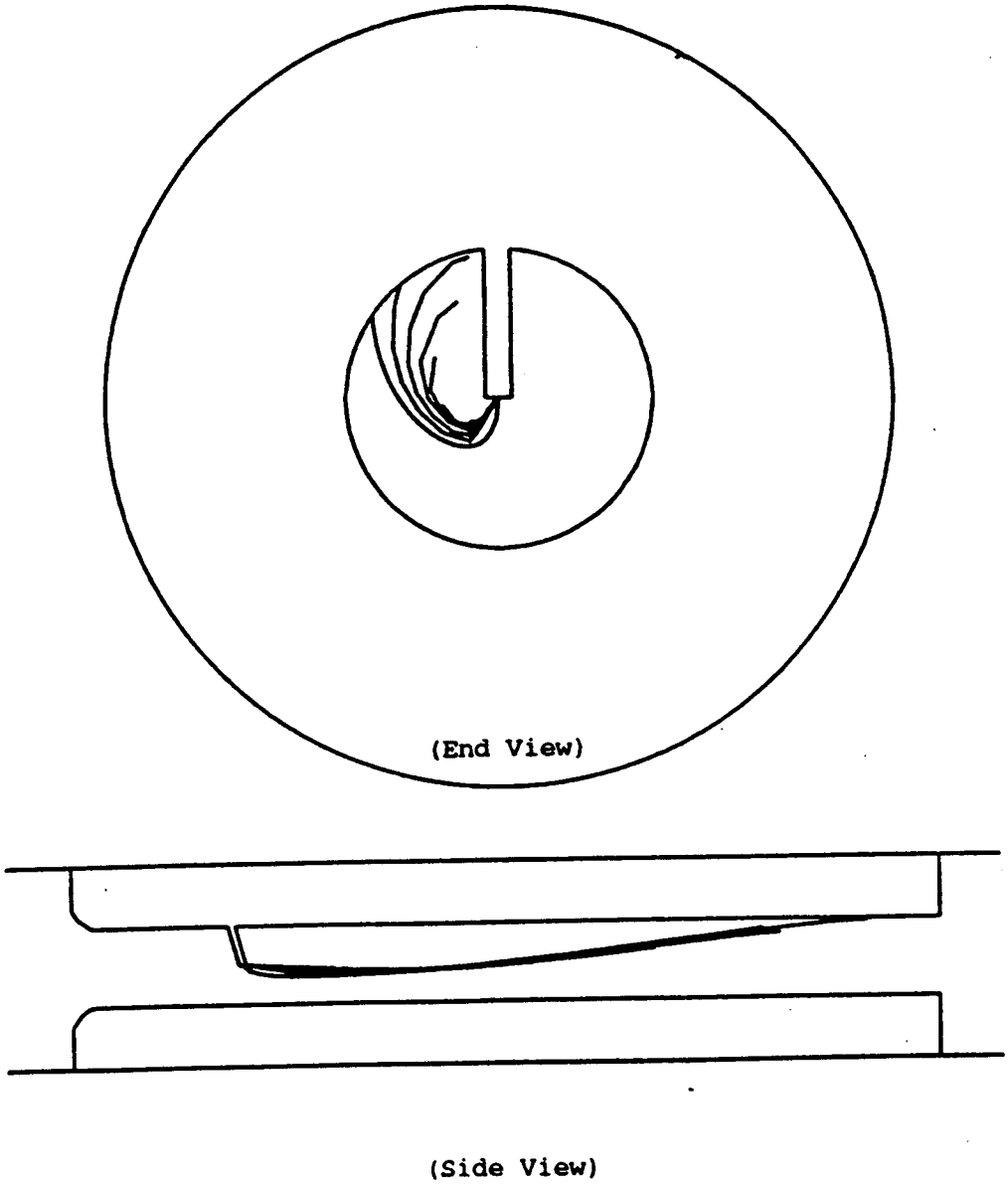


Figure 1.20 - CONCERT 3D results for IMFH tube. Plots of fuel droplet trajectories are shown in the radial-circumferential plane and the radial-axial plane. The 4 spent cooling air holes equally spaced around the tube wall. 50% immersion of the fuel injector tube. Results are with 11.5-degree swirl angle (Configuration 5A).

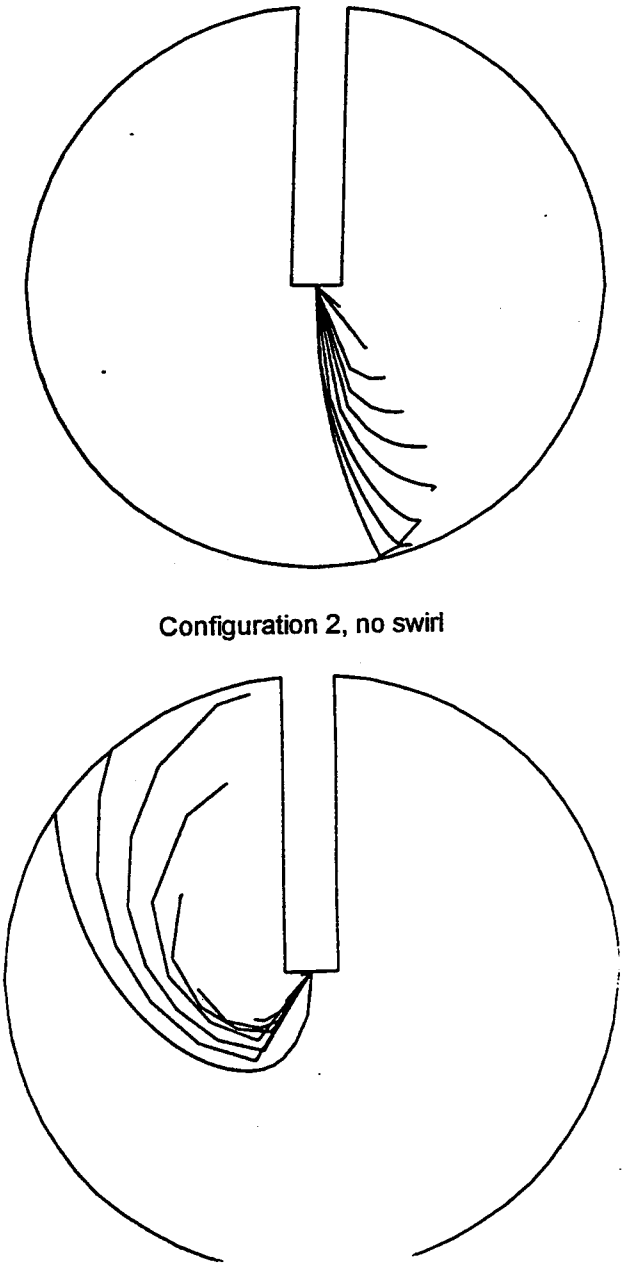
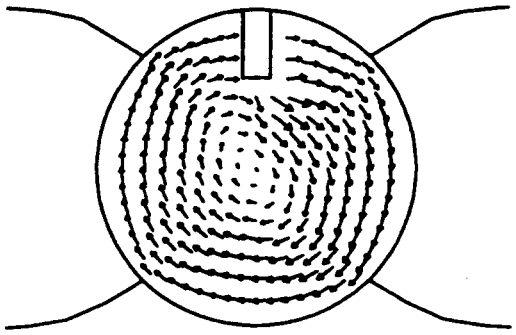
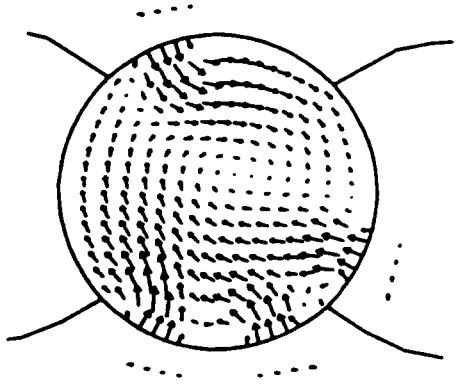


Figure 1.21 - CONCERT 3D results for IMFH tube. Plots of fuel droplet trajectories are shown in the a radial-circumferential plane. The 4 spent cooling air holes equally spaced around the tube wall. 50% fuel injector immersion. The results for no swirl (Configuration 2) are compared to 11.5-degree swirl (Configuration 5A).



→ 124.828

Plane of the fuel injector



→ 128.948

Plane of the 4 spent cooling air injection holes

Figure 1.22 - CONCERT 3D results for IMFH tube. Configuration 6. Plots of velocity vectors are shown in the radial-circumferential plane in the plane of the fuel injector and in the plane of the 4 spent cooling air holes unequally spaced around the tube wall. The **fuel injector immersion is 20%. The flow in the tube has an** 11.5 degree swirl angle.

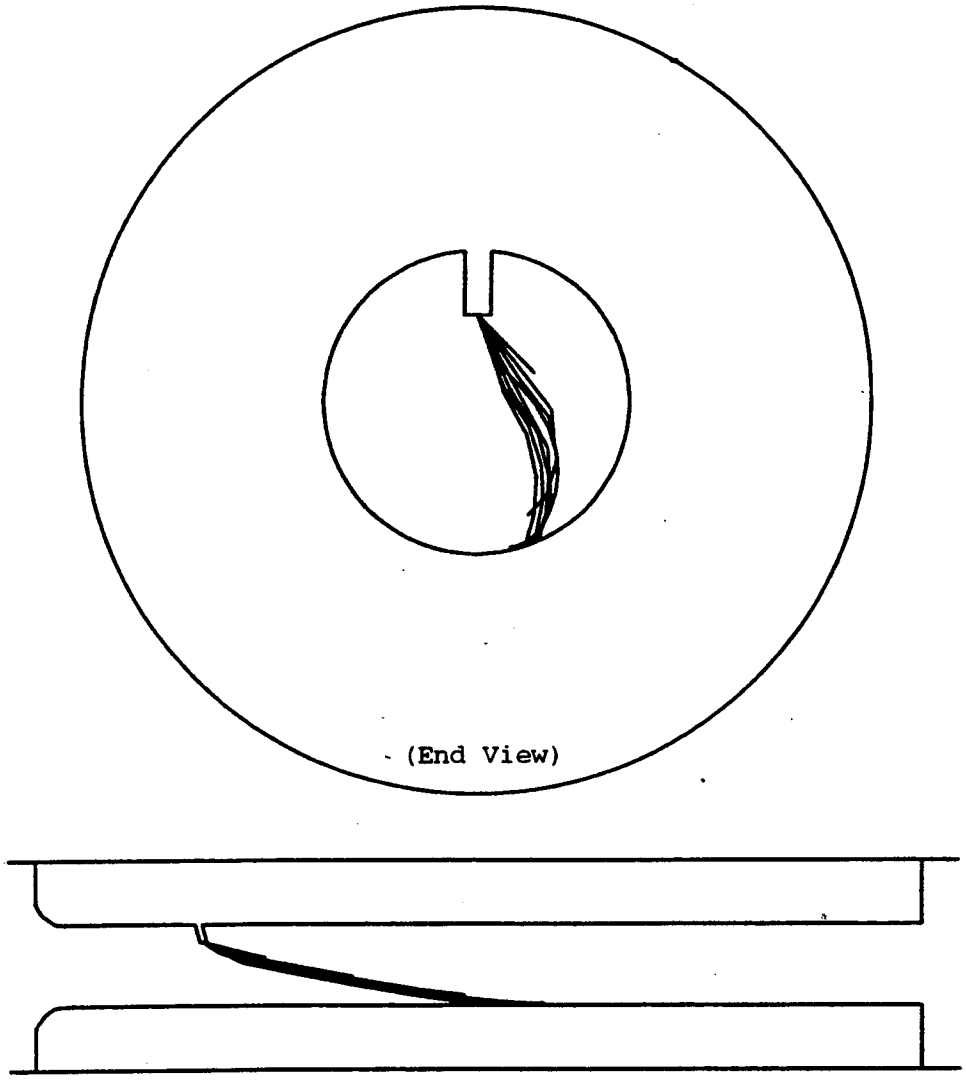


Figure 1.23 - CONCERT 3D results for IMFH tube. Plots of fuel droplet trajectories are shown in the radial-circumferential plane and the radial-axial plane. The flow in the tube has an 11.5-degree swirl angle. The fuel injector has a 20% immersion. The 4 spent dome cooling air holes are unequally spaced.

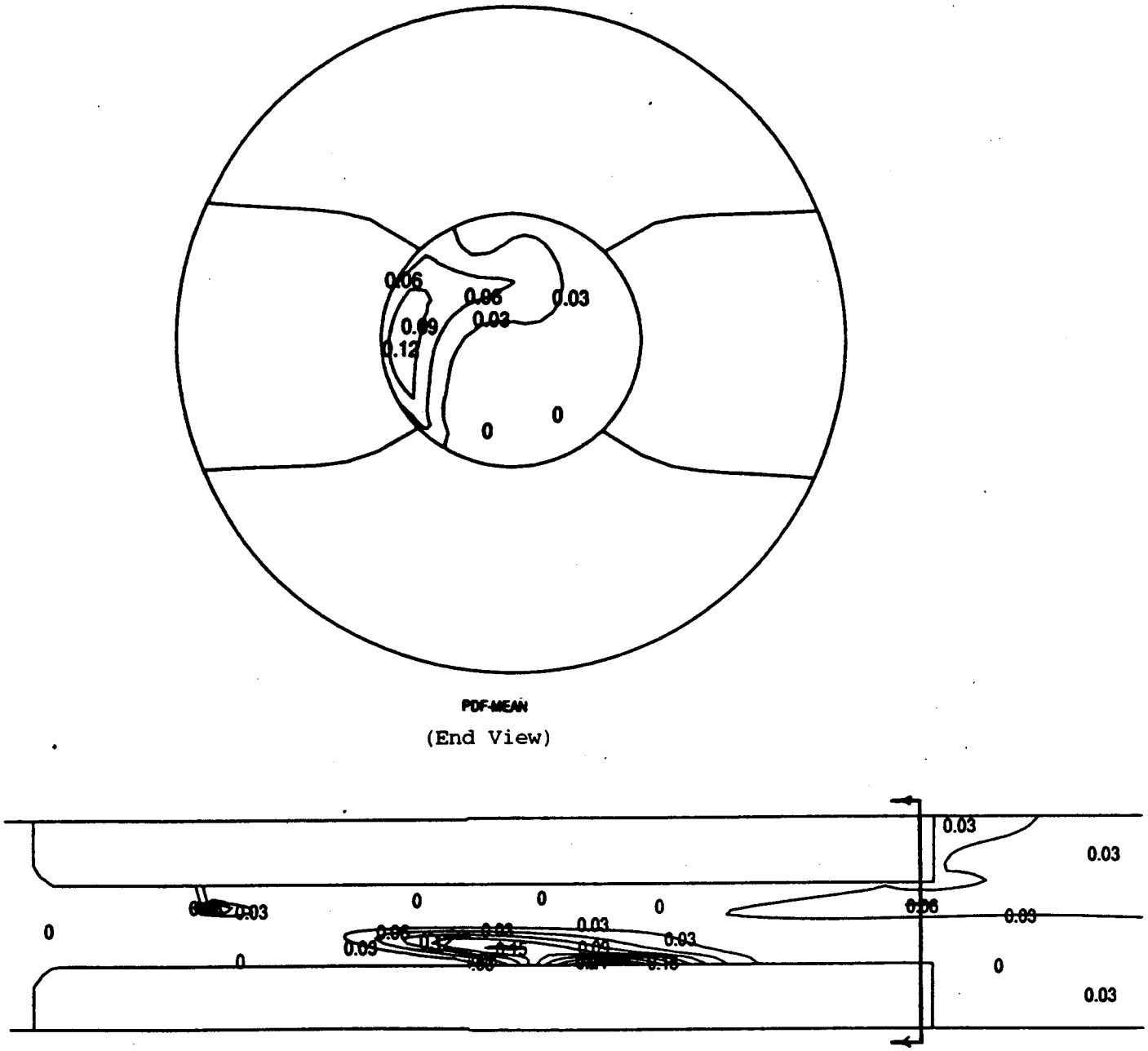


Figure 1.24 - CONCERT 3D results for IMFH tube. Plots of contours of constant fuel vapor mass fraction are shown in the radial-circumferential plane and the radial-axial plane. The flow in the tube has an 11.5-degree swirl angle. The fuel injector has a 20% immersion. The 4 spent dome cooling air holes are unequally spaced.

developed). An engineering flowpath sketch of the original MRA is shown in Figure 1.25. All the design variations of the original MRA combustor have in common a single-annular dome of Cyclone Swirler pilots (30 to 36 cups) with the IMFH mixer tube injection from the outer combustor liner (16 - 23 IMFH tubes per Cyclone Swirler). The IMFH mixer tube arrangement, jet deflection angle, and swirl angle orientation were investigated in the CFD modeling. Ground idle, subsonic cruise, and supersonic cruise conditions were simulated. At ground idle, all the Cyclone Swirlers were fueled and the IMFH mixers unfueled. At subsonic cruise, a small fraction (4 - 6 per cup) of the IMFH mixers were fueled at an equivalence ratio equal to the Cyclone Swirler pilots. At supersonic cruise, all IMFH mixers were fueled at the equivalence ratio of the pilot swirlers.

In the initial MRA design, idle and subsonic cruise conditions were characterized by peaked exhaust gas temperature profiles caused by poor mixing patterns of the unfueled IMFH jets. Figure 1.26 shows the grid for the MRA combustor model. Figure 1.27 shows some typical CFD model results of an early version of the MRA combustor at subsonic cruise conditions.

The modeling activities focused on trying to determine a design which yielded increased penetration of the unfueled IMFH tube exit jets so that the turbine inlet profile was acceptable during partial fuel staging. The critical cycle point chosen was subsonic cruise. The independent design parameters included were the IMFH mixer tube arrangement on the outer liner, the IMFH tube jet axial injection angle, and the IMFH circumferential (swirl) injection angle. The principle barrier to obtaining good exit temperature profiles was limited penetration of the unfueled IMFH jets. Three strategies for maximizing the penetration of the unfueled IMFH jets were investigated:

1. Placement of the IMFH jets in the wakes of the upstream IMFH jets.
2. Use of the jet angle to optimize the penetration of the IMFH jets.
3. Maximize the utilization of the vortex from the Cyclone Swirler pilots to augment the penetration by using alternating swirl directions in the pilots.

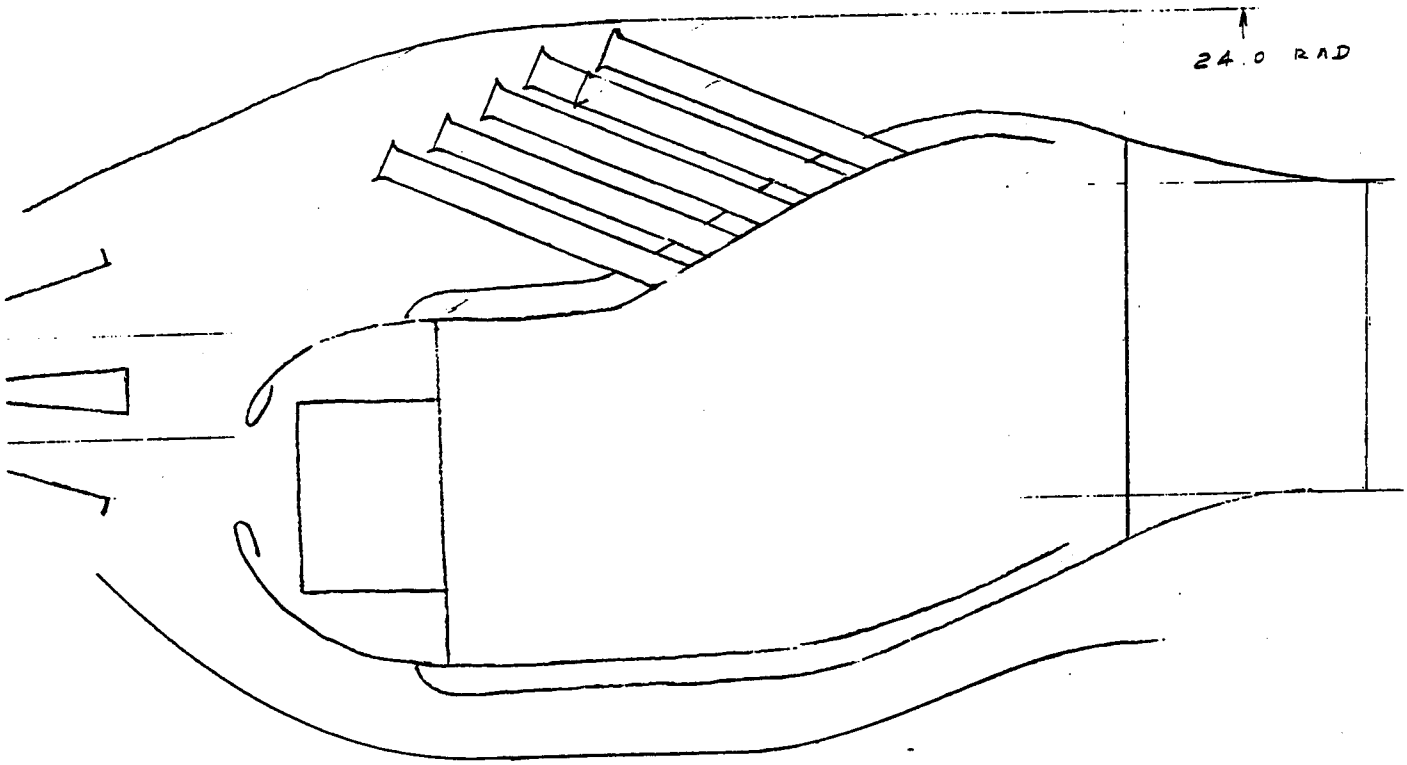
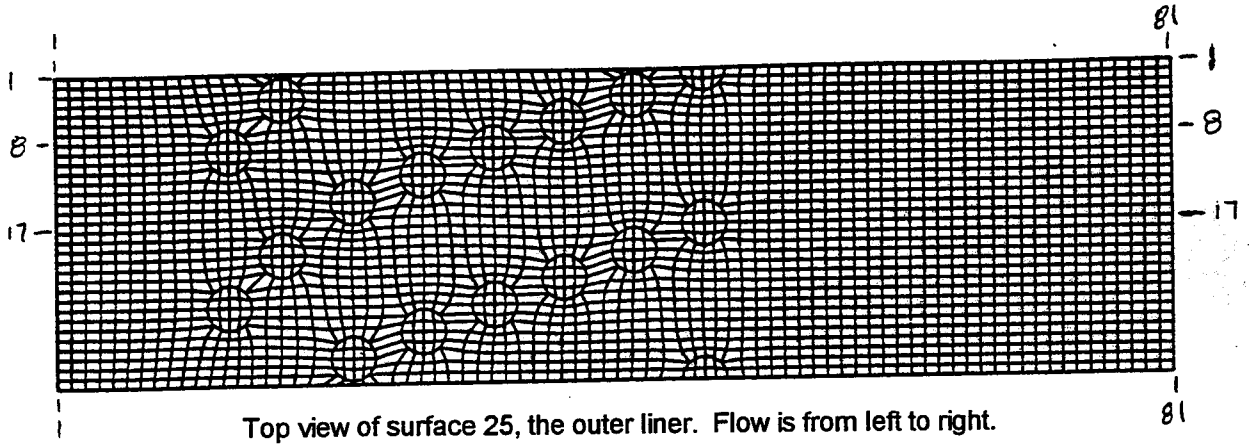
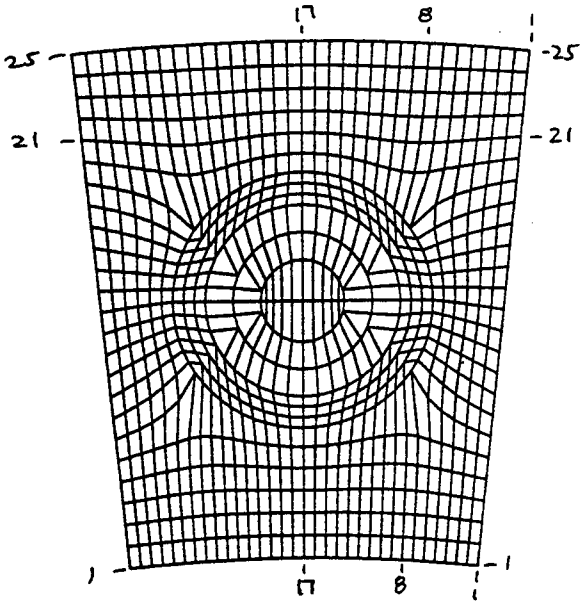


Figure 1.25 - Engineering flowpath sketch of an early Multi-Stage Radial-Axial (MRA) combustor system.





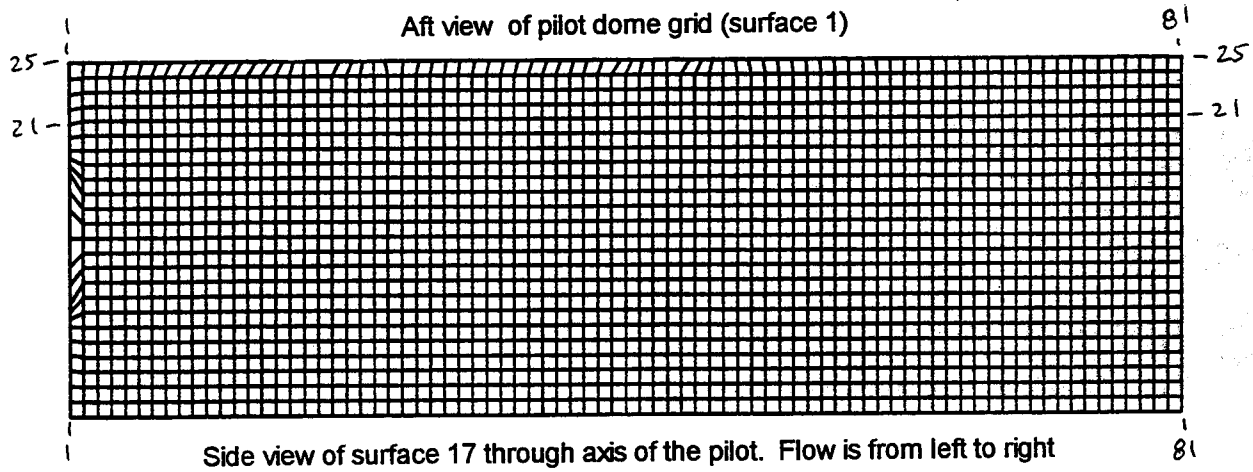
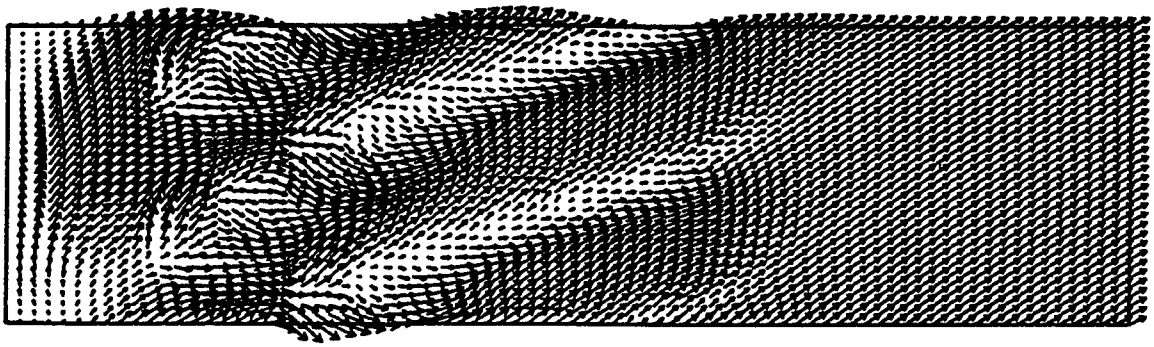
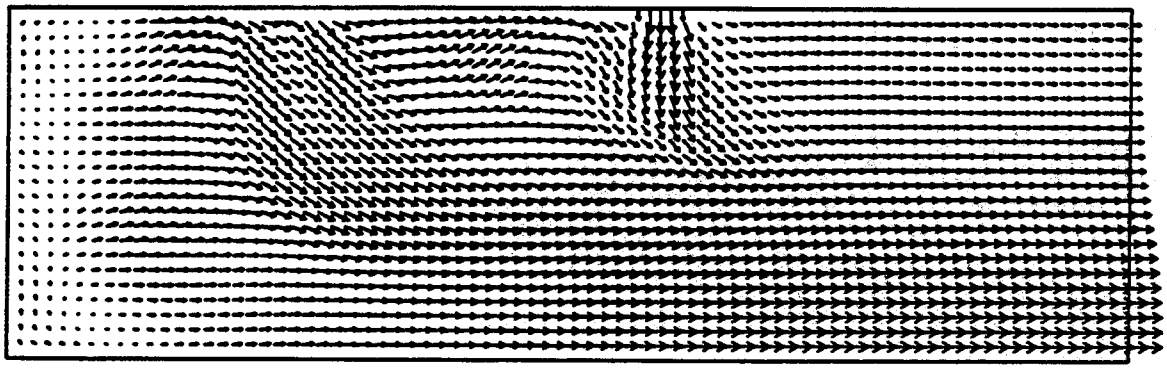


Figure 1.26 - Grid for the CONCERT 3D CFD model of a version of the Multi-Stage Radial-Axial (MRA) combustor. Shown are the top view of the grid, the pilot dome and the side view of the surface through the axis of the pilot. This version placed the jets from the IMFH tubes in the wakes of the upstream jets to maximize their penetration.



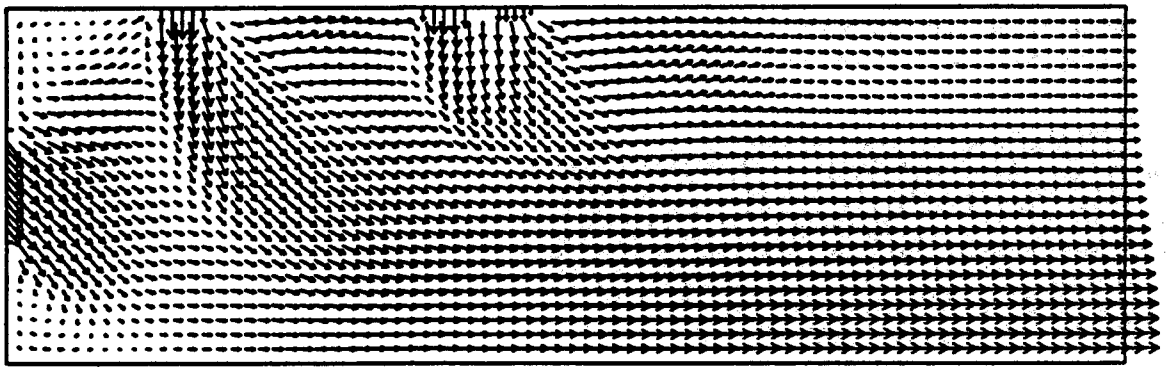
→ 239.146

Velocity vectors near outer liner. Surface 21. Flow is from left to right.



→ 449.978

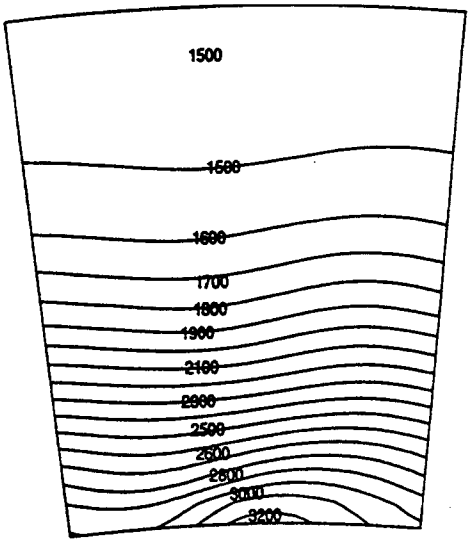
Velocity vectors in radial-axial plane. Surface 1 of grid. Flow is from left to right.



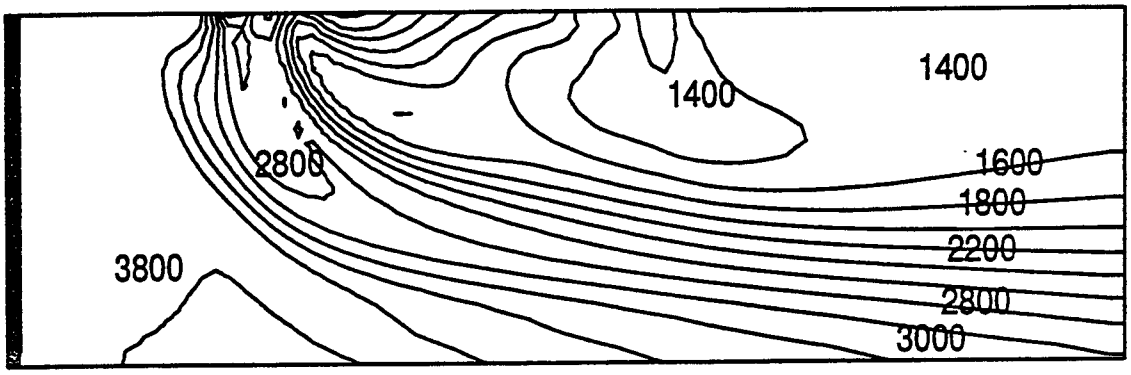
→ 458.633

Velocity vectors in radial-axial. Surface 8 of grid. Flow is from left to right.

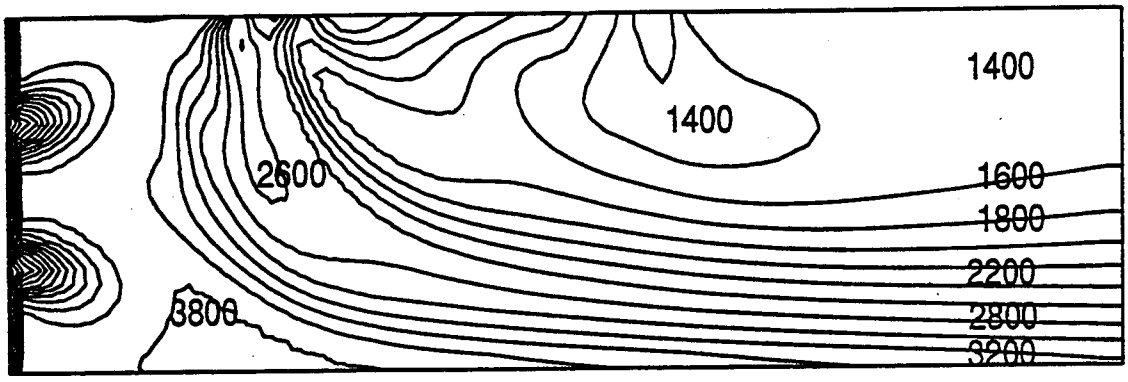
Figure 1.27a - CONCERT 3D CFD model velocity results for a version of the Multi-Stage Radial-Axial (MRA) combustor. This version placed the jets from the IMFH tubes in the wakes of the upstream jets to maximize their penetration. Subsonic cruise conditions are simulated. Shown are velocity vector fields on a surface near the outer liner and two surfaces in the radial-axial plane.



Temperature contours in degrees R at the exit plane.



Temperature contours in radial-axial plane. Surface 1 of grid. Flow is from left to right.



Temperature contours in radial-axial plane. Surface 17 of grid. Flow is from left to right.

Figure 1.27b - CONCERT 3D CFD model temperature results for a version of the Multi-Stage Radial-Axial (MRA) combustor. This version placed the jets from the IMFH tubes in the wakes of the upstream jets to maximize their penetration. Subsonic cruise conditions are simulated. Shown are the exit plane temperature contours and the temperature contours on two radial-axial planes. Temperatures are in degrees R.

The best profile/pattern factor predicted by the CFD after applying the first two strategies was 1.8/1.8 at subsonic cruise. These profiles were inboard peaked. These profile factors were calculated as $(T_M-T_3)/(T_A-T_3)$. The profile factor defines T_M as the maximum circumferentially-averaged radial temperature, while pattern factor defines T_M as the maximum local temperature. T_A is the average combustor exit temperature.

For the third strategy, pairs of the Cyclone Swirler pilot were arranged in alternating swirl directions. The alternating swirl directions augment the strength of the Cyclone Swirlers, resulting in stronger downward and upward flow fields for improved mixing. A two-cup sector was modeled which still allowed the use of the periodic boundary condition feature of CONCERT 3D. The grid is shown in Figure 1.28. Figures 1.29 and 1.30 characterize the inlet flow field for the MRA combustor and compare it to the inlet flow field of the Stepped-Dome combustor. IMFH mixer arrangement and jet angle were selected to enhance mixing in the MRA's flow field. In Figure 1.30, the circumferential velocity component of the flow leaving the IMFH tubes and entering the combustor is a result of the canted angle of the tubes. Table 1.3 compares the input parameters for the MRA and Stepped-Dome subsonic cruise CFD models.

Table 1.3 - Inlet Parameters for Subsonic Cruise CFD Models

Parameter	MRA	Stepped-Dome
Sector	2-Cup	1-Cup
Inlet Temperature	1073 R	1073 R
Pressure (psia)	86.18	86.18
Local equivalence ratio	0.775	0.775
IMFH tubes/cup	18	10
Fired IMFH tubes/cup	4	2.5
Side wall boundary condition	Periodic	Wall
Inlet fuel vaporization	90%	100%

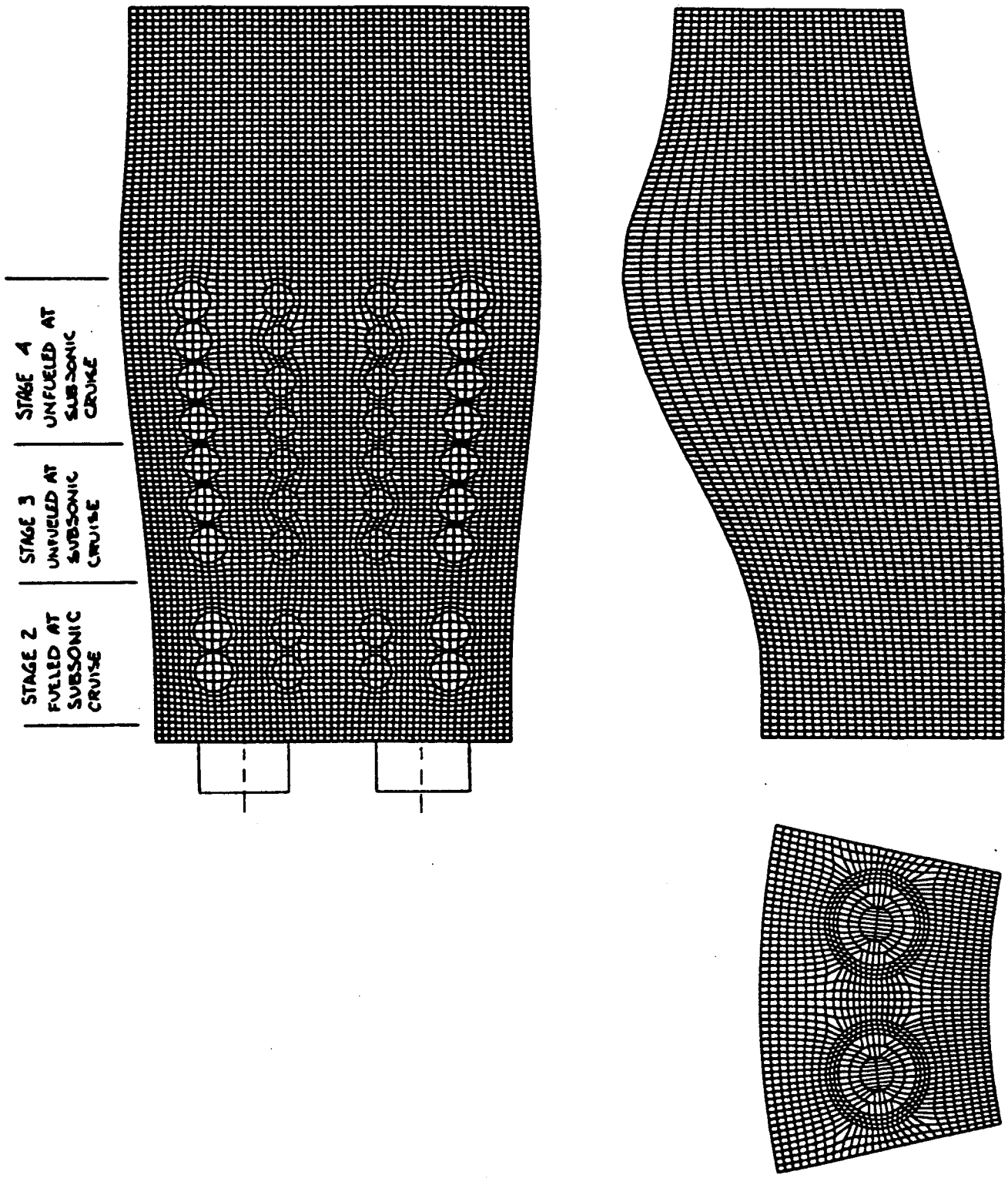
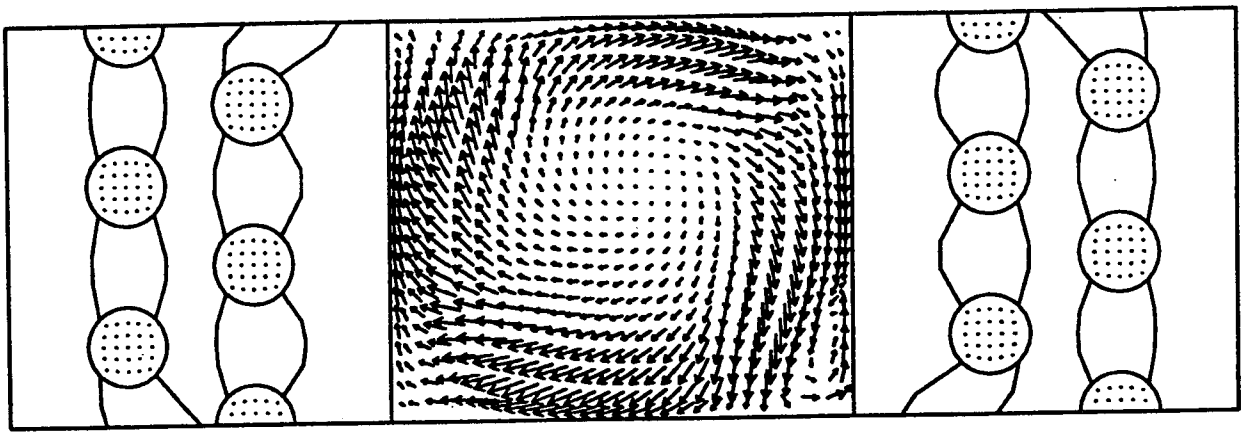


Figure 1.28 - Grid for the CONCERT 3D CFD model of a version of the Multi-Stage Radial-Axial (MRA). This version placed the IMFH tubes so the jets penetration was enhanced by the twin vortices initiated by the pilots. The pilot swirl direction alternated from cup-to-cup.



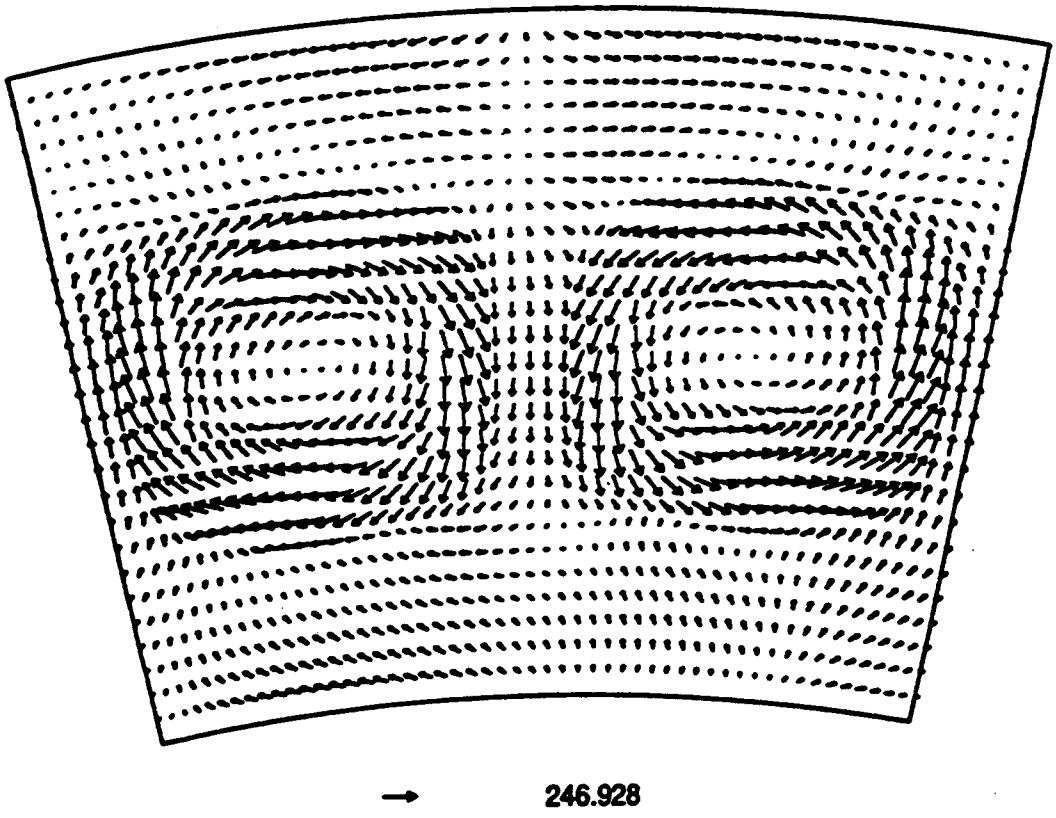


Figure 1.29 - Comparison of CONCERT 3D results for the velocity vectors at the dome of the Stepped-Dome Rectangular Sector (top) and the MRA combustor (bottom). The scales are different.

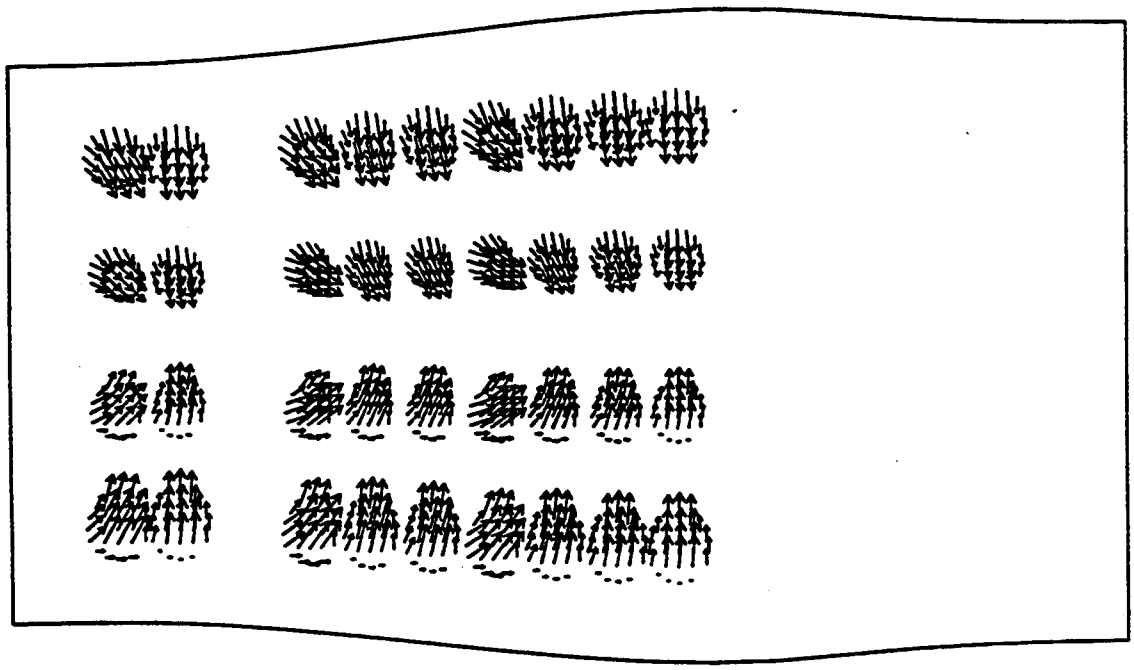


Figure 1.30 - CONCERT 3D results for the velocity vectors at the IMFH tube exits at the outer liner of the MRA combustor.

Table 1.4 summarizes some of the results of the two models.

Table 1.4 - Results of Subsonic Cruise CFD Models		
Parameter	**MRA**	**Stepped-Dome**
CO EI (g/kg)	1.11	5.15
Combustion efficiency	99.9%	99.8%
Profile factor	1.26 @ 83% span	1.72 @ 75% span
Pattern factor	2.02 @ 41% span	2.01 @ 78% span

Further results of these subsonic cruise CFD models are compared in Figures 1.31 through 1.35 at subsonic cruise conditions. Figures 1.31 and 1.32 compare the internal velocity flowfields of the stepped-dome and the MRA in radial-axial planes. In the stepped-dome, the plane is through the axis of the Cyclone Swirler pilot. In the MRA, the plane is through the edge of the pilot and the exits of a row of IMFH tubes. The temperature contours for the two combustors are compared in the radial-axial plane in Figure 1.33 and the radial-circumferential plane at the exit in Figure 1.34. Performance attributes of the MRA combustor included a center-peaked exit gas temperature profile, with a cold spot at the inner liner between cups. Figure 1.35 shows the circumferentially-averaged combustor exit temperature profiles and the envelope of the peaks for the two combustors corresponding to the profile and pattern factors in Table 1.4.

Based upon these initial results for the alternating rotation of the pilots in the MRA, the positions of the IMFH tubes that were unfired during subsonic cruise were adjusted so that the tubes that were "aimed" at the hottest spots. This change improved the MRA's exit temperature profile/pattern factor to 1.095/1.33 at the A5B subsonic cruise cycle condition, as shown in Figure 1.36. This was accomplished at the price of slightly irregular arrangement of the IMFH tubes. Figure 1.37 shows the inlet velocity field to the combustor resulting from the new tube arrangement. The location of the exits of the tubes and the velocity vectors at the exits shown in Figure 1.37 should give the reader a rough understanding of the tube arrangement. There is further discussion about this combustor in Section 6. A combustor layout of one attempt to fit the new tube arrangement into an engine flowpath is shown there in Figure 6.4.

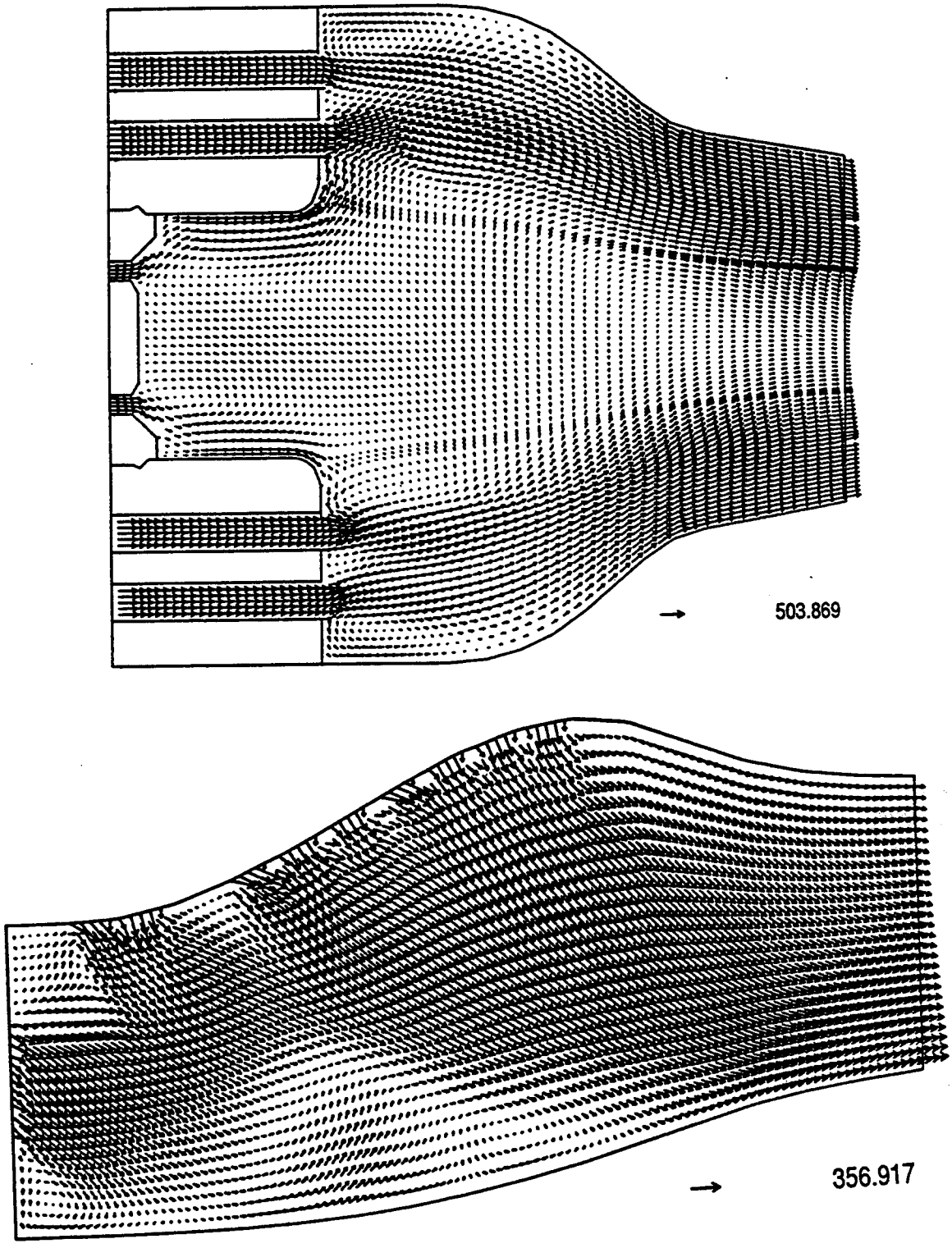


Figure 1.31 - Comparison of CONCERT 3D results for the velocity vectors in the radial-axial plane on a surface through the axis of the Cyclone Swirler pilot in the stepped-dome rectangular sector combustor (top) and a surface through the edge of the pilot and through a row of the IMFH tube exits in the MRA combustor (bottom). The scales for the results are different.

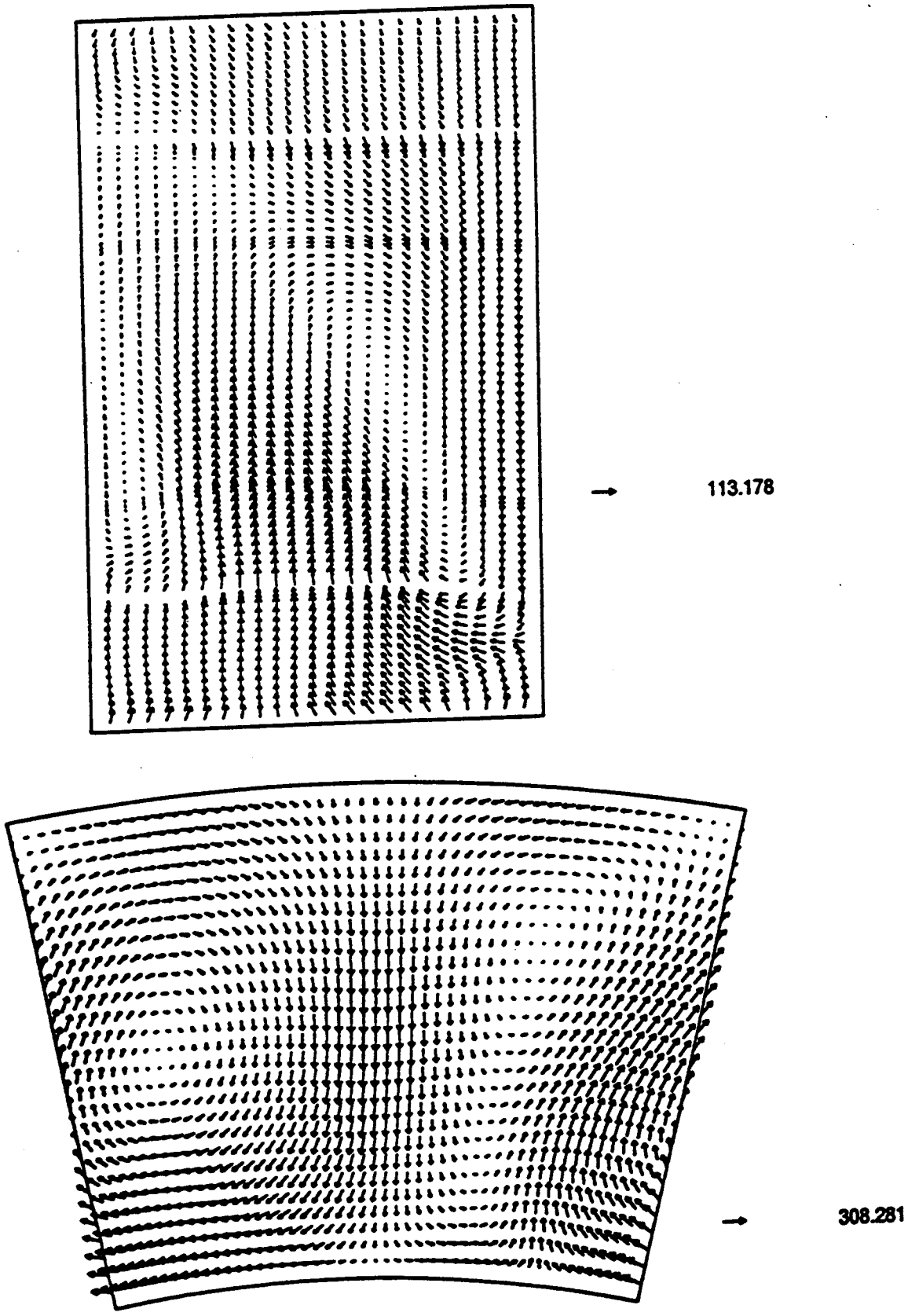


Figure 1.32 - Comparison of CONCERT 3D results for the velocity vectors at the exit planes of the stepped-dome rectangular sector combustor (top) and the MRA combustor (bottom).

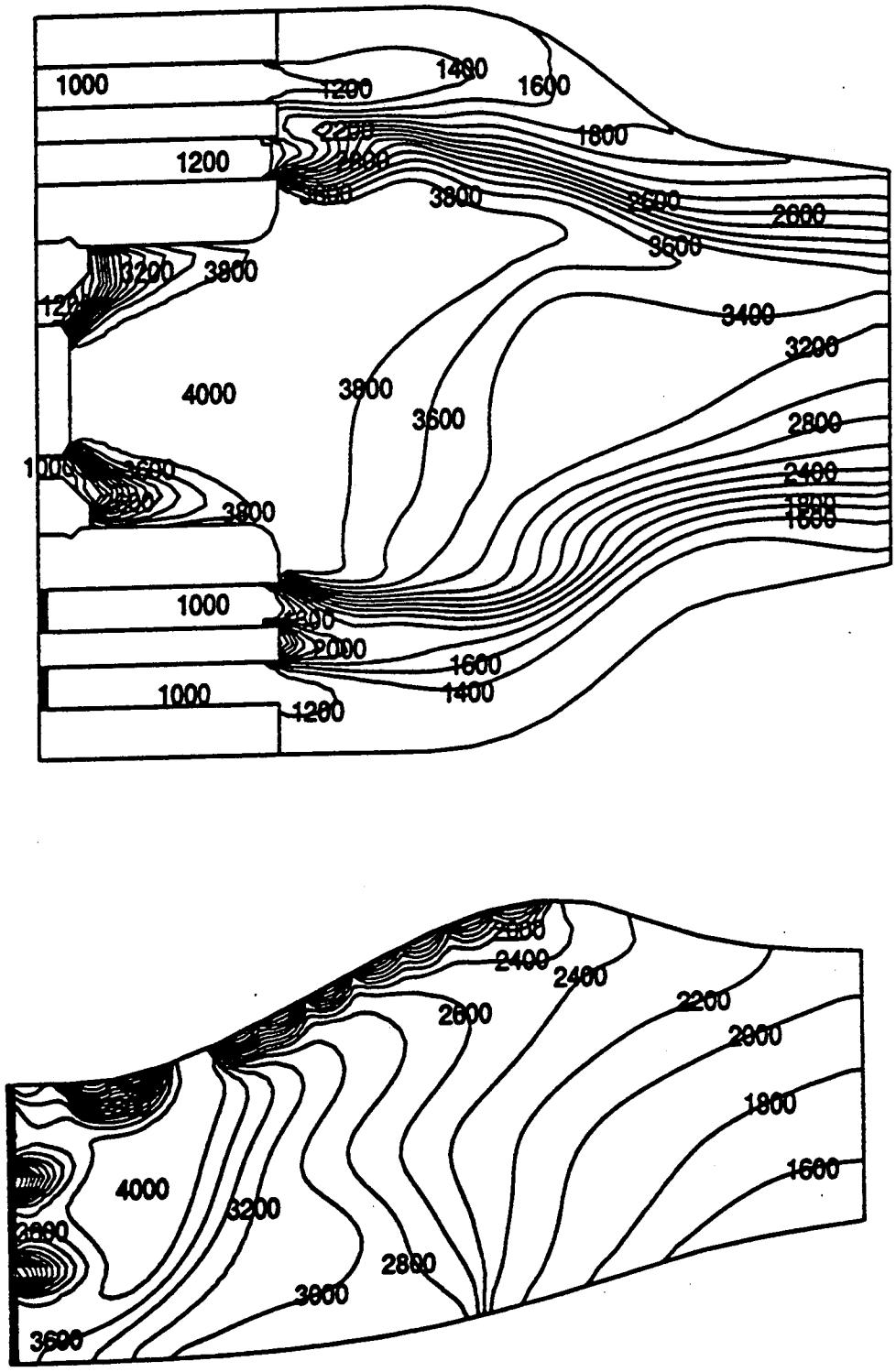


Figure 1.33 - Comparison of CONCERT 3D results for contours of constant temperature in degrees R on a surface through the axis of the Cyclone Swirler pilot of the stepped-**dome rectangular sector combustor (top) and** the MRA combustor (bottom).

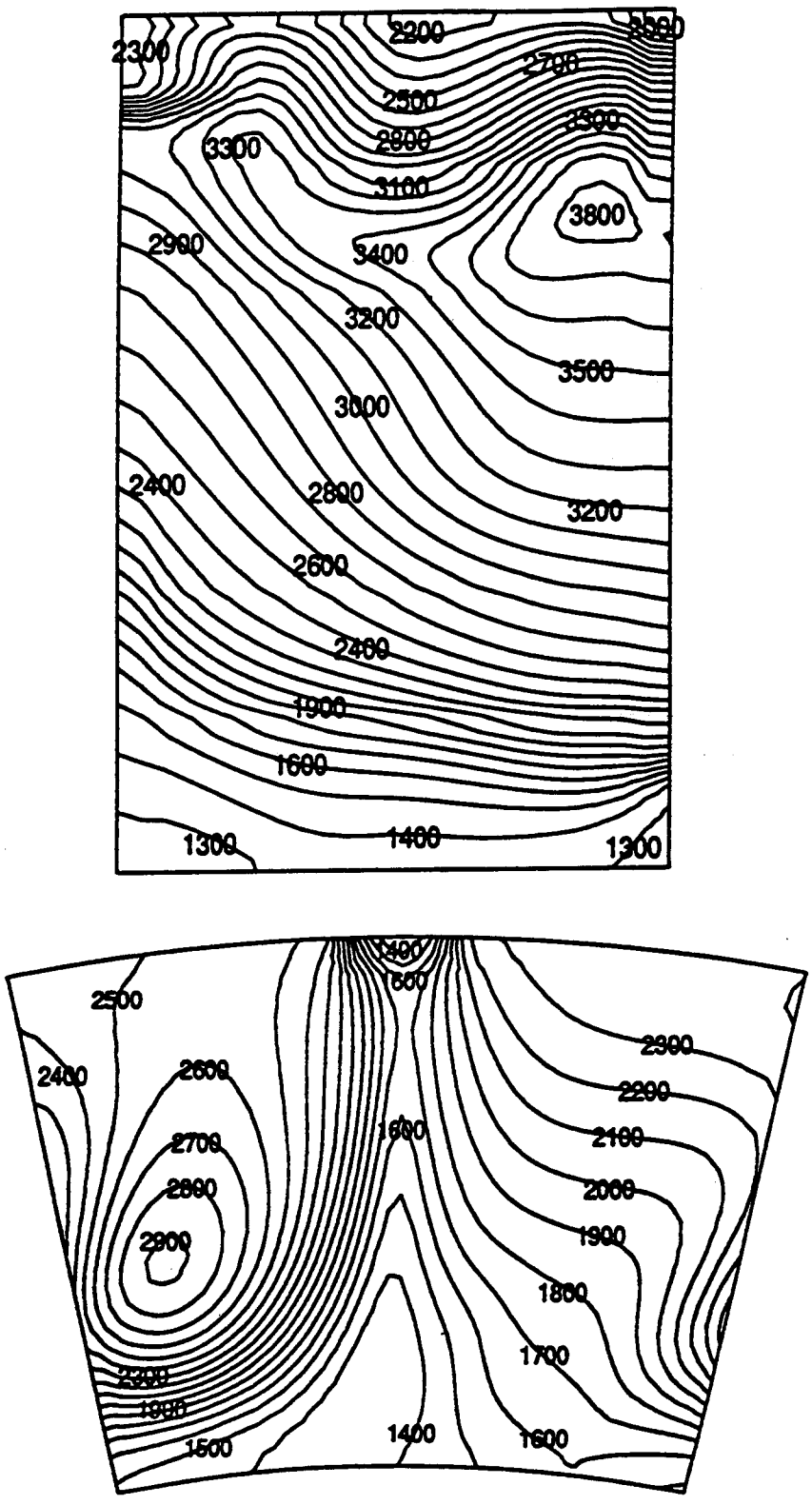


Figure 1.34 - Comparison of CONCERT 3D results for contours of constant temperature in degrees R at the exit planes of the stepped-dome rectangular sector combustor (top) **and the MRA combustor (bottom).**

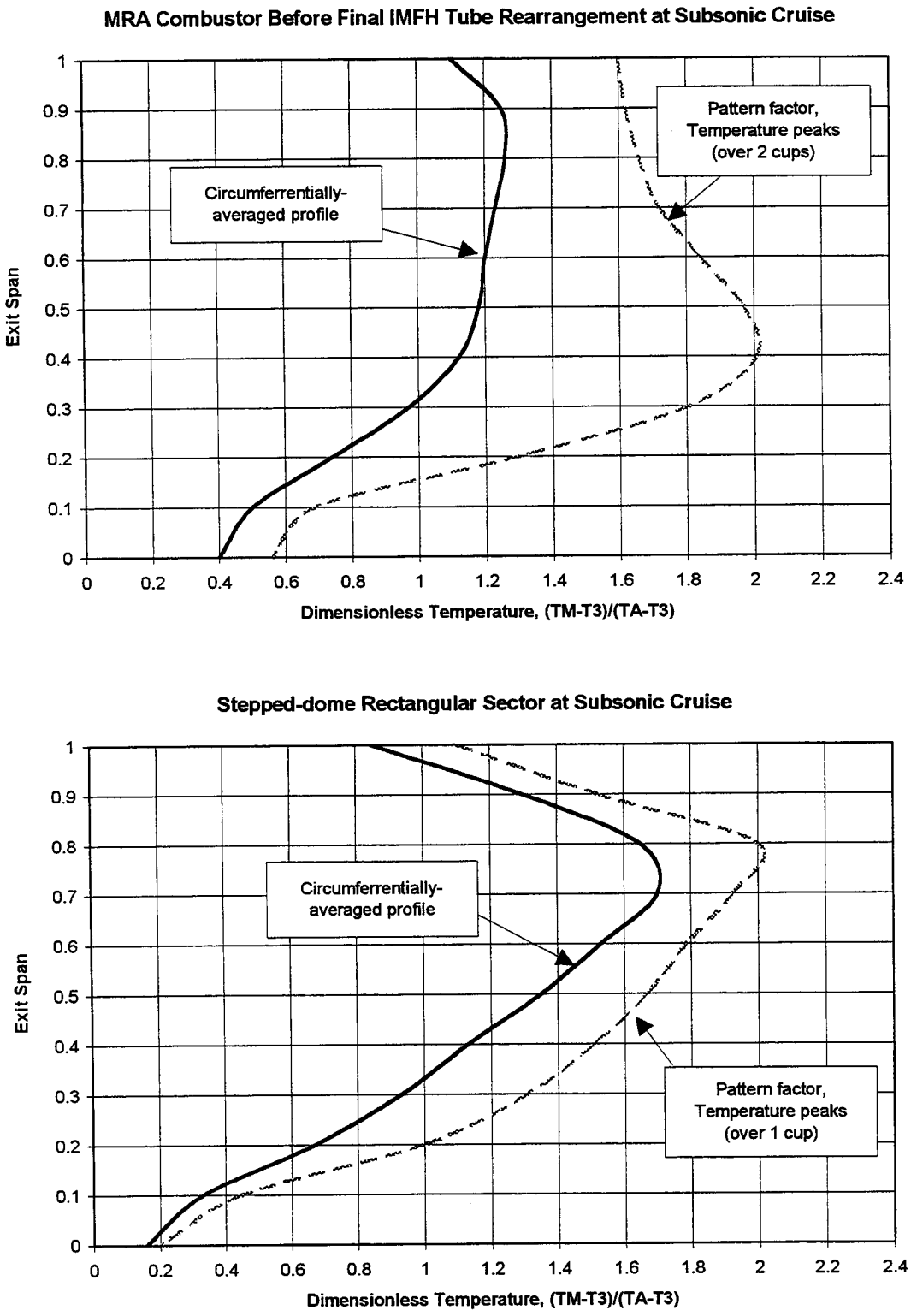


Figure 1.35 - Comparison of CONCERT 3D results for the Pattern and Profile Factors of the stepped-dome rectangular sector and the MRA combustors.

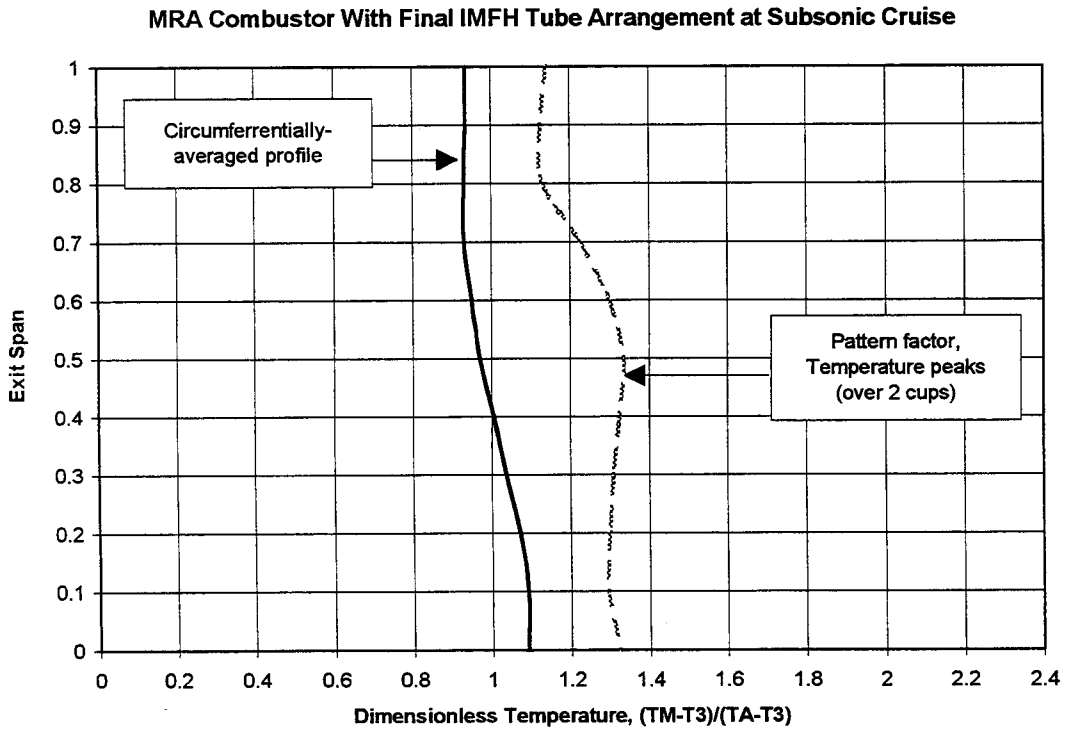
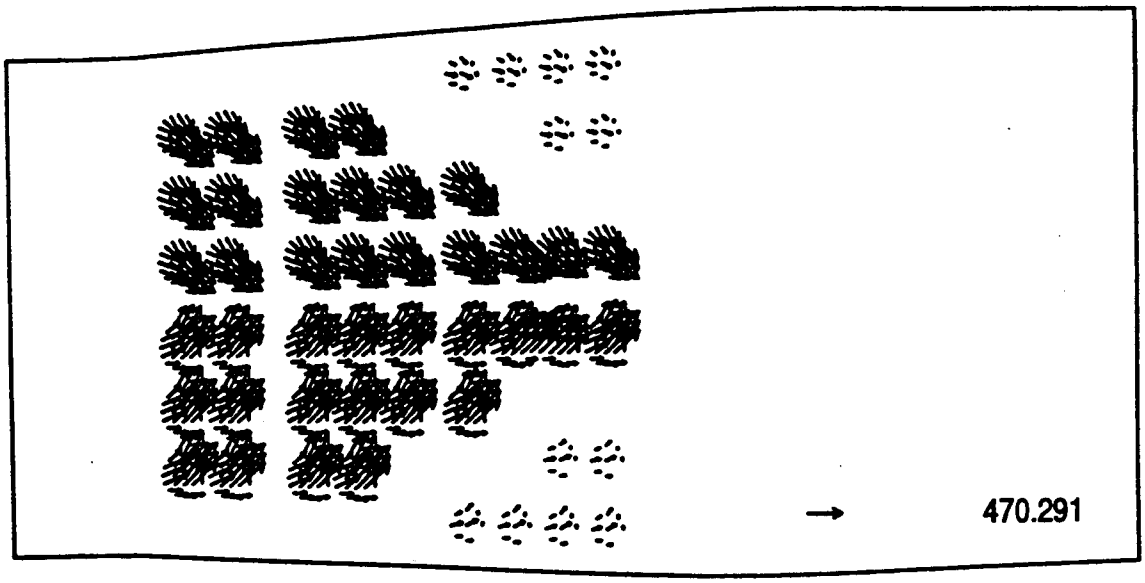
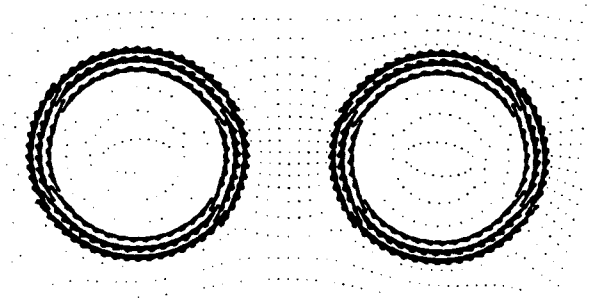


Figure 1.36 - CONCERT 3D results for the Pattern and Profile Factors of the MRA combustor with its IMFH tubes positioned to minimize hot streaks at the exit.

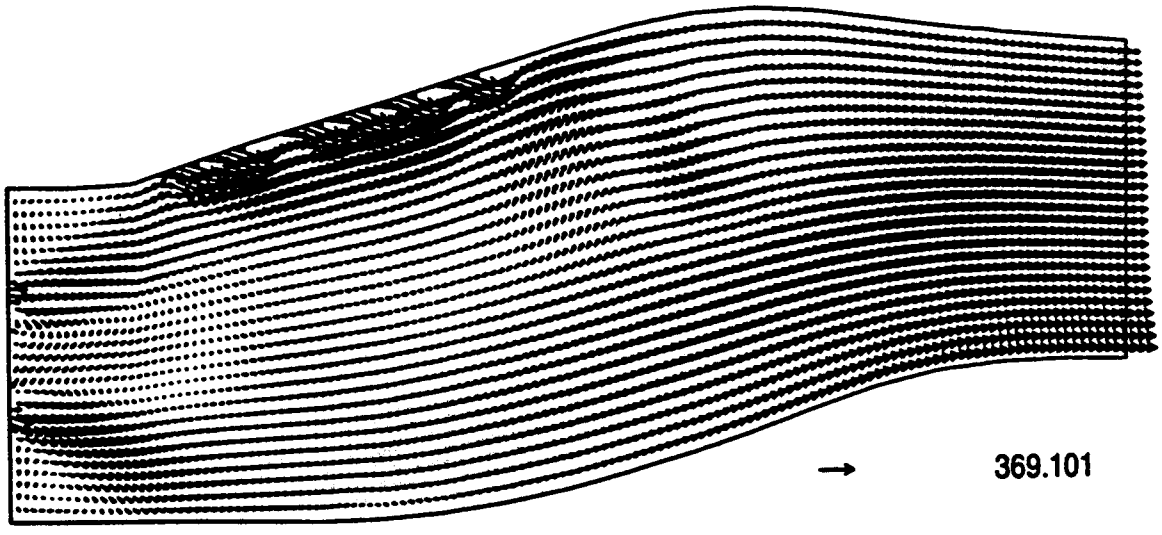
Figure 1.38 shows the velocity field and the temperature field at the exit plane using the new tube arrangement in the MRA. Note that the exit temperature field is asymmetrical, even though the model and all the boundary conditions are symmetrical with respect to the plane bisecting the model between the two cups. That this occurs physically, should not be surprising. The two vortices move to locations giving them more space. It is reassuring that CONCERT 3D predicts the asymmetry, despite the symmetry of the inputs to the model. These exit temperature profile results indicate that the MRA has the potential for a much flatter average circumferential temperature profile during partial fuel staging, making this MRA concept attractive in terms of turbine efficiency and turbine life.



Top View



Front View (FLA)



Side View

Figure 1.37 - CONCERT 3D results for velocity vectors in the MRA combustor at the exit of the IMFH tubes at the outer liner, at the pilot dome, and on a radial-axial surface through the axis of the cyclone swirler pilot.

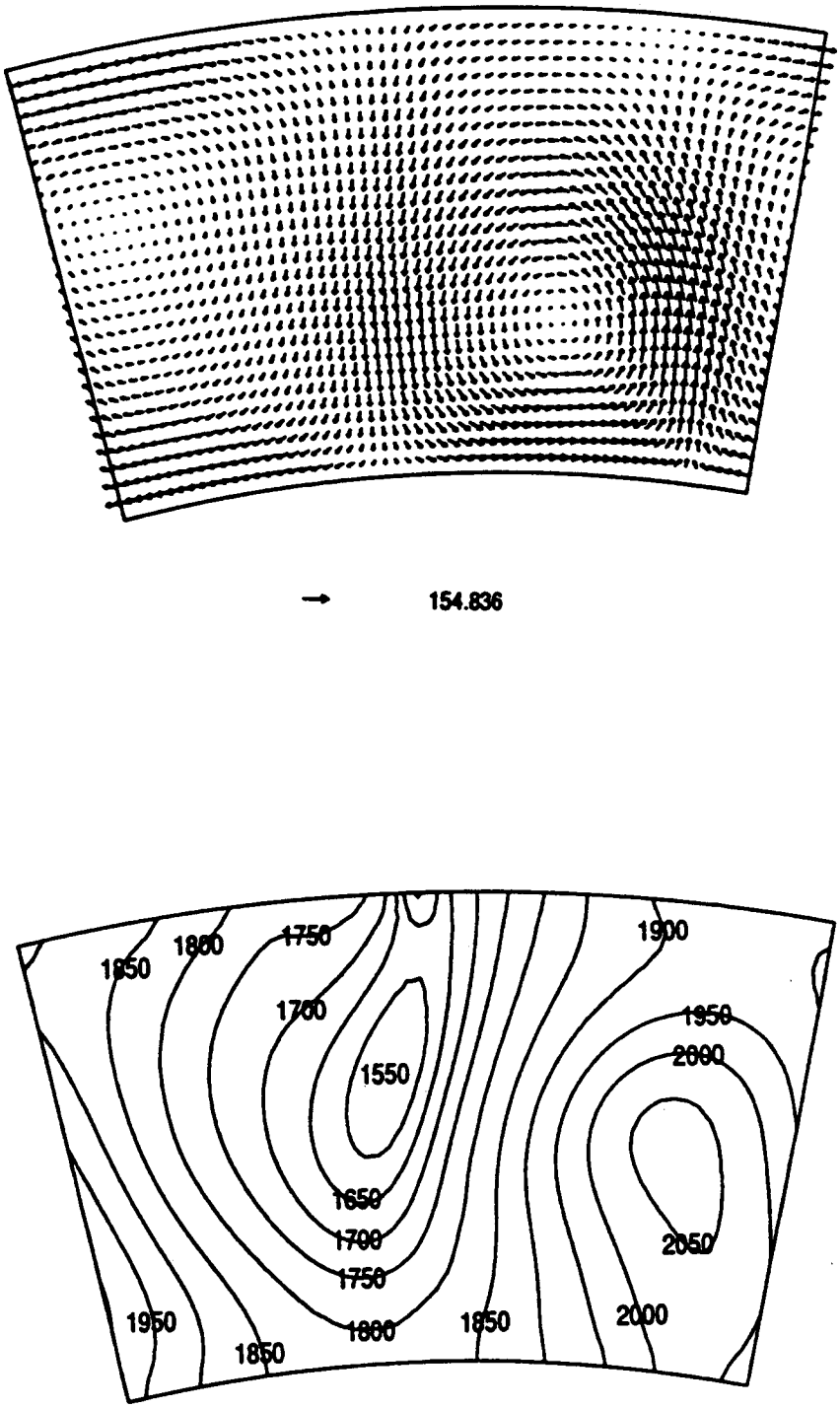


Figure 1.38 - CONCERT 3D results for the for the velocity vectors and contours of constant temperature at the exit plane of the MRA combustor with its IMFH tubes positioned to minimize hot streaks at the exit.

1.2 Spreadsheet Models of Combustor Systems

Spreadsheet models of the HSCT combustor systems were first generated in the conceptual design phase of APT Task 5. The models were motivated by the convenience of automating tedious calculations which had to be repeated each time a combustor system design changed.

1.2.1 General Description of Spreadsheet Combustor System Models

The spreadsheet combustor system models were generated in several different applications, including Excel (Microsoft, Inc.) and Matlab (MathWorks, Inc.). Most of the models were generated using Mathcad (Mathsoft, Inc.). The choice of application depends mainly on the engineer's preferences. A generic outline of the format of the spreadsheet model follows.

1. Steady-state engine cycle data is read as input. Generally, these data include altitude, Mach number, power code, thrust, fuel flow rate, air flow rates, cycle pressures, cycle temperatures, and mission time (for mission data). Early models used only about two dozen mission points. Later models used hundreds of cycle points covering the entire flight envelope, as well as specific mission profiles. Special cycle points such as those used to calculate the landing-takeoff (LTO) emissions parameters were included.

2. Specific combustor performance correlations are defined. A correlation for flame temperature calculations is always necessary, since flame temperature is the principle factor in determining the emissions performance of an LPP combustor. Since emissions performance is the primary metric of the HSCT combustor, emissions correlations were always provided. Optional correlations which might be supplied depending on the refinement of the model and which performance projections were desired, are: 1) stability (lean blow out); 2) diffuser

performance in terms of static pressure recovery; 3) fuel jet penetration; 4) heat transfer; and 5) combustor exit profile. These correlations come from text books, the open literature, proprietary design practices, or combustor data bases developed in the HSR Program.

3. The diffuser system design is defined and its performance in terms of static pressure recoveries is estimated using correlations. This step was omitted in early models and the pressure recoveries at the combustor's dome were estimated and given as input.

4. The number of fuel stages and their flow splits are defined and the geometry of the combustor system is determined interactively.

5. Basic parameters of the combustor are calculated; such as residence times and dome and passage velocities. These are compared to the standard design practices, when appropriate.

6. An automated control function for the fuel staging is defined. The control function is applied by the system model to determine the number of fuel stages used at each cycle point.

7. Emissions performance is determined at each cycle point using the correlations. LTO emissions parameters are calculated.

8. Other details of the combustor operation can be examined depending on the correlations provided. Often all that is desired are the minima and maxima of critical parameters over the entire flight envelope. These might include: 1) for a given fuel system design, the maximum fuel manifold pressure and the minimum injector pressure drop; 2) the maximum and minimum fuel jet penetration; 3) an estimate of maximum fuel temperature rise; 4) the cooling effectiveness required to maintain the liner temperature below a given limit; 5) an estimate of the combustor exit profile factor 6) an estimate required turbine vane cooling

effectiveness to maintain the vane material temperatures below a given limit; and 7) an estimate of the minimum margin on combustor stability.

9. The extensive input data for the CFD models can be generated.

The usefulness of these spreadsheet combustor system models was evident as soon as they were developed. The system models were refined in numerous ways in LET Task 10 and on into Phase II of the HSR program.

1.2.2 IMFH Fuel Jet Penetration Study

An IMFH Fuel Injector Penetration study was conducted in order to obtain experimental correlations relating to the penetration of liquid jets that are injected normal to an air stream. The results of this study were used to better determine the optimum radial location of the IMFH fuel injectors. The fuel jet penetration results complement the CFD studies of the same topic reported above in Section 1.1.2. The correlations from this study were ultimately used in the spreadsheet combustor system models. There, the correlations could be used to make a global assessment of fuel jet penetration everywhere in the flight envelope, not just the few cases that could be run with CFD. Also, the jet penetration correlations, although basically empirical, have the advantage of being based upon data, whereas the CFD models of two-phase flow require simplifying assumptions. This jet penetration study consisted of a review of open literature in order to obtain experimental correlations relating to the penetration of liquid jets that are injected normal into an air stream.

The IMFH mixer design studies have addressed fuel injection from the wall and from a fuel injector cantilevered out into the centerline of the air stream. The Pennsylvania State University (PSU) diagnostic studies, to be discussed in Section 2.1, indicated that fuel injected normal to the air stream from a fuel injector immersed to the premixer tube centerline penetrated to the opposite wall, whereas the fuel injected at the wall penetrated to the mixer tube centerline where it mixed well with the air. However, IMFH single-cup burning tests with wall injection were characterized by low combustion efficiencies relative to centerline injection. Trying to

understand this apparent contradiction was one of the driving forces for the attention given to the topic of fuel jet penetration.

From the literature search, five jet penetration correlations were identified. Their predictions are summarized for the case of a 0.02-inch inner diameter fuel injector in Figure 1.39. The predicted penetration is plotted versus injector pressure drop for 36 different HSCT mission points for the A5B cycle. The predictions by the different correlations are referred to by the last name of the first author of the publication; Chelko [1-2], Schetz [1-3], Adelberg [1-4], Yates [1-5], and Geery [1-6]. The predictions of these correlations for the fuel penetration ranged from 0.1 to 0.4 inches and show trends similar to the results obtained in the PSU studies discussed in the next section of this report. The Adelberg correlation is based upon data taken with supersonic air velocities, so its predictions are expected to be the least reliable for IMFH conditions. The results from the Adelberg and the Schetz correlations suggests that when the IMFH fuel injectors are immersed to the premixer tube centerline, the fuel penetrates to the opposite wall at many cycle conditions. If this actually occurs, it is not desirable. However, the 50% immersion of a transverse fuel injector tube has yielded the lowest emissions in the fired tests of the 0.5-inch diameter IMFH tube.

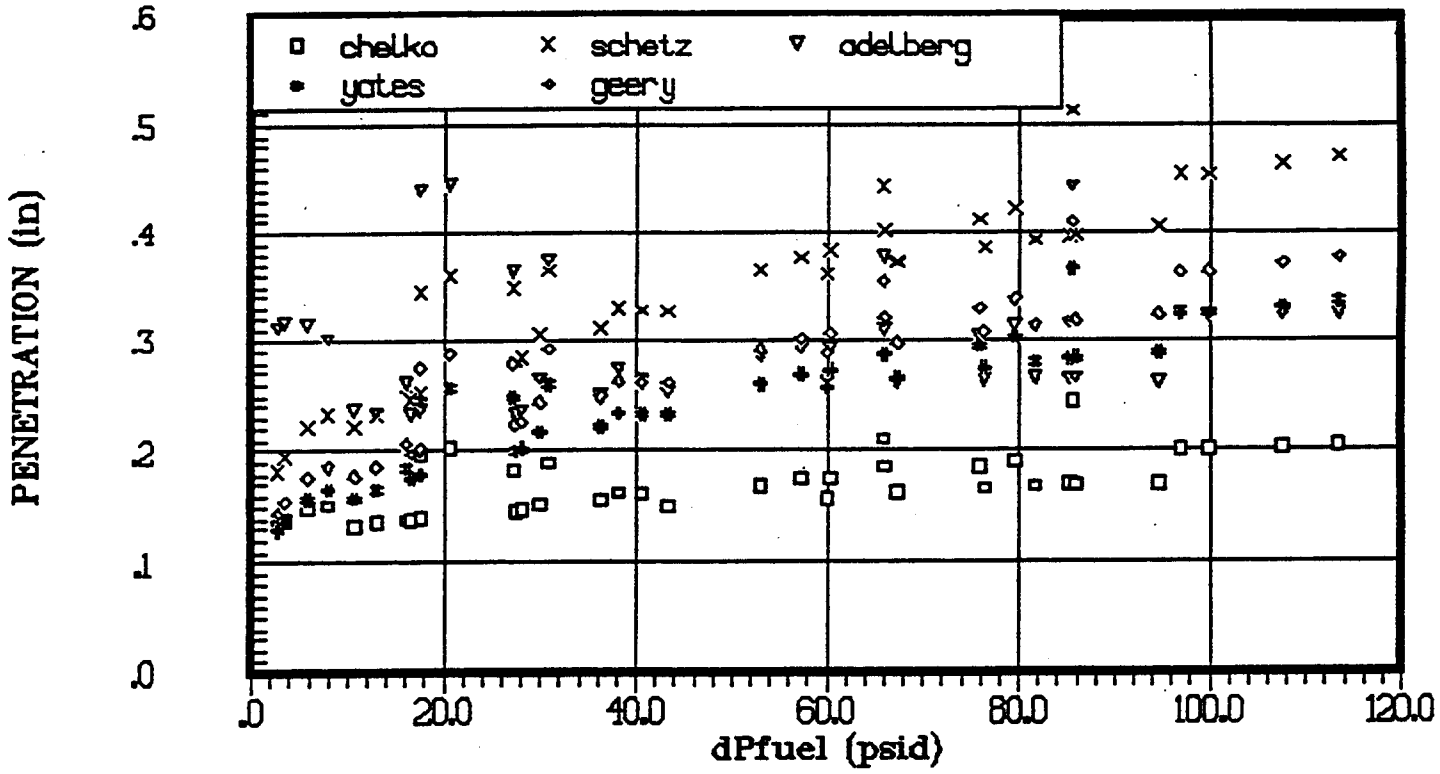


Figure 1.39 - Fuel jet penetration transverse to air flow in an IMFH tube plotted versus injector pressure drop. The predictions of five correlations from the open literature are compared. The points each correspond to an actual engine operating point on a mission. The cycle is the A5B MFTF.

Section 2

Premixer Laser Diagnostic Studies

Laser diagnostic studies of the premixers were performed at the Pennsylvania State University (PSU) and GE Corporate Research and Development (GE CR&D). These laser diagnostic studies were initiated under Task 5 of NASA Contract NAS3-25951, the Aero Propulsion Technology (APT) Program. Follow-on studies were continued under this Task of NASA Contract NAS3-26617, the Large Engine Technology (LET) Program.

The primary focus of the PSU program was to identify an injector geometry for an Integrated Mixer Flame Holder (IMFH) configuration that would enhance the fuel/air mixing and vaporization. A secondary objective was to improve the packaging of the injector/IMFH tube system into a more practical design for an engine. (During the program, the priorities of these two objectives were switched.) The study investigated three different variations of injector tube tips: two fan-shaped and one with a beveled tip. Based on the laser diagnostics, a Lee Company Spin Jet nozzle appeared to have a slight advantage over the best tube-type fuel injector. A complete copy of the final report for the PSU program is included in Appendix B of this report.

The primary purpose of the GE CR&D diagnostics program was to identify the cause of the transition to higher NOx emissions as the severity of the inlet conditions increased. The laser diagnostic tools available at CR&D included a Raman system for the measuring temperature and species and a Phase Doppler Particle Analyzer (PDPDA) for measuring velocity flow fields and droplet size distributions.

2.1 Pennsylvania State University Combustor Diagnostics Program

The PSU HSCT Combustor Diagnostics Program was directed by Professor Dom Santavicca. The principle investigator was Richard Steinberger. The overall objective of

defining an IMFH fuel injector system with improved fuel/air mixing and vaporization for the IMFH configuration was to be accomplished in four steps:

1. Fuel injector modifications.
2. Mixer tube length reduction.
3. Mixer tube diameter modifications.
4. Air injection at the mixer tube exit.

Tasks 1 and 2 were completed as planned. The equipment for Tasks 3 and 4 was designed and fabricated. However, the decision was made at GEAE to shift the emphasis of the laser diagnostics from a study of the fundamental fuel-air mixing to the secondary goal of improving the packaging of the IMFH fuel injectors. The desire to have more information about a new and more practical injector geometry caused deferral of work for Tasks 3 and 4 and expansion of work in Tasks 1 and 2 to include new geometries. Results of the Task 1 and 2 testing will be summarized later in this section of the report. Details may be found in the body of the PSU Final Report to GEAE on Mixing and Vaporization Evaluation of IMFH Configurations contained in Appendix B of this report.

Table 2.1 summarizes the test conditions for all the PSU testing unless otherwise specified. The high temperature, high pressure continuous flow system used for these tests was capable of operation at inlet temperatures to about 1300° F (1760 R) and pressures to 10 atmospheres. The exciplex fluorescence measurements were carried out in an oxygen-free environment. Images were recorded using a Princeton Instruments image intensifying camera employing a 578 x 384 pixel CCD. The camera was always positioned to view the test section from the side. Images were recorded with the CCD camera, stored on disk, and later viewed and analyzed with the Princeton Instruments CCD Spectrometric Multichannel Analysis Software. Details on the design and structure of the test apparatus and test procedures are found in Appendix B.

Table 2.1 Experimental Conditions for LET Task 10 PSU Diagnostics Studies		
Parameter	Case A (High Inlet T)	Case B (Low Inlet T)
Air inlet temperature	950° F (510° C)	650° F (344° C)
Pressure	65 psia	65 psia
N2 flow rate	0.049 lb/sec	0.063 lb/sec
Mixer tube velocity	100 m/sec	100 m/sec
Major component of fuel	Tetradecane (84%)	Tetradecane (84%)
Fuel flow rate	4.84 to 7.26 lb/hr	9.22 to 12.3 lb/hr
Equivalence ratio	0.4 to 0.6	0.6 to 0.8

Task 1 involved testing the IMFH mixer with an coaxial injector tube, a transverse injector tube, and an axial Lee Company Spin Jet atomizer. The coaxial injector hardware incorporated a 0.042-inch outer diameter, 0.020-inch inner diameter injector tube situated on the centerline and supported by an aerodynamic strut. This tube projected 1.3 inches downstream from the rounded inlet to the IMFH tube. Refer to Figure 3 in the PSU final report (Appendix B) for a schematic of the injector. A completely vaporized uniform mixture was created for exciplex calibration purposes, which allowed the exciplex data to be calibrated before or after an actual injector test. At low inlet temperature, the liquid and vapor appeared to be confined to a core region near the centerline; the liquid especially showed very little spreading. At high inlet temperature, the liquid and vapor were still heavily concentrated in the central core region.

A coaxially-mounted, conical spray fuel injector (Lee Company Spin Jet) was tested in a 0.5-inch inner diameter IMFH mixer tube. The Spin Jet was chosen because of its small outer diameter (0.187 inches). At 950° F (1410 R) inlet temperature, the Spin Jet injector appeared to generate a less concentrated central fuel streak and to have improved vaporization at the mixer tube. A comparison of the test results of a coaxially-mounted, conical spray fuel injector with that of the baseline transverse (wall-mounted) injector tube revealed that the transverse injector tube dispersed the fuel liquid and vapor almost as well as the conical spray fuel **injection by the**

time the mixture reached the mixer tube exit. A comparison of the Spin Jet injector, the coaxially-mounted injector tubes, and some previous data from tests of a transversely mounted hypo injector indicated that the axial injector tube performed the worst in that it left much of the liquid unvaporized and produced a very non-uniform vapor field. Both the transverse injector tube and Spin Jet performed similarly, although there was less liquid fuel remaining unvaporized at the IMFH tube exit with the Spin Jet. Figures 2.1 and 2.2 showing false color representations of the liquid and vapor concentrations at the exit of the IMFH mixer tube (Figures 6 and 7 from PSU Final Report) support these observations. The results indicate only the slightest indication of any liquid only at the highest equivalence ratio tested (0.6). Refer to Figure 2 in the PSU Final Report for a schematic of the experimental setup and the measurement section. Based on these results, the Spin Jet was chosen for Task 2 testing described at the beginning of this section.

Based on the PSU diagnostic results, GEAE made the decision to modify the designs of the tips of the injector tubes so that they might perform as well as the Spin Jet. Three injector tips were sent to PSU for testing: two producing a fan-type spray (#2 and #5) and one syringe-type injector tip (#8). Figure 2.3 (Figure 15 from the PSU Final Report) show the tips and their positioning. Exciplex imaging experiments were run on these three tips at an inlet temperature of 650° F (1110 R) and an equivalence ratio of 0.6. The images for all three injectors showed that neither vapor nor liquid was significantly present in the bottom quarter of the mixing tube. The injector tube apparently created a wake region and the fuel never got into that region of the mixing tube. In general, the liquid and vapor were still confined to the middle region of the mixer tube. Fan tip #5 did a poorer job than either fan tip #2 or the syringe cut tip #8 in terms of spreading the fuel out vertically. It was concluded that no injector tube tip configuration performed much better than any other, at least with their tips positioned at the centerline. Fuel was not distributed well to the combustor, and the vapor and fuel tended to remain confined to a core, jet-like region near the centerline.

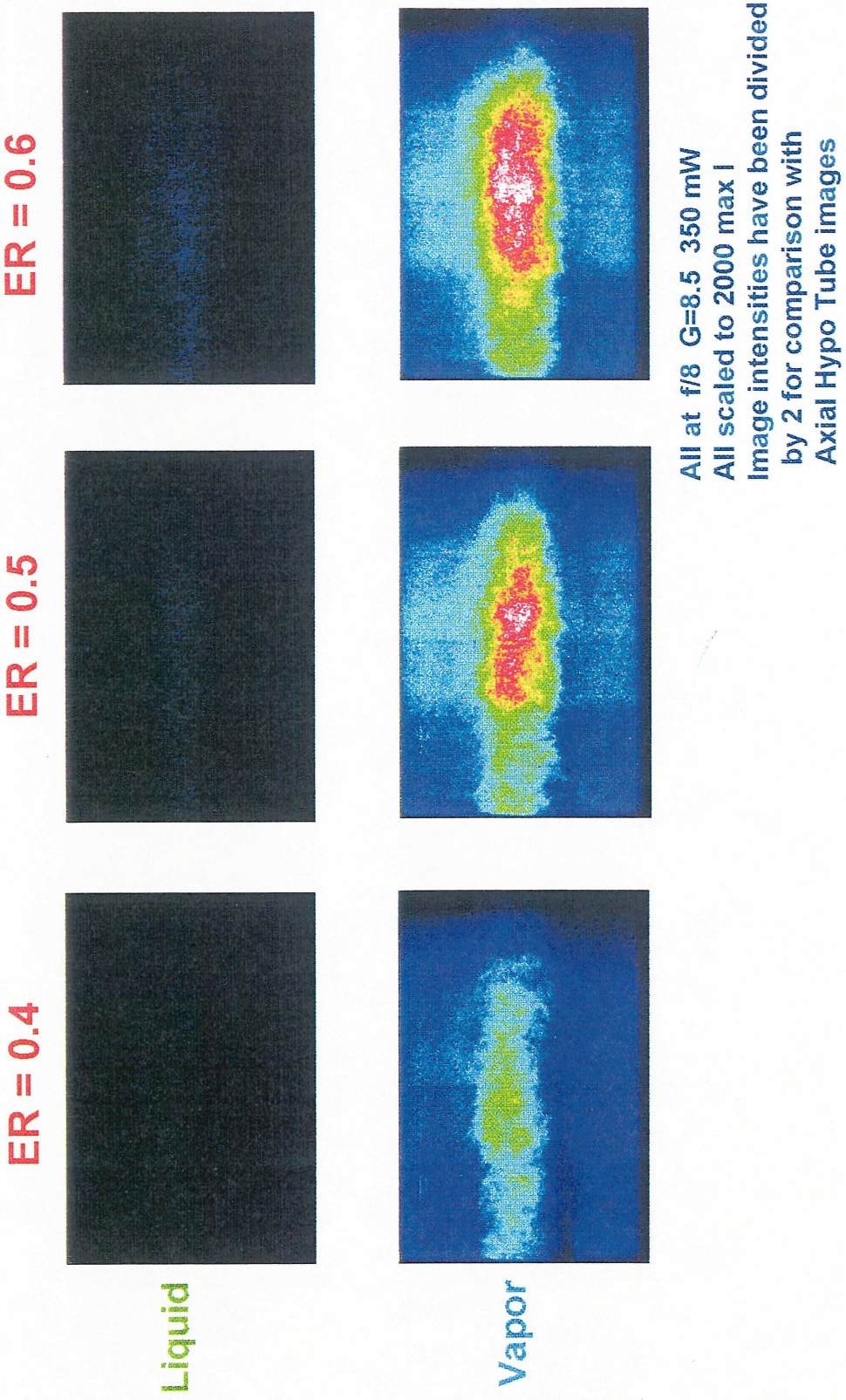


Figure 2.1 - False color representation of fuel liquid and vapor concentrations. Lee Company Spin Jet Atomizer used for fuel injection. Images show the concentration of fuel liquid and vapor at the IMFH tube exit at an inlet nitrogen temperature of 950 F and equivalence ratios of 0.4, 05 and 0.6.

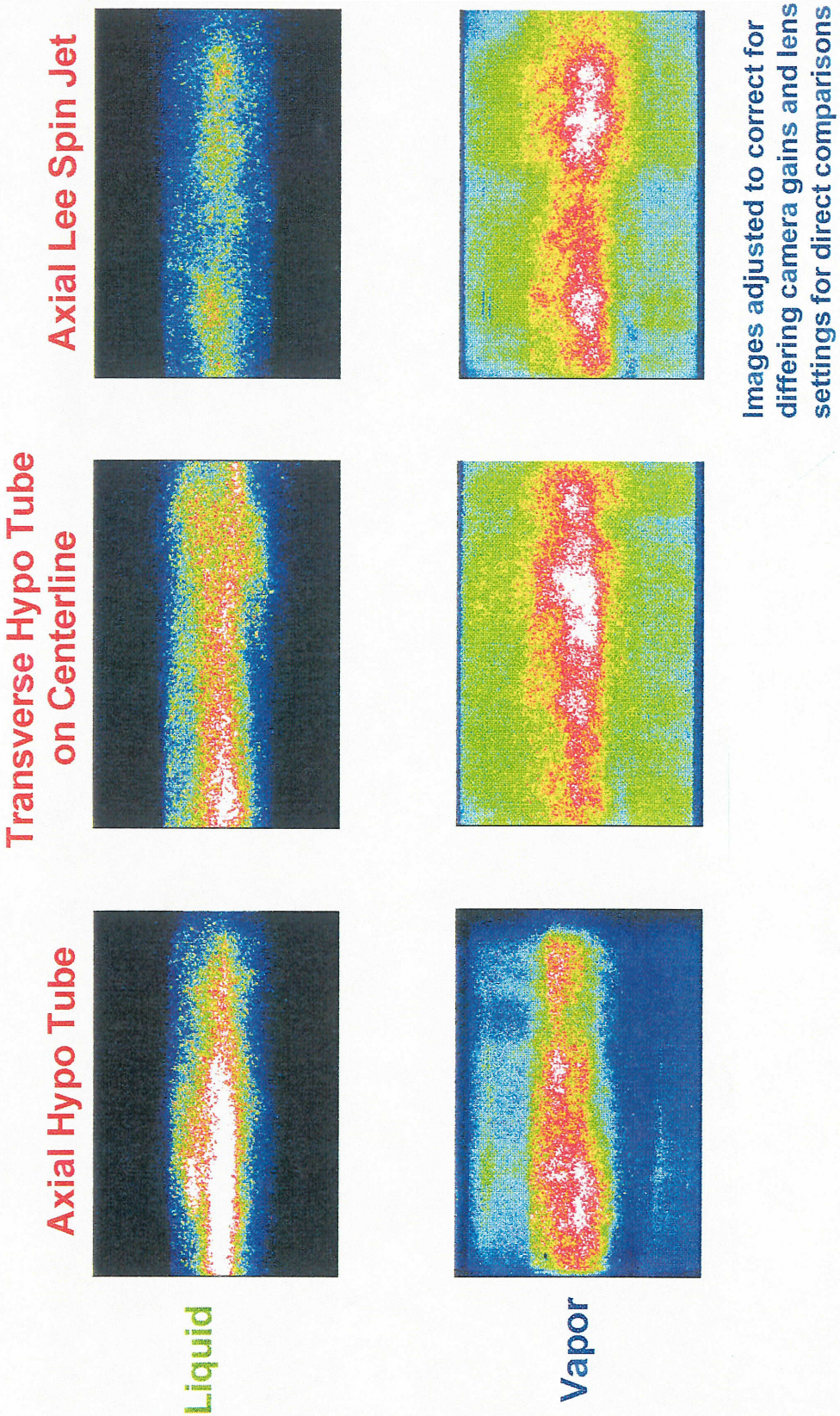
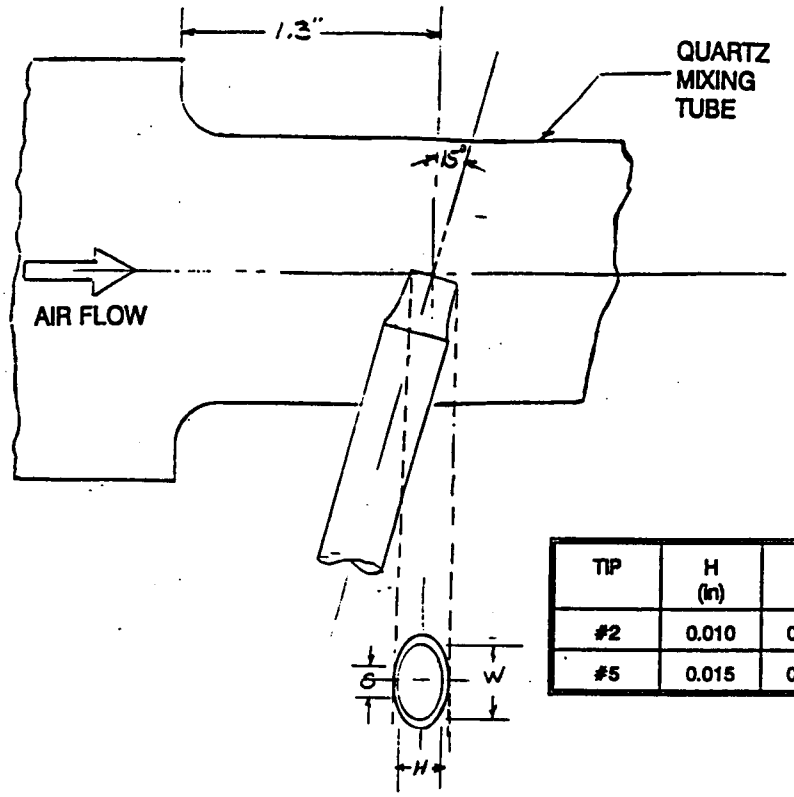
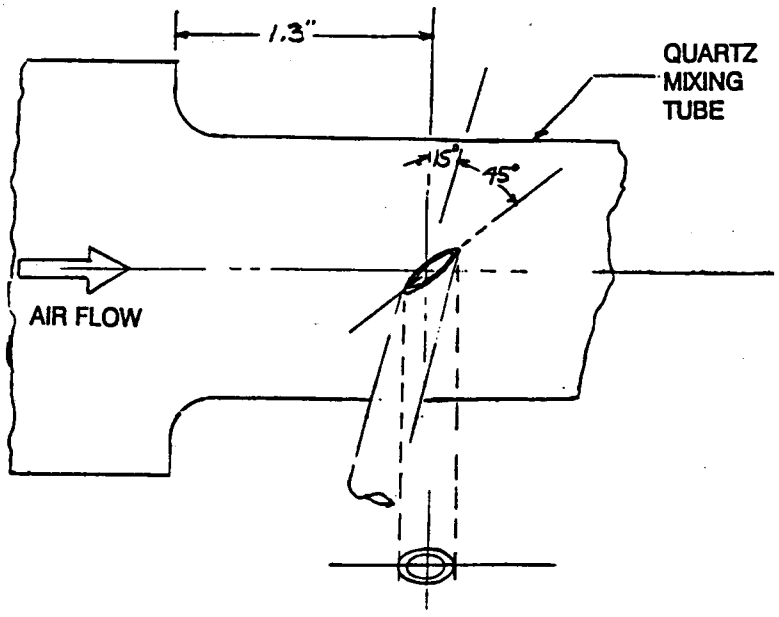


Figure 2.2 - Effect of fuel injector type on the concentration of fuel liquid and vapor at the IMFH tube exit at an inlet nitrogen temperature of 650 F and an equivalence ratio of 0.6.



TIP	H (in)	W (in)	S (in)
#2	0.010	0.026	0.016
#5	0.015	0.023	0.008

A) #2 & #5 OVALIZED FAN SPRAY TIPS



B) #8 SYRINGE CUT TIP

Figure 2.3 - Details of injector tube modifications. A) Injector tubes #2 and #5 with ovalized fan spray tips. B) Injector tubes #8 with syringe tip (beveled).

In Task 2, the Lee Spin Jet injector was used as the injector because it provided the best mixing performance in Task 1. Experiments were conducted that recorded exciplex images along the length of the mixer tube, both at low and high temperature conditions, at an equivalence ratio of 0.6. Figure 2.4 (Figures 12 and 13 from PSU Final Report) shows that when the Lee Spin Jet injector was used, the mixing tube length could not be reduced below its standard 4.5 inch length without reducing the amount of vaporization at the mixing tube exit well below the desired 98%.

Another conclusion from this study will affect future testing where highly turbulent flows are involved. It was concluded that for meaningful comparisons of imaging data with combustion performance test data, averaging over many images is required. The technique of employing on-chip accumulation of images for this averaging was tested and proved to be an excellent and practical method of obtaining average images of these flows.

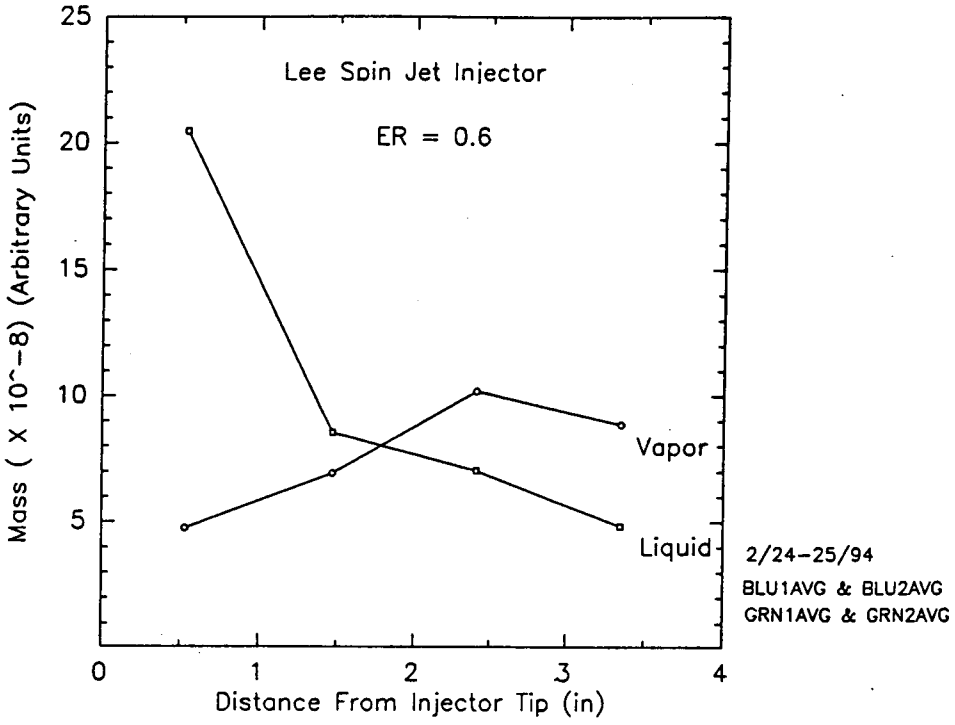


Figure 2.4a - Calculated mass parameter for fuel liquid and vapor versus axial position in IMFH tube using Lee Company Spin Jet atomizer. Inlet temperature = 650° F.

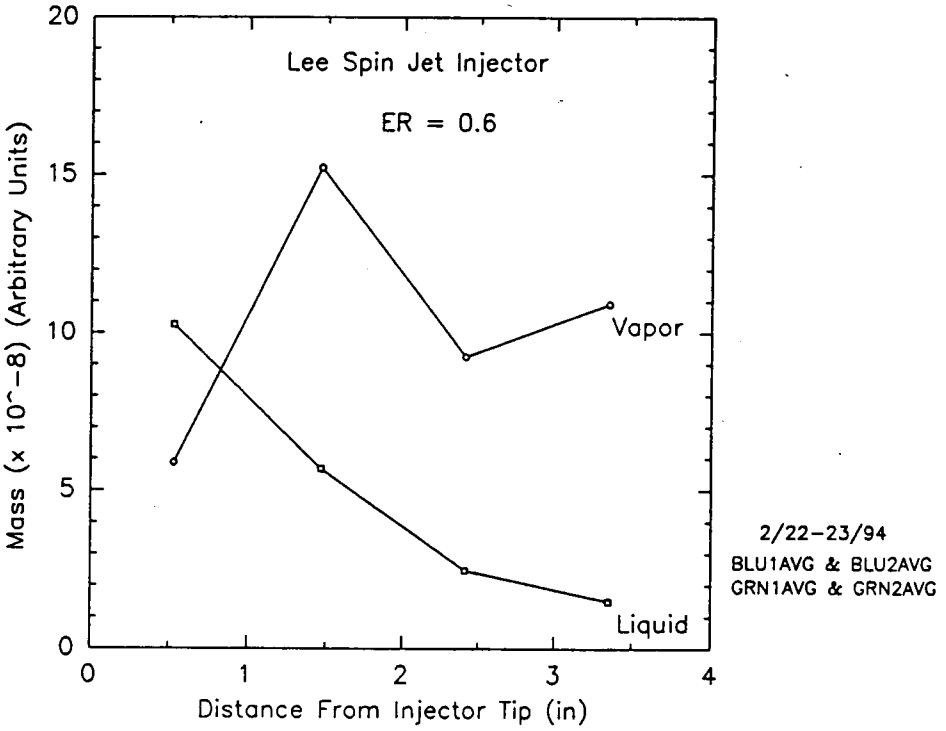


Figure 2.4b - Calculate mass parameter for fuel liquid and vapor versus axial position in IMFH tube using Lee Company Spin Jet atomizer. Inlet Temperature = 950° F.

2.2 GE Corporate R&D Diagnostics Studies

The GE CR&D combustor rig has a large space between the windows, making the rig especially suitable for larger fuel-air mixers with swirling, diverging flows. Therefore, the CR&D diagnostic program concentrated on the Cyclone Swirler pilot. The GE CR&D rig operates with inlet conditions up to 990° F (1450 R) and 15 atmospheres. The specific objectives of the GE CR&D diagnostics program were to:

1. Reduce the Cyclone Swirler's NOx emissions at cruise conditions by studying and improving the uniformity of fuel/air mixture leaving the Cyclone Swirler.
2. Develop a better understanding of the droplet size distribution of the unvaporized fuel leaving the Cyclone Swirler at low inlet temperatures.
3. Develop a better understanding of the velocity flow field downstream of the Cyclone Swirler.
4. Make visual observations and recordings of combustor operation at pressure.

The Cyclone Swirler tests at GE CR&D were performed with Configuration 2. That configuration was the original HSCT design (Configuration 1) with the added spent dome cooling air injection holes. Configuration 2 is very close in design to Configuration 3 used in the rectangular sector combustor discussed in Section 4. A cross-section of the Configuration 3 single-cup version is shown in Figure 3.37 in Section 3.4. The primary differences between Configuration 2 and 3 is that the size and effective flow area was reduced from Configuration 2 to Configuration 3. Configuration 2 had an effective flow area of 0.74 in^2. Configuration 3 had an effective flow area of 0.57 in^2. The number of fuel injectors was reduced from eight in Configuration 2 to six in Configuration 3 (injectors per effective flow area was kept roughly constant). The Configuration 3 hardware was generally much more robust, mechanically, than the Configuration 2 design.

The laser diagnostic capabilities of GE CR&D included Raman measurements of temperature and major species, and Phase Doppler Particle Analyzer (PDPA) measurements of the velocity flow field and fuel droplet size distribution of the unvaporized fuel emitted from the

Cyclone Swirler. PDPA measurements were taken using ambient and preheated air at atmospheric pressure. Droplet size and distribution measurements were made at a number of axial planes with liquid fuel over a range of simulated low power conditions. The effect of fuel injector tube diameter and fuel jet velocity on droplet sizes and NOx emissions exiting the Cyclone Swirler was studied using fuel injector tubes with 0.020-inch and 0.012-inch inner diameters.

2.2.1 PDPA Measurements in an Unfired Cyclone Swirler Pilot

Test conditions for the initial studies of fuel atomization in the Cyclone Swirler Pilot are summarized in Table 2.2. Figures 2.5 and 2.6 present PDPA droplet diameter data taken at the Cyclone Swirler exit. D_{10} is the mean diameter which is calculated from the "number" mean, calculated from $\Sigma n_i d_i / \Sigma n_i$. D_{32} is the Sauter mean diameter which is calculated by dividing the volume of the droplets by the surface area. The Sauter mean diameter equals $\Sigma n_i d_i^3 / \Sigma n_i d_i^2$. Droplet exit profiles in this test ($D_{10} < 10$ μm and $D_{32} < 15$ μm most places) indicated that the degree of atomization of the kerosene droplets leaving the Cyclone Swirler was excellent. At low inlet temperatures (ambient) the small droplet sizes are attributed mainly to the effect of atomization rather than vaporization.

Table 2.2 Experimental Conditions for CR&D PDPA Measurements with Ambient Inlet Temperature

Inlet Air Temperature	80° F (27 C)
Pressure	Ambient
Swirler pressure drop	5%
Fuel	Kerosene
Fuel Injector I.D.	0.012 inches
Fuel flow rate	14.2 PPH

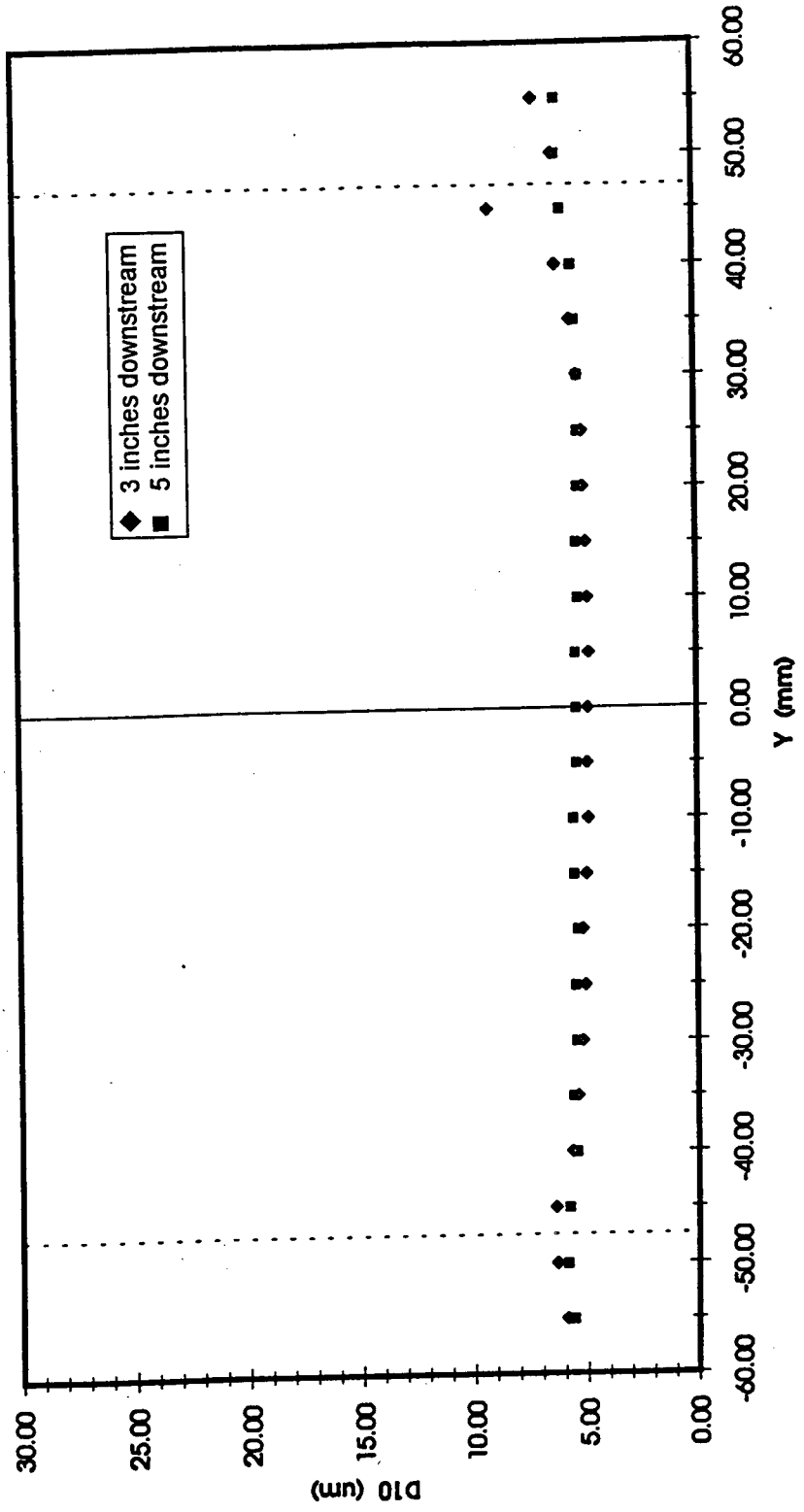


Figure 2.5 - Cyclone Swirler PDPA results for mean droplet diameter at 3 inches and 5 inches downstream from the exit plotted versus radial position. The inlet air temperature is 80° F.

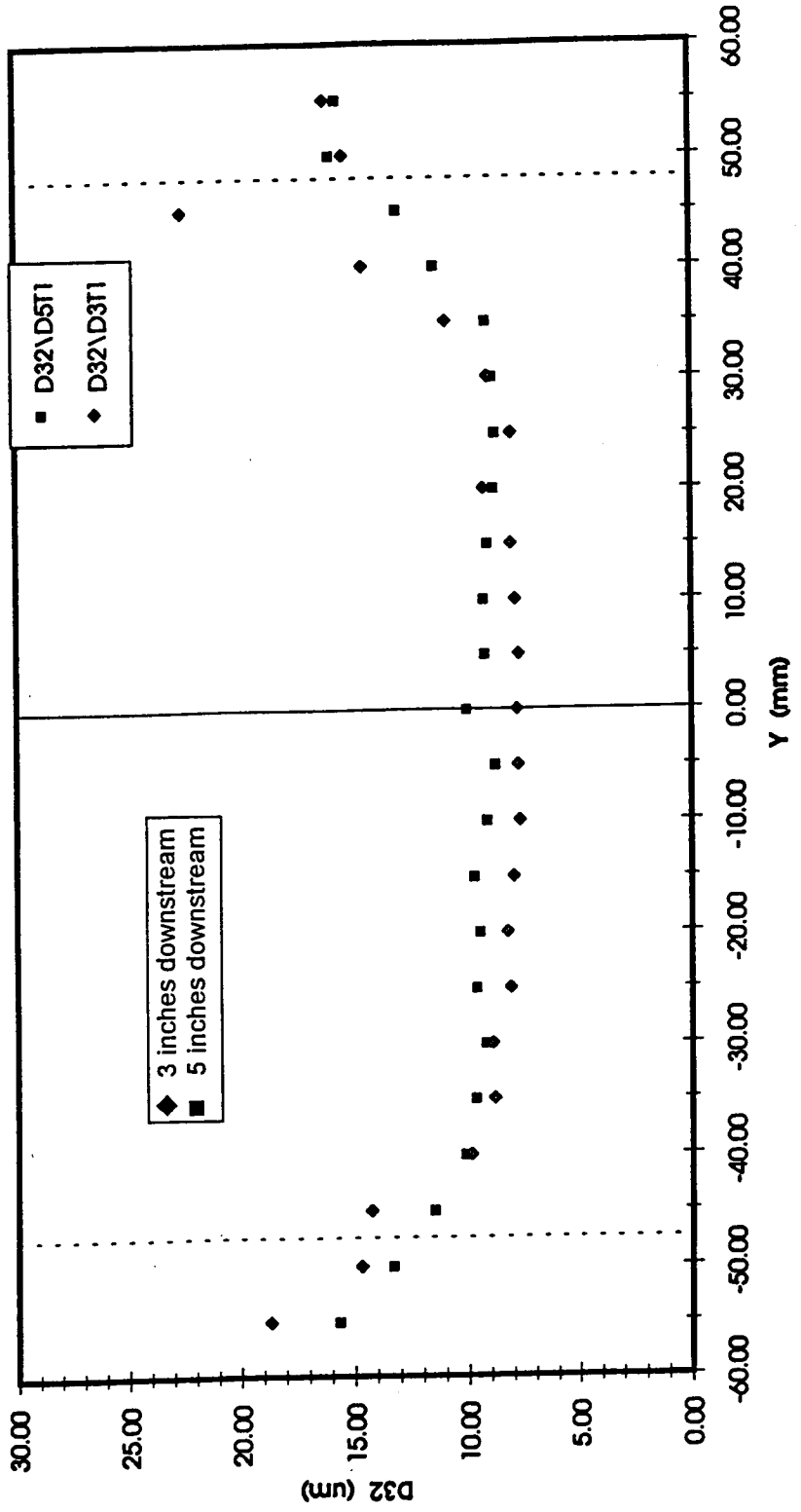


Figure 2.6 - Cyclone Swirler PDPA results for Sauter mean droplet diameter at 3 inches and 5 inches downstream from the exit plotted versus radial position. Inlet air **temperature is 80° F.**

The corresponding results for the axial component of the mean droplet velocity are shown in Figures 2.7. Figure 2.8 shows the velocity of the air. The air velocity is determined from the smallest droplets (< 3 μm), assuming that they track with the air. Because none of the droplets are much bigger than 3 μm and the axial component does not accelerate (relative to the tangential component), the difference between the velocities in Figures 2.7 and 2.8 are detectable only upon close examination.

To determine the relative effectiveness of fuel atomization by the Cyclone Swirler versus by the air blast fuel injector alone, PDPA measurements were made on one of the eight radial air blast fuel injectors while not installed in the Cyclone Swirler. All conditions in terms of air temperature, pressure drop, etc. were kept the same as those listed in Table 2.2. Figures 2.9 compares the mean droplet size of both tests three inches downstream from the exit of the Cyclone Swirler to three inches downstream from the fuel injector exit. Figure 2.10 makes the same comparison using the Sauter mean diameter. These data indicate that atomization of the air blast fuel injector alone was in a typical range for an airblast atomizer. The Cyclone Swirler significantly reduces the droplet size from the plain jet airblast atomizer. This could be due atomization and/or vaporization. The strong vortex in the Cyclone Swirler should enhance both atomization and vaporization. The vapor pressure of kerosene at room temperature is high enough that significant vaporization cannot be ruled out. Additional measurements would be required to determine the relative effects of atomization and vaporization. Figure 2.11 compares the droplet velocities from the Cyclone Swirler with the atomizer nozzle.

In the next series of tests, the inlet air temperature was increased and the measurements were repeated. In this case, the fuel/air ratio was also varied to determine their effects on droplet size distributions. Table 2.3 summarizes the test conditions during these measurements. Figures 2.12 and 2.13 compare the mean droplet sizes and Sauter mean droplet sizes at 400° F versus 80° F (860 R versus 540 R) versus radial position. The plots verify that higher inlet temperatures produce smaller droplets from the Cyclone Swirler (all other conditions being the same as the prior tests). The reduced droplet size should be primarily an effect of increase vaporization rate.

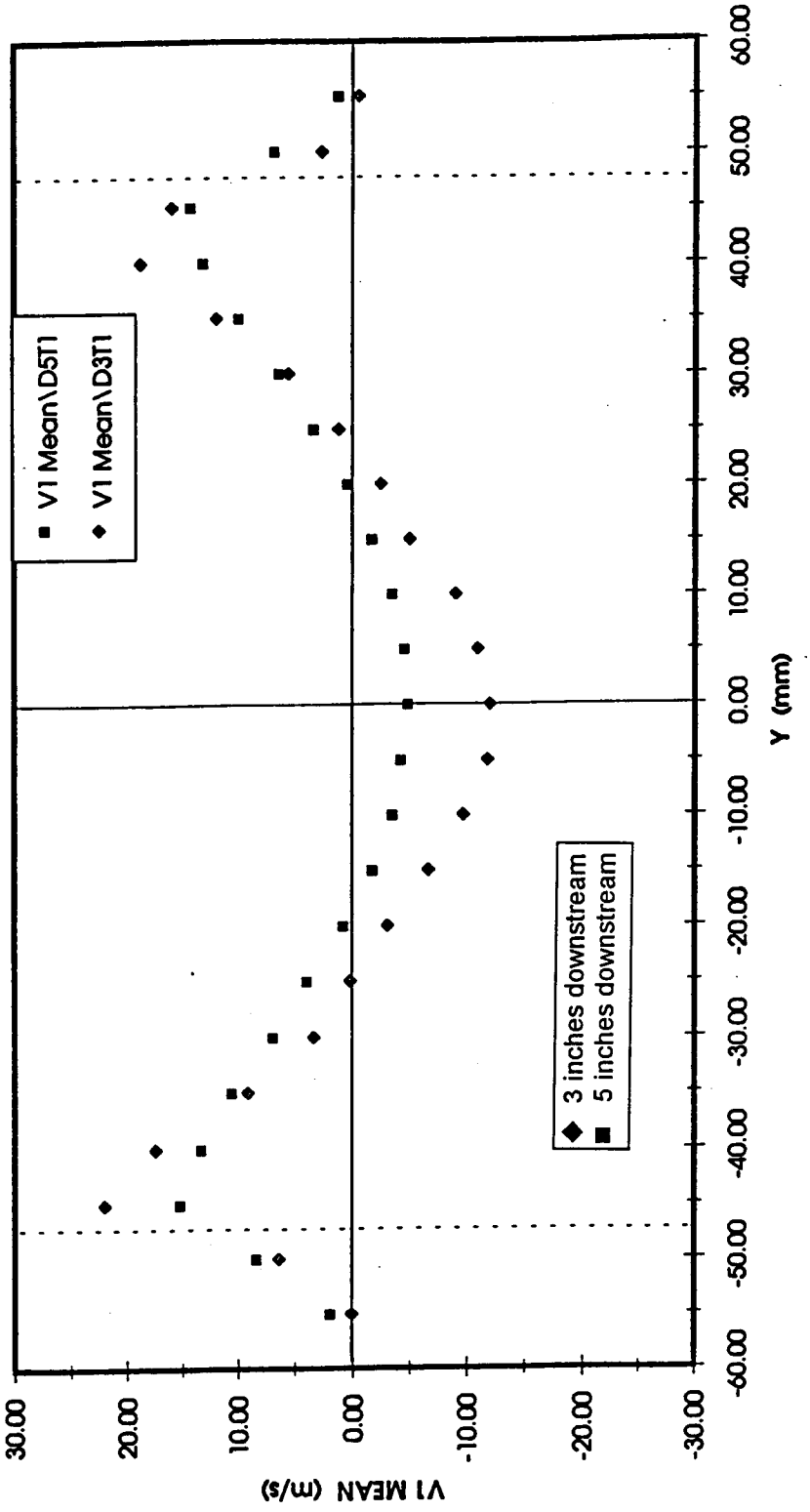


Figure 2.7 - Cyclone Swirler PDPA results for the mean droplet axial velocity component at 3 inches and 5 inches downstream from the exit plotted versus radial position. The inlet air temperature is 80° F. The fuel injector tube inner diameter is 0.012 inches. The fuel flow rate is 14.2 pounds per hour.

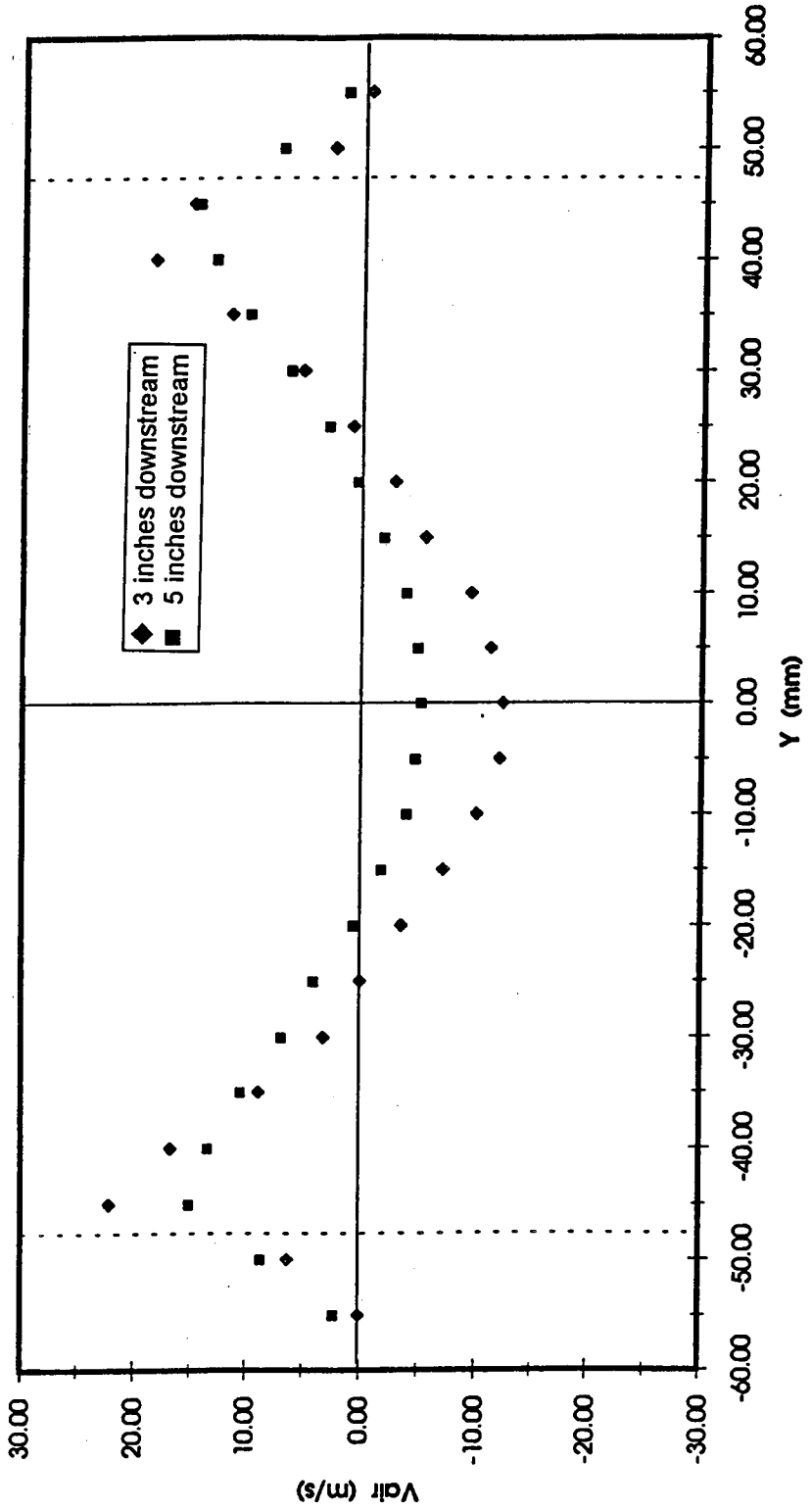


Figure 2.8 - Cyclone Swirler PDPA results for the mean axial velocity component of the air at 3 inches and 5 inches downstream from the exit plotted versus radial position. The inlet air temperature is 80° F. The fuel injector tube inner diameter is 0.012 inches. The fuel flow rate is 14.2 pounds per hour.

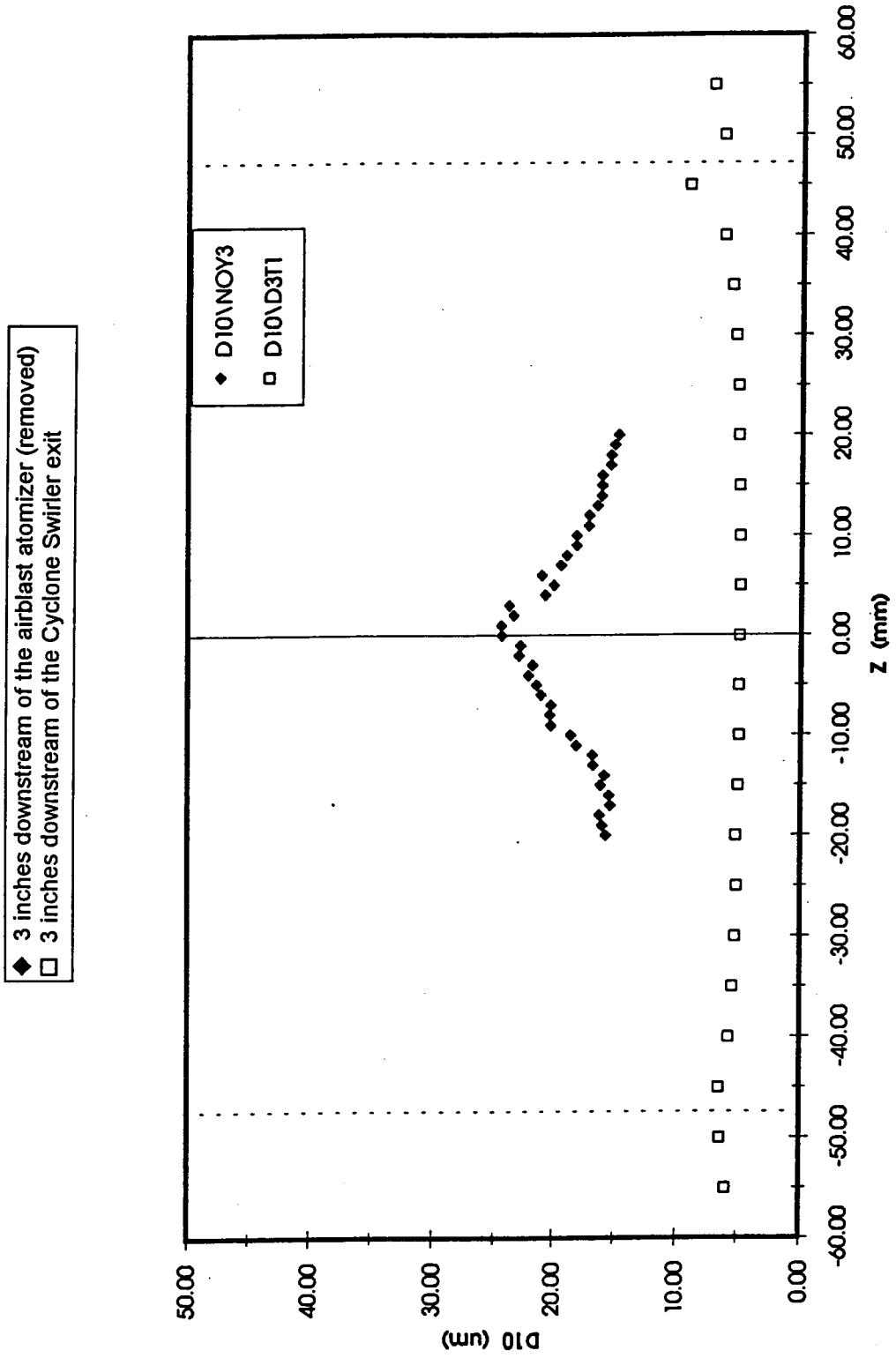


Figure 2.9 - PDPA results for mean droplet diameter at 3 inches downstream from the exit of the Cyclone Swirler compared with the same measurement 3 inches downstream of the airblast atomizer (uninstalled), both plotted versus radial position. Inlet air temperature is 80° F.

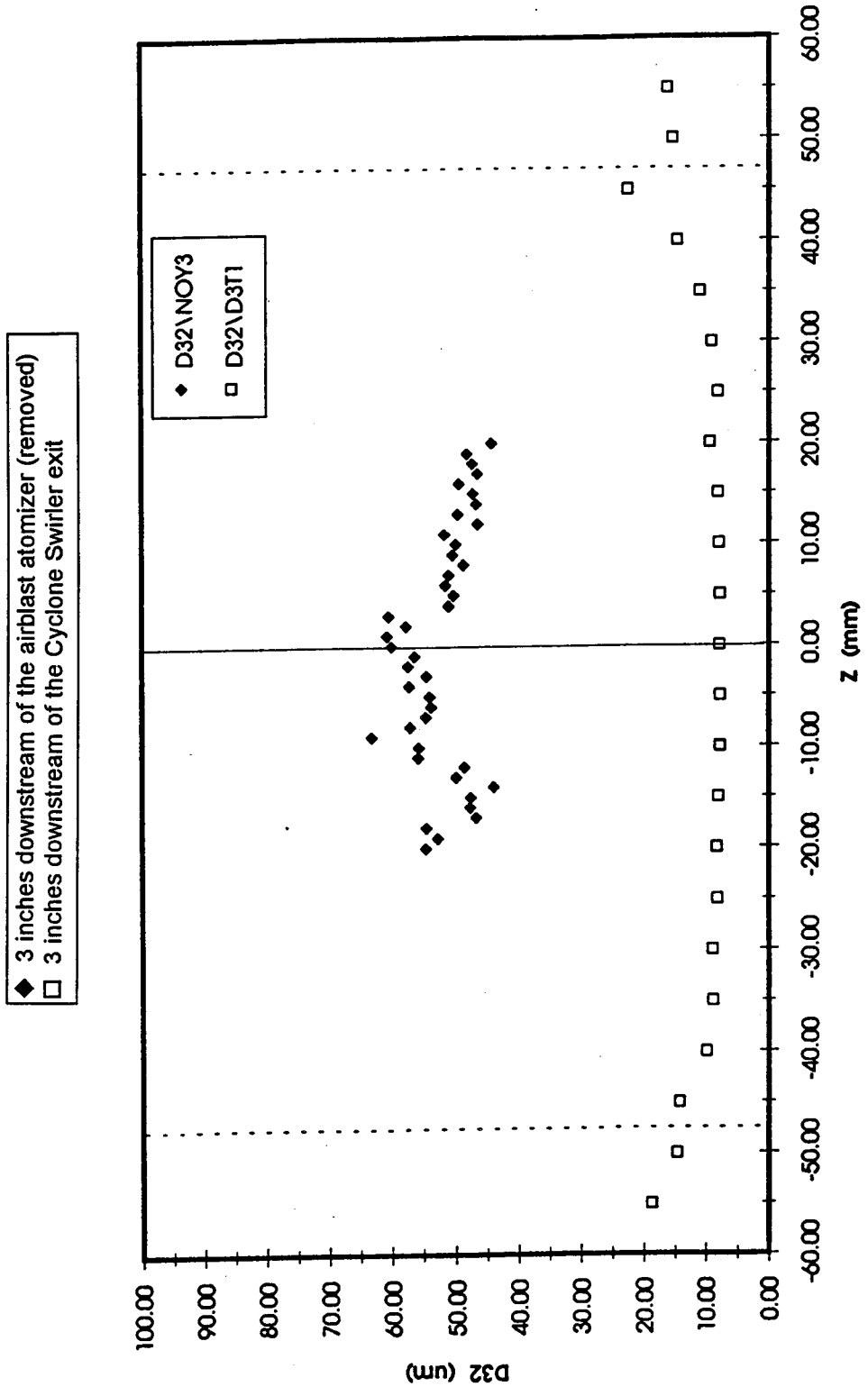


Figure 2.10 - PDPA results for Sauter mean droplet diameter at 3 inches downstream from the exit of the Cyclone Swirler compared with the same measurement 3 inches downstream of the airblast atomizer (uninstalled), both plotted versus radial position. Inlet air temperature is 80° F.

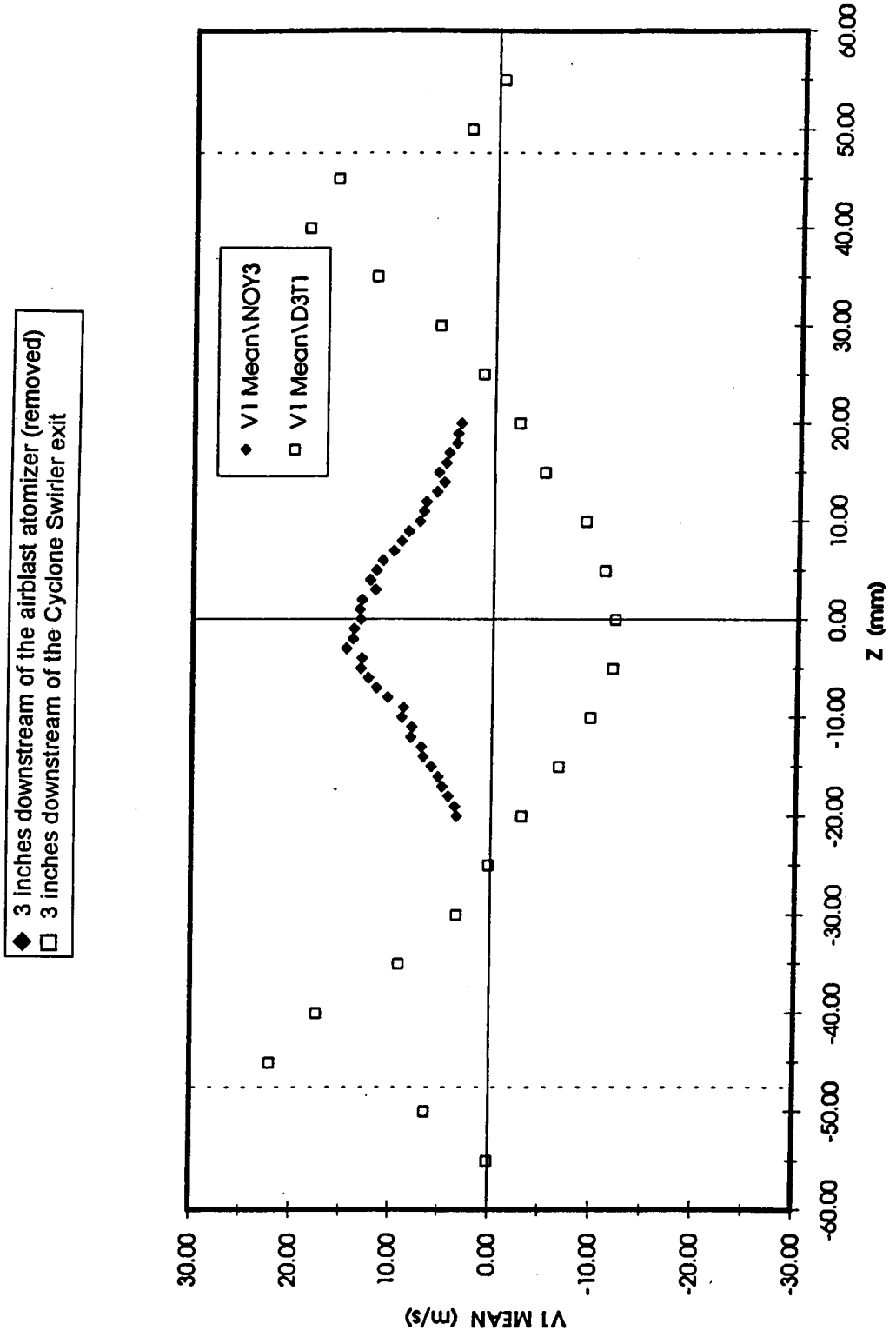


Figure 2.11 - PDPA results for the mean axial component of the droplet velocity at 3 inches downstream from the exit of Cyclone Swirler compared with the the same measurement 3 inches downstream of the plain-jet airblast atomizer (uninstalled), both plotted versus radial position. Inlet air temperature is 80° F.

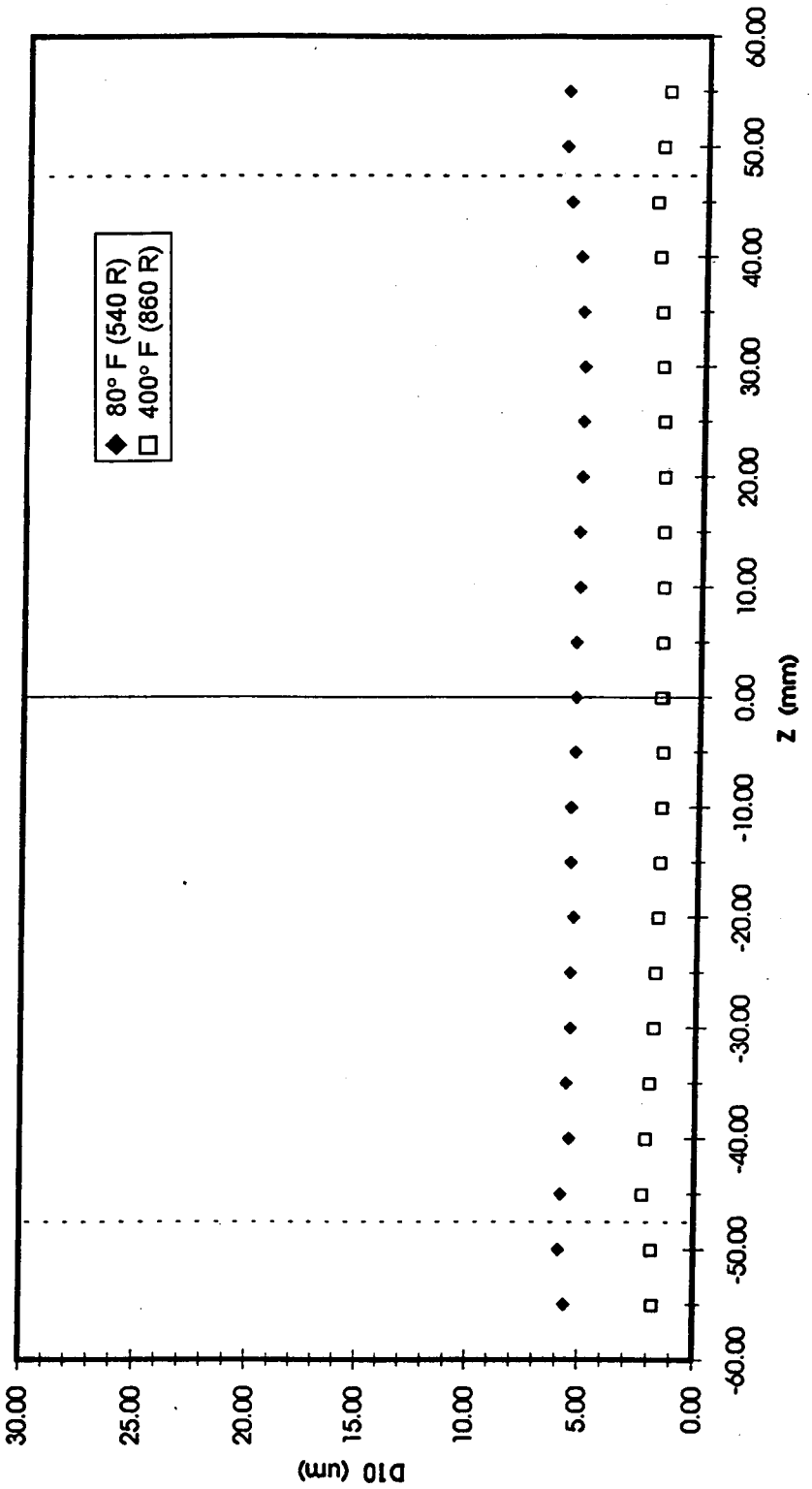


Figure 2.12 - PDPA results for the mean droplet diameter at 5 inches downstream from the exit of Cyclone Swirler plotted versus radial position. Results for an inlet air temperature of 80° F (540 R) compared with results for an inlet air temperature of 400° F (860 R).

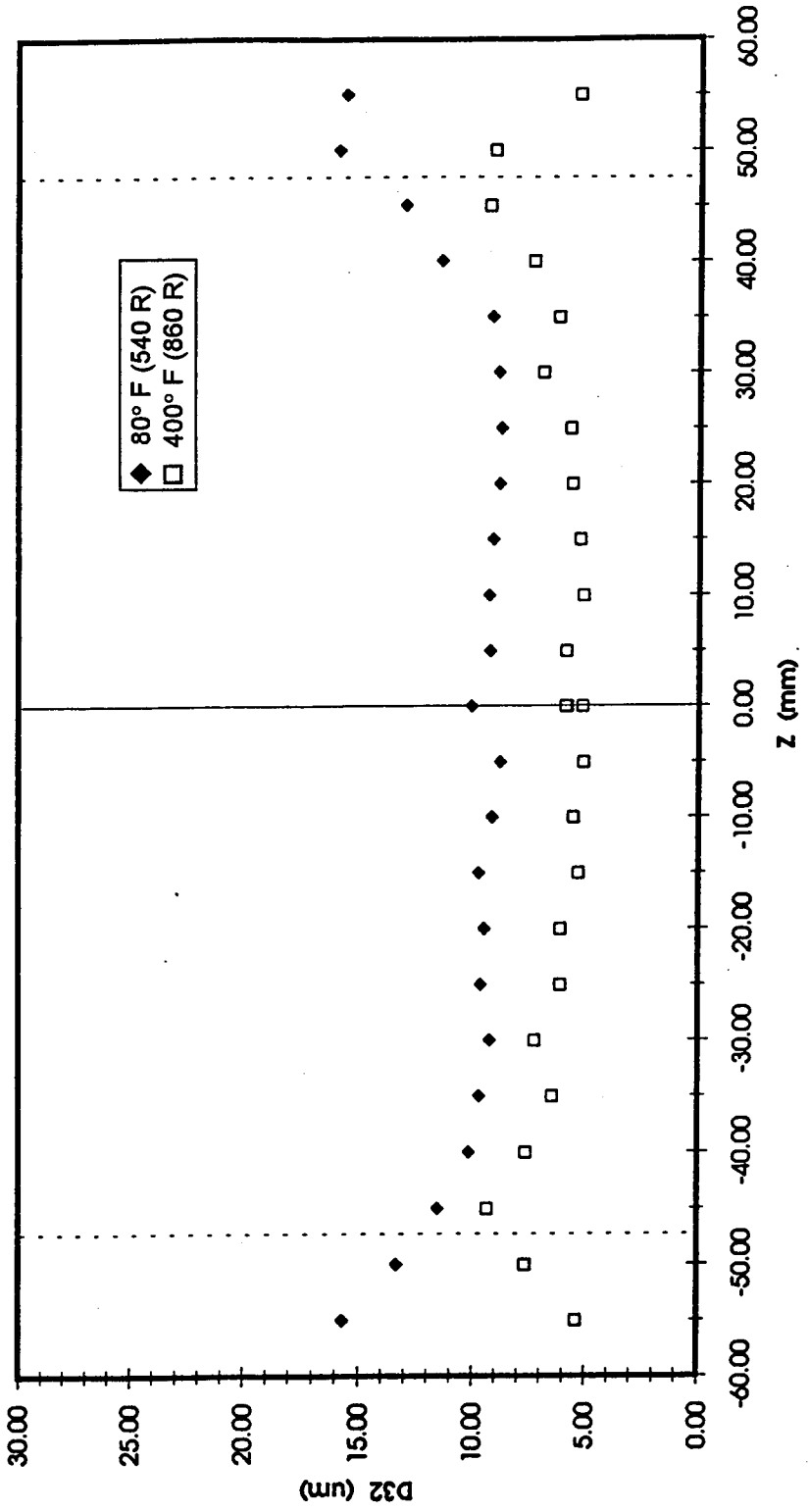


Figure 2.13 - PDPA results for the Sauter mean droplet diameter at 5 inches downstream from the exit of Cyclone Swirler plotted versus radial position. Results for an inlet air temperature of 80° F (540 R) compared with results for an inlet air temperature 400° F (860 R).

Varying fuel/air ratio did not produce any significant effect on the droplet sizes or their distribution, so these results are not shown.

Table 2.3 Experimental Conditions for CR&D PDPA Measurements with Heated Inlet Temperature	
Inlet Air Temperature	400° F (204 C)
Pressure	Ambient
Swirler pressure drop	5%
Fuel	Kerosene
Fuel flow rate	14.2 PPH

2.2.2 Mie Scattering Tests

A complete image of the flow field downstream of the Cyclone Swirler exit plane was constructed using an Argon-Ion laser sheet operating at 2W and placed normal to the flow direction. Mie scattering from liquid droplets in the plane of the light was collected using a standard video camera operating at shutter speeds between 1/60 and 1/4000 second. The observations and video were made at an inlet air temperature low enough to prevent fuel from fully vaporizing (so that Mie scattering was strong), but not so low in inlet air temperature that the fuel hit the observation windows. Observations based on the video images obtained from this simple system included:

1. There was significant unsteadiness in the flow field.
2. Fuel streaks from all eight injectors were clearly discernible at 0.5 inches downstream. Farther downstream these streaks appeared to have different lifetimes and the surviving streaks moved around. This could have been due to unsteady fuel flow rates from the individual injectors, or unsteady degree of atomization from the eight injectors, or variations

in lifetimes of parcels of fuel and air resulting from differing degrees of vaporization as they exited the Cyclone Swirler due to the unsteadiness of the flow field.

3. The fuel left the Cyclone Swirler in a hollow cone spray; this was expected given the large center-body and the characteristics of the vortex flow field.
4. The images showed increasing amounts of liquid fuel as the temperature of the inlet air was lowered.

An increased awareness of the unsteadiness of the flow field resulted from these observations. However, unsteadiness is known to be a dominant characteristic of all turbine combustor flow fields.

2.2.3 Fired Tests

The Cyclone Swirler was installed in the CR&D single-cup combustor diagnostics rig. The rig is an 8-inch diameter pressure vessel with a quartz liner with an inner diameter of 3.7 inches. The fuel injector tube inner diameter for these tests was 0.012 inches. The combustor was operated at a pressure up to 125 psig with the flame front recorded using standard video equipment. NOx measurements were obtained simultaneously using conventional probe sampling. It was found that the combustor operated in two modes during this test:

1. At lean equivalence ratios (just above LBO), the flame was only anchored to the center-body. The flame increased in area and filled the liner as it did so.
2. At higher equivalence ratios the flame was anchored to the centerbody and in the corner of the recirculation zones. The mode was also characterized by an increase in NOx emissions.

That the flame did not appear to be stabilized in the outside corners at the dome is inconsistent with GEAE experience, especially in the sector combustors. This difference is

thought to be due to leakage at the seal between the dome and the upstream end of the quartz liner in the CR&D rig.

Additional fired tests were then run at a pressure of 200 psia with the Cyclone Swirler in the single-cup 8-inch diameter rig at GE CR&D. The tests were also conducted with a 3.7 inch inner diameter ceramic liner. The fuel injector tube inner diameter for these tests was increased to 0.020 inches, consistent with Configuration 3. Inlet temperatures were varied from 600° F (1060 R) to a maximum of 900° F (1360 R). NOx, CO and CO_2/O_2 emissions data with standard probe sampling were obtained at various steady state conditions at a number of pressures. The following observations were made:

1. When inlet temperature was increased beyond 800° F (1260 R), the combustion oscillations observed in the previous tests did not occur, while at lower inlet temperatures they did occur.
2. Most of the emissions data agreed with emissions data taken in tests at GEAE.
3. The sudden rise in NOx with elevated pressures and temperatures that was observed in GEAE single cup testing did not occur in these tests up to the maximum conditions of 200 psia and 900° F (1360 R).

Figure 2.14 shows the CR&D NOx emissions measurements for Cyclone Swirler Configuration 2. Figure 2.15 show that there was a increase in NOx emissions with inlet temperature when the flame temperature was held at a constant value of 3500 R. These results indicated the presence of a break point where the NOx emissions transition to a steeper dependence on inlet temperature.

The experiment was repeated. To improve the determination of the inlet temperature at which the slope change occurs, the measurements were made at smaller increments of inlet temperature. The pressure and the constant flame temperature were selected to be more relevant to supersonic cruise conditions. Flame temperature was held constant at 3550 R.

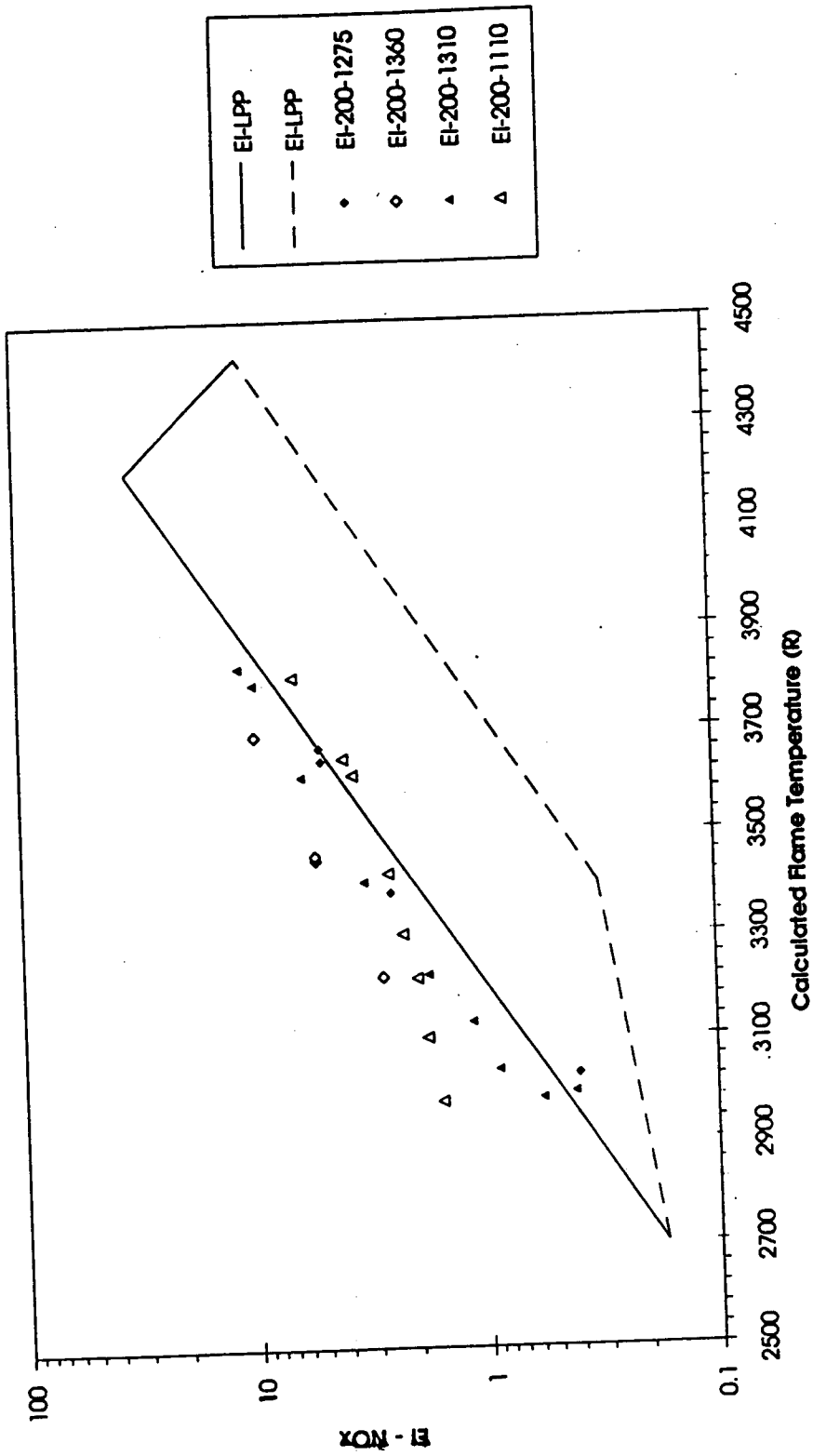


Figure 2.14 - NOx Emissions Index plotted versus flame temperature at inlet air temperatures ranging from 1110 R to 1360 R according to the legend. Pressure is 200 psia. These test conditions and the results are comparable to test results obtained at GEAE.

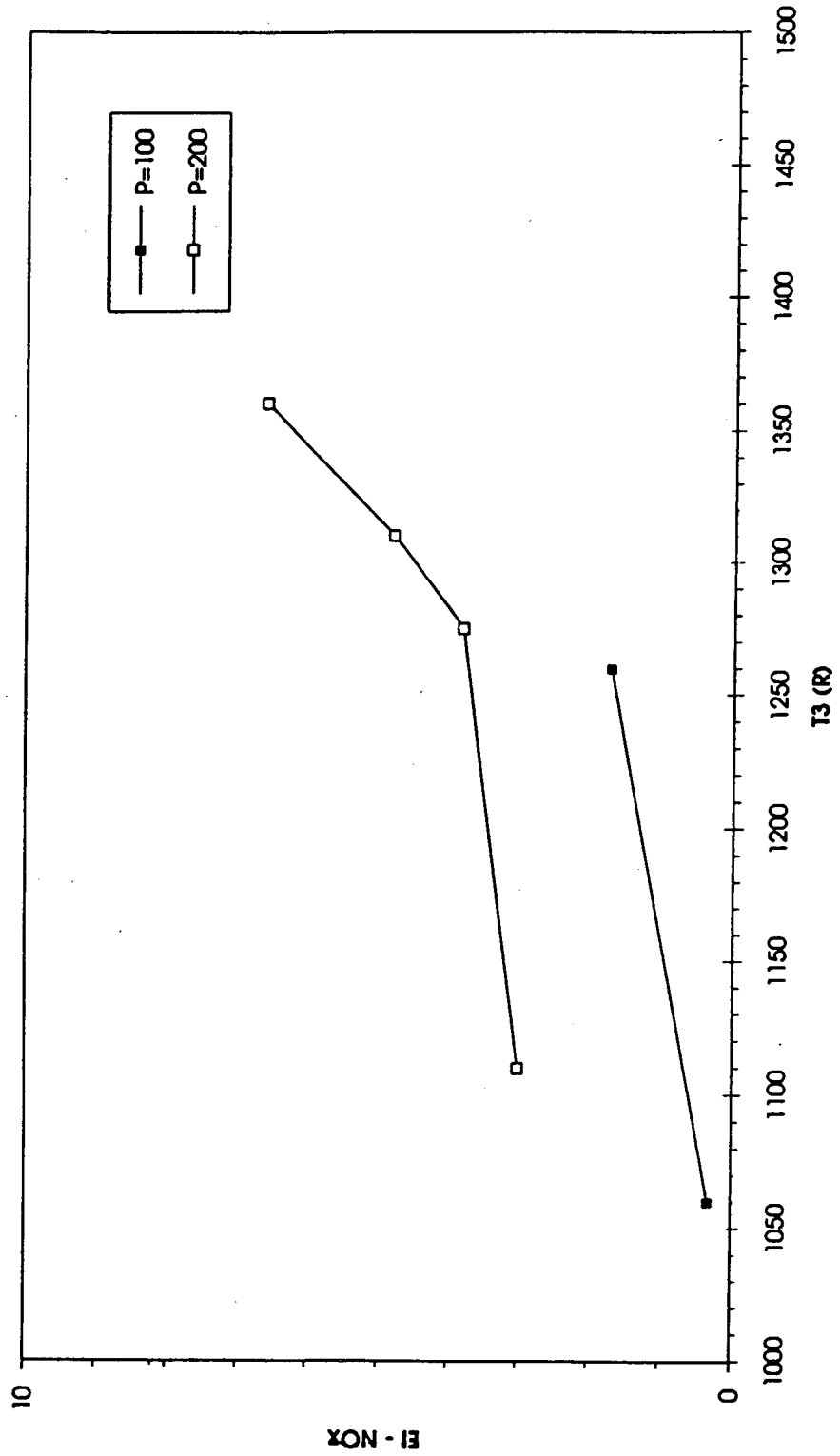


Figure 2.15 - NOx Emissions Index plotted versus inlet air temperature with flame temperature held constant at 3500 R. Inlet pressure is 100 psia and 200 psia as indicated by the legend.

Inlet pressure was held at 150 psia. Inlet temperature was varied from 590° F to 820° F (1050 R to 1280 R). The pressure drop across combustor was held at 5%. The NOx emissions are plotted versus inlet temperature in Figure 2.16. Over the range of inlet temperatures studied, the NOx emissions were observed to increase gradually. There were no sudden increase in the measured NOx emissions, but the slope relative to inlet temperature did change at about 740° F (1200 R).

The purpose of these pressure tests of the Cyclone Swirler and the probe measurements of the NOx emissions were supposed to be preliminary in preparation to making detailed Raman measurements of all the major species. The Raman measurements were to be done at supersonic cruise conditions, except that T_3 would be have to be lower, subject to the same facility limits as the above tests. The Raman measurements were to be done point-wise and were to map out the flame zone. A few preliminary Raman measurements were done at atmospheric pressure, but the Raman measurements were not completed before the budget was expended.

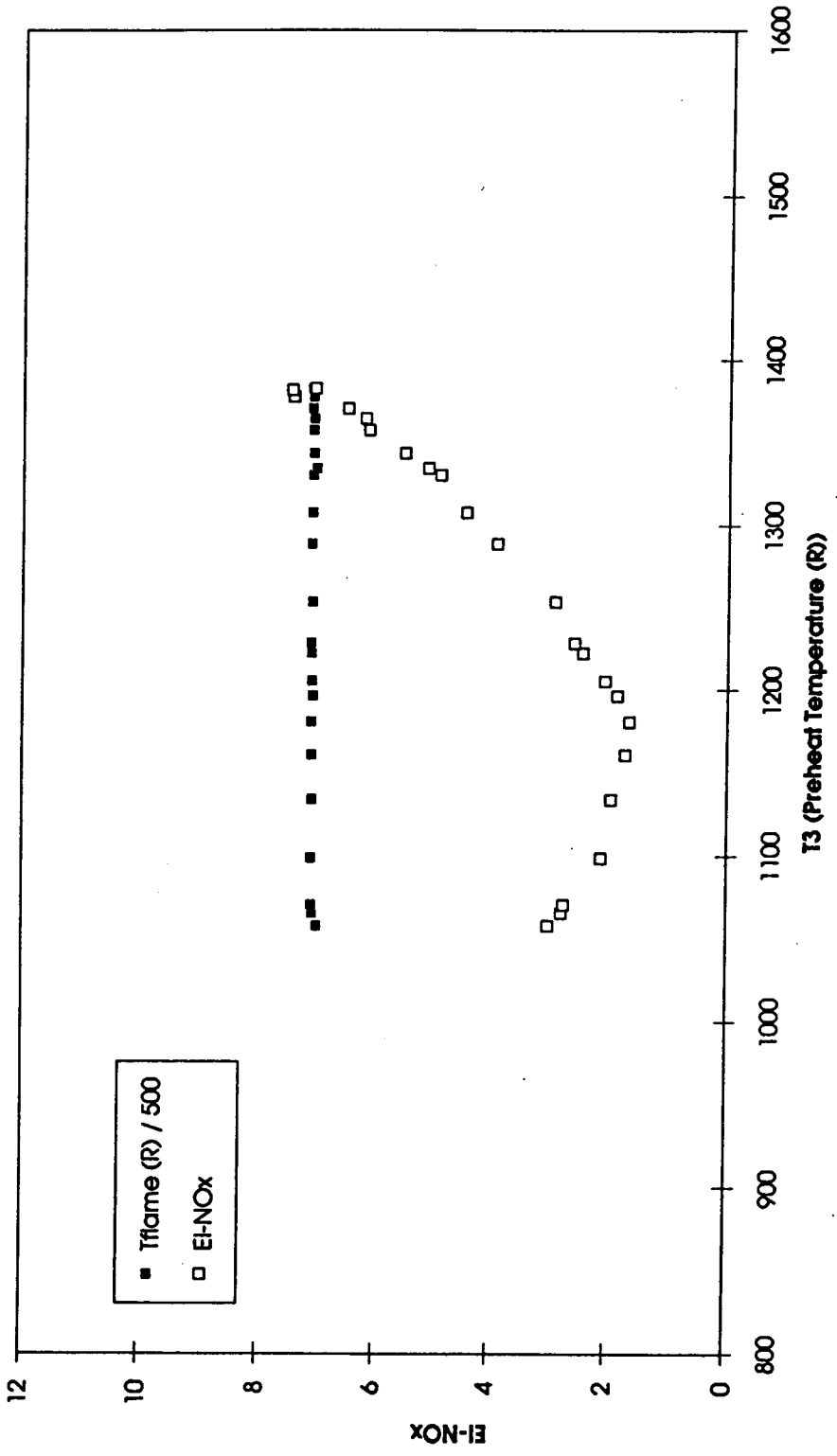


Figure 2.16 - Measured NOx Emissions Index plotted versus inlet air temperature with flame temperature maintained constant at 3550 R. Pressure drop is 5%. Inlet pressure is 150 psia.

Section 3

Subcomponent Evaluations

This section describes the development and testing of six fuel-air premixer concepts selected for development in LET Task 10. These six fuel-air premixer concept studies are continuations of studies of the same concepts (or very similar concepts) in NASA Contract NAS3-25951, Aero-Propulsion Technology, Task 5. The six fuel-air premixer concepts are:

1. Integrated Mixer Flame Holder (IMFH)
2. Curved Tube IMFH
3. Swirl-IMFH
4. Cyclone Swirler
5. Mini-Swirl IMFH
6. Swirl-Jet

The IMFH tube is the underlying concept for four of the above concepts. The IMFH is a straight tube with a fuel injector near the entrance. The tube exits through the combustor dome resulting in a perforated plate-type flame-holder. Hence the name. The Cyclone Swirler utilizes the high radial acceleration inside a radial swirler to maintain a relative velocity between the fuel and air, thereby enhancing fuel atomization and vaporization. The Swirl-Jet is another adaptation of a swirler for prevaporizing and premixing fuel in air. In the Swirl-Jet the premixing takes place in an axial flow after the swirler, rather than inside the swirler. The swirl is generally fairly weak to help prevent recirculation. The APT Task 5 Final Report [3-1] should be referred to for more detail on the LPP premixer concepts and their early development history.

Throughout Section 3, IMFH Configurations 5A and 5B will be used as the baseline for comparison with the new designs for the main stage premixers. The designations A and B refer to the low pressure and the high pressure flame tube rigs, respectively. There are no design

differences between the A and B versions. The IMFH configuration was the same in both installations. However, there were differences in the combustion zone. The low pressure rig had a combustor diameter of 4.89 inches and a length to the sample probe of 7.42 inches. The high pressure rig had a combustor diameter of 4.5 inches and a length from the dome to the probe of 9.45 inches. Configuration 5 of the IMFH is the design used in the stepped-dome sector combustor.

3.1 Integrated Mixer Flame Holder (IMFH) Evaluations

The development program for the IMFH emphasized the evaluation of the performance of alternative fuel injector concepts and the effects of mixer tube length and diameter. Minor design variations such as the spent dome cooling air injection hole design were also studied. A third generation (Gen III) of the IMFH flametube hardware was designed and fabricated for these tests. The hardware was designed to be modular for maximum flexibility in the test configurations. The Gen III modules consisted of an inlet section, mixer tubes, impingement baffle, and flame holder. The modules were bolted together in a way that allowed for the convenient variation of the mixer tube lengths. The coaxial fuel injector supports were attached to the inlet section of the premixer. Some form of coaxial injector bodies would allow the fuel injector to be separated from the IMFH tube, possibly allowing a more conventional fuel injection system for the IMFH. A typical 7-tube configuration is shown in Figure 3.1.

Two configurations were tested using coaxially-mounted, 0.190 inch outer diameter, conical spray Lee Spin Jet fuel injectors. Configuration 7 located the Lee Spin Jet injector tips 1.0 inch downstream from the mixer tube inlets, which yields a fuel-air mixing length of 4.5 inches. Configuration 8 increased the mixing length to 5.25 inches by moving the injector tips forward 0.75 inches. The tests were generally run with a pressure drop of 4.4 to 5.0%. When pressure drop was varied from this nominal range, the values are noted in the legends of the plots. NOx emissions for Configuration 7 were slightly higher than the IMFH Configurations 5A and 5B single-cup results as shown in Figure 3.2, at inlet temperatures ranging from 495° F to

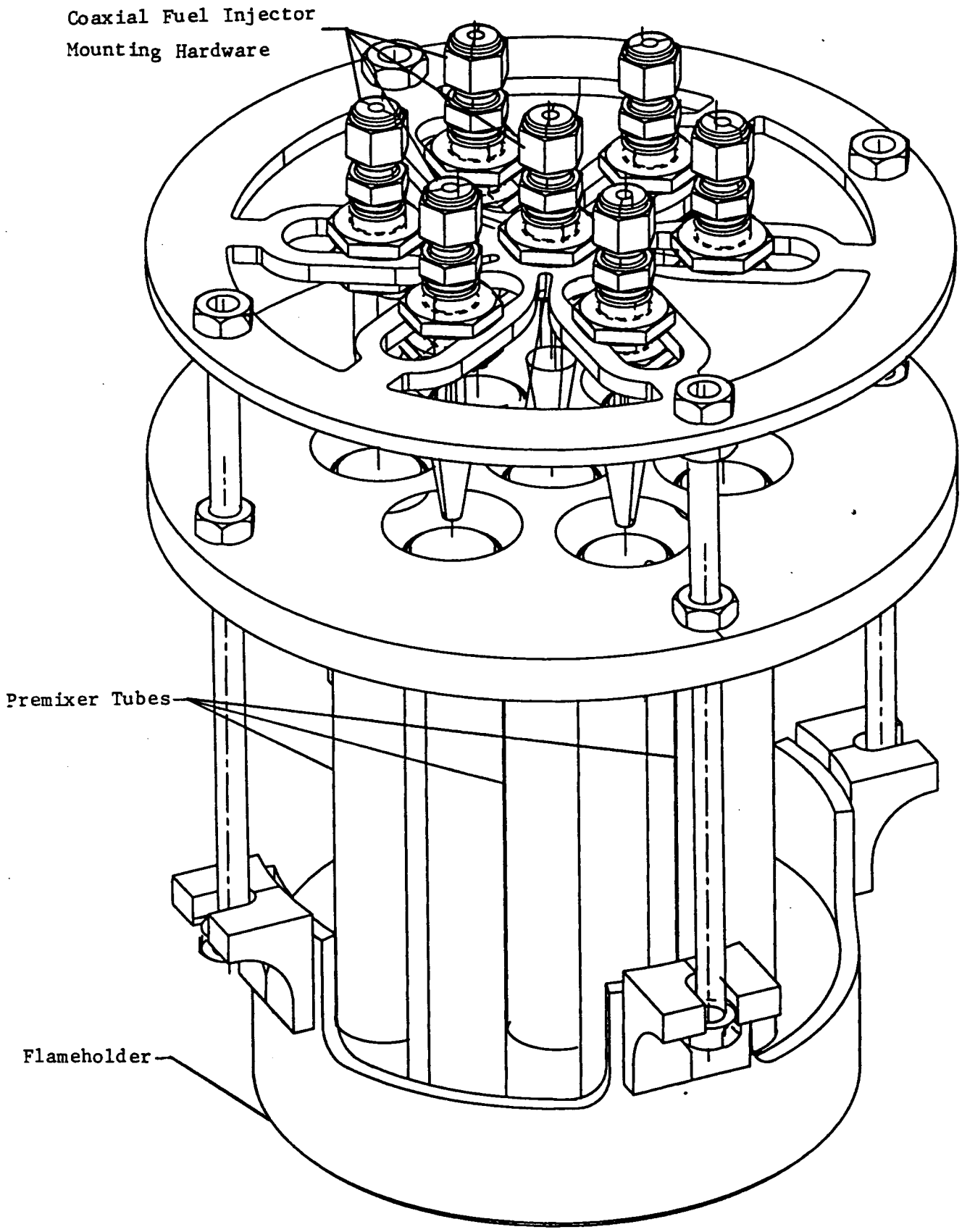


Figure 3.1 - IMFH Generation III premixer hardware. The Generation III hardware was modular in design to facilitate modifications.

950° F (955 to 1410 R) at 4 atmospheres inlet pressure. The dashed line in Figure 3.2 defines the envelope of the NOx EI's from a number of laboratory studies of LPP combustion. As shown in Figure 3.3, CO emissions for Configurations 5 and 7 were comparable at an inlet temperature of 650° F (1110 R), while Configuration 7's CO emissions were higher than Configuration 5 at 950° F (1410 R). Increasing the mixing length in Configuration 8 had a minor impact on NOx. In Figure 3.4, Configuration 8's NOx emissions were slightly lower than Configuration 7's at an inlet temperature of 650° F (1110 R) and higher at inlet temperature of 950° F (1410 R) when flame temperatures were less than 3500 R. In Figure 3.5, the difference in CO emissions was slight.

Coaxially-mounted, conical spray, Textron fuel injectors were tested as Configuration 9 of the IMFH. Configuration 9 resulted in higher NOx and CO emissions when compared to the baseline transverse mounted tube injector (Configurations 5A and 5B) or the Lee Spin Jet results. The emissions for Configuration 9 are compared to Configurations 7 and 8 in Figure 3.6 (NOx emissions) and Figure 3.7 (NO emissions). These tests completed the coaxial spray injector evaluation testing.

The IMFH baseline fuel injector configuration was retested with the Gen III hardware to establish the IMFH data baseline for a seven mixer tube assembly (Configuration 11) and for comparison with the previous baseline results with the thirteen mixer tube IMFH assembly (Configuration 5). There was no other change in mixer or injector features between the two configurations. However, Configuration 11 had more combustor liner area per unit dome effective flow area. This was quantified as the ratio C/A_{EFF} (the flame tube liner inner circumference divided by the combustor dome effective flow area). This ratio was 6.8 for Configuration 5 and 8.1 for Configuration 11. Therefore, Configuration 11 heated nearly 20% more liner area for a given heat release than the mixers in Configuration 5. There was no discernible impact on NOx emissions for data compared at similar inlet conditions (Figures 3.8 and 3.9). There was, however, a significant difference in combustion efficiency, as show in Figure 3.10. Based on this observation of the effect of C/A_{EFF}, a reassessment of IMFH mixers with NOx emissions similar to or lower than IMFH Configuration 5, but with poorer combustion

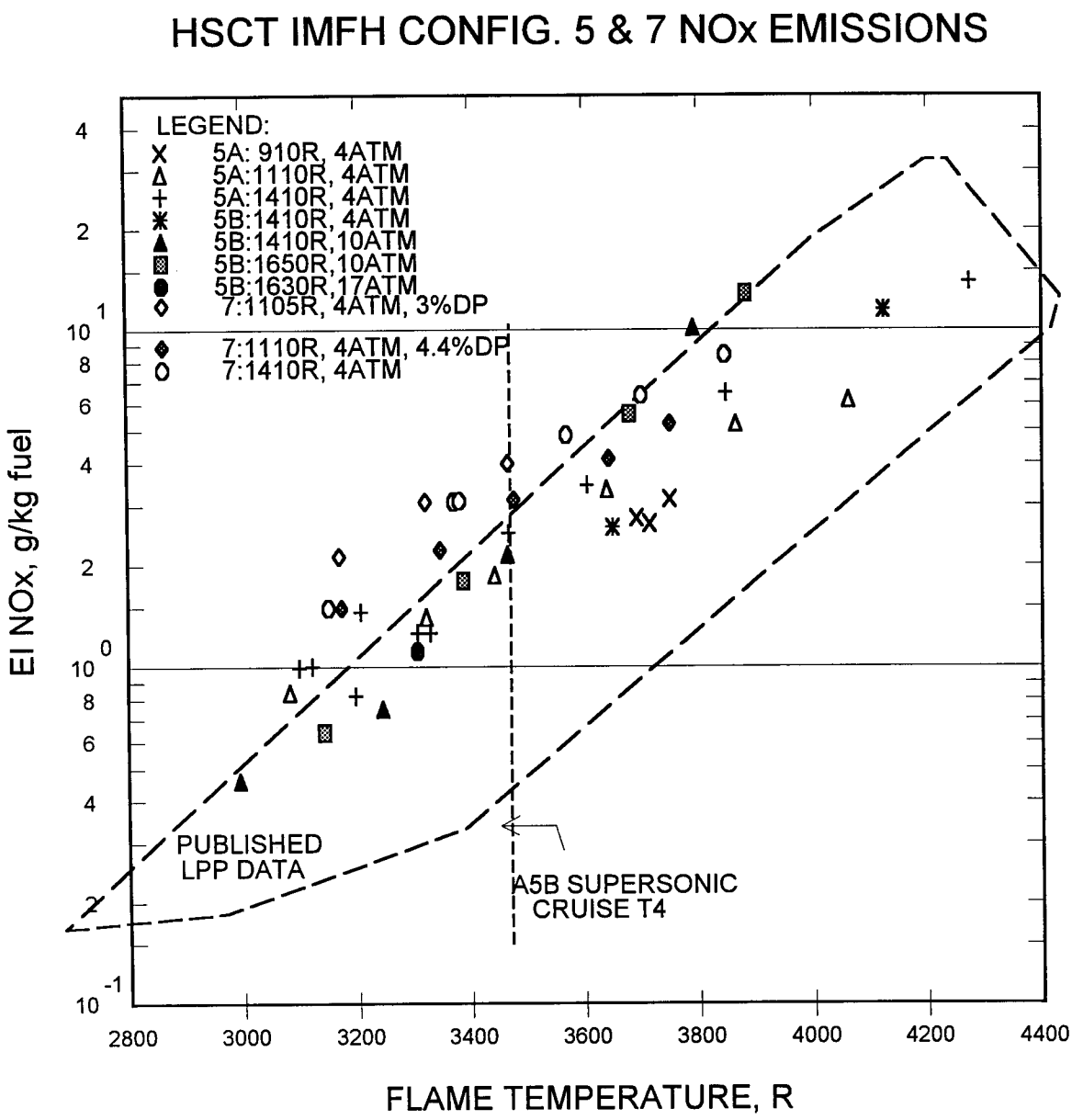


Figure 3.2 - NOx Emissions Index plotted versus flame temperature for IMFH Configurations 5A, 5B and 7. Data obtained at several combinations of inlet temperature and pressure as indicated by the legend. The pressure drop was 4.4% unless indicated otherwise. The dashed boundary indicates the envelope of LPP NOx emissions obtained in several laboratory flame tube studies published in the open literature.

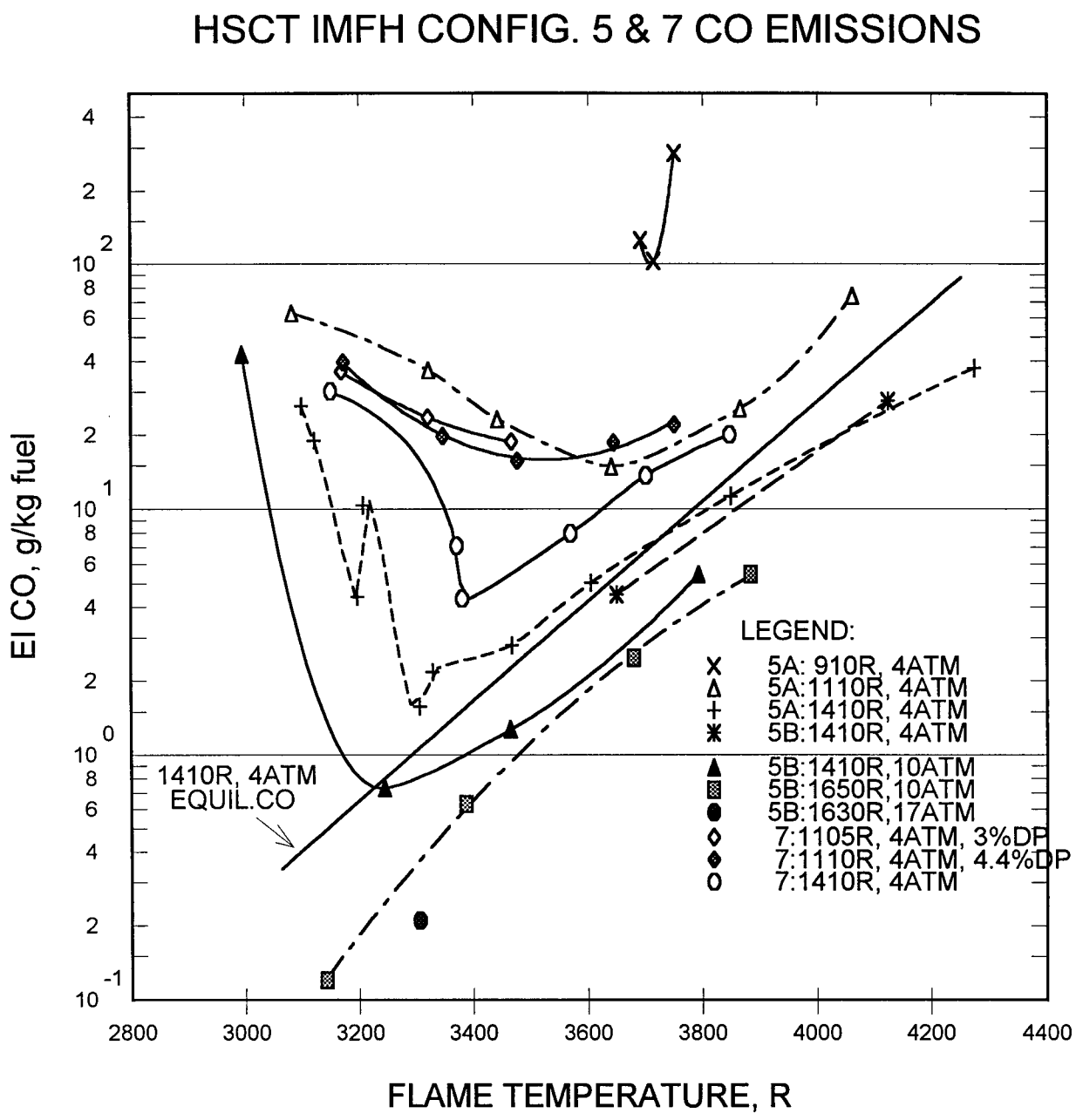


Figure 3.3 - CO Emissions Index plotted versus flame temperature for IMFH Configurations 5A, 5B and 7. Data obtained at several combinations of inlet temperature and pressure as indicated by the legend. The pressure drop was 4.4% unless indicated otherwise.

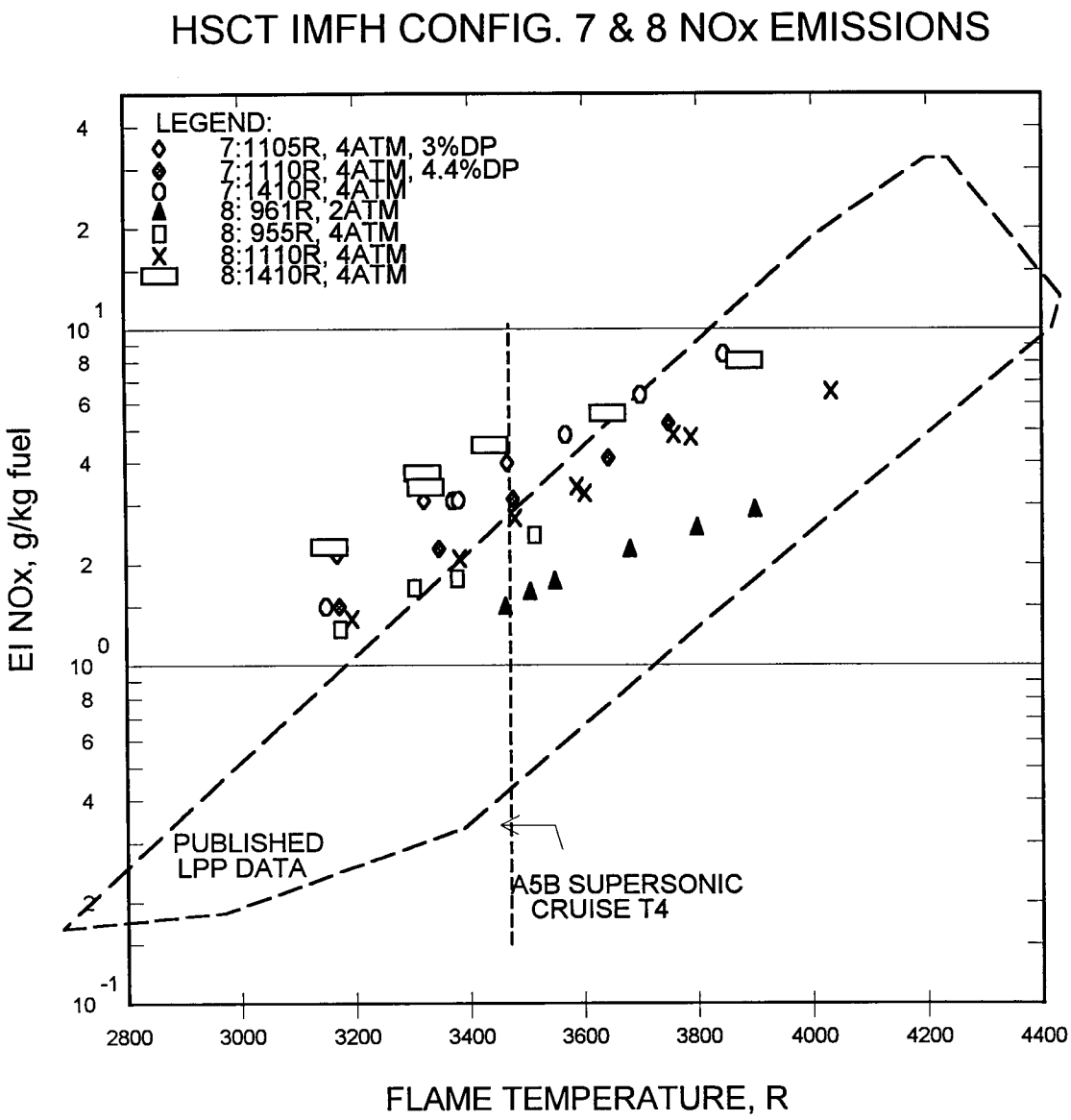


Figure 3.4 - NOx Emissions Index plotted versus flame temperature for IMFH Configurations 7 and 8. Data obtained at several combinations of inlet temperature and pressure as indicated by the legend. The pressure drop was 4.4% unless indicated otherwise. The dashed boundary indicates the boundary of LPP NOx emissions obtained in several laboratory flame tube studies.

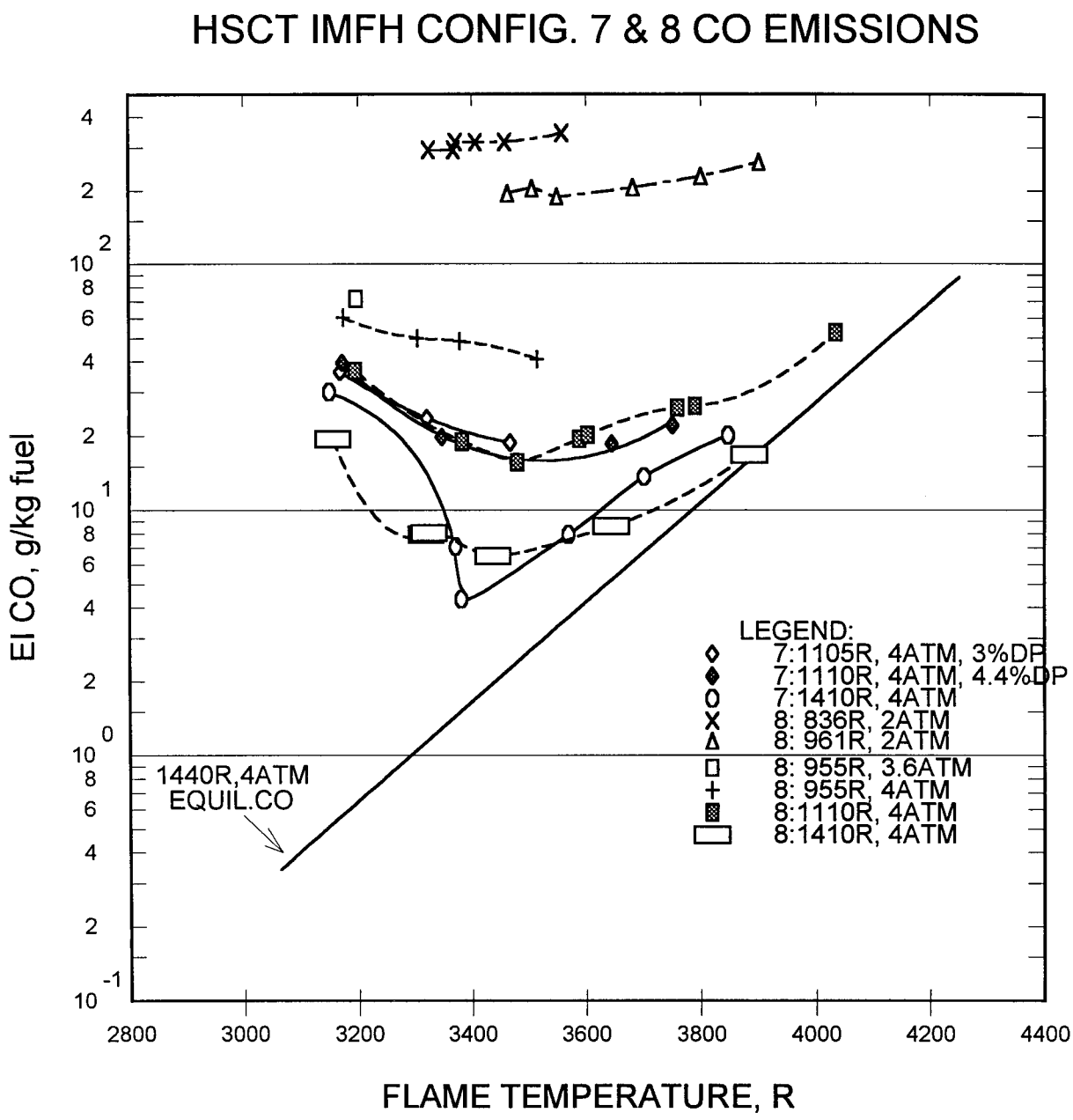


Figure 3.5 - CO Emissions Index plotted versus flame temperature for IMFH Configurations 7 and 8. Data obtained at several combinations of inlet temperature and pressure as indicated by the legend. The pressure drop was 4.4% unless indicated otherwise. The equilibrium line is for an inlet temperature of 1410 R and pressure of 4 atmospheres.

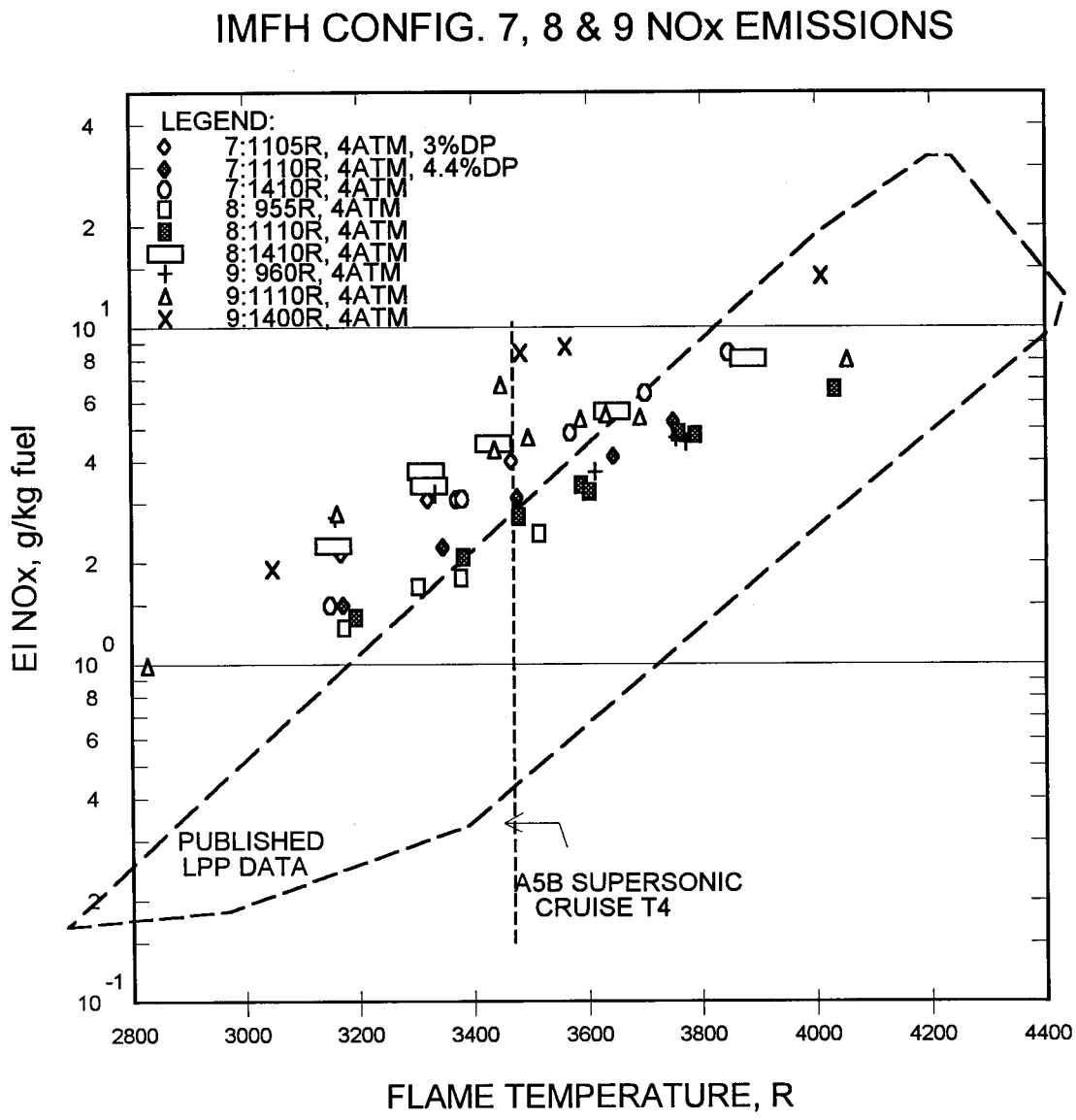


Figure 3.6 - NOx Emissions Index plotted versus flame temperature for IMFH Configurations 7, 8 and 9. Data obtained at several combinations of inlet temperature and pressure as indicated by the legend. The pressure drop was 4.4% unless indicated otherwise. The dashed boundary indicates the boundary of LPP NOx emissions obtained in several laboratory flame tube studies.

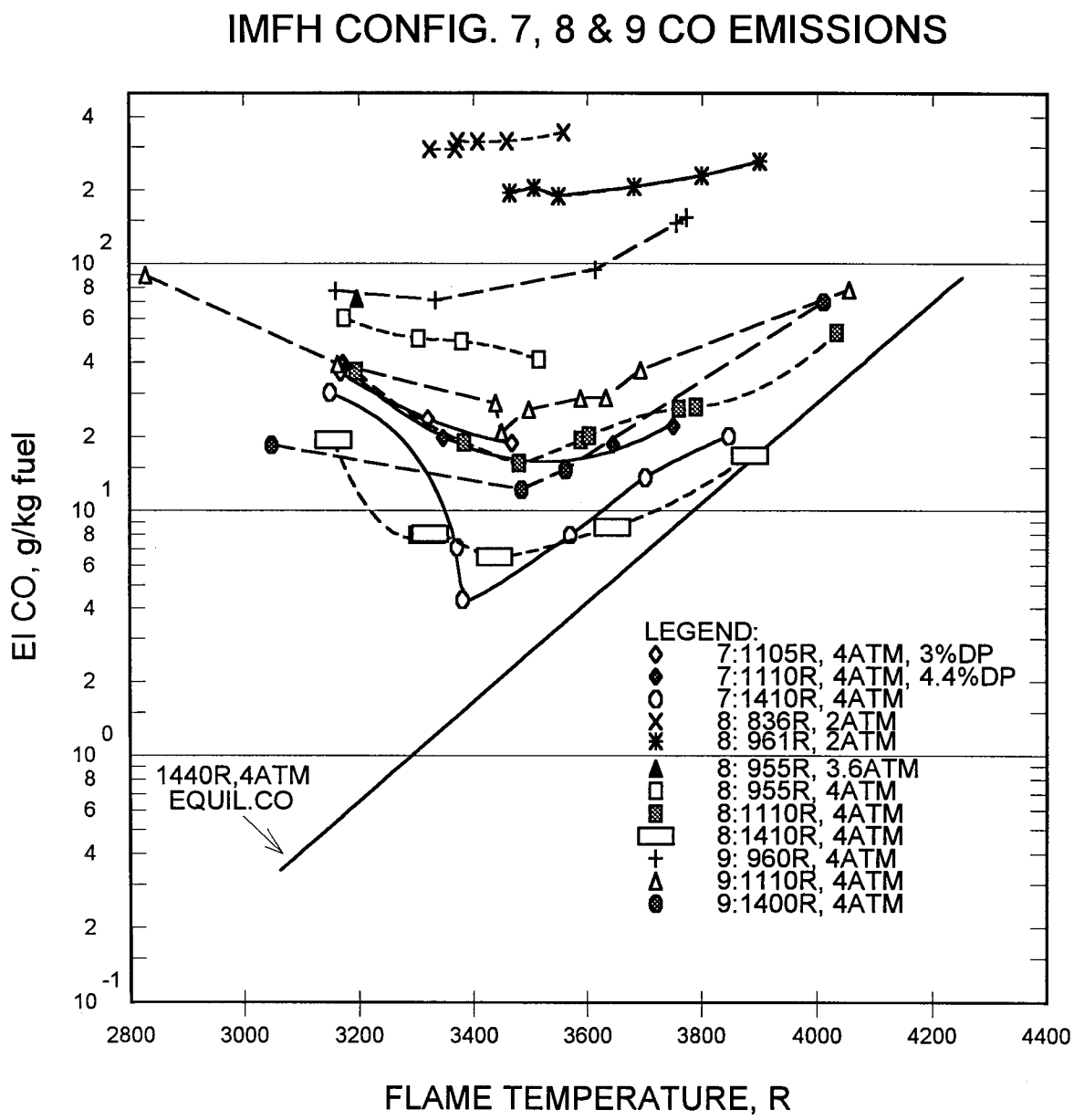


Figure 3.7 - CO Emissions Index plotted versus flame temperature for IMFH Configurations 7, 8 and 9. Data obtained at several combinations of inlet temperature and pressure as indicated by the legend. The pressure drop was 4.4% unless indicated otherwise. The equilibrium line is for an inlet temperature of 1410 R and pressure of 4 atmospheres.

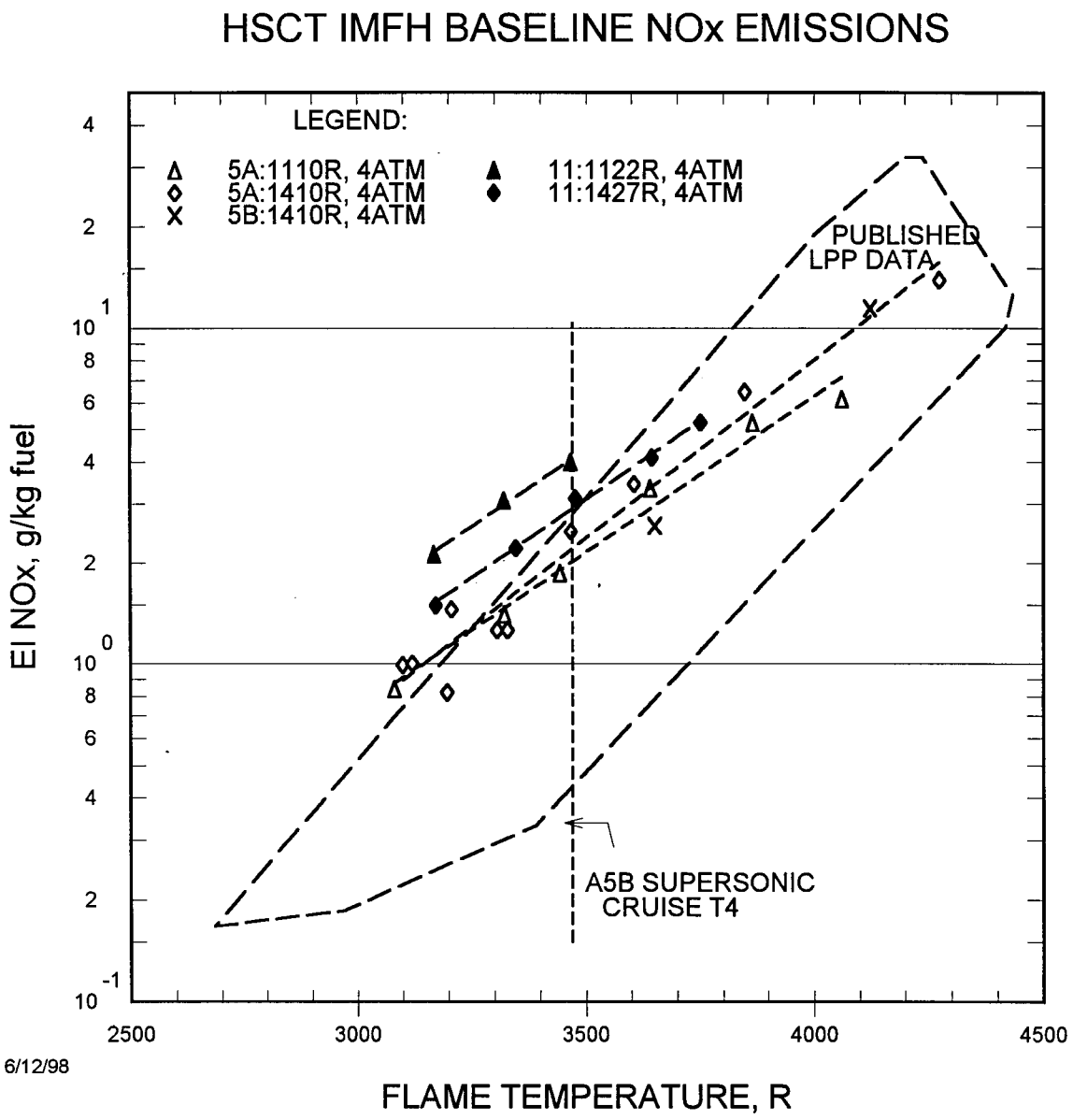


Figure 3.8 - NOx Emissions Index plotted versus flame temperature for IMFH Configurations 5 and 11. NOx EI on a log scale. Data obtained at several combinations of inlet temperature and pressure as indicated by the legend. The pressure drop was 4.4%. The dashed boundary indicates the boundary of LPP NOx emissions obtained in several laboratory flame tube studies.

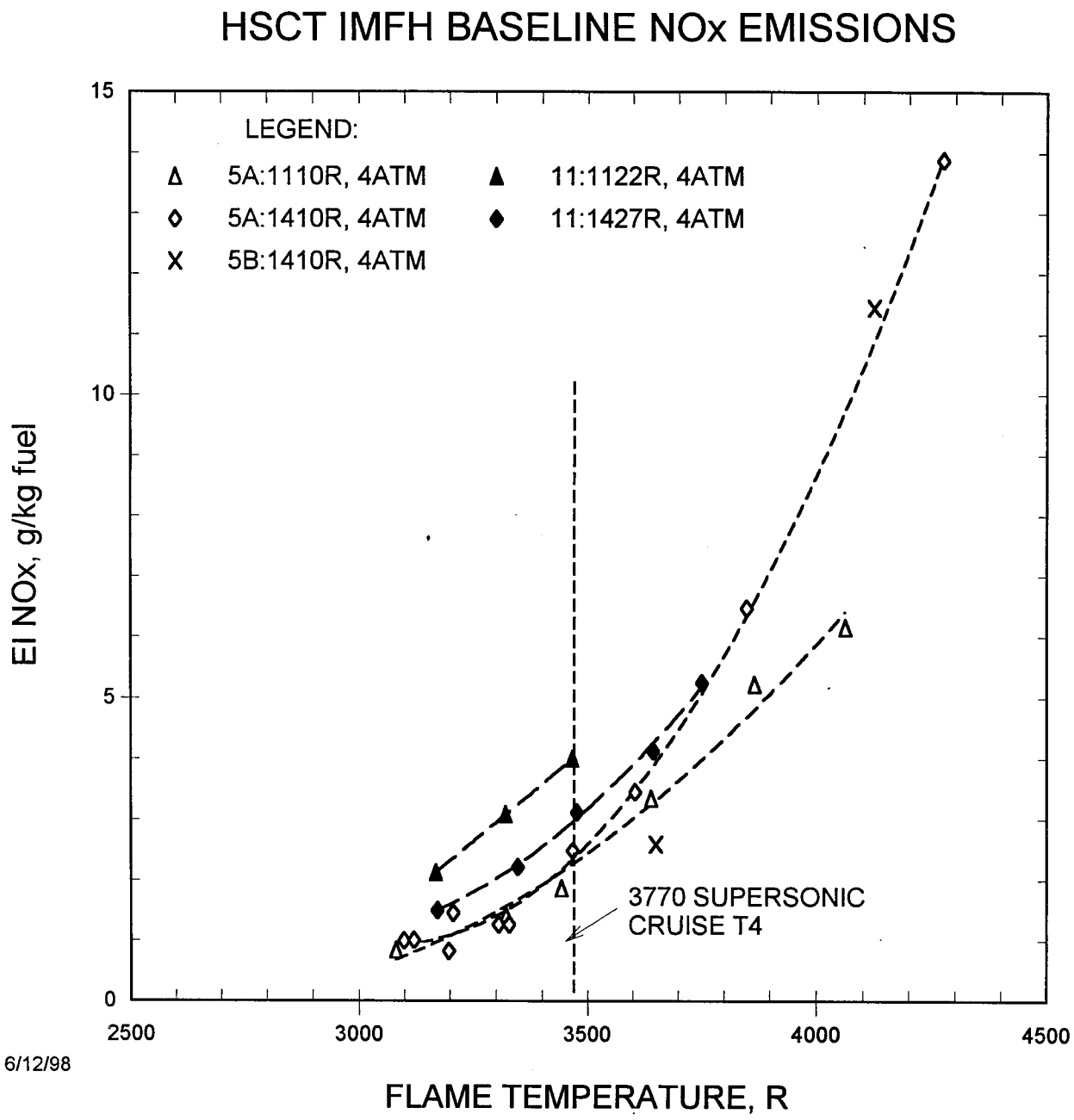


Figure 3.9 - NOx Emissions Index plotted versus flame temperature for IMFH Configurations 5 and 11. NOx EI on a linear scale. Data obtained at several combinations of inlet temperature and pressure as indicated by the legend. The pressure drop was 4.4%. The dashed boundary indicates the boundary of LPP NOx emissions obtained in several laboratory flame tube studies.

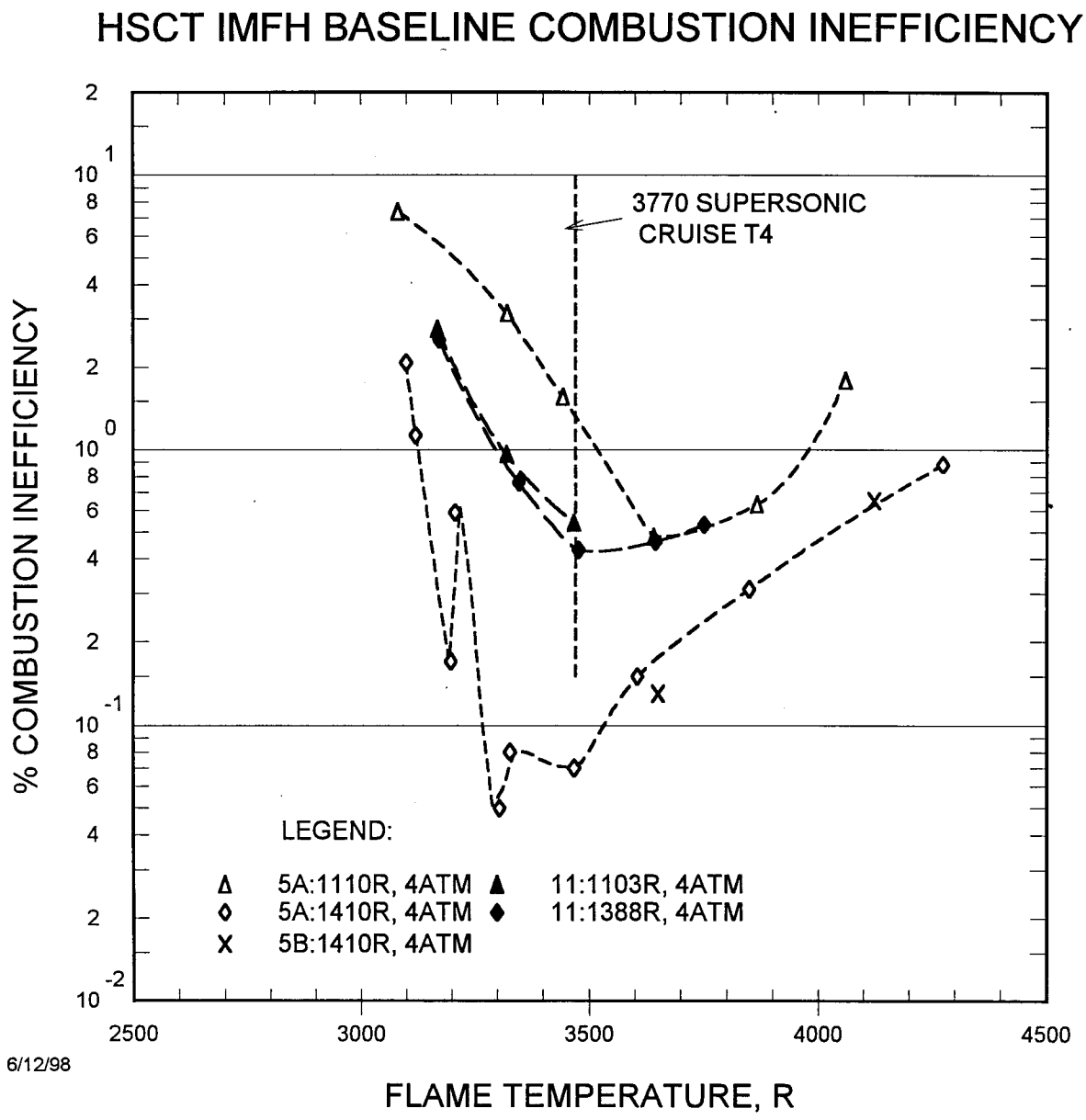


Figure 3.10 - CO Emissions Index plotted versus flame temperature for IMFH Configurations 5 and 11. Data obtained at several combinations of inlet temperature and pressure as indicated by the legend. The pressure drop was 4.4%.

inefficiency was needed. If the C/A_{EFF} of these mixers are closer to that of Configuration 11, then the comparison of combustion efficiency was made to Configuration 11. If the mixer's C/A_{EFF} was closer to that of Configuration 5, then the original comparison of combustion efficiency was used (with Configuration 5). Mixers with NOx emissions worse than the Configuration 5 baseline were still considered poor performers. One interesting conclusion reached as a result of these baseline tests was that when the test results of the 0.652-inch diameter mixer tube in a 3.7 inch diameter flame tube (Performed in CPC Program, NASA contract NAS3-27235) were compared with the test results of the above configurations (0.495 inch diameter mixer tubes), the conclusion was that the 0.652-inch mixer tube had significantly poorer combustion efficiency than the 0.495-inch diameter mixer tube configurations.

Table 3.1 contains a list of the IMFH configurations tested as part of LET Task 10 of the NAS3-26617 contract. The table summarizes the design parameters and the test conditions.

TABLE 3.1 - Summary of IMFH Fuel-Air Mixer Development History

Boxed information indicates a change from previous configuration

Conf. #	Test Date	Mixer Tube: Description	Mixer Tube #	Exit Diam. in.	Total Length in.	Mixing Length in.	Inlet Radius in.	Dome Cooling Air	Injector: Type	Each Inj. Flow #	Injector Discharge #	I.D., in.	O.D., in.	Axial Dist. from inlet	Immers. %	Combustor Liner: Type	Diam., in.	Exit to Sample Probe,in.	Test Type: High pressure / Low pressure / Atms.dsch.
Developed under NAS3-25552:																			
1	05-91	0.769" ID Straight mixer tube	7	0.769	5.100	4.500	20 deg.flare	Bypass comb.	Large ID,transverse tube	1.5	1	0.069	0.125	0.600	50	Metal:H2O Cooled	4.300	6.800	Atm.& Low p.
2	07-91	0.769" ID Straight mixer tube	7	0.769	5.100	4.500	20 deg.flare	Bypass comb.	Transverse tube with 4 injection holes	1.4	4	0.008	0.125	0.600	30 & 70	Cast ceramic with air passages	4.300	6.800	Low pressure
3A1	09-91	0.560" ID Straight mixer tube	7	0.560	5.100	4.500	20 deg.flare	Bypass comb.	Transverse tube with 2 injection holes	1.3	2	0.008	0.125	0.600	50	Cast ceramic with air passages	4.300	6.800	Low pressure
3A2	09-91	0.560" ID Straight mixer tube	7	0.560	5.100	4.500	20 deg.flare	Bypass comb.	Transverse tube with 2 injection holes	1.3	2	0.008	0.125	0.600	50	Cast ceramic with air passages	4.300	3.825 Half comb.res. time of 3A1	Low pressure
3B	09-91	0.560" ID Straight mixer tube	7	0.560	5.100	4.500	20 deg.flare	Bypass comb.	Fine tube angled 15 deg.	1.2	1	0.020	0.040	0.600	50	Cast ceramic with air passages	4.300	6.800	Low pressure
4A	11-91	0.495" ID Straight mixer tube	13	0.495	5.500	4.500	0.188	Exit: 90 holes 0.086"diam.at dome ring	Fine tube angled 15 deg.	1.3	1	0.020	0.040	1.000	50	Cast ceramic with backside air cool.	4.500	9.450	High presssure
Developed under NAS3-25951:																			
4B	01-92	0.495" ID Straight mixer tube	13	0.495	5.500	4.500	0.188	Bypass comb.	Fine tube angled 15 deg.	1.3	1	0.020	0.040	1.000	50	Cast Ceramic with air passages	4.888	7.423	Low pressure
5A	03-92	0.495" ID with dome cool.air inj.into aft end of mixer tube	13	0.495	5.500	4.500	0.188	Inj. into mixers 6x 0.090" holes	Fine tube angled 15 deg.	1.3	1	0.020	0.040	1.000	50	Cast Ceramic with backside air cool.	4.888	7.423	Atm.& Low P.
5B	07-92	0.495" ID with dome cool.air inj.into aft end of mixer tube	13	0.495	5.500	4.500	0.188	Inj. into mixers 6x 0.090" holes	Fine tube angled 15 deg.	1.3	1	0.020	0.040	1.000	50	Cast Ceramic	4.500	9.450	High presssure
6A	10-92	0.560" ID with dome cool.air inj.thru dome near mixer exit	7	0.560	5.100	4.500	20 deg.Flare	Through dome 6x 0.100" holes	Fine tube angled 15 deg.	1.3	1	0.020	0.040	1.000	50	Cast Ceramic	4.300	3.800	Low pressure
6B	01-93	0.560" ID with dome cool.air inj.thru dome near mixer exit	7	0.560	5.100	4.500	20 deg.Flare	Through dome 6x 0.100" holes	Fine tube wall injection	1.3	1	0.020	0.040	1.000	0	Cast Ceramic	4.300	3.800	Low pressure
Developed under NAS3-26617:												Spray Angle							
7	12-93	0.495" ID with dome cool.air inj.into aft end of mixer tube	7	0.495	5.500	4.500	0.210	Inj. into mixers 6x 0.090" holes	Axial, blunt end, hollow conical spray injector	1.4	1	70		1.000	50	Cast Ceramic	2.800	7.423	Low pressure
8	01-94	0.495" ID with dome cool.air inj.into aft end of mixer tube	7	0.495	5.500	4.500	0.210	Inj. into mixers 6x 0.090" holes	Axial, blunt end, hollow conical spray injector	1.4	1	70		0.250	50	Cast Ceramic	2.800	7.423	Low pressure
9	04-94	0.495" ID with dome cool.air inj.into aft end of mixer tube	7	0.495	5.500	4.500	0.210	Inj. into mixers 6x 0.090" holes	Axial,tapered end,hollow conical spray injector	1.6	1	54		0.050	50	Cast Ceramic	2.800	7.423	Low pressure
10	03-94	0.495" ID with dome cool.air inj.into red. length mixer tube	7	0.495	3.500	2.500	0.210	Inj. into mixers 6x 0.090" holes	Axial,tapered end,hollow conical spray injector	1.6	1	54		0.050	50	Cast Ceramic	2.800	7.423	Low pressure
11	11-94	0.495" ID with dome cool.air inj.into aft end of mixer tube	7	0.495	5.500	4.500	0.210	Inj. into mixers 6x 0.090" holes	Fine tube angled 15 deg.	1.6	1	0.020	0.040	1.000	50	Cast Ceramic	2.800	7.423	Low pressure

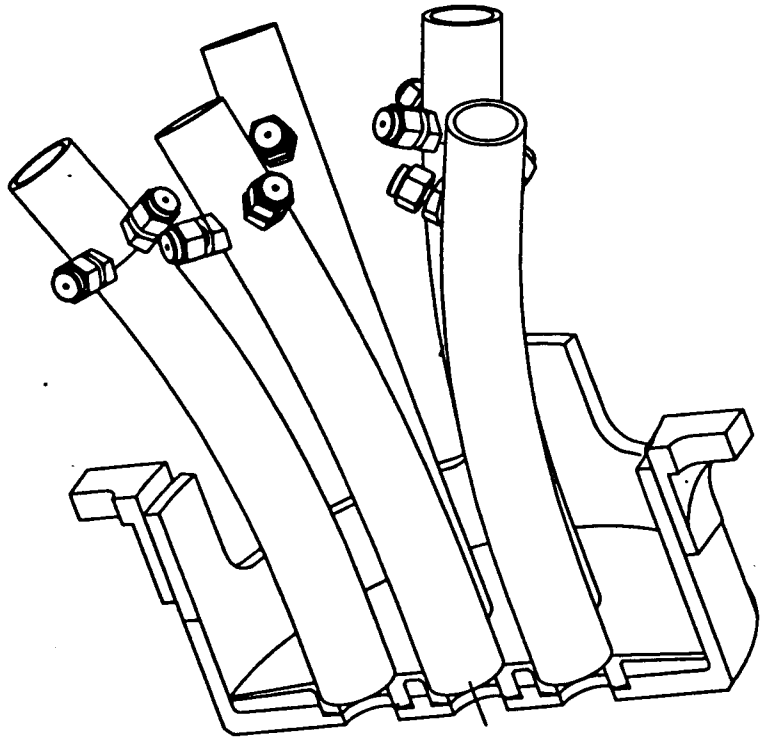
3.2 Curved Tube IMFH Evaluations

Single-cup IMFH configurations using curved IMFH premixer tubes were designed and tested. These were driven by engine envelope considerations for the original version of the Multistage Radial Axial (MRA) combustor shown in Figure 1.25. The evolution of the MRA combustor is discussed further in Section 6 of this report. Prior to the testing of the curved IMFH tube configurations, there were concerns about potential problems caused by curving the IMFH tubes. These were identified as:

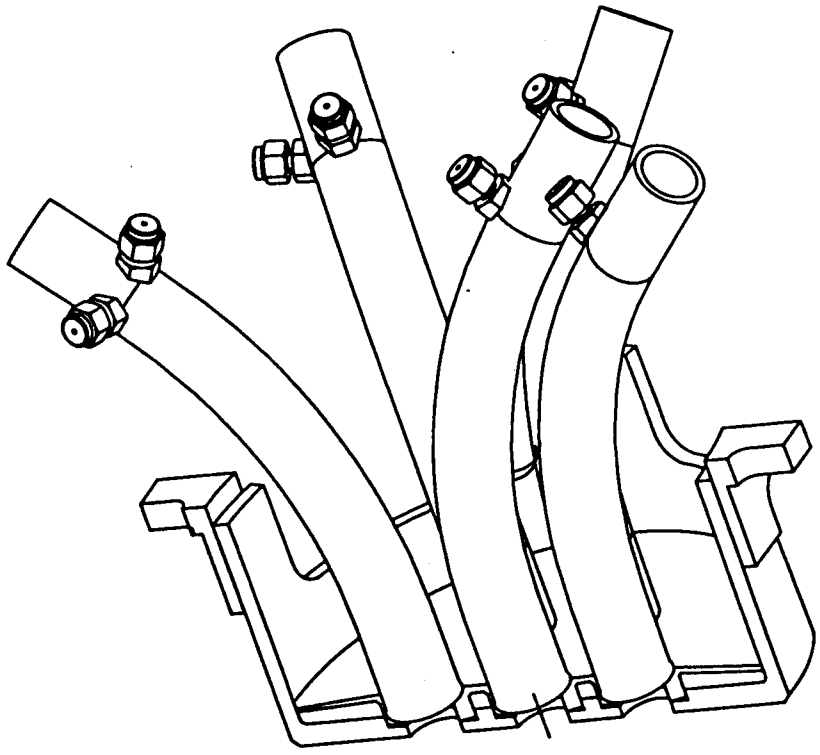
1. Flashback or autoignition caused by a large boundary layer building up along the inside radius of the curve, and
2. Poor fuel/air distribution at the exit of the premixer, possibly increasing NOx emissions and decreasing combustion efficiency and stability limits.

Three mixer tube turning angles were selected for investigation: 22.5, 45, and 90 degrees. 90 degrees was the maximum turning angle that would be useful in the layouts of the MRA. Figure 3.11 illustrates two of the configurations considered. The mixer tubes themselves had a total centerline length of 5.5 inches, an outside diameter of 0.5 inches, and straight sections of 1.0 inch each at the inlet and exit of the tube. The transverse fuel injector tube was located 1.0 inch downstream of the inlet and was tested at various circumferential locations. The radii of curvature were: 90° - 2.23 inches, 45° - 4.46 inches, and 22.5° - 8.91 inches.

The 22.5 degree Curved Tube IMFH (CT-IMFH) configuration was tested at inlet temperatures ranging from 450 to 950° F (910 to 1410 R) and inlet pressures varying between 4.0 and 5.5 atmospheres. NOx emissions were slightly higher and combustion efficiency was poorer than the IMFH Configurations 5A and 5B and lean stability was poor at all conditions tested. Post test inspection revealed a crescent shaped hole in the dome that resulted when a mixer tube/dome weld failed during the test. Therefore, the test was considered inconclusive with respect to NOx, combustion efficiency, and lean stability. Plots of the data are not included here.



22.5° TUBE CONFIGURATION



45° TUBE CONFIGURATION

Figure 3.11 - Curved IMFH Tube subcomponent test hardware. 22.5-degree bend and 45-degree bend versions.

None of the evidence suggested that the hardware damage was due to flashback or autoignition within the mixer tubes themselves.

The MRA combustor would probably use tubes with bends in the range most closely approximated by the 45 degree tubes. Atmospheric testing of the 45 degree CT-IMFH with 75% fuel injector immersion showed a flame structure that appeared to be very similar to the straight tube IMFH configurations previously tested. No obvious fuel maldistribution was evident at the premixer tube exit. However, it would be expected that the radial acceleration of the flow field in the curved tubes would tend to separate the fuel towards the outside wall of the tube.

Three tests were conducted with the 45 degree CT-IMFH. They were performed at 4 atmospheres pressure at three immersions of the fuel injector tubes, 20%, 50% and 75%. Figures 3.12 through 3.14 compare NOx emissions, combustion inefficiency, and CO emissions results for the 45 degree CT-IMFH for two immersions of the fuel injector tubes, 20% (short immersion) and 50% (center immersion). The two immersions had roughly comparable emissions performance, although the shorter immersion appears to yield lower NOx emissions. Figure 3.15 shows that the NOx emissions for the short injector immersion in CT-IMFH were very similar to Configuration 5A. However, Figures 3.16 and 3.17 show that combustion efficiency and CO emissions for the CT-IMFH with the short immersion injector was significantly worse than Configuration 5A at all except the lowest inlet temperature of 450° F (910 R). This may be due to poor fuel distribution. When compared to Configuration 5A, Figure 3.18 shows that the CT-IMFH with 75% immersion demonstrated good NOx emissions performance. Apparently, the high immersion offset the radial acceleration effects, to some degree. However, the combustion efficiency, CO emissions, and stability were still poor relative to Configuration 5 (Figures 3.19 and 3.20).

Inspection of the hardware after the 75% immersion test revealed a small hole burned through the dome. The hole was apparently caused by the loss of the TBC coating, which appeared to result from over-heating of the dome face. Some sort of flashback or autoignition was suspected of causing the dome failures. Additional observation revealed evidence that fuel

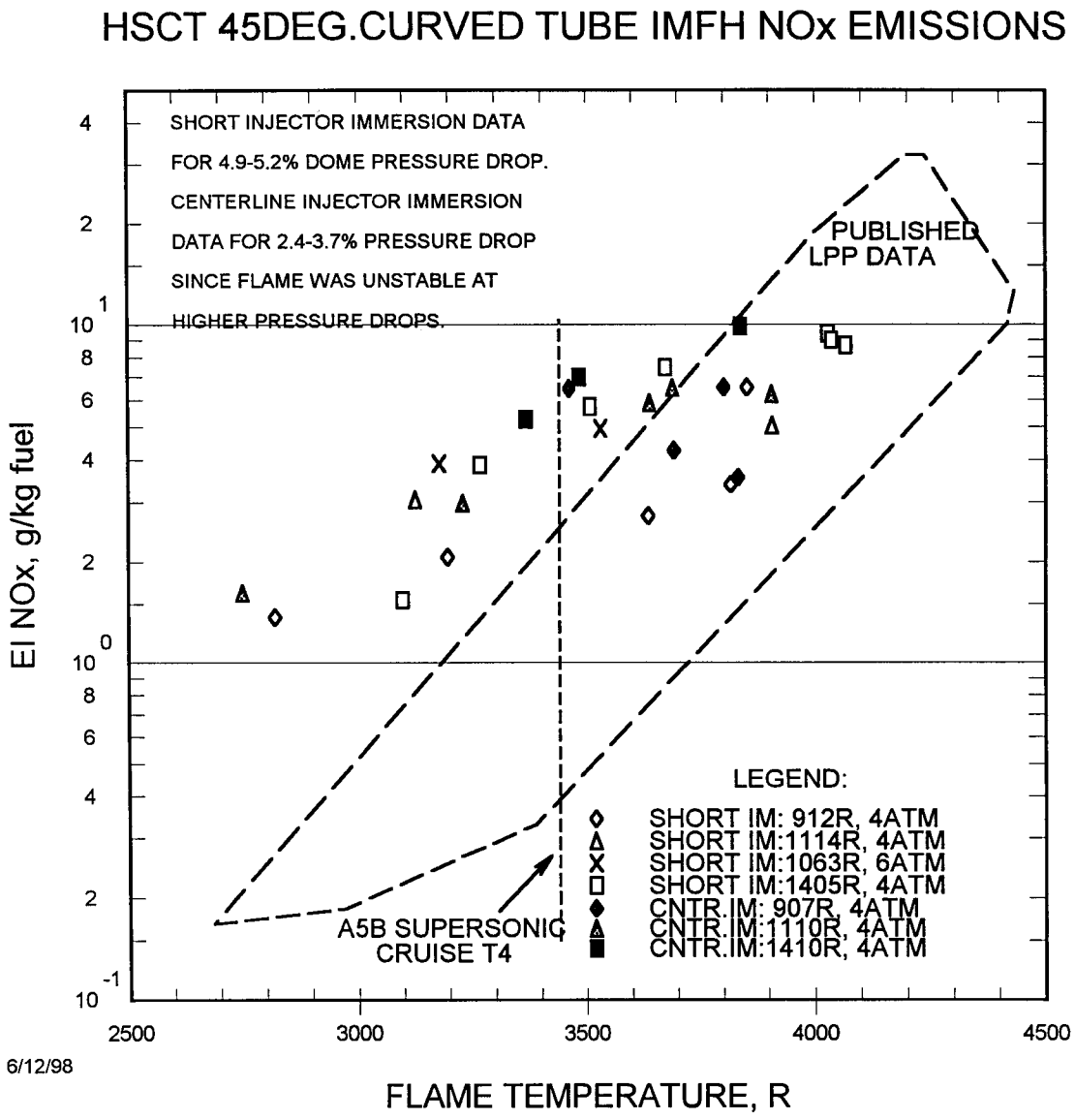


Figure 3.12 - NOx Emissions Index plotted versus flame temperature for 45-degree curved tube IMFH. Data shown for 20% immersion (short) and 50% immersion (center) of the fuel injector tube. The dashed boundary indicates the envelope of LPP NOx emissions obtained in several laboratory flame tube studies published in the open literature.

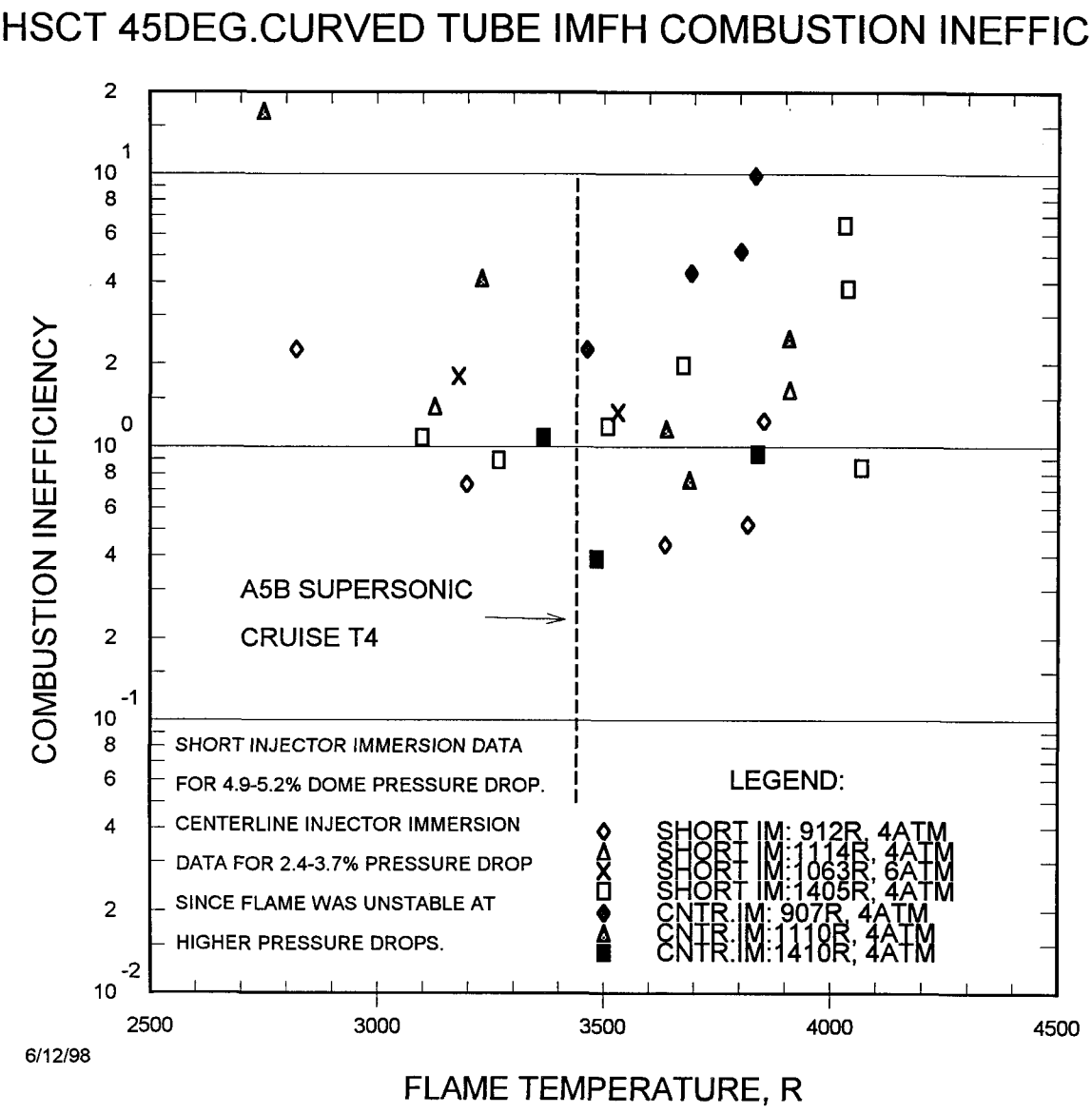


Figure 3.13 - Combustion Inefficiency plotted versus flame temperature for 45-degree curved tube IMFH. Data shown for 20% immersion (short) and 50% immersion (center) of the fuel injector tube.

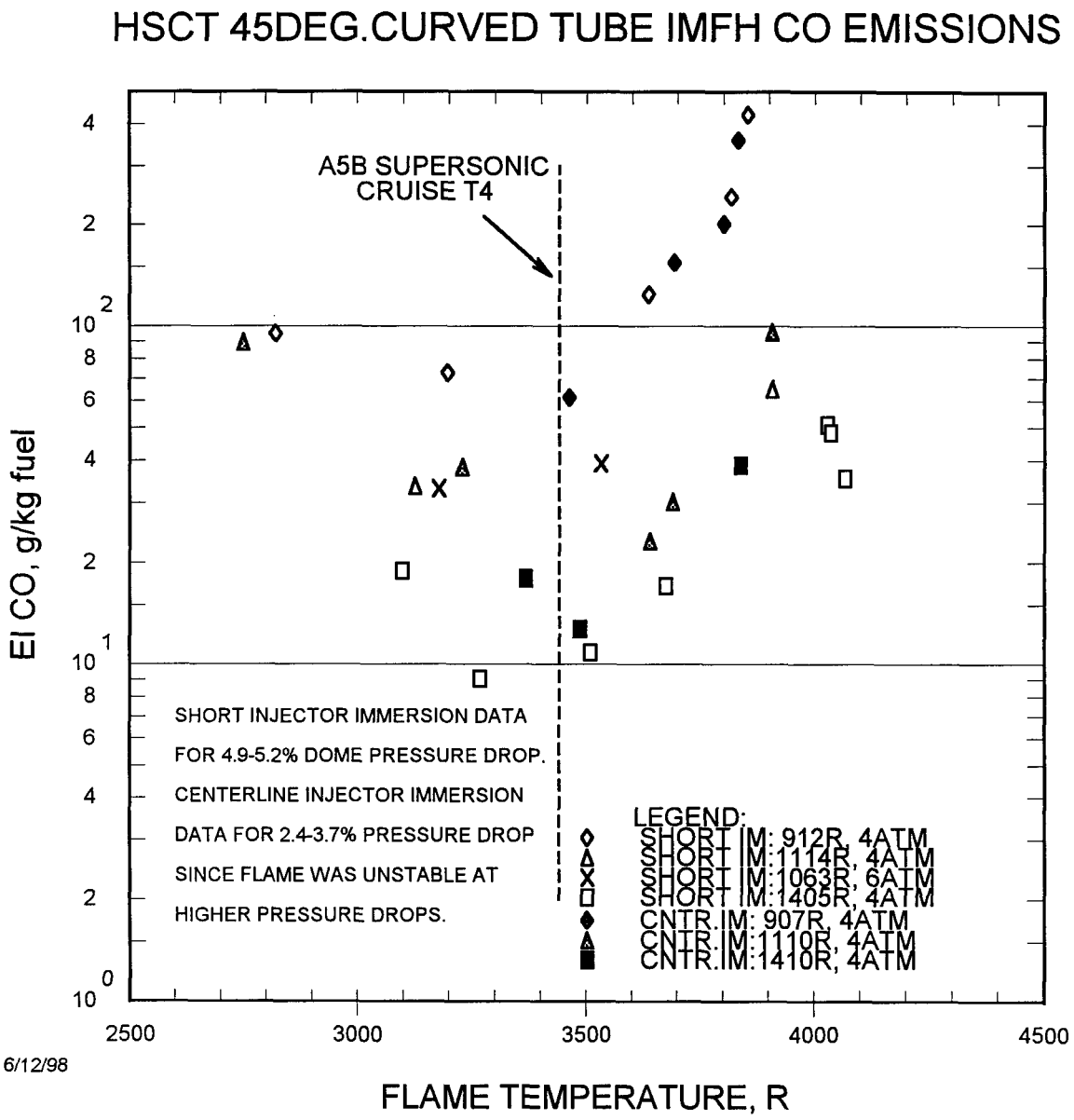


Figure 3.14 - CO Emissions Index plotted versus flame temperature for 45-degree curved tube IMFH. Data shown for 20% immersion (short) and 50% immersion (center) of the fuel injector tube.

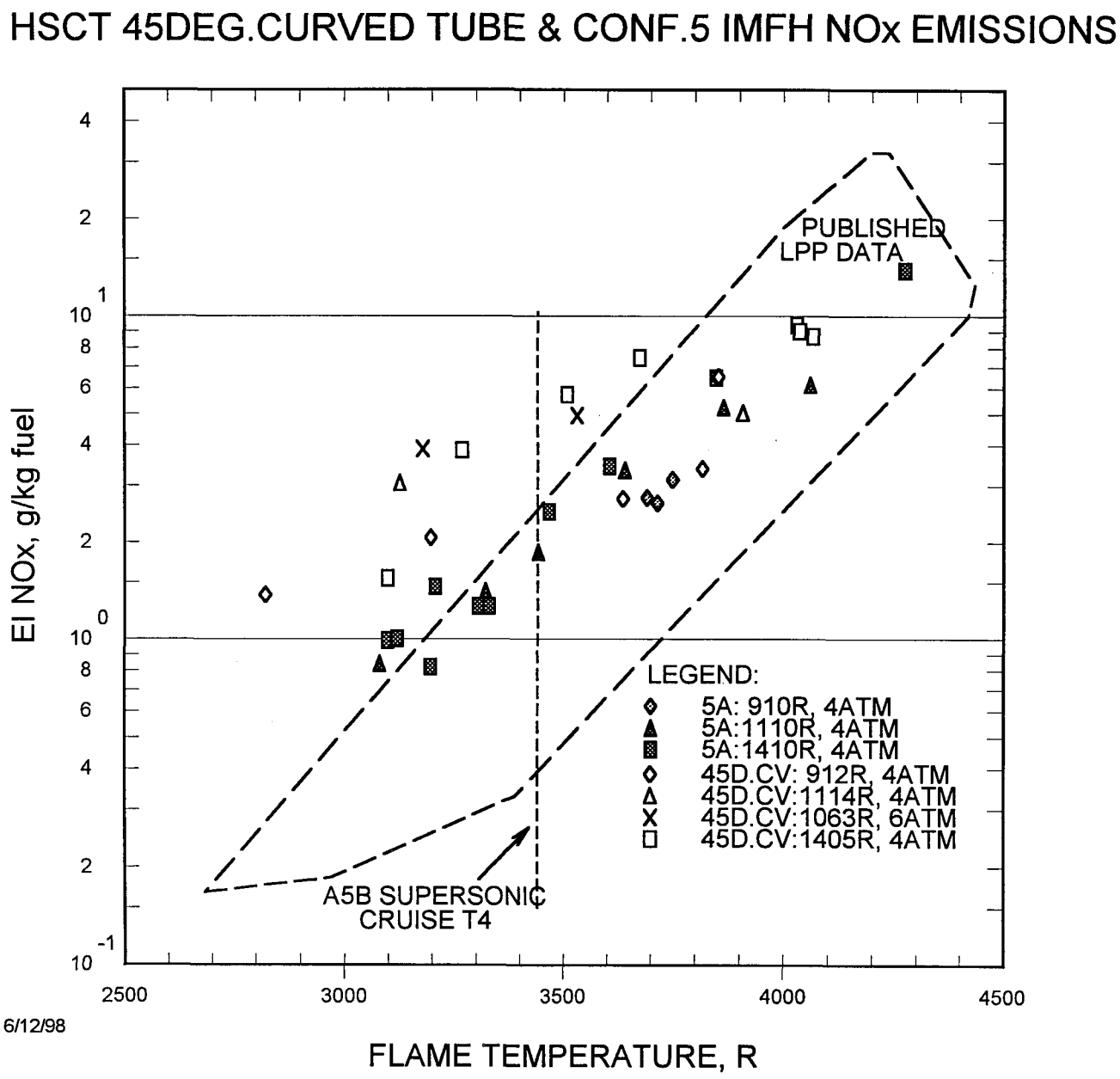


Figure 3.15 - NOx Emissions Index plotted versus flame temperature for 45-degree curved tube IMFH. Data for 20% immersion (short) of fuel injector tube is compared to the baseline straight IMFH tube which has a 50% immersion (Configuration 5). The dashed boundary indicates the boundary of LPP NOx emissions obtained in several laboratory flame tube studies published in the open literature.

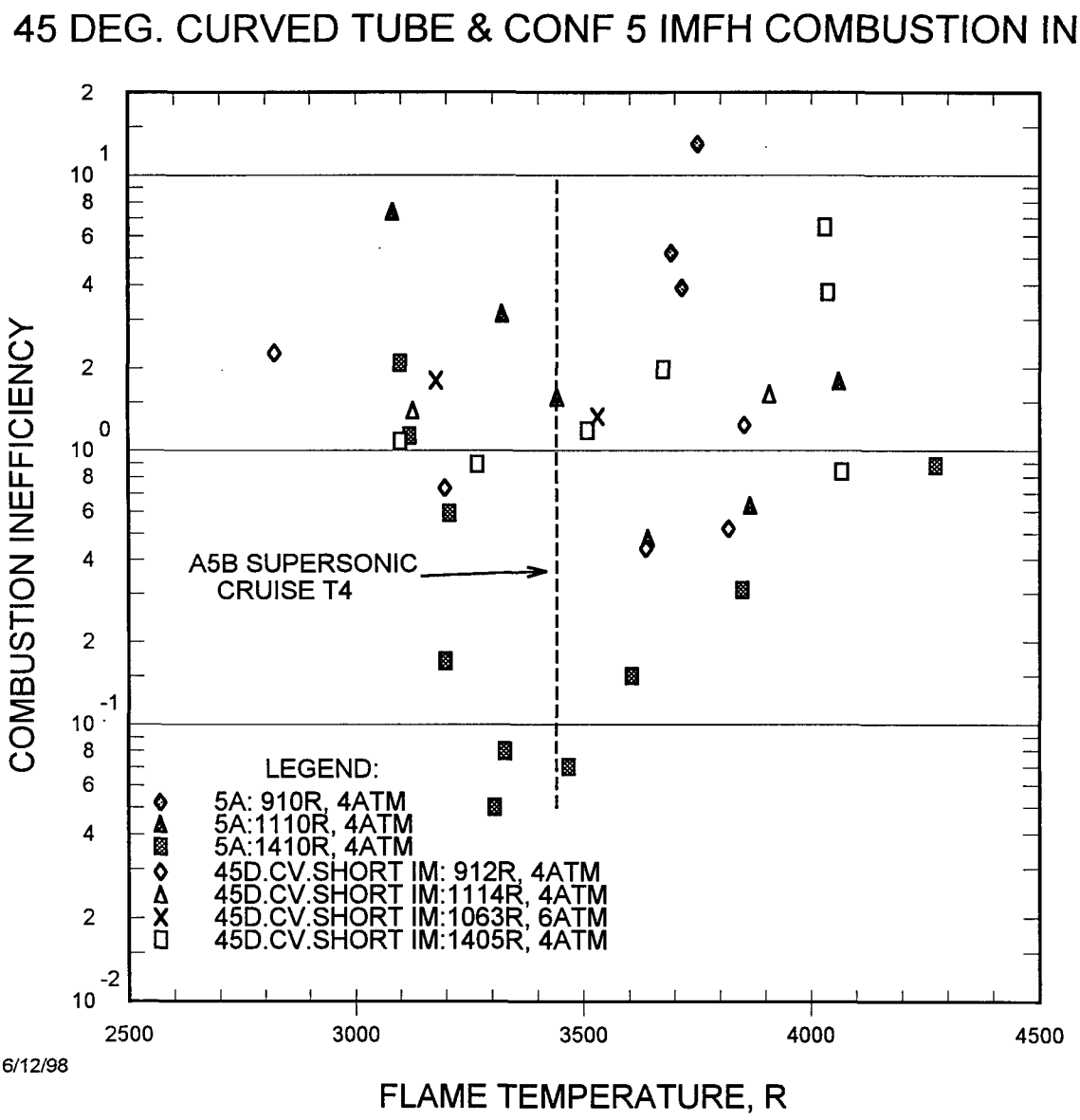


Figure 3.16 - Combustion inefficiency plotted versus flame temperature for 45-degree curved tube IMFH. Data for 20% immersion (short) of fuel injector tube is compared to the baseline straight IMFH tube which has a 50% immersion (Configuration 5).

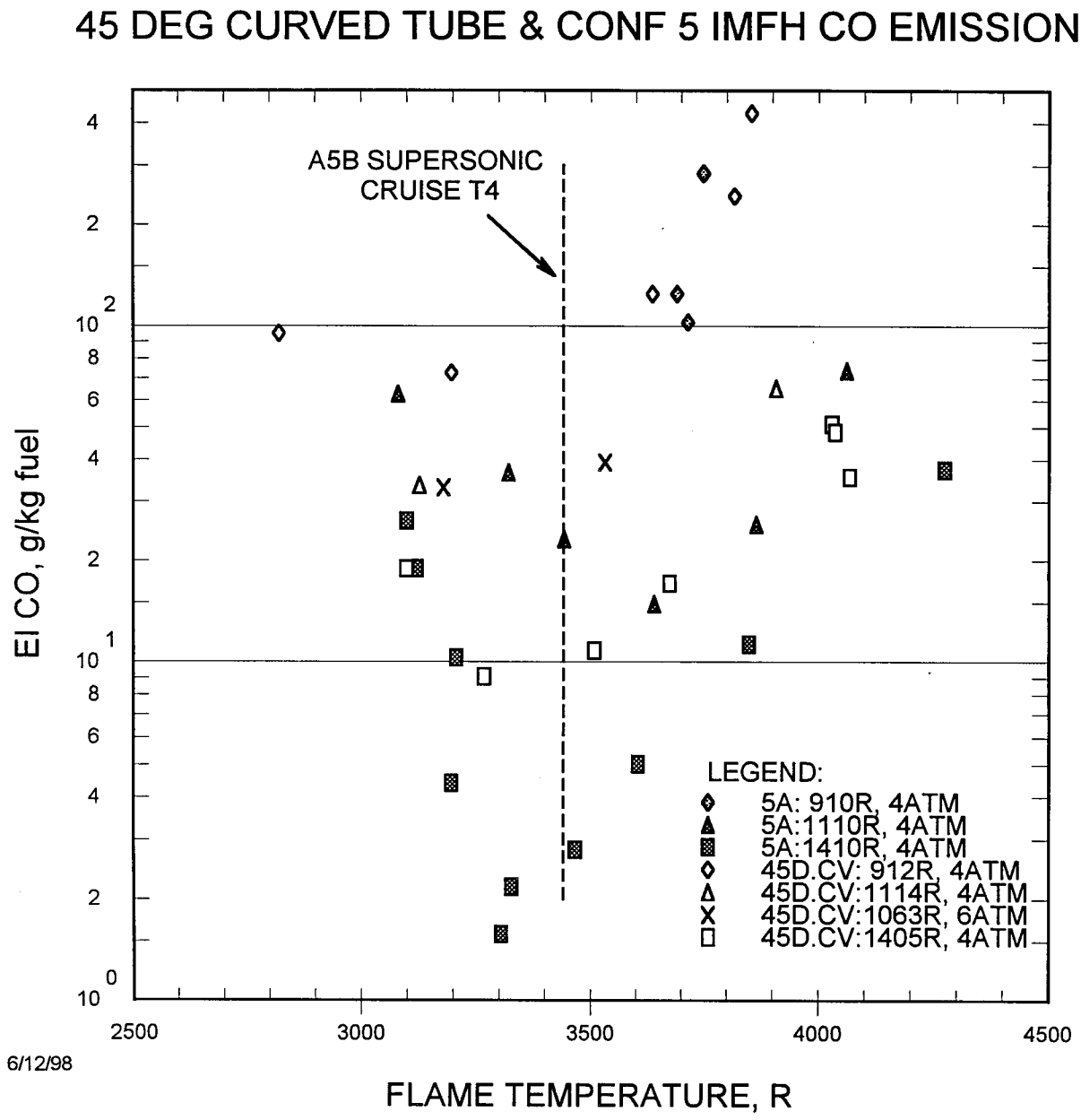


Figure 3.17 - CO Emissions Index plotted versus flame temperature for 45 degree curved tube IMFH. Data for 20% immersion (short) immersion of fuel injector tube is compared to the baseline straight IMFH tube which has a 50% immersion (Configuration 5).

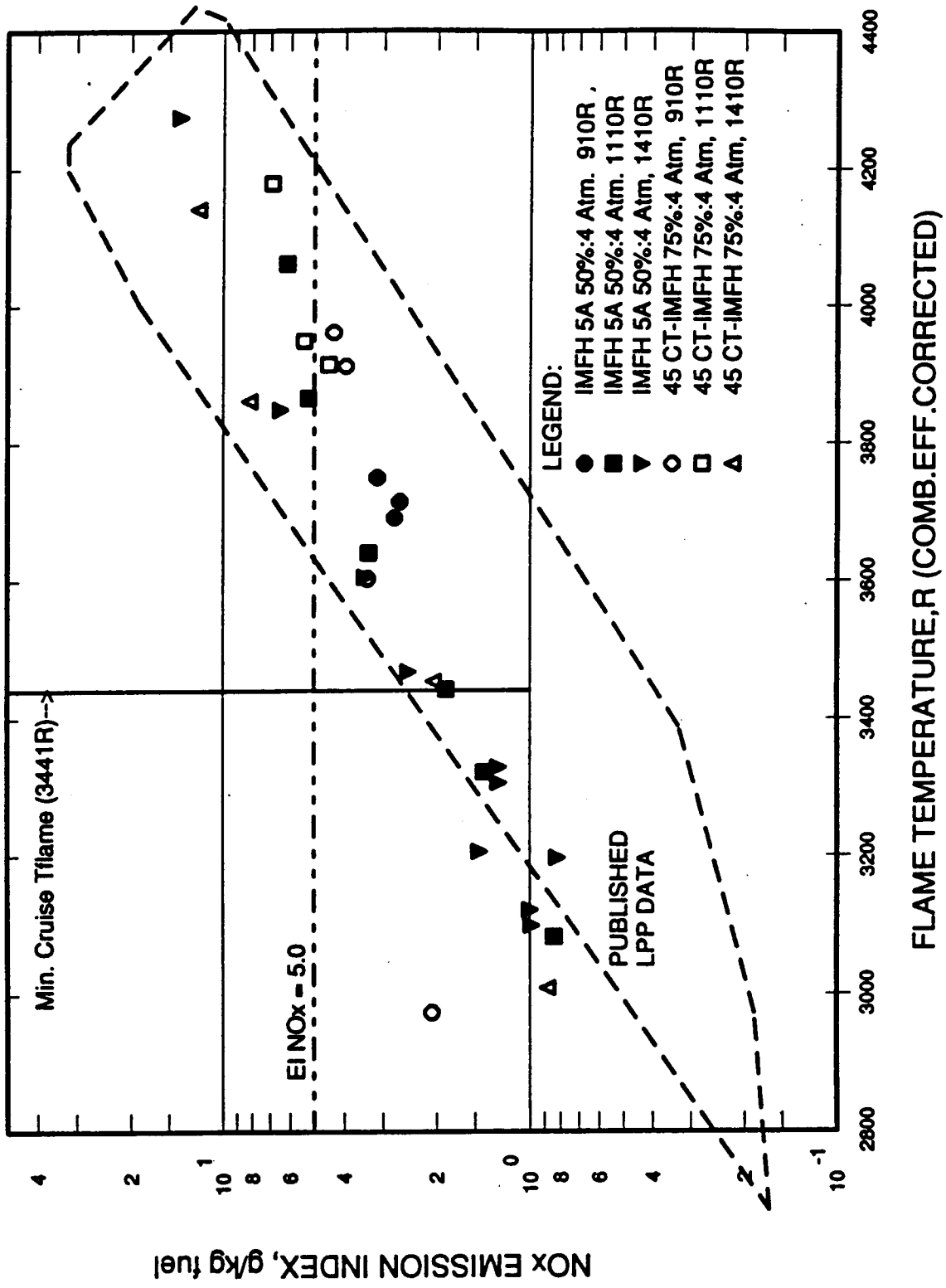


Figure 3.18 - NOx Emissions Index plotted versus flame temperature for 45 degree curved tube IMFH. Data for 75% immersion of the fuel injector tube is compared to the baseline straight IMFH tube which has a 50% immersion (Configuration 5). The dashed boundary indicates the envelope of LPP NOx emissions obtained in several laboratory flame tube studies published in the open literature.

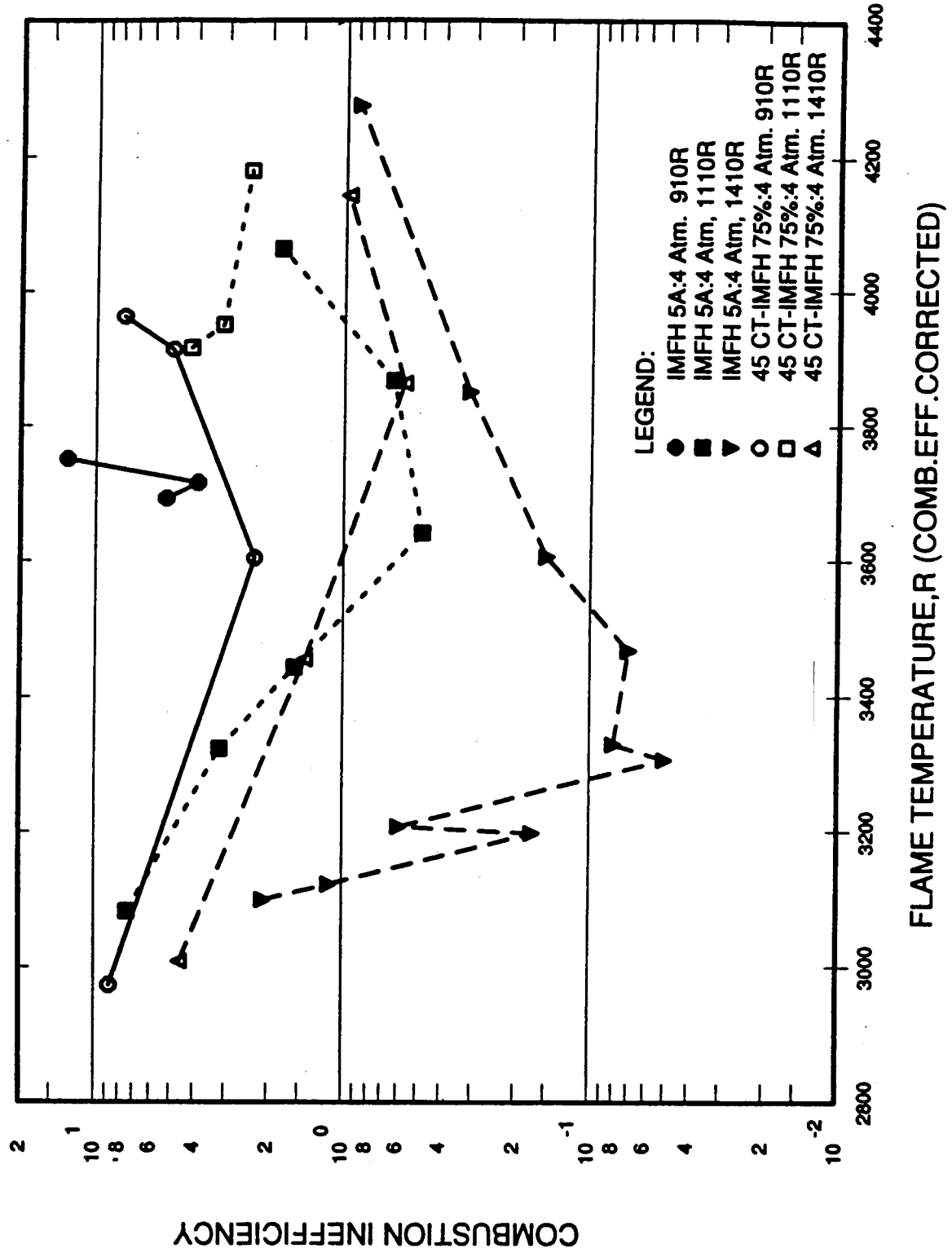


Figure 3.19 - Combustion inefficiency plotted versus flame temperature for 45 degree curved tube IMFH. Data for 75% immersion of the fuel injector tube is compared to the baseline straight IMFH tube which has a 50% immersion (Configuration 5).

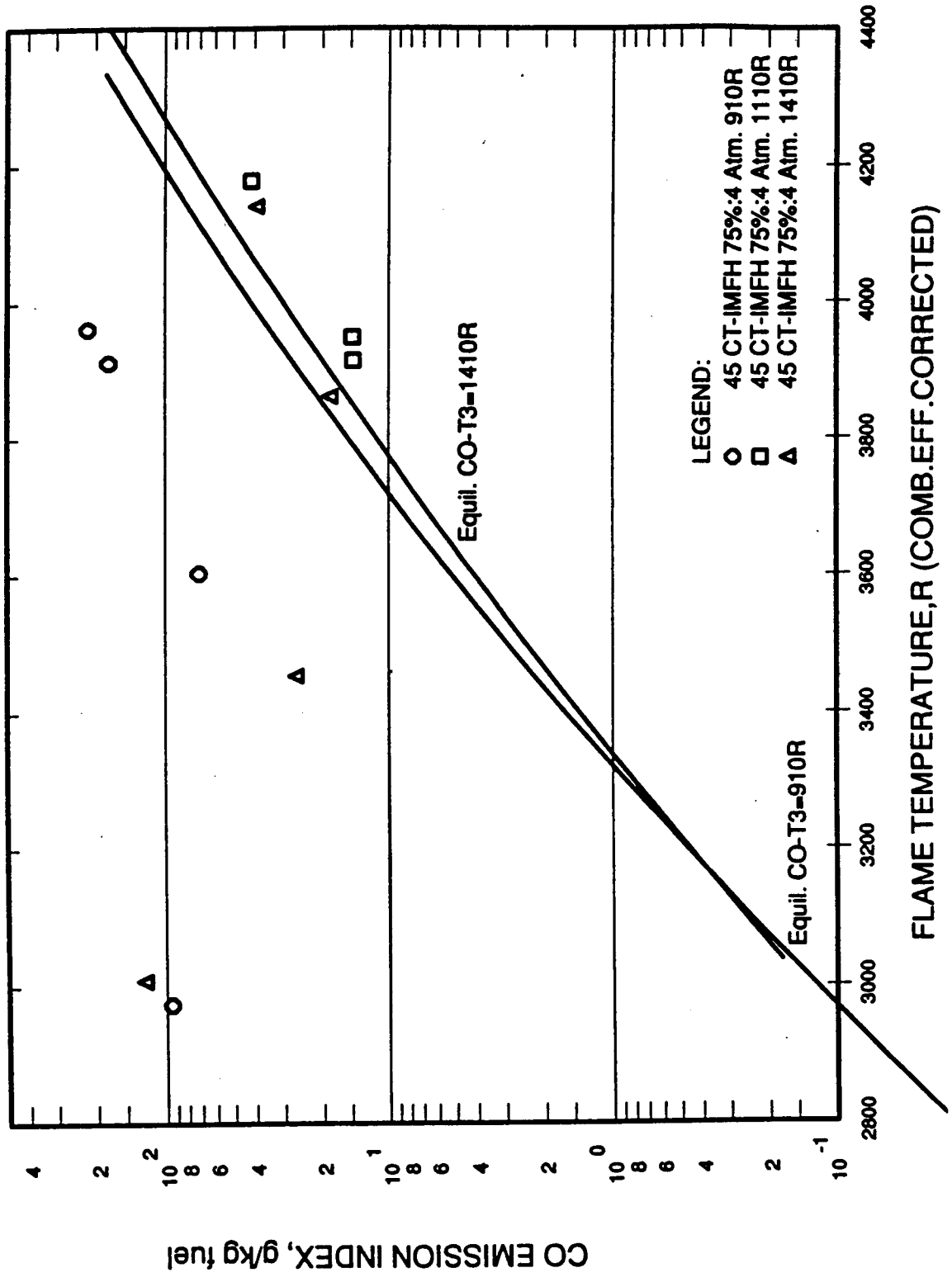


Figure 3.20 - CO Emissions Index plotted versus flame temperature for 45 degree curved tube IMFH. Data for 75% immersion of the fuel injector tube.

was impinging on the mixer tube wall just downstream of the fuel injector and was washed down the side of the tube by high velocity air. It was also observed that nearly all of the fuel evaporated off the mixer tube wall before exiting the premixer tube, indicating a very skewed fuel/air profile at the exit of the premixer tube.

In general, the curved tube configurations had poorer combustion efficiency, stability problems, and higher NOx emissions than the IMFH 5B configuration. Also, there was evidence that the performance of the CT-IMFH has a high sensitivity to pressure drop (or velocity in the tube). These problems were probably due to poor fuel distribution caused by radial acceleration of the flow field in the curved tube. There was also an increased risk of flashback and autoignition within the curved tube configurations. By itself, the poor stability of the curved tube IMFH is not considered to be a disadvantage. The original MRA combustor design provides a forced flow of burnt gases from the pilot across the IMFH dome. This flow of burnt gases provides the stability of the combustor. The pilot gases would ignite and stabilize the fueled IMFH jets. However, the other disadvantages of the curved tube IMFH were considered unacceptable and it was eliminated from consideration for further development. Meanwhile, the MRA combustor evolved to a design not requiring curved IMFH tubes. This change in the MRA combustor's design was principally driven by the lack of a workable fuel injector design for the original MRA, although the poor performance of the curved IMFH tubes was also a consideration. The evolution of the MRA combustor design is discussed in more detail in Section 6.5.

3.3 Swirl-IMFH Evaluations

The Swirl-IMFH refers to the concept of combining a small number of IMFH tubes in a package with an integrated fuel injection system. The individual IMFH tubes did not have any swirl in the flow but the tubes were arranged to impart a net swirl to the flow exiting the package. The Swirl-IMFH concept was thought to offer the following advantages over previous IMFH configurations:

1. The introduction of swirl could improve mixing of the discrete jets exiting the fuel/air mixer and improve emissions and/or allow reduction of the IMFH tube length.
2. The swirl could increase recirculation in the combustion zone for improved combustion stability.
3. The circular arrangement of the mixer tubes was analogous to a conventional swirl cup package and lends itself to conventional fuel injector concepts which could simplify the combustor mechanical design.
4. The fuel system passages could be an integral part of the tube casting (in production). This would greatly reduce the complexity of the fuel system for the IMFH design. It also would allow for a single flow divider or staging valve to be used for all mixer tubes in a Swirl-IMFH group.
5. The centerline simplex pilot nozzle could potentially improve stability. This "concentric" staging concept could make the Swirl-IMFH acceptable as a pilot, thereby eliminating the need for a separate pilot stage in the combustor.

3.3.1 Swirl-IMFH (Standard Tube Dimensions) Evaluations

The Swirl-IMFH fuel/air mixer concept, shown in Figure 3.21, packaged the IMFH mixer tubes into a 2.5 inch diameter circular pattern with each tube angled to impart a small amount of swirl (13.5°) into the combustion zone. The IMFH tubes had a 0.50-inch inner diameter and were

5.5 inches long. The tube exit matrix formed a perforated plate flame holder. Fuel injector tubes had the standard 0.020-inch inner diameter.

Four configurations of fuel injector tubes were used: 1) coaxial into the mixer tube inlet terminating one inch from the tube entrance, 2) transverse injection one inch downstream from the tube entrance with the injector ending at the wall, 3) with 20% immersion, and 4) with 50% immersion. This provided 4.5 inches of mixing/vaporization length in all cases. The schematic in Figure 3.22 compares the coaxial configuration with the transverse configuration with 50% immersion. A simplex pressure atomizing fuel injector was located at the centerline of the Swirl-IMFH module to act as a pilot. This pilot burns in a diffusion flame and would be used only during low power conditions to improve combustion efficiency and stability.

An atmospheric pressure test of the Swirl-IMFH with the coaxial injector configuration consisting of main stage only (premixer only) operation was run at inlet temperatures ranging from ambient up to 650° F (1110 R). Stability appeared to be good. The lean blowout data are plotted versus inlet temperature in Figure 3.23. The flame was mostly blue, with a yellow flame near the center at some operating conditions. The flame exiting each premixer tube appeared to have a blue streak at the center.

Figures 3.24 through 3.26 compare the results of the 50% immersion wall injector (data points F and G) and coaxial injectors (data points H and I) in four-atmosphere tests. NOx emissions were significantly higher for the coaxial injection case, while combustion inefficiencies were similar for both configurations. At elevated inlet temperatures, the wall injection configuration reached equilibrium CO levels and had a lower CO at the bucket than the coaxial configuration. It was concluded that the coaxial injectors had the more non-uniform of the fuel/air profiles at the exit of the premixer tubes. The observation of centerline streaks in the atmospheric test of the coaxial injector configuration is consistent with this conclusion.

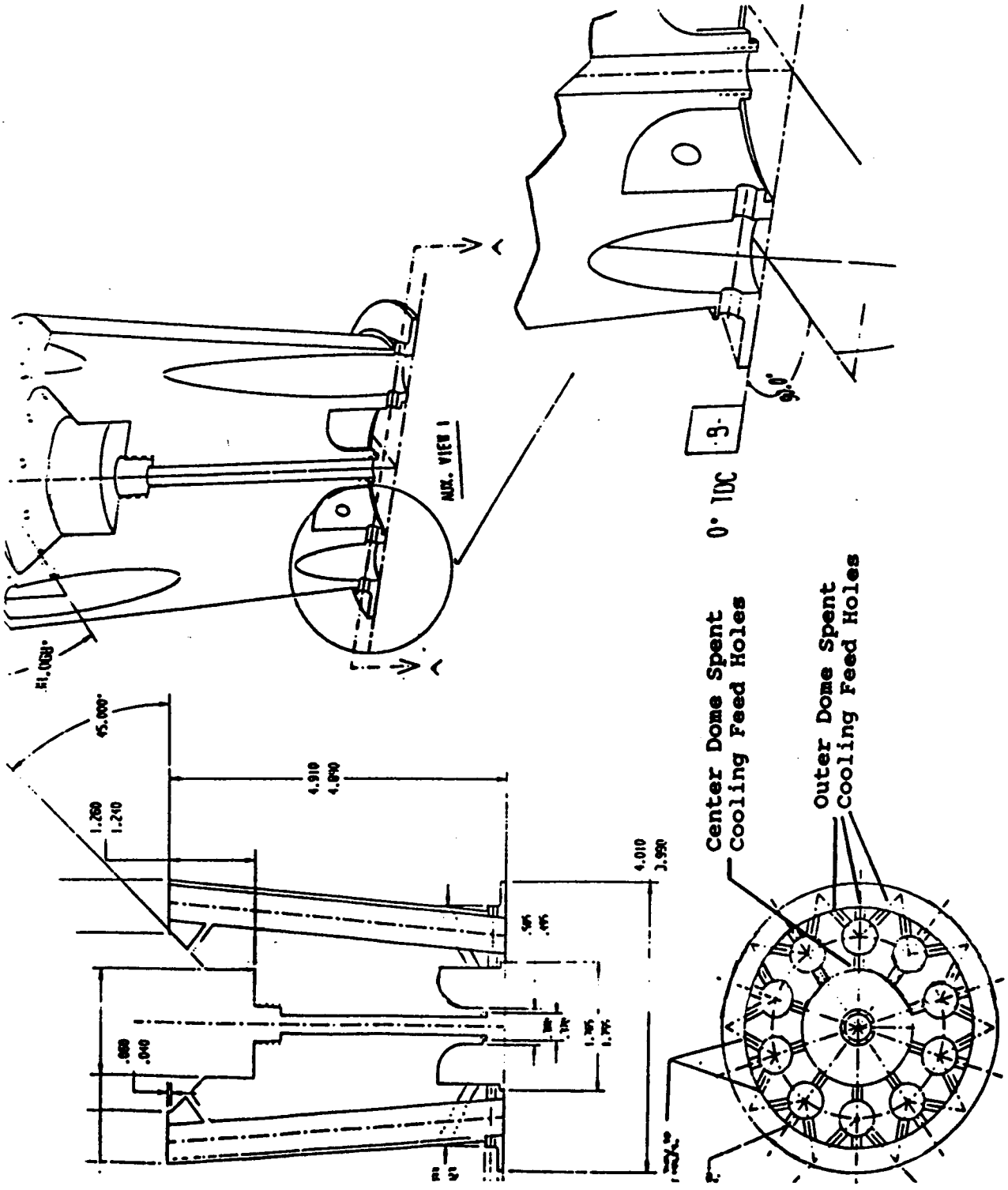


Figure 3.21 - Swirl-IMFH Fuel-Air Mixer subcomponent test hardware.

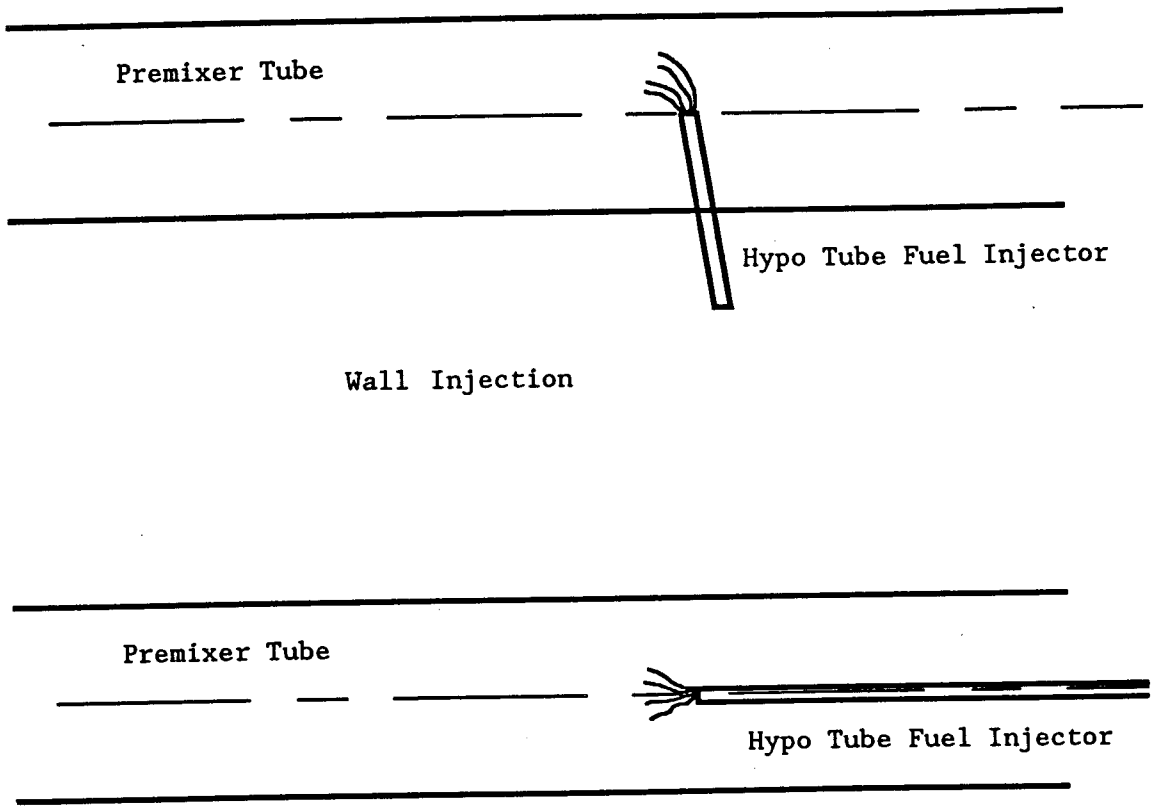


Figure 3.22 - Swirl-IMFH fuel injector configurations. The 50% immersion transverse injector and coaxial injector are standard injector configurations also tested in the baseline IMFH configuration. The air flow is right to left in this figure.

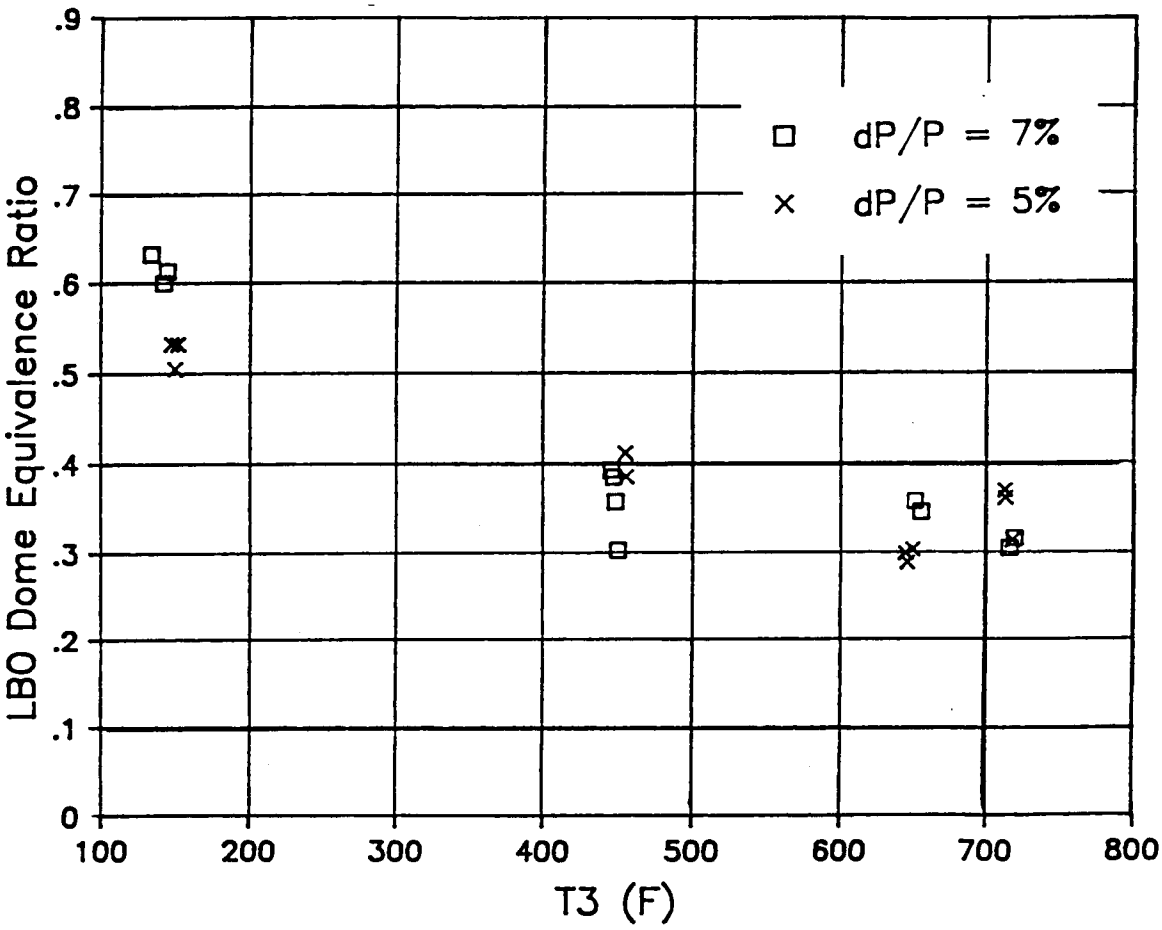


Figure 3.23 - Lean blow out Results for the Swirl-IMFH with the coaxial injector at 5% and 7% dome pressure drop. Lean blow out equivalence ratio is plotted versus T_3.

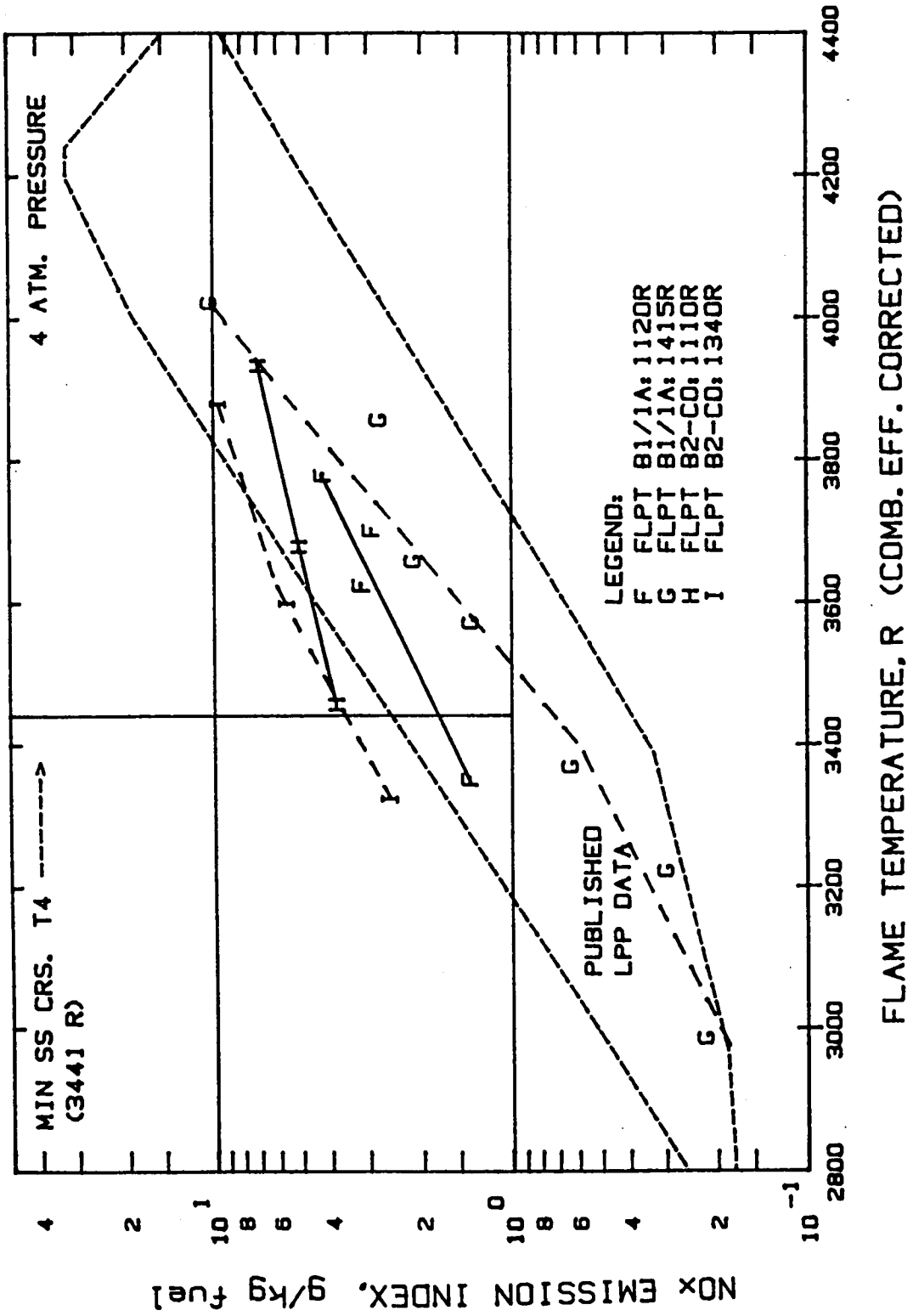


Figure 3.24 - NOx emissions index plotted versus flame temperature for the Swirl-IMFH with the 50% immersion transverse fuel injector (Build 1, points F and G) compared to the coaxial fuel injector configuration (Build 2, points H and I).

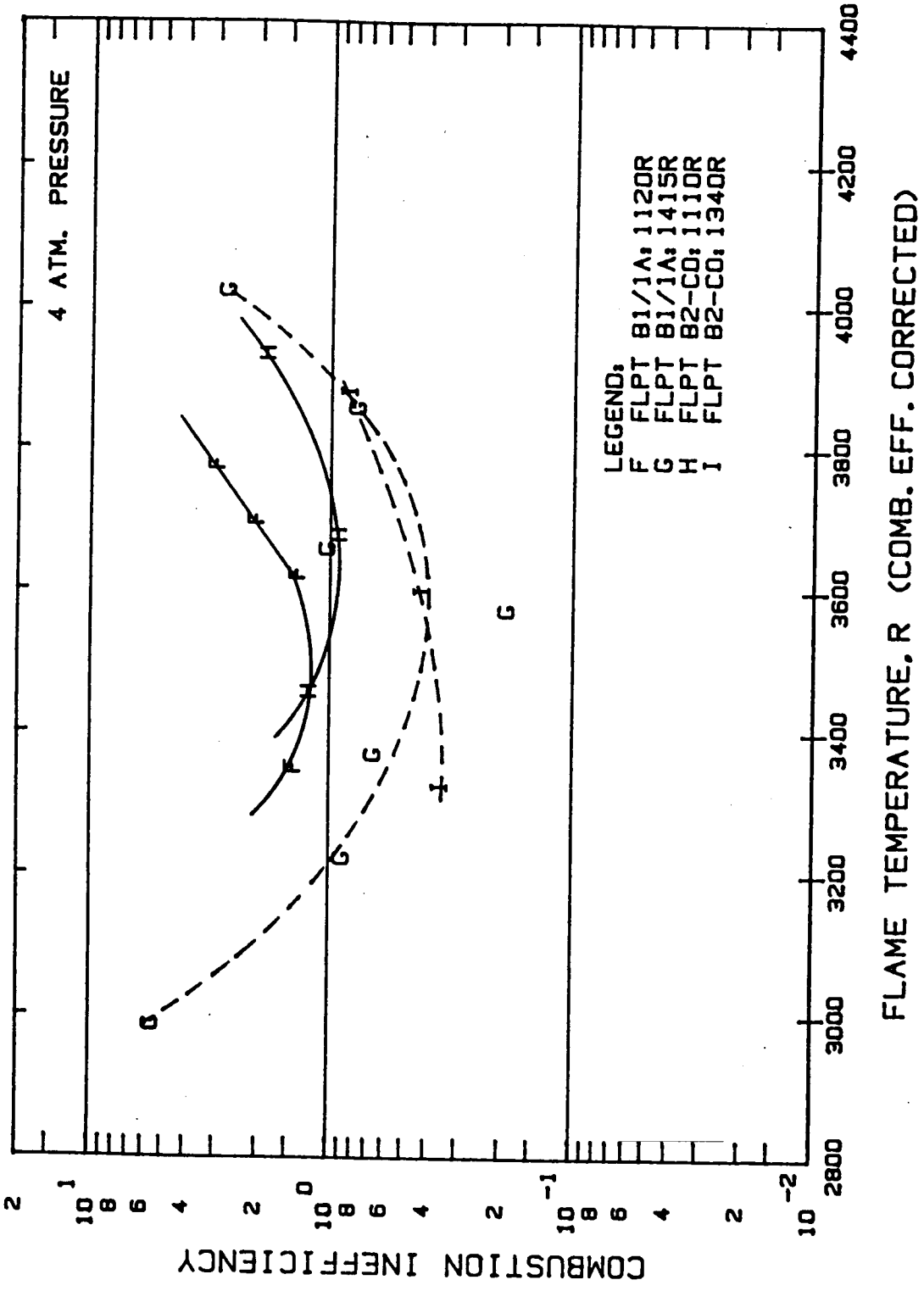


Figure 3.25 - Combustion inefficiency plotted versus flame temperature for the Swirl-IMFH with the 50% immersion transverse fuel injector (Build 1, points F and G) compared to the coaxial fuel injector configuration (Build 2, points H and I).

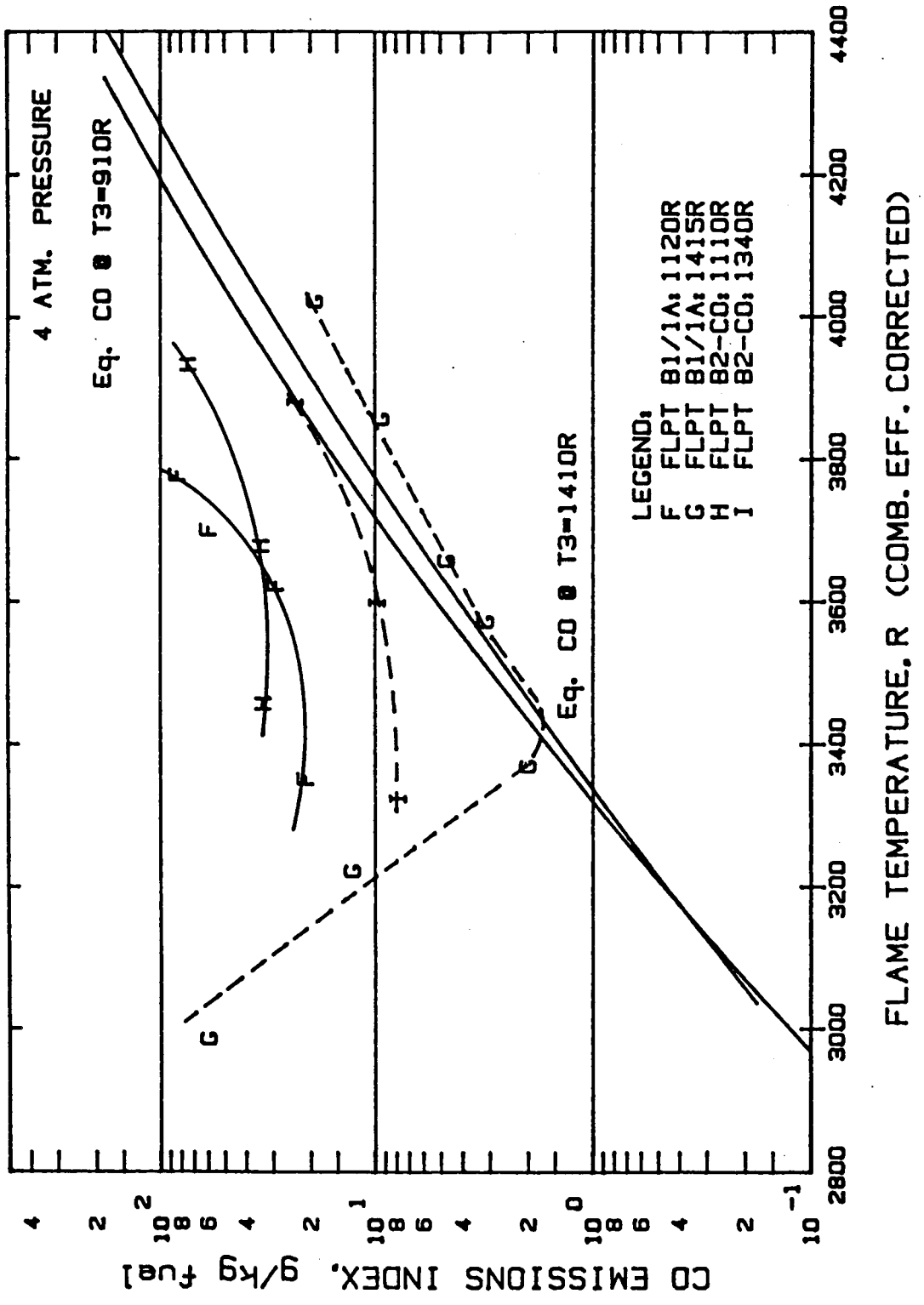


Figure 3.26 - CO emissions index plotted versus flame temperature for the Swirl-IMFH with the 50% immersion transverse fuel injector (Build 1, points F and G) compared to the coaxial fuel injector configuration (Build 2, points H and I)

Figures 3.27 through 3.29 compare NOx emissions, combustion inefficiency, and CO emissions for the Swirl-IMFH for 20% and 50% fuel injector immersions. The 20% fuel injector tube immersion produced significantly higher NOx emissions than either the 50% immersion or IMFH Configuration 5A at flame temperatures below 3900 R. At high inlet temperatures (1410 R), the combustion inefficiency for the 20% immersion Swirl-IMFH was similar to IMFH Configuration 5A and lower than the 50% immersion. The low NOx emissions for the 50% immersion injector were offset by the poor combustion efficiency results relative to Configuration 5A shown in Figure 3.28. The flatness of the NOx data versus calculated flame temperature for the 20% immersion Swirl-IMFH and the wide range of the combustion inefficiencies, suggests that the flame had some diffusion burning. It is also possible that at the higher inlet temperatures, the fuel was prevaporized, but not uniformly premixed. Post-test inspection of the 50% immersion configuration revealed significant carbon formation in the center of the dome after only 6 hours of testing, as well as a dime-sized hole burned through the dome.

3.3.2 Mini Swirl-IMFH Evaluations

A new set of hardware for the Swirl-IMFH with scaled-down dimensions was designed and fabricated. The intent was to investigate a Swirl-IMFH concept that could be substituted for the Cyclone Swirler pilot in the pilot dome of the rectangular sector combustor and to provide data on the minimum premixer tube length required for fuel vaporization. The inner diameter of the IMFH mixer tubes was reduced to 0.36 inches. The fuel injector retained the standard inner diameter (0.020 inches). The hardware was modular. Two mixing lengths for the IMFH tubes could be used, the standard 4.5 inches (to allow the effects of the other changes to be isolated) or 3.2 inches. Two domes were available with two diameters of the exit circle for the IMFH tubes; 0.900 inches and 1.163 inches. Both domes maintained the pilot simplex atomizer at the module centerline. Figure 3.30 shows a cross-section of the Mini Swirl-IMFH.

Only one configuration was tested and that test was a visual test at atmospheric pressure. The configuration used the 4.5 inch mixing length, a 50% immersion of transverse fuel

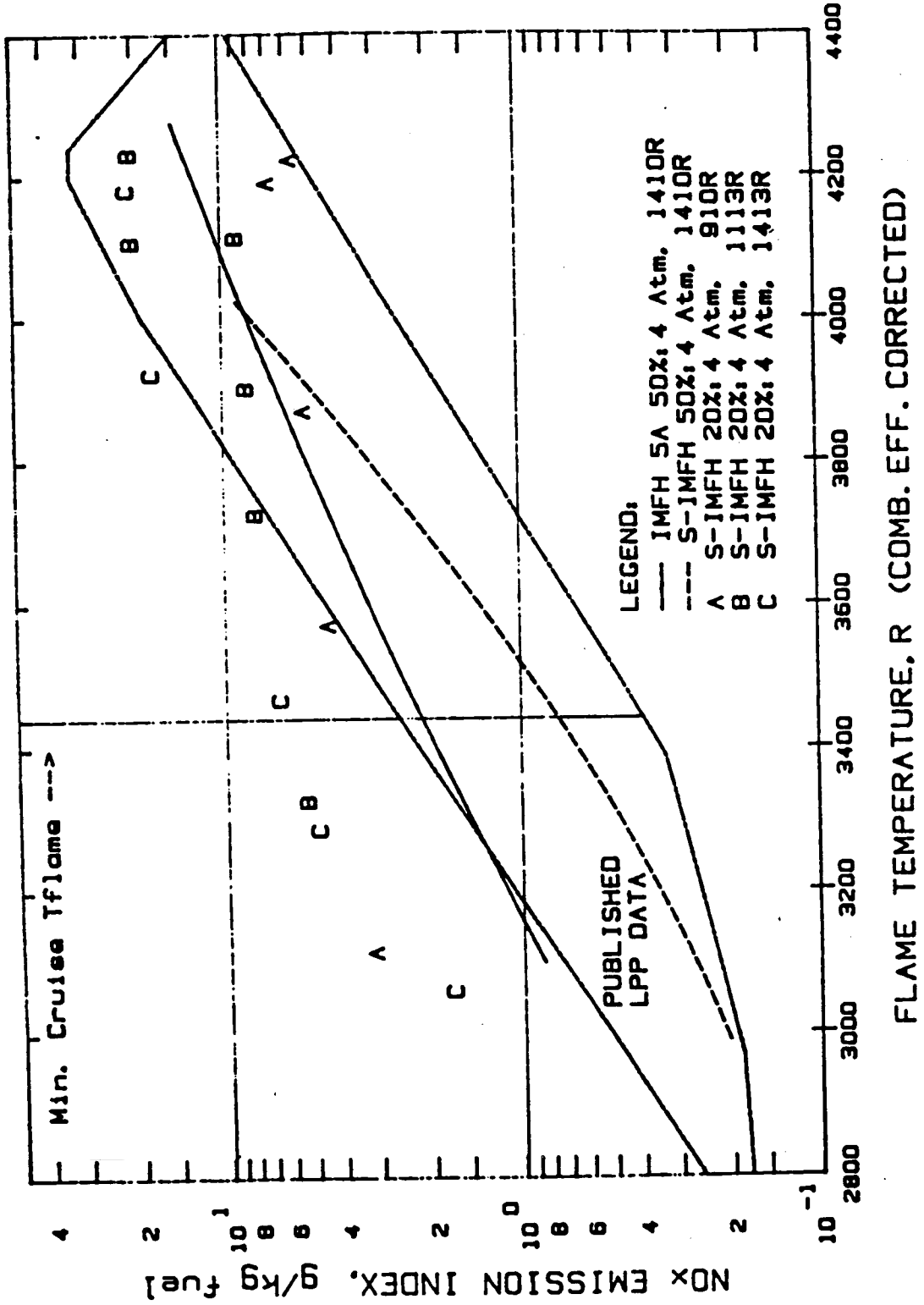


Figure 3.27 - NOx emissions index plotted versus flame temperature for the Swirl-IMFH with the 20% immersion transverse fuel injector (points A, B and C) compared to fit lines of emissions data for the 50% immersion transverse injector in the Swirl-IMFH and 50% immersion injector in the baseline IMFH configuration (Configuration 5). The dot-dash boundary indicates the envelope of LPP NOx emissions obtained in several laboratory flame tube studies published in the open literature.

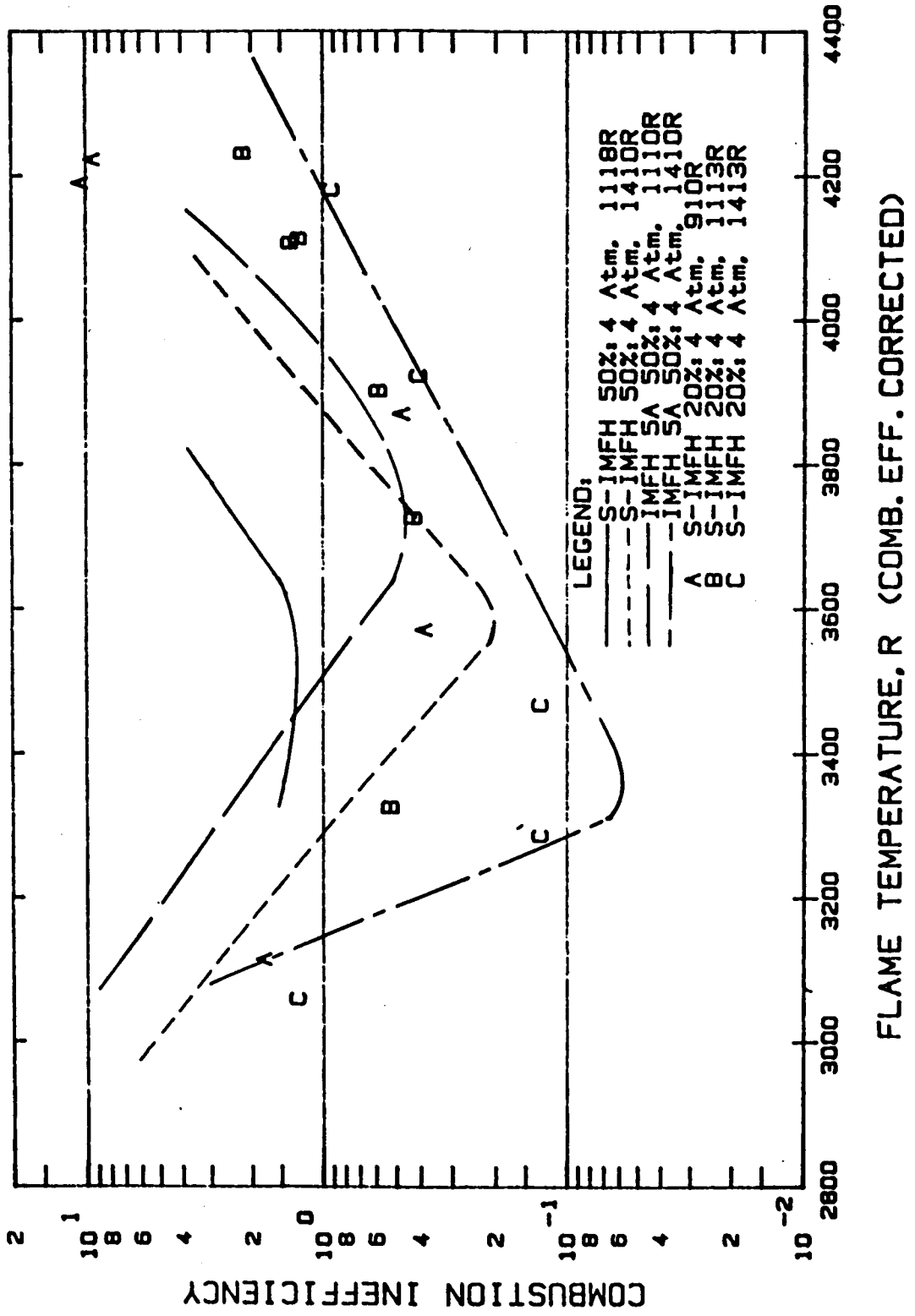


Figure 3.28 - Combustion inefficiency plotted versus flame temperature for the Swirl-IMFH with the 20% immersion transverse fuel injector (points A, B and C) compared to fit lines of emissions data for the 50% immersion transverse injector in the Swirl-IMFH and 50% immersion injector in the baseline IMFH configuration (Configuration 5).

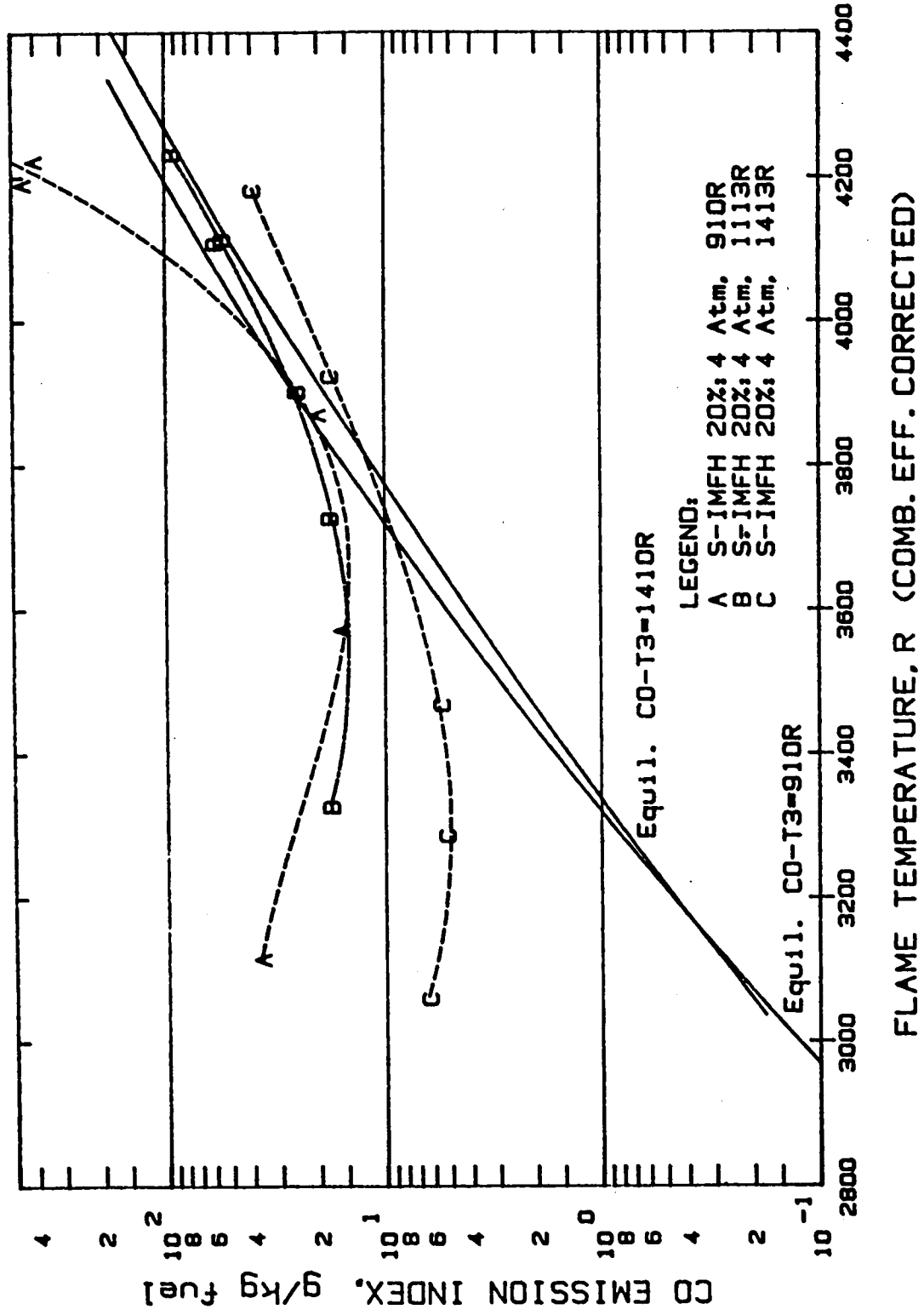


Figure 3.29 - CO emissions index plotted versus flame temperature for the Swirl-IMFH with the 20% immersion transverse fuel injector (points A, B and C) compared to fit lines of emissions data for the 50% immersion transverse injector in the Swirl-IMFH and 50% immersion injector in the baseline IMFH configuration (Configuration 5).

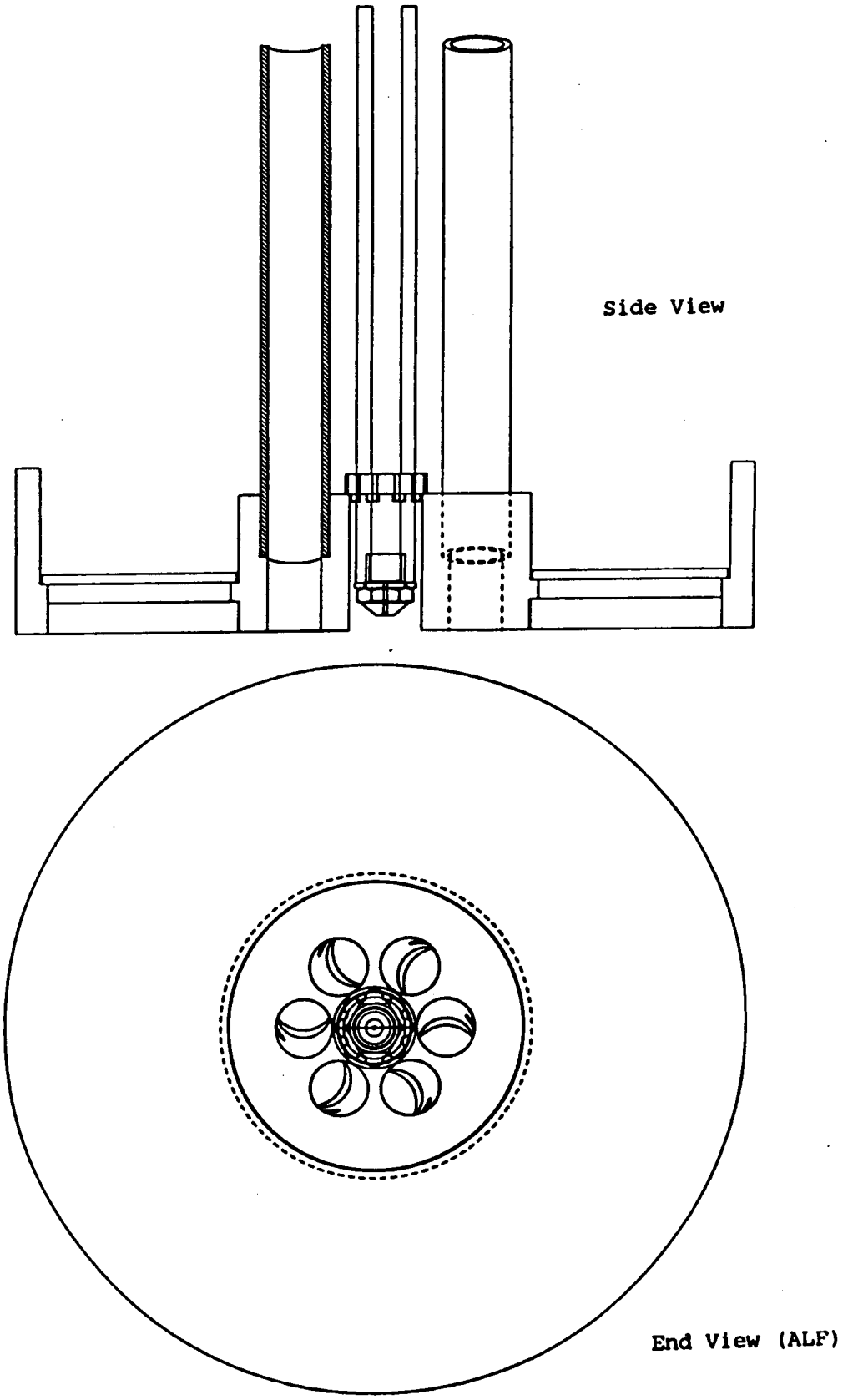


Figure 3.30 - Mini Swirl IMFH subcomponent test hardware

injector tubes, and the dome with the 0.900 inch diameter exit circle. The visual observations of the combustion indicated the flame was lifted off the dome at all conditions tested. The post-test inspection revealed that the dome and about 1 inch of the forward length of the liner was coated with carbon. As the internal configuration of the individual IMFH tubes was that of the baseline design, the conclusion was that the small exit circle and close proximity of the tube exits resulted in high local dome velocities. This prevented a sufficient recirculation zone from forming, hampering stability. No other configurations of the Mini Swirl-IMFH were tested.

3.3.3 Venturi Swirl-IMFH Evaluations

The potential advantages of the Venturi-IMFH are discussed in the APT Task 5 Final Report [3-1]. The primary benefit of a venturi is that it yields higher local velocities at the point of fuel injection, resulting in better fuel atomization. Disadvantages of the venturi include the requirement for added length if a constant residence time is maintained (not done in these designs), added cost, and the potential for separation in the conical diffuser (which may lead to flashback). An additional advantage is that the static temperature of the air is reduced in the throat, which calculations indicate adds significantly to the autoignition delay. This could be exploited by further increases in length. However, with a high Mach number in the throat, the friction losses became significant. Thus, the throat lengths need to be kept short to obtain the intended velocities. Calculations indicated that there should still be a net improvement in mixing performance. Carburetors used for premixing gasoline and air for internal-combustion engines generally use a venturi at the point of fuel injection.

In this development effort, the Venturi-IMFH and the Swirl-IMFH concepts were merged and called the Venturi Swirl-IMFH (VS-IMFH). Three designs for the venturi were investigated. Figure 3.31 is a schematic of Configurations 1 and 2. All three designs had 0.75-inch long converging sections, used wall fuel injectors immersed to the centerline and located 1.0 inch from the inlet, and injected the spent cooling air 0.2 inches upstream of the dome. The inlet had a diameter of 0.600 inches. The throat had a diameter of 0.475 inches. The exit diameter was

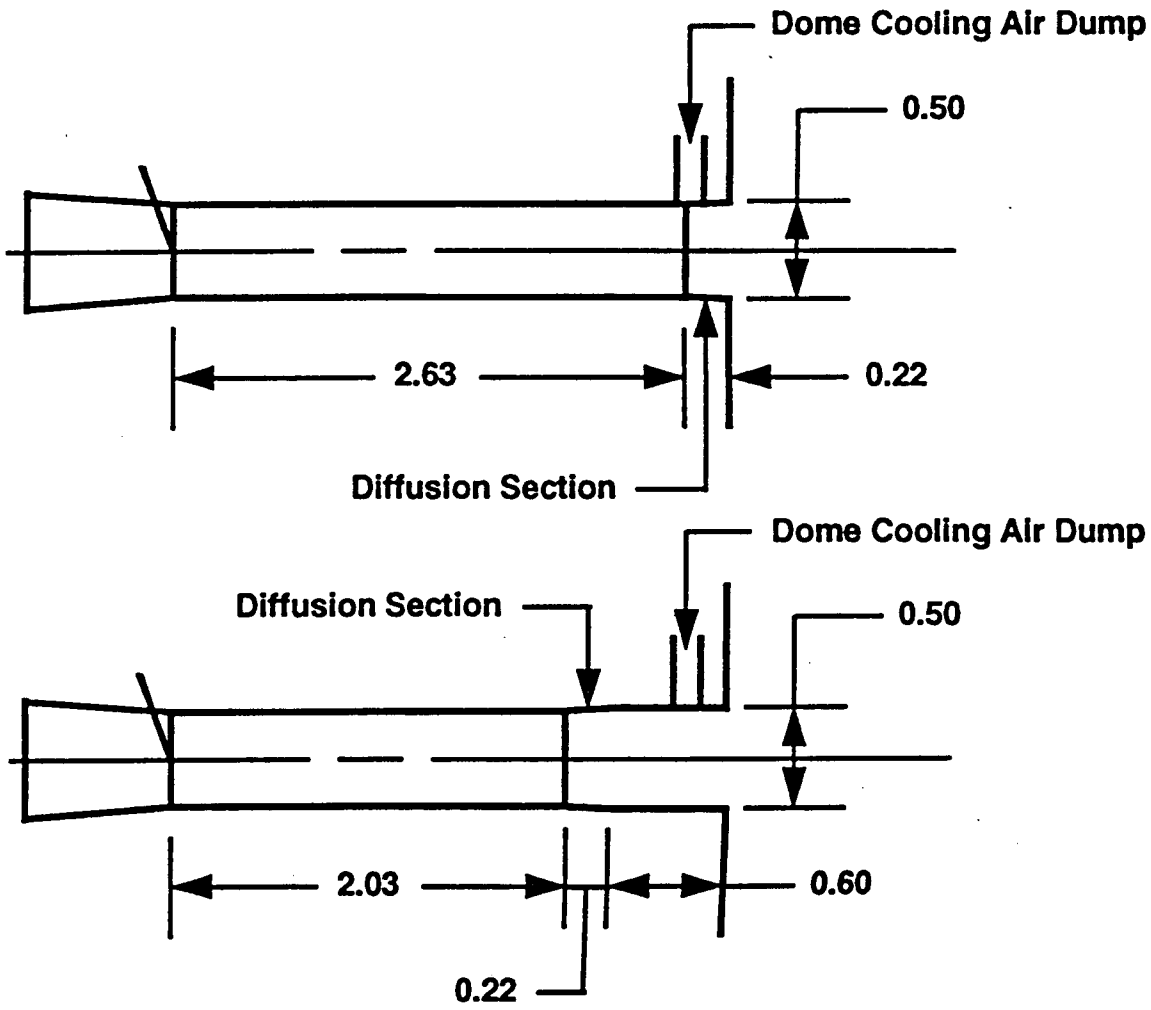


Figure 3.31 - Venturi Swirl IMFH configurations with the 2.63-inch (Configuration 1, shown at the top) and 2.03-inch (Configuration 2, shown at the bottom) long throats. The diameter of the throats is 0.475 inches.

0.500 inches. The half-angle of the diverging section of all the designs was 3.25 degrees. The area ratio of the conical diffuser was intentionally kept small to maintain a conservative design. Larger area ratios could always be investigated later, if a benefit was observed. Configuration 1 had the longest throat length (2.63 inches), with a conical diffuser section that was 0.22 inches long, ending at the dome. The overall length was 3.60 inches. Configuration 2 had a 2.03-inch long throat, a 0.22-inch long conical diffuser, and a 0.60-inch straight section. Configuration 3 had a 0.53-inch long throat, a 0.22-inch long conical diffuser, and a 2.10-inch straight section.

Configuration 1 was tested at 4 atmospheres and inlet temperatures of 450° F and 650° F (910 R and 1110 R). Although the emissions data were comparable to IMFH Configuration 5A, the effective flow area data indicated the diffuser was separated. The pressure drop characteristics of Configuration 1 acted like the dump from a 0.475-inch diameter tube, or the venturi's throat diameter. This indicated that the flow was separating in the diverging section, probably because of interaction with the spent cooling air jets.

A pre-test pressure flow check of Configuration 2 indicated there was no flow separation in the venturi's diffuser. This conclusion was based upon the observed pressure loss appearing to correspond to a dumping loss consistent with the calculated velocity at the exit of tube rather than the throat. Thus, the flow in the diffuser section of the venturi appeared to remain attached. Possibly, the flow separated and then re-attached (if so, the design would be prone to flashback/autoignition. However, observations during the test and the post-test inspection were consistent with the conclusion that no separation occurred within the premixer tubes. Configuration 2 emissions data were taken at 4 and 6 atmospheres inlet pressure and inlet temperatures ranging from 446° F and 674° F (906 R to 1134 R). Figure 3.32 shows the VS-IMFH NOx emissions plotted versus flame temperature and compares these results to the IMFH Configuration 5A and straight tube Swirl-IMFH (S-IMFH) data at 4 atmospheres inlet pressure and 1410 R inlet temperature. The VS-IMFH NOx emissions were similar to Configuration 5A, particularly at elevated inlet temperatures. The combustion inefficiency data and the CO

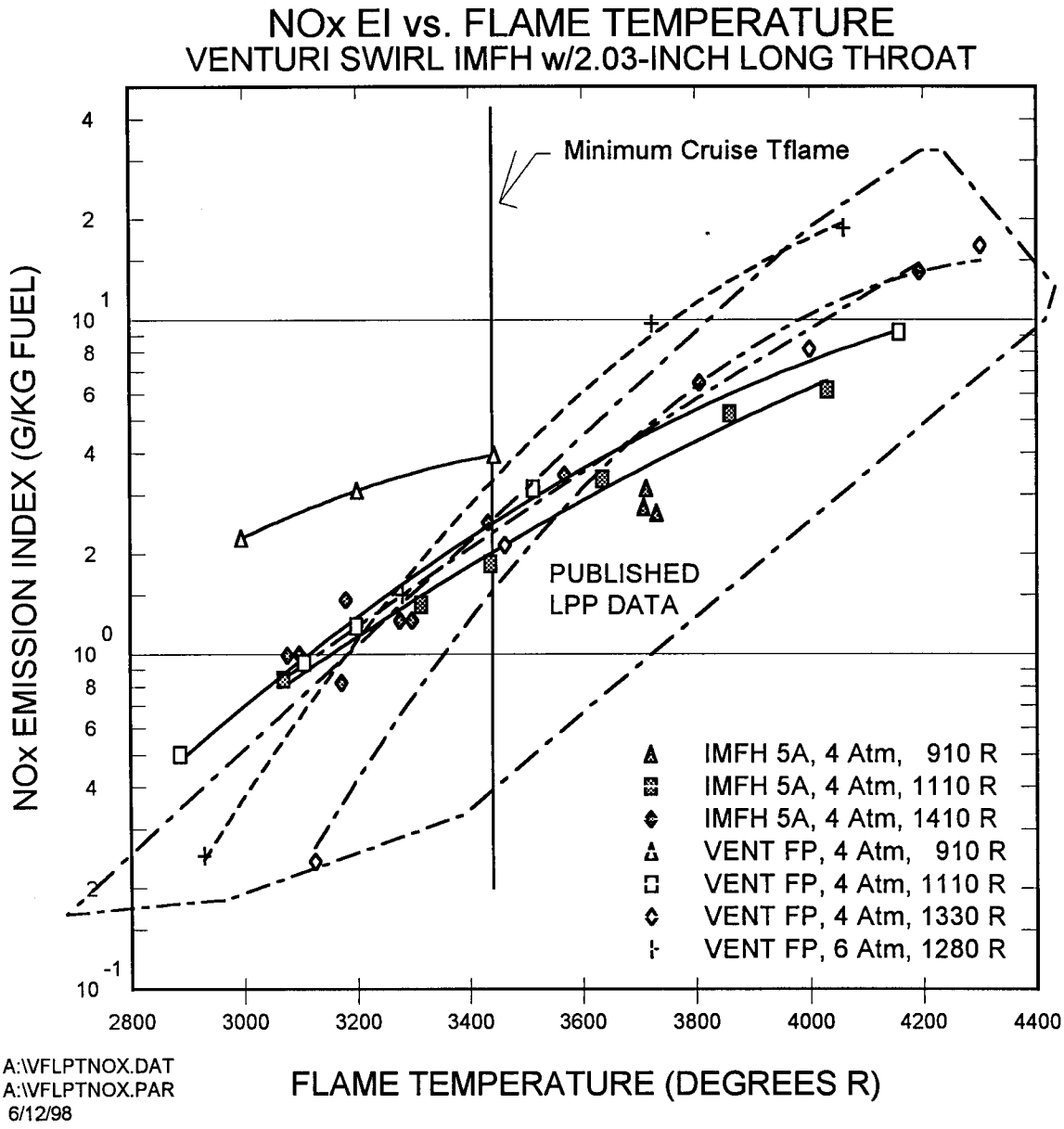


Figure 3.32 - NOx emissions index plotted versus flame temperature for Configuration 2 of the Venturi Swirl-IMFH (2.03-inch long throat). Results are compared to the baseline configuration of the IMFH (Config 5) and the Swirl-IMFH with the 50% immersion fuel injector.

emissions data are plotted in Figures 3.33 and 3.34. The combustion inefficiency at intermediate inlet temperatures was lower for the VS-IMFH than for either the IMFH Configuration 5A or the S-IMFH.

An atmospheric test of the Venturi Swirl-IMFH with a 0.53-inch long throat (Configuration 3) showed a well mixed and circumferentially uniform flame structure attached to the dome. Initial emissions measurements at 4 atmospheres pressure were similar to earlier data. NOx, CO, and UHC emissions measurements were taken at inlet temperatures ranging from 450° F to 950° F (910 to 1410 R). The NOx and CO emissions data are presented in Figures 3.35 and 3.36. In general, NOx emissions were higher than for Configuration 2 (with the 2.03-inch long throat) and the combustion efficiency was poorer. The increase in NOx and combustion inefficiency was attributed to poorer fuel dispersion within the 0.5-inch length throat premixer tube, which in turn was due to a greater fraction of the fuel entering the diffusion section not being vaporized.

Based on these results, it was concluded that the longer venturi (approx. 2.0 inches) design (Configuration 2) might provide some benefit relative to the basline Configuration 5 in improving combustion efficiency at the inlet temperatures of 650° F (1110 R) and above with the possibility of a small NOx penalty. This improvement in performance at subsonic cruise combustor inlet conditions is especially attractive for the IMFH main stages operating at subsonic cruise. Based upon IMFH flametube emissions results, combustion efficiency has been a concern. NOx emissions at subsonic cruise are not as critical as supersonic cruise.

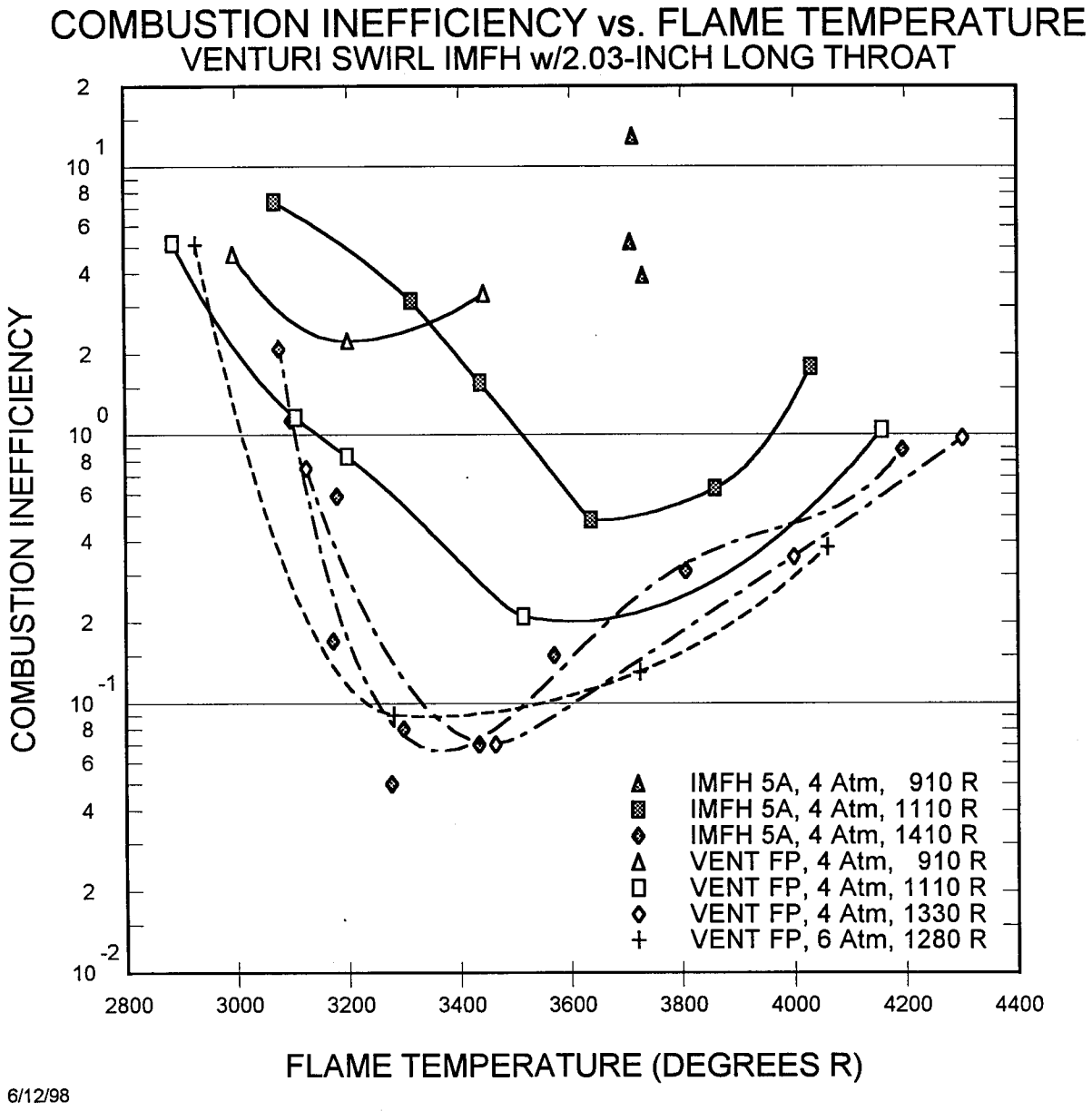


Figure 3.33 - Combustion inefficiency plotted versus flame temperature for Configuration 2 of the Venturi Swirl-IMFH (2.03-inch long throat). Results are compared to the baseline configuration of the IMFH (Configuration 5) and the Swirl-IMFH with the 50% immersion fuel injector.

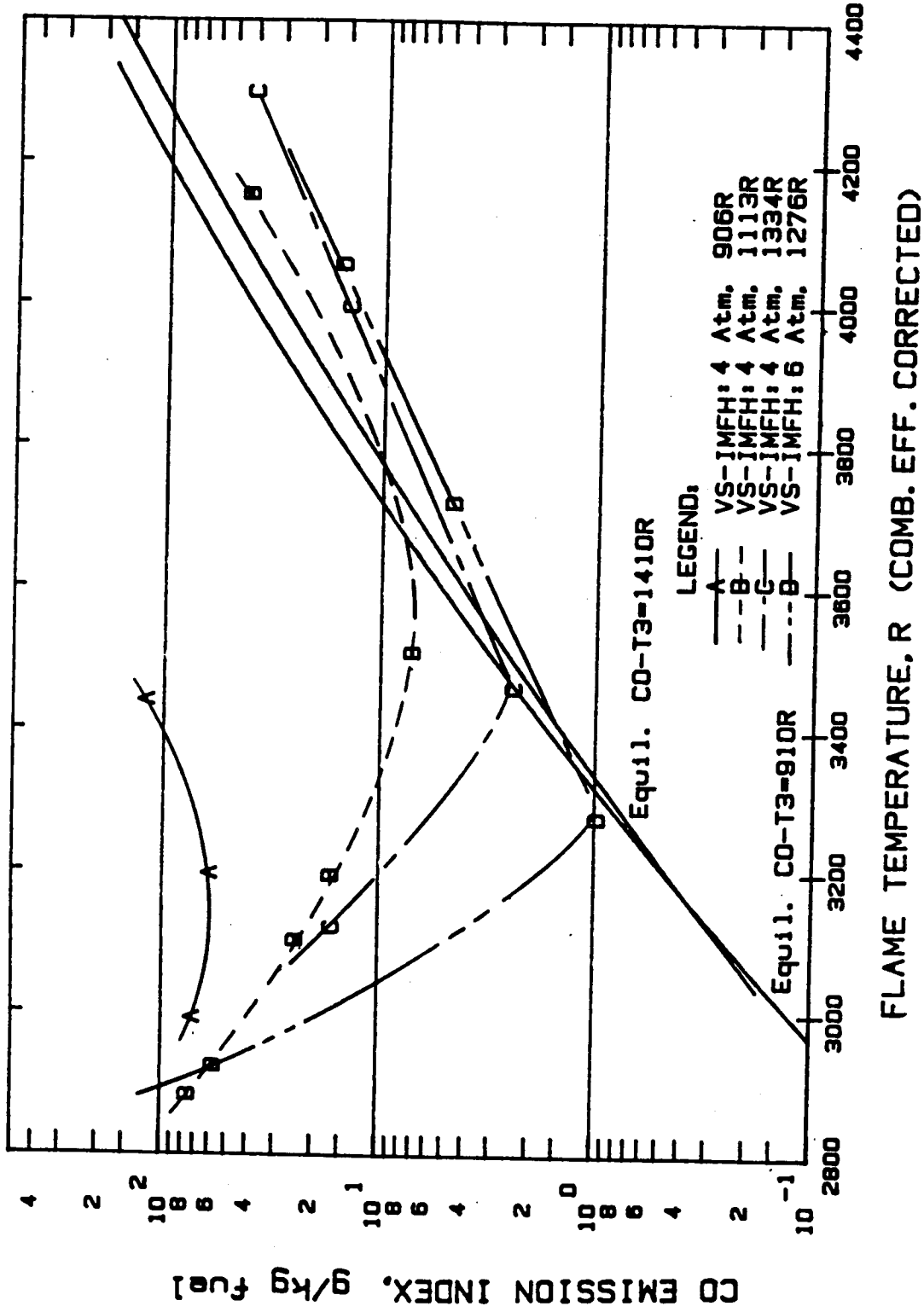


Figure 3.34 - CO emissions index plotted versus flame temperature for Configuration 2 of the Venturi Swirl-IMFH (2.03-inch long throat). Results are compared the calculated equilibrium line for CO for inlet temperatures of 910 R and 1410 R.

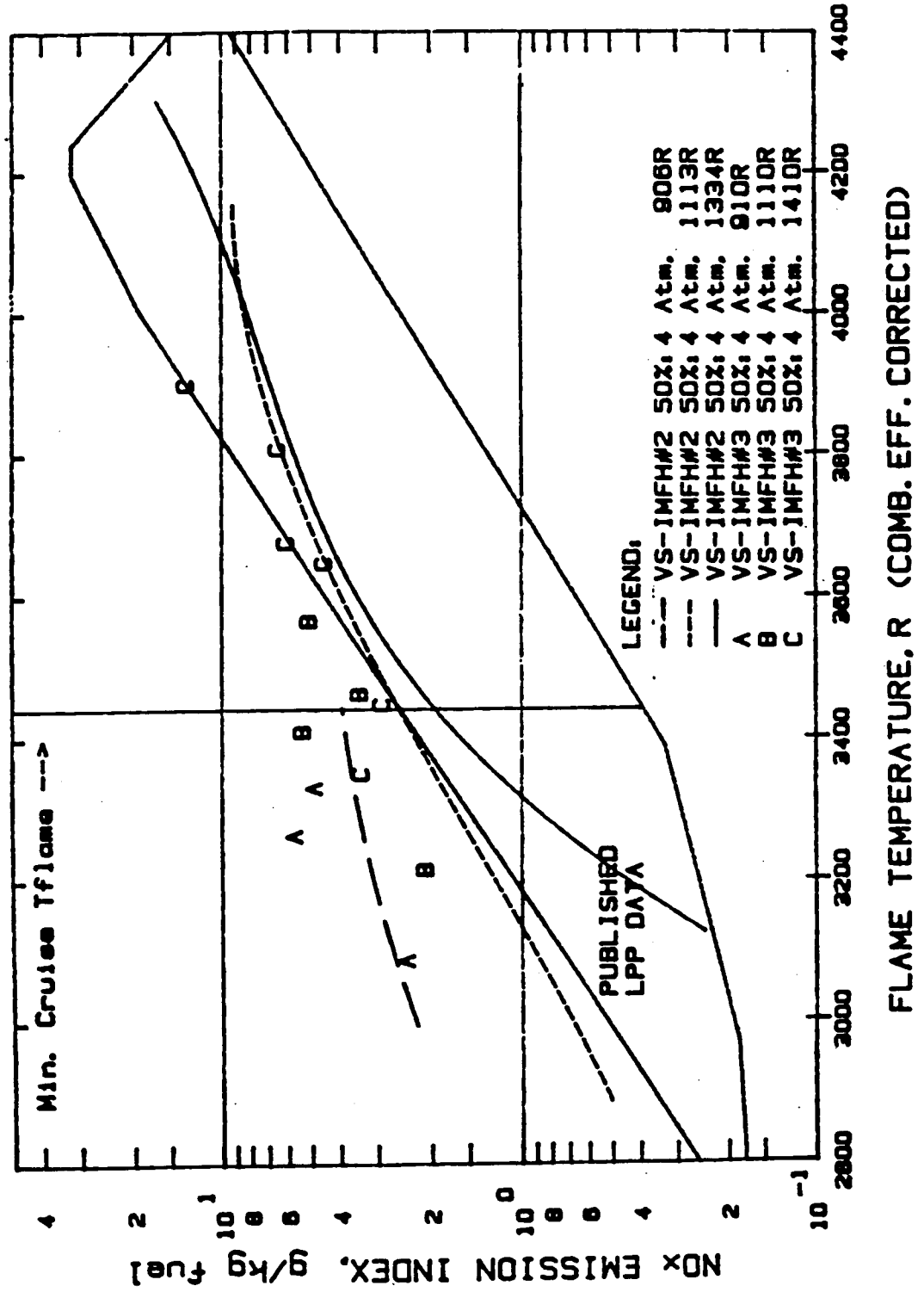


Figure 3.35 - NOx emissions index plotted versus flame temperature for Configuration 2 (2.03-inch long throat) and Configuration 3 (0.53-inch long throat) of the Venturi Swirl-IMFH. The dot-dash boundary indicates the envelope of LPP NOx emissions obtained in several laboratory flame tube studies published in the open literature.

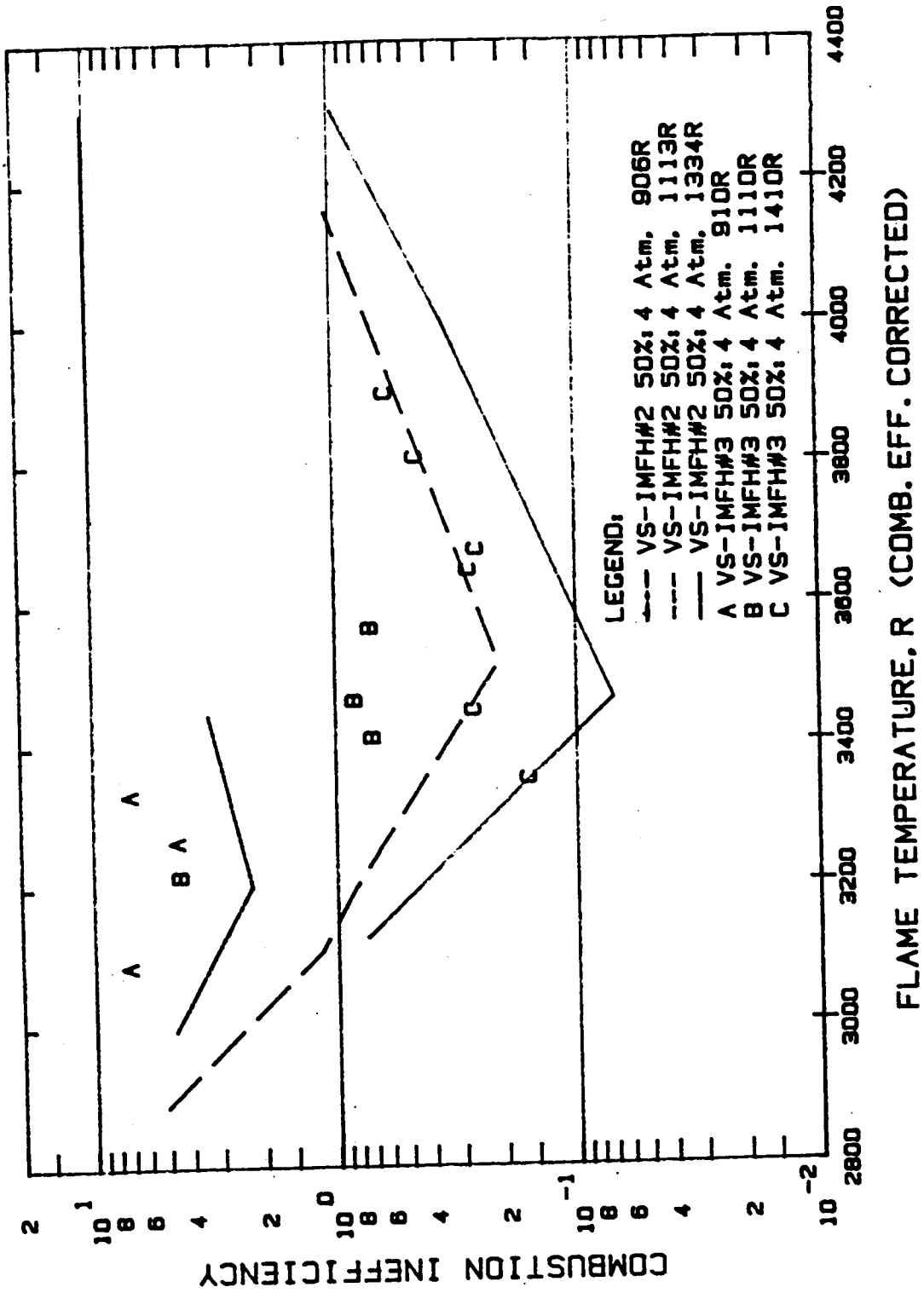


Figure 3.36 - Combustion inefficiency plotted versus flame temperature for Configuration 2 (2.03-inch long throat) and Configuration 3 (0.53-inch long throat) of the Venturi Swirl-IMFH.

3.4 Cyclone Swirler Evaluations

Configurations 3 and 4 of the Cyclone Swirler pilot were evaluated in single-cup tests in LET Task 10. Configuration 3 was a slightly scaled down version of Configuration 2 (in terms of size and effective flow area). The number of plain-jet air-blast fuel injectors mounted radially on the centerbody was reduced from eight injectors in Configuration 2 to six injectors in Configuration 3. The inner diameter of the fuel injector tubes was increased from 0.012 inches to 0.020 inches (Configuration 2 was eventually retrofitted with 0.020-inch injectors for the CR&D tests discussed in Section 2.2). Configuration 3 is the pilot used in the stepped dome sector combustor (discussed in Section 4 of this report) and the highly-mixed MRA sector combustor [3-2]. A cross-section of the Cyclone Swirler Configuration 3 single-cup hardware is shown in Figure 3.37. Configuration 4 is identical to Configuration 3, except the atomizing air passage was partially restricted. Configuration 5 was designed and fabricated in LET Task 10. It modified the centerbody/fuel nozzle design to incorporate a simplex fuel atomizing nozzle into the centerbody. The simplex fuel nozzle operated on a second fuel circuit, separate from the air-blast nozzles. The simplex fuel nozzle could be used to extend the operating range of the cyclone, if necessary. The Configuration 5 hardware was never tested. Table 3.2 summarizes the design parameters of Cyclone Swirler configurations 1 through 5.

Table 3.2 - Summary of Single-cup Cyclone Swirler Design Parameters

Cyclone Config #	Ae total Meas. (in^2)	Calc. Swirl Number	Slot Length (in)	Slot Width (in)	# of Slots	Swirler Aphys (in^2)	Slot Angle (deg.)	# Fuel Inj.	Comment
0	-	0.94	0.60	0.030	60	1.08	70	8	
1	0.74	0.94	0.60	0.030	60	1.08	70	8	0 with fuel injector tubes added
2	0.74	0.94	0.60	0.030	60	1.08	70	8	1 with spent cooling air injection
3	0.57	1.04	0.50	0.025	60	0.75	70	6	2 scaled down
4	-	1.04	0.50	0.025	60	0.75	70	6	3 with reduced air-blast air flow
5	-	1.04	0.50	0.025	60	0.75	70	6	Simplex nozzle at centerbody end

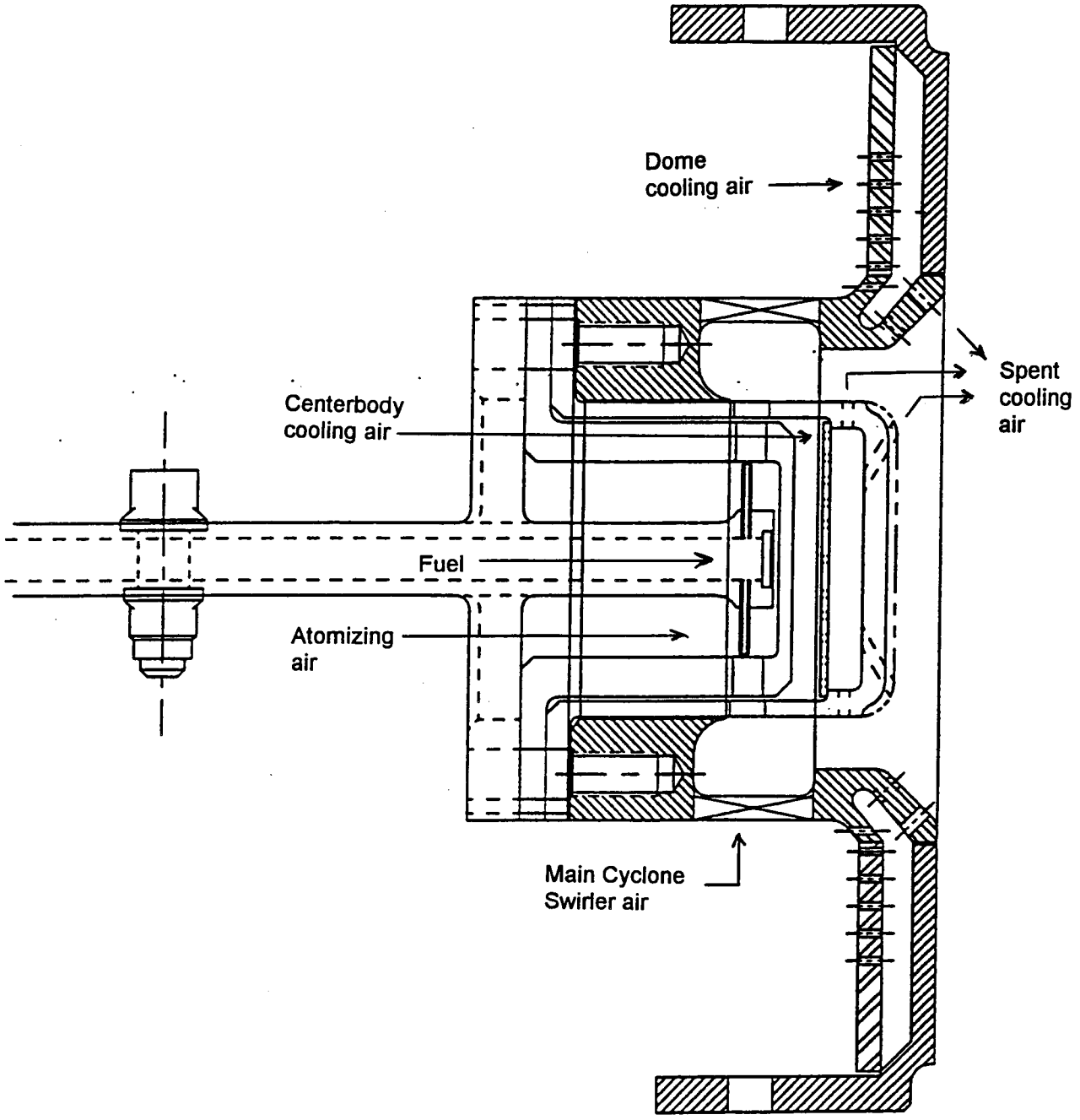


Figure 3.37 - Cyclone Swirler single-cup test hardware. Configuration 3 is shown. The same hardware was used for Configuration 4 by restricting the atomizing air inlet passage.

A four atmosphere test of Configuration 3 yielded excellent emissions performance. However, some combustion oscillations were audible. Configuration 3 was then tested in a high pressure rig in GEAE's Cell A5 to obtain data at full supersonic cruise conditions. In the Cell 5 test, the rig was instrumented with dynamic pressure transducers. During the Cell 5 test no combustion oscillations were audible, nor detected with the instrumentation. The occurrence of combustion oscillation is very dependent on the acoustic characteristics of the particular rig installation. The emissions data for the different tests of Configuration 3 are shown in Figures 3.38 and 3.39. The NOx results indicated that combustion transitioned to a diffusion flame at higher pressures. This was similar to the observations of a previous Configuration 2 Cyclone Swirler test. This indicates that the performance of the Cyclone Swirler was not sensitive to the changes made from Configuration 2 to Configuration 3. This robust behavior of the Cyclone Swirler has continued through later versions. Its performance has remained relatively constant, despite the numerous changes in its design. The 3% and 5% combustor pressure drop NOx and CO emissions data were in excellent agreement, consistent with past evaluations of the Cyclone Swirler. This suggests that simplified variable geometry schemes which would result in large changes in combustor pressure drop might be feasible. The high NOx emissions at high pressures noted for Configuration 3 were hypothesized to be the result of rich streaks of partially vaporized fuel. These streaks were generated by smaller droplets of fuel prematurely exiting the swirler, and burn either in a diffusion type flame or in a premixed mode close to stoichiometric.

A test of Configuration 4, which reduced the air flow rate for the plain-jet air-blast fuel atomization nozzles from Configuration 3, was run at 4 atmospheres. The reduced airflow for the atomization nozzles was predicted to roughly double the Sauter mean diameter (SMD) from plain-jet air-blast fuel nozzles. The larger SMD could have a positive or negative impact on NOx emissions in a Cyclone Swirler. The Cyclone Swirler depends on the radial acceleration to maintain relative velocity between unvaporized fuel and the air. The radial accelerations can easily exceed 10^4 g's. The effectiveness of the radial acceleration in generating high relative

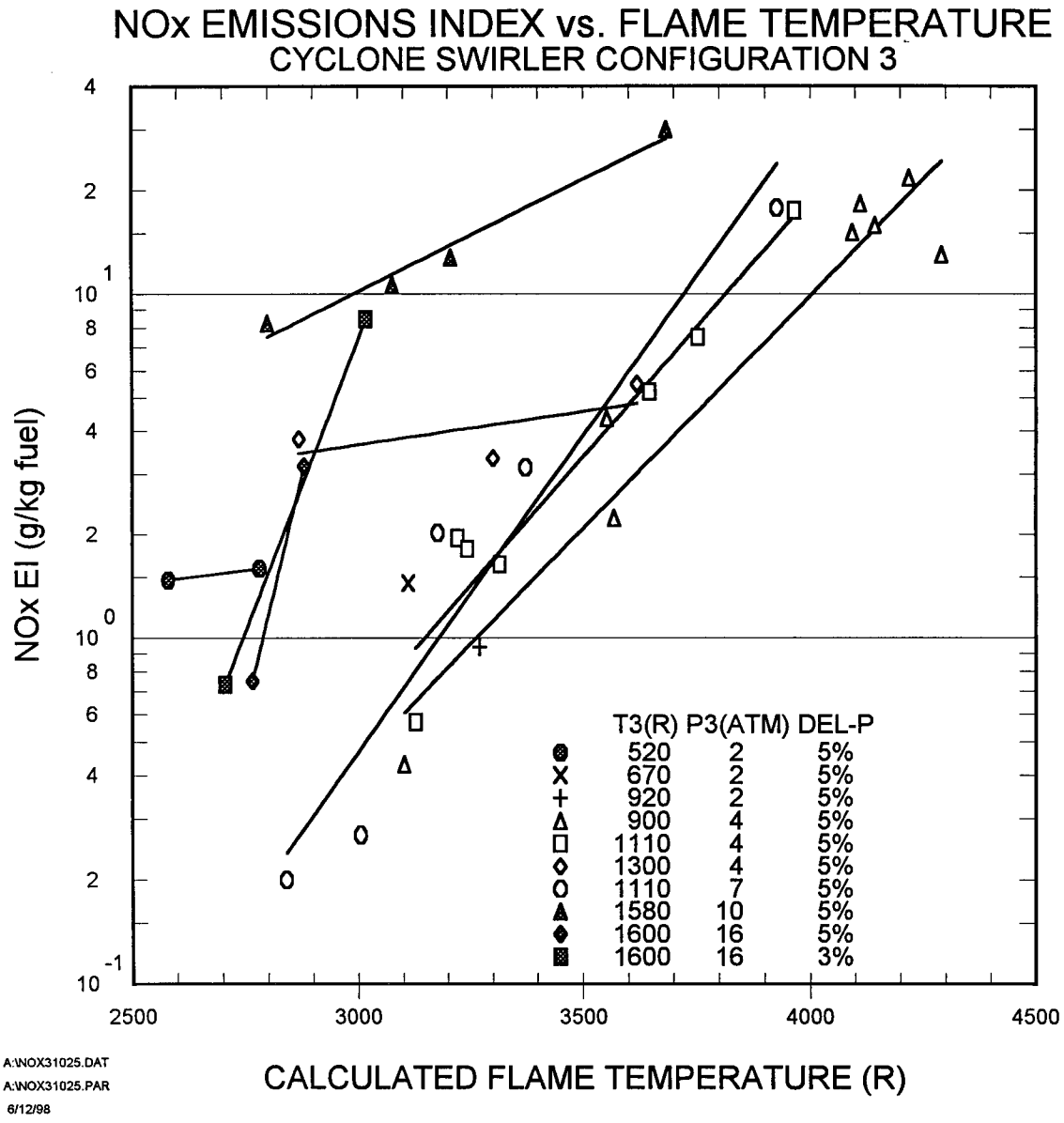


Figure 3.38 - NOx emissions index plotted versus flame temperature for Configuration 3 of the Cyclone Swirler.

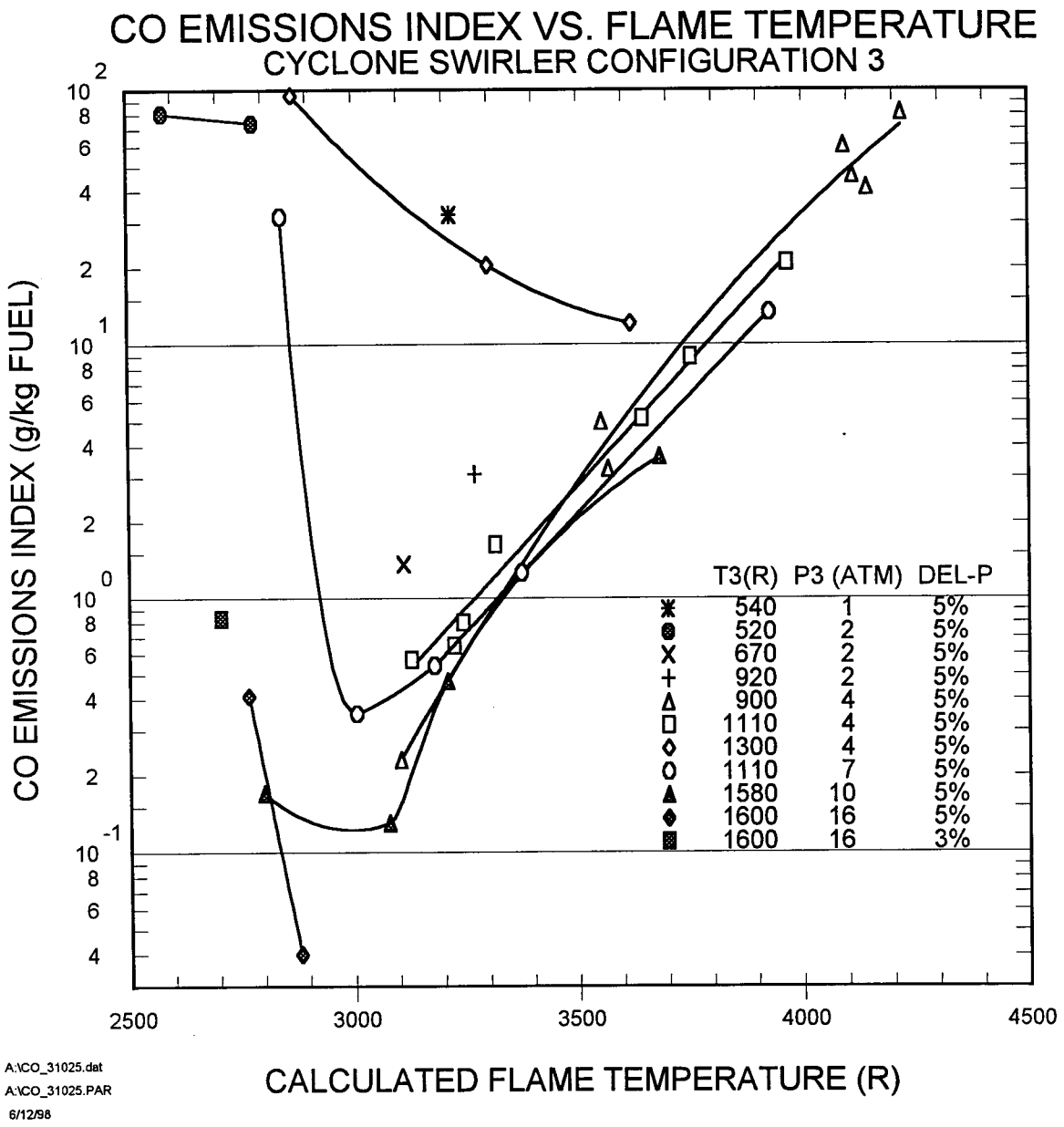


Figure 3.39 - CO emissions index plotted versus flame temperature for Configuration 3 of the Cyclone Swirler.

velocities between the unvaporized fuel and the air improves with larger drop sizes. There are also a number of mechanisms by which the droplets can be further atomized in the cyclone. These mechanisms could blanket the effect of reducing the atomizing air flow rate to the nozzles.

Figure 3.40 shows that the NOx emissions for a repeat of the baseline test of Configuration 3. This test was repeated in preparation for the test of Configuration 4, because test Configuration 4 test was to be performed in another test cell. The NOx emissions in Figure 3.40 are in good agreement with the NOx emissions in Figure 3.38, indicating there was no effect in switching test cells.

The NOx emissions for Configuration 4 are plotted in Figure 3.41 and compared to the average of the two plots in Figure 3.40 (Figure 3.41 would be too cluttered if both curves in Figure 3.40 were shown. The similar emissions performance of Configurations 3 and 4 is evidence that the Cyclone Swirler itself atomizes the fuel. This is consistent with the drop size measurements made at GE CR&D for the Configuration 2 fuel nozzle, with and without the Cyclone Swirler. The CR&D results are reported in Section 2.

The follow-on efforts in the Cyclone Swirler pilot development were performed in LET Task 43. Those results are reported in the Final Report for LET Task 43 [3-2].

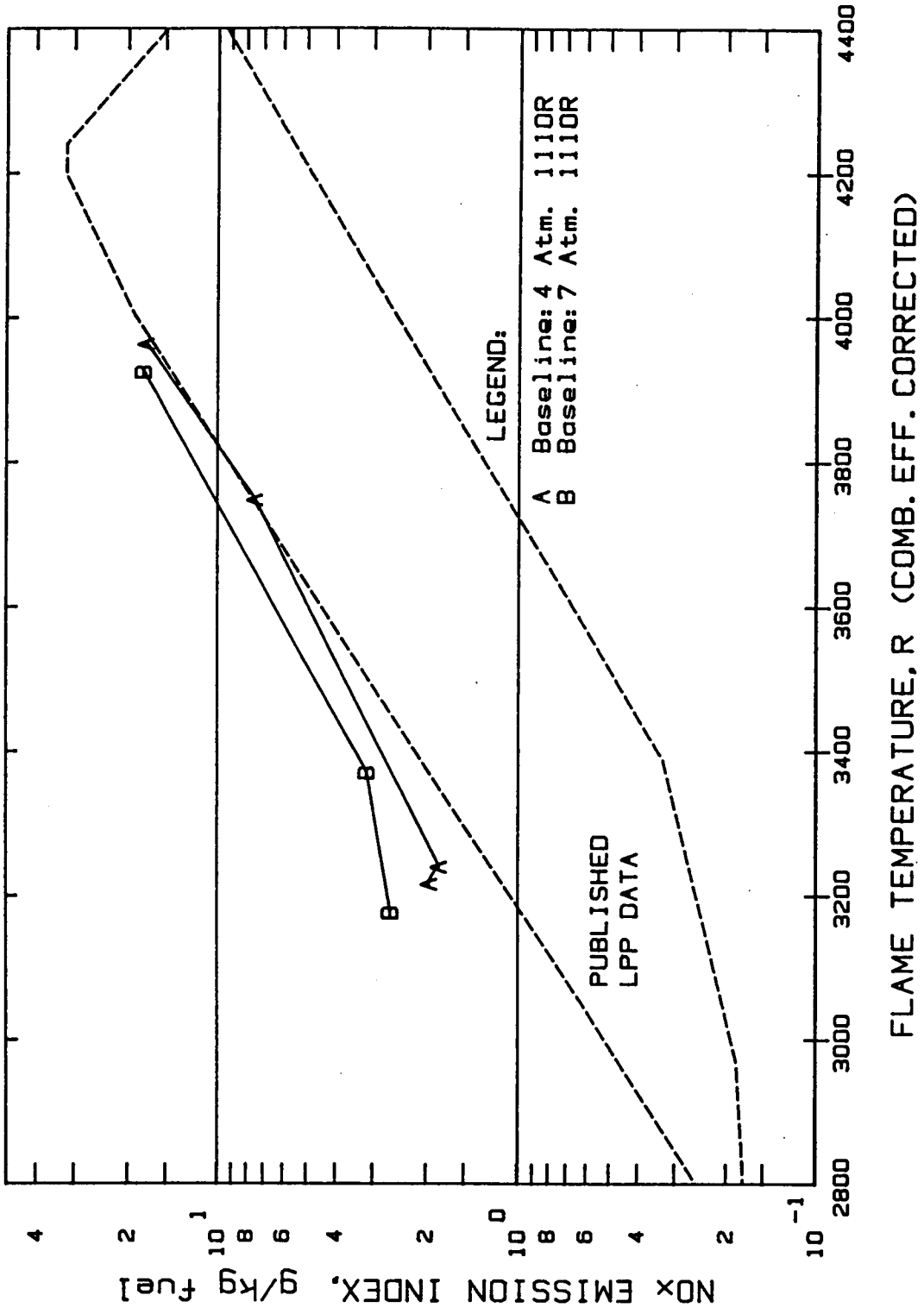


Figure 3.40 - NOx emissions index plotted versus flame temperature for Configuration 3 of the Cyclone Swirler. These were obtained in a different cell than those in Figure 3.38. The dashed boundary indicates the envelope of LPP NOx emissions obtained in several laboratory flame tube studies published in the open literature.

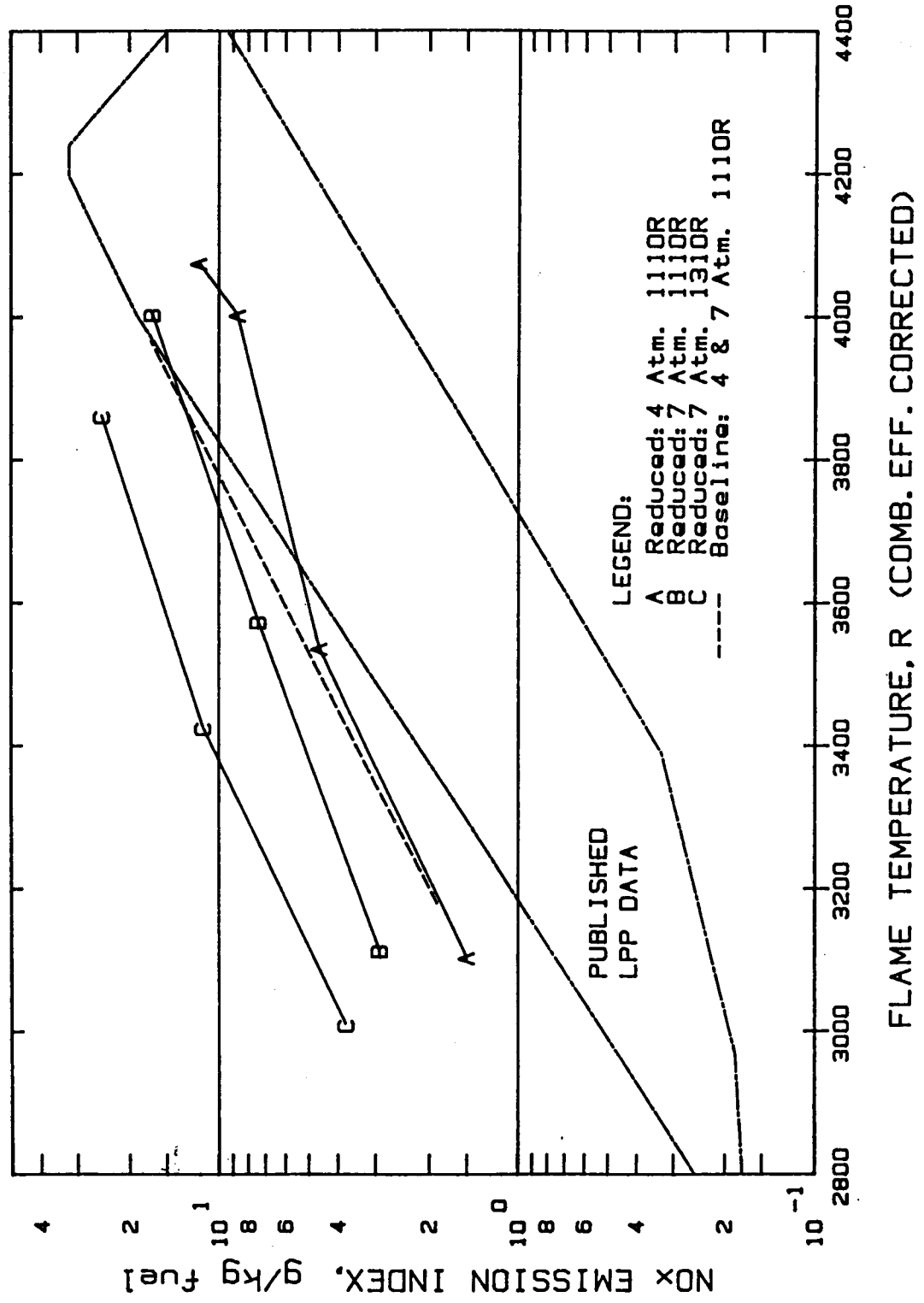


Figure 3.41 - NOx emissions index plotted versus flame temperature for Configuration 4 of the Cyclone Swirler. The average of the Configuration 3 NOx emissions results obtained at the two inlet conditions in Figure 3.40 are shown for reference. The dashed boundary indicates the envelope of LPP NOx emissions obtained in several laboratory flame tube studies published in the open literature.

3.5 Swirl-Jet Premixer Evaluations

The Gen I Swirl-Jet premixer was designed and evaluated under Task 5 of the APT Program, NASA Contract NAS3-25951. The principle advantage of the design was that it had a very large effective flow area even when compared to swirlers for conventional diffusion flame combustors. Having a larger than normal swirler size is not unreasonable, since the HSCT combustor is several times as large as a conventional combustor in a large subsonic jet engine. With the large Swirl-Jet premixer, the number of premixers required for a full size HSCT combustor could be kept comparable to the number of swirlers in a conventional combustor. Because the Swirl-Jet was physically large, the tolerances for locating the fuel nozzles could also be larger. As will be discussed in Section 6 of this report, these factors allowed somewhat conventional fuel systems to be considered. However, the emissions performance of the Gen I Swirl-Jet was poor.

Because of the potential advantages of the Swirl-Jet concept, the decision was made to evaluate a second generation of Swirl-Jet designs in LET Task 10. Gen II would be smaller and simpler than Gen I. The Gen II design had some similarity to a large IMFH with a swirler at the inlet. The swirl was to be kept low, and like the Gen I Swirl-Jet, an axial jet, either swirled or non-swirled, would be used instead of a center-body to counteract the tendency for a recirculation zone to form within the premixer. Several configurations of the Gen II Swirl-Jet were planned. All of those configurations had an internal diameter of the tube of 1.25 inches. The design effective flow areas and the premixer length of all the designs yielded a bulk residence time of about 0.7 milliseconds (roughly equal to that of the IMFH).

Figure 3.42 shows a cross-section of Configuration 1 of the Gen II Swirl-Jet. It utilized an axial swirler and air-blast fuel atomizer. In Configuration 1, the center jet was swirled. The first test of Configuration 1 was at atmospheric pressure. The test focused on establishing lean blowout limits and visual examination of combustion flame quality. The lean blowout data are plotted versus inlet temperature in Figure 3.43 and compared to the required lean blowout for a combustor system design over a range of engine operating conditions. The results were

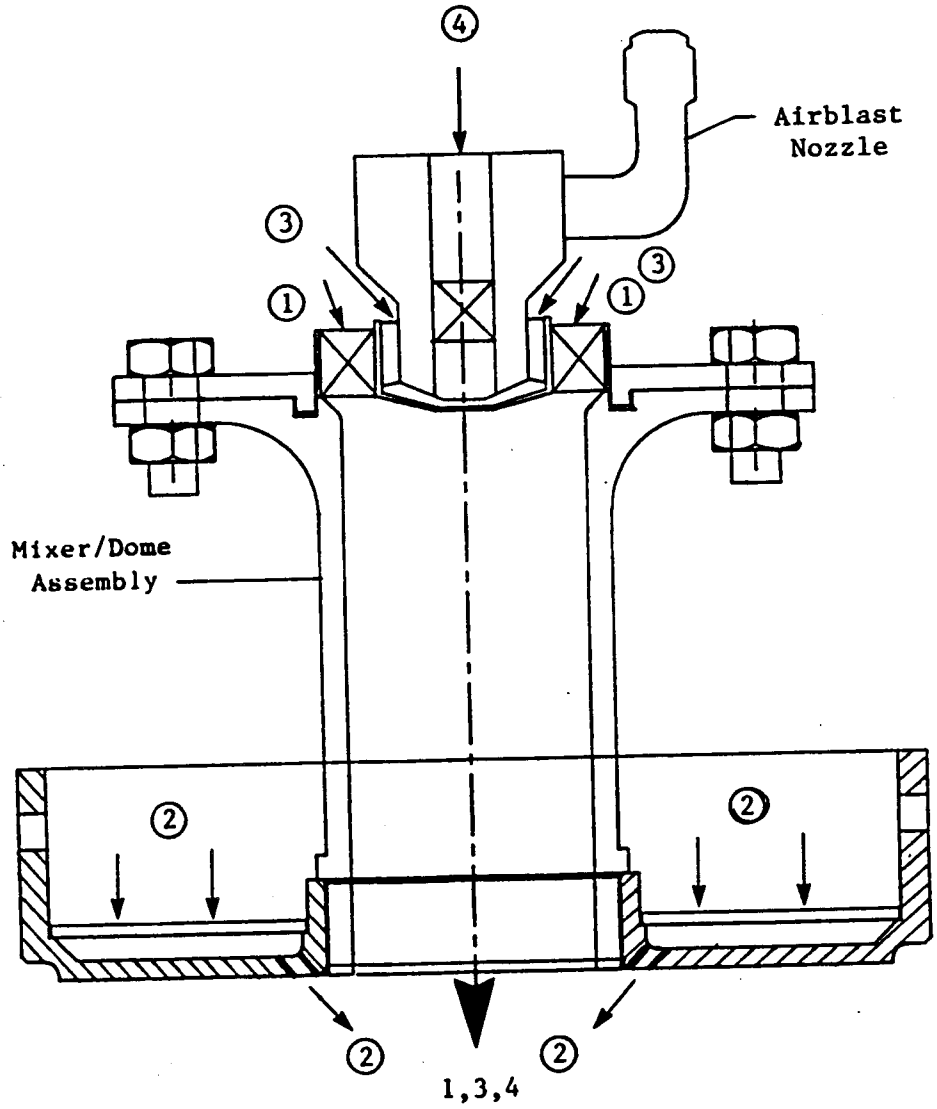


Figure 3.42 - Configuration 1 of Swirl-Jet Gen II fuel-air mixer subcomponent test hardware. The internal diameter of the tube is 1.25 inches. An axial swirler is used. The fuel is injected with an air-blast atomizer. The numbered passages are as follows: (1) the primary air swirler (axial), (2) the dome cooling air in (baffle) and out (spent cooling holes), (3) airblast nozzle air, and (4) center swirler of airblast nozzle.

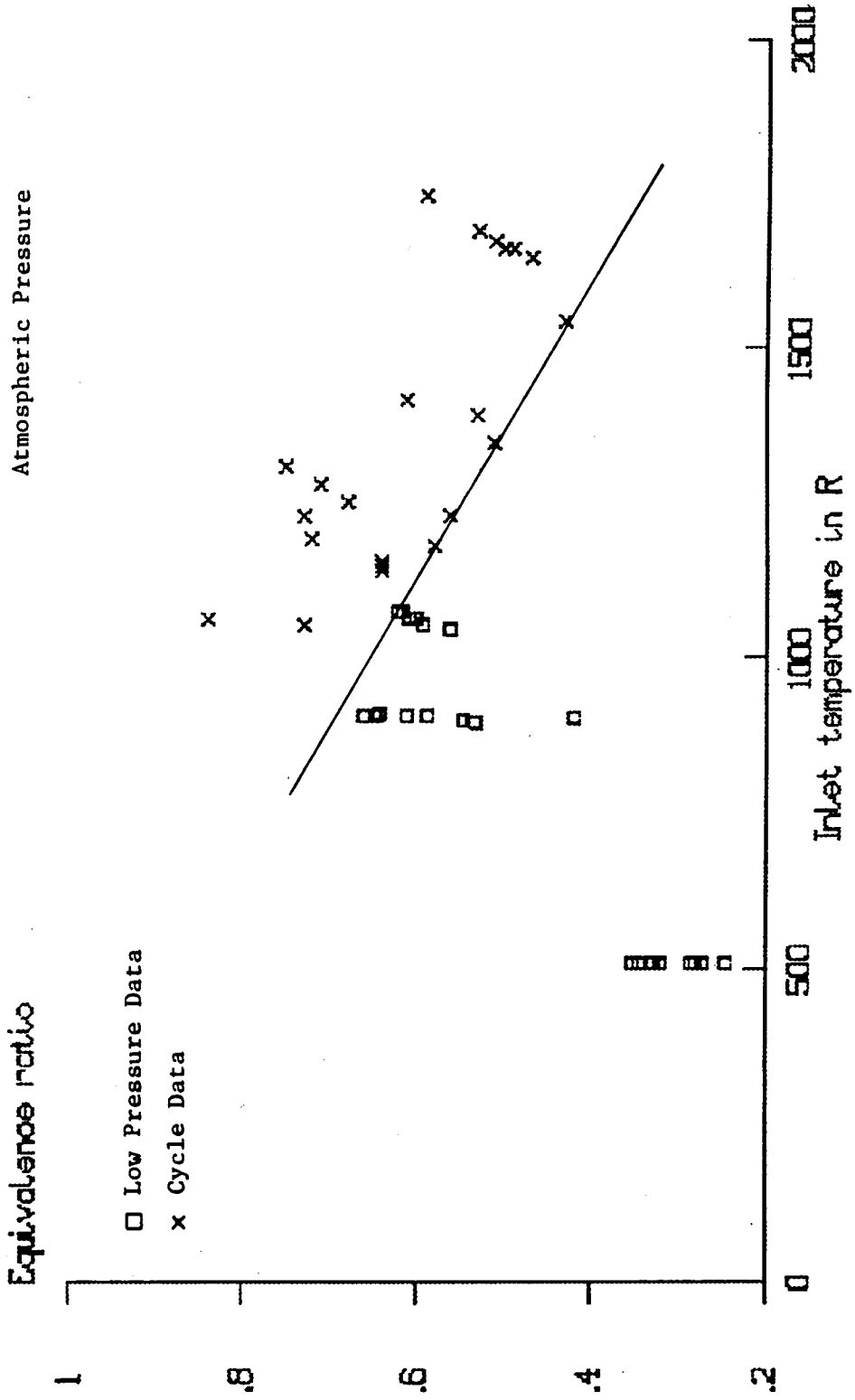


Figure 3.43 - Swirl-Jet Gen II lean blow out equivalence ratio's (squares) plotted versus inlet temperature for Configuration 1 of the Gen II Swirl-Jet. The X's denote where the Swirl-Jet would operate over a mission in an actual engine.

promising, especially considering the flame gases from the pilot stage might enhance the stability of the Swirl-Jet. A four-atmosphere test was then performed to obtain emissions data. The NOx emissions results are summarized in Figures 3.44. The NOx EI values at flame temperatures around 3600 R were at best, a little greater than 5 g/kg, which is about double the IMFH Configuration 5A. The higher NOx values were attributed to inadequate prevaporization and premixing due to large droplet sizes from the air-blast atomizer. The Swirl-Jet Configuration 1 inefficiency results are compared to IMFH Configurations 5A and 5B inefficiency results in Figure 3.45. The Swirl-Jet combustion efficiencies were only fair, by comparison.

Configuration 2 of the Gen II Swirl-Jet used Configuration 1's air-blast fuel injector, but with the center axial swirler removed. An orifice plate was used to provide blockage similar to the center swirler that was removed from the air-blast nozzle. Figure 3.46 shows that the NOx emissions are still roughly double the IMFH Configuration 5A. The CO emissions and inefficiency data are plotted in Figures 3.47 and 3.48. The efficiency results are similar to Configuration 1 of the Swirl-Jet and averaged over the flame temperature range about as good as the IMFH Configuration 5A. Figure 3.49 compares the lean blowout characteristics of Configuration 1 and Configuration 2. Operating conditions in a combustor system design for key mission conditions for the A5B MFTF cycle are also shown. These results show that Configuration 1 had better stability characteristics than Configuration 2. It was concluded that elimination of the center swirler did not have a significant impact on NOx and only served to narrow the range of flame temperatures at which the device could operate efficiently.

Configuration 3 used a radial swirler at the inlet with a relatively low swirl instead of the axial swirler. A cross-section is shown in Figure 3.50. An axial jet was used to prevent recirculation. An atmospheric test was conducted. As shown in Figure 3.51, lean blowout equivalence ratio decreased as the inlet temperature increased. At low inlet temperatures, the air-blast fuel nozzle in Configurations 1 and 2 had a lower lean blowout limit; however at inlet temperatures above 800 R, the lean blowout limits were similar. Examination of the test video tape showed a yellow swirling flame that indicated the premixer was not vaporizing and mixing the fuel before combustion. This was probably due to the coaxial air jet around the fuel nozzle

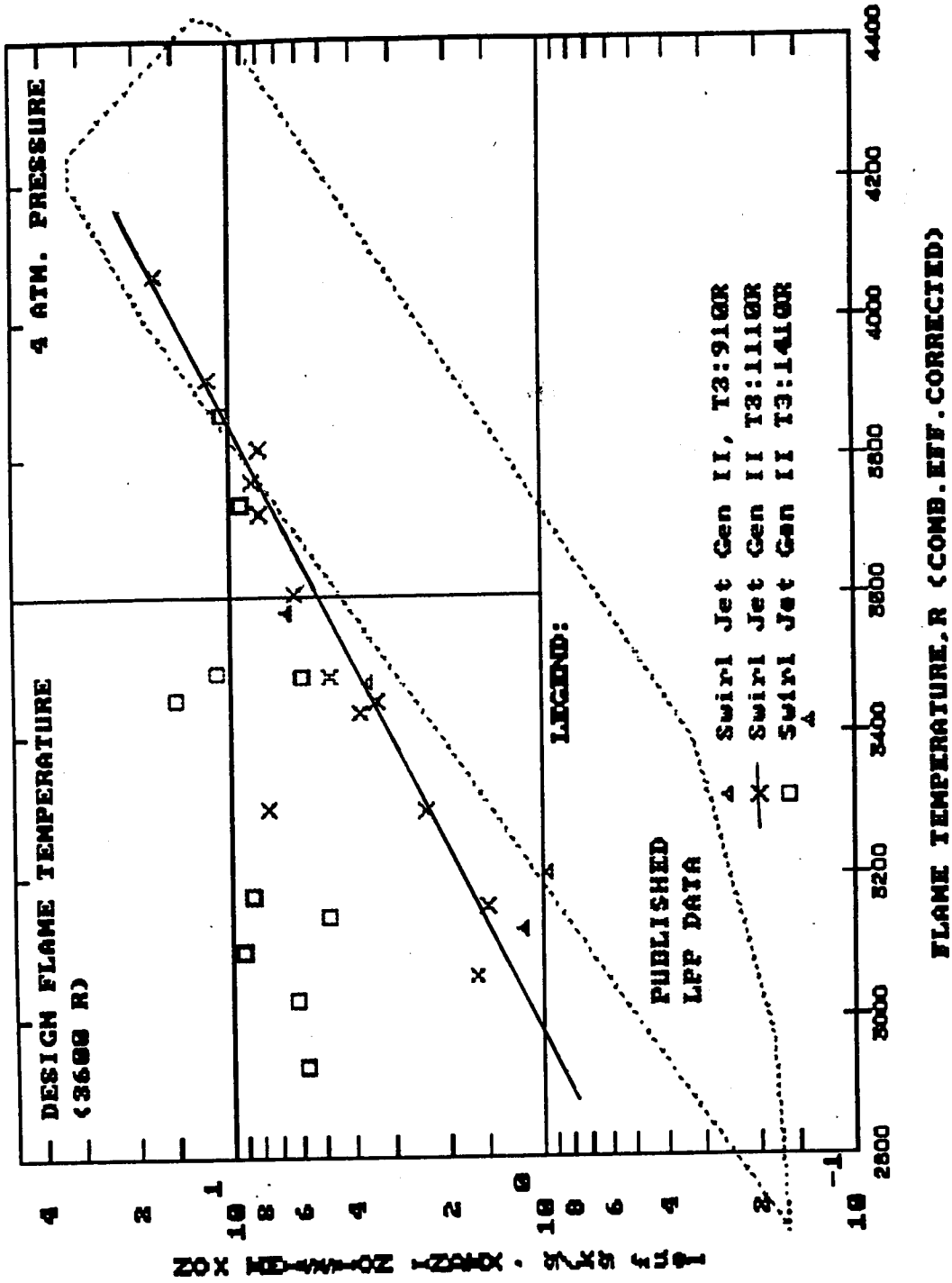


Figure 3.44 - NOx Emissions Index for Configuration 1 of the Swirl-Jet Gen II plotted versus flame temperature. The dotted line boundary indicates the envelope of LPP NOx emissions obtained in several laboratory flame tube studies published in the open literature.

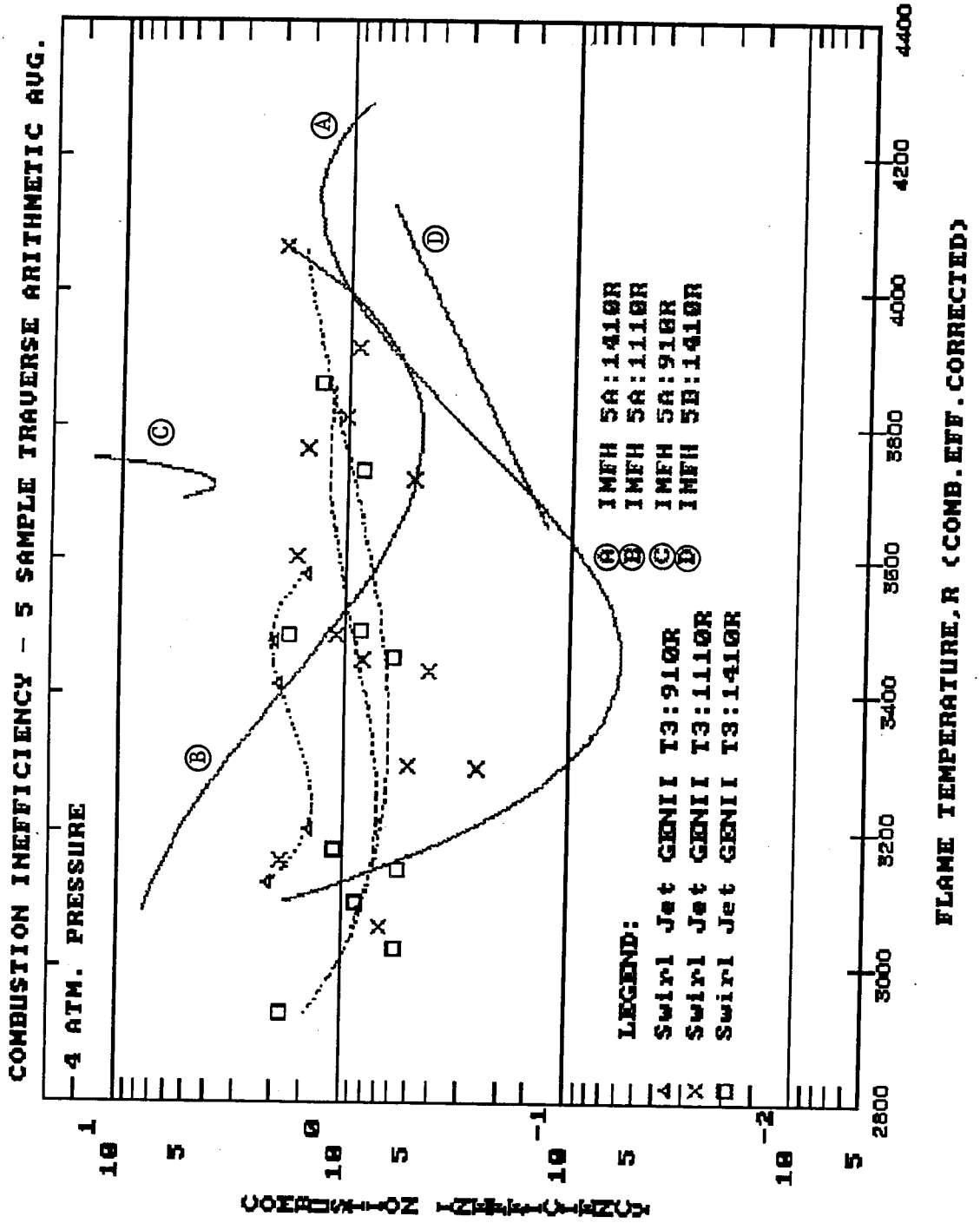


Figure 3.45 - CO Emissions Index for Configuration 1 of the Swirl-Jet Gen II plotted versus flame temperature.

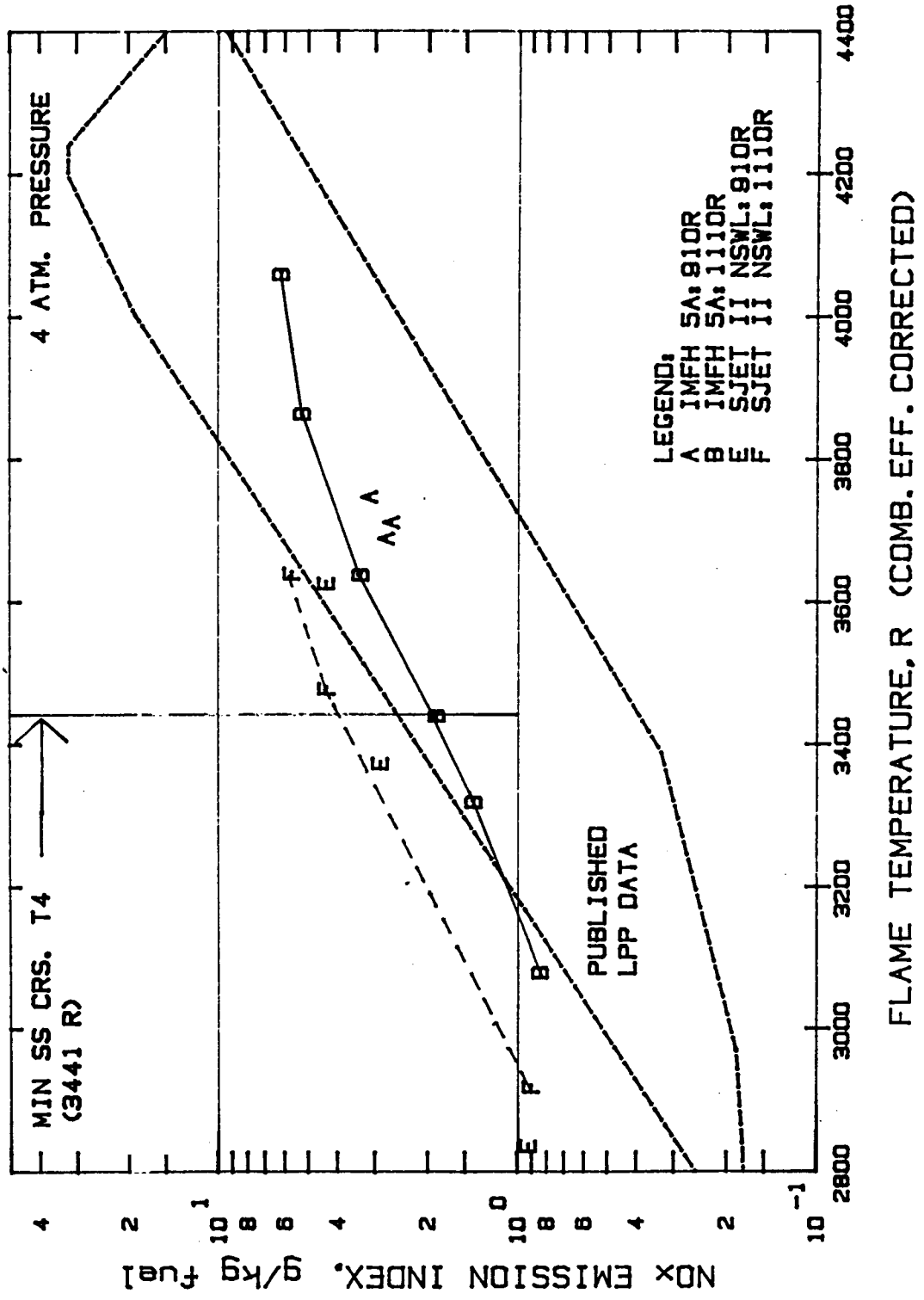


Figure 3.46 - NOx Emissions Index for Configuration 2 of the Swirl-Jet Gen II plotted versus flame temperature. The dotted line boundary indicates the envelope of LPP NOx emissions obtained in several laboratory flame tube studies published in the open literature.

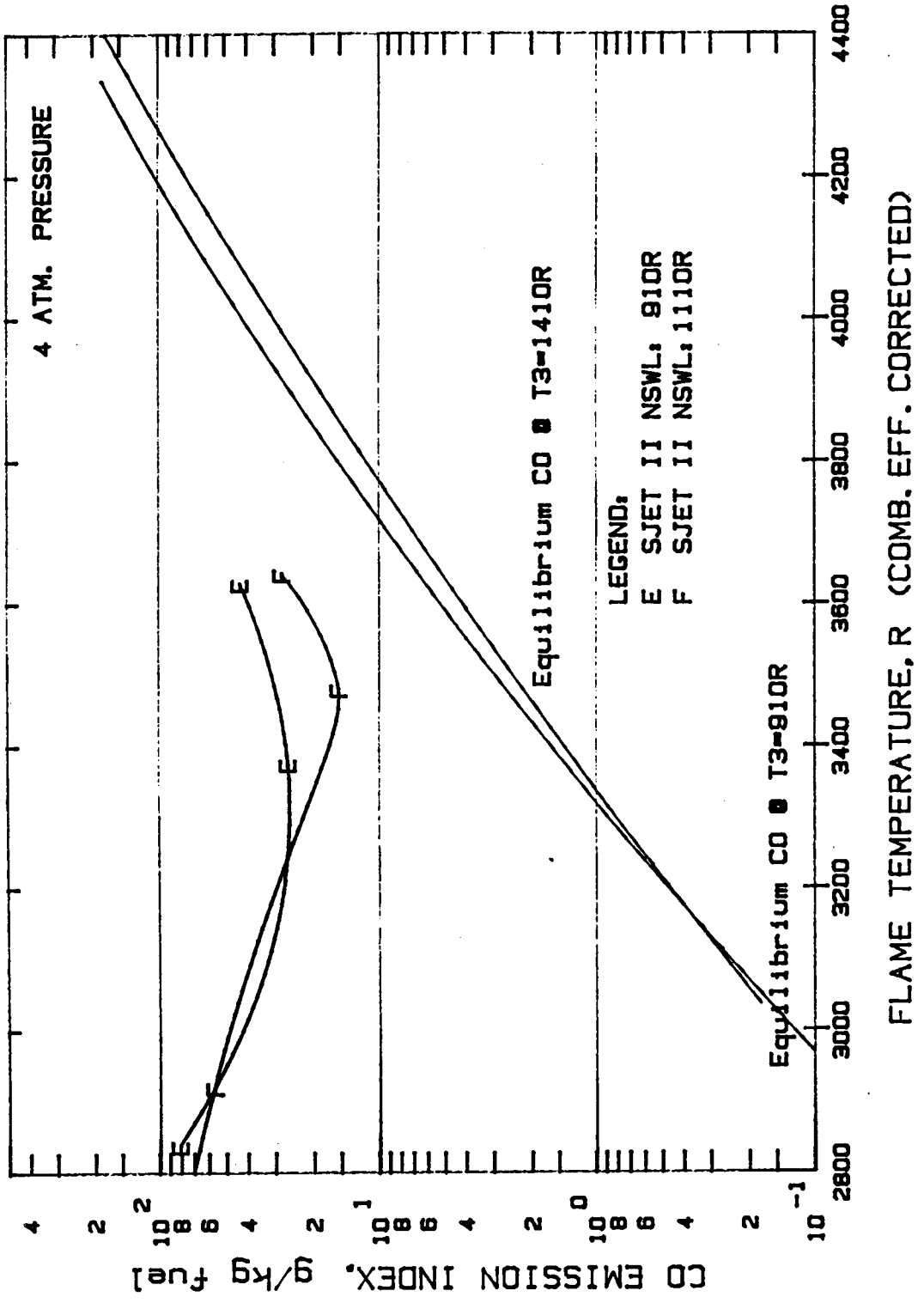


Figure 3.47 - CO Emissions Index for Configuration 2 of the Swirl-Jet Gen II plotted versus flame temperature. The calculated CO equilibrium line at 60 psia with 1410 R inlet temperature is shown for reference.

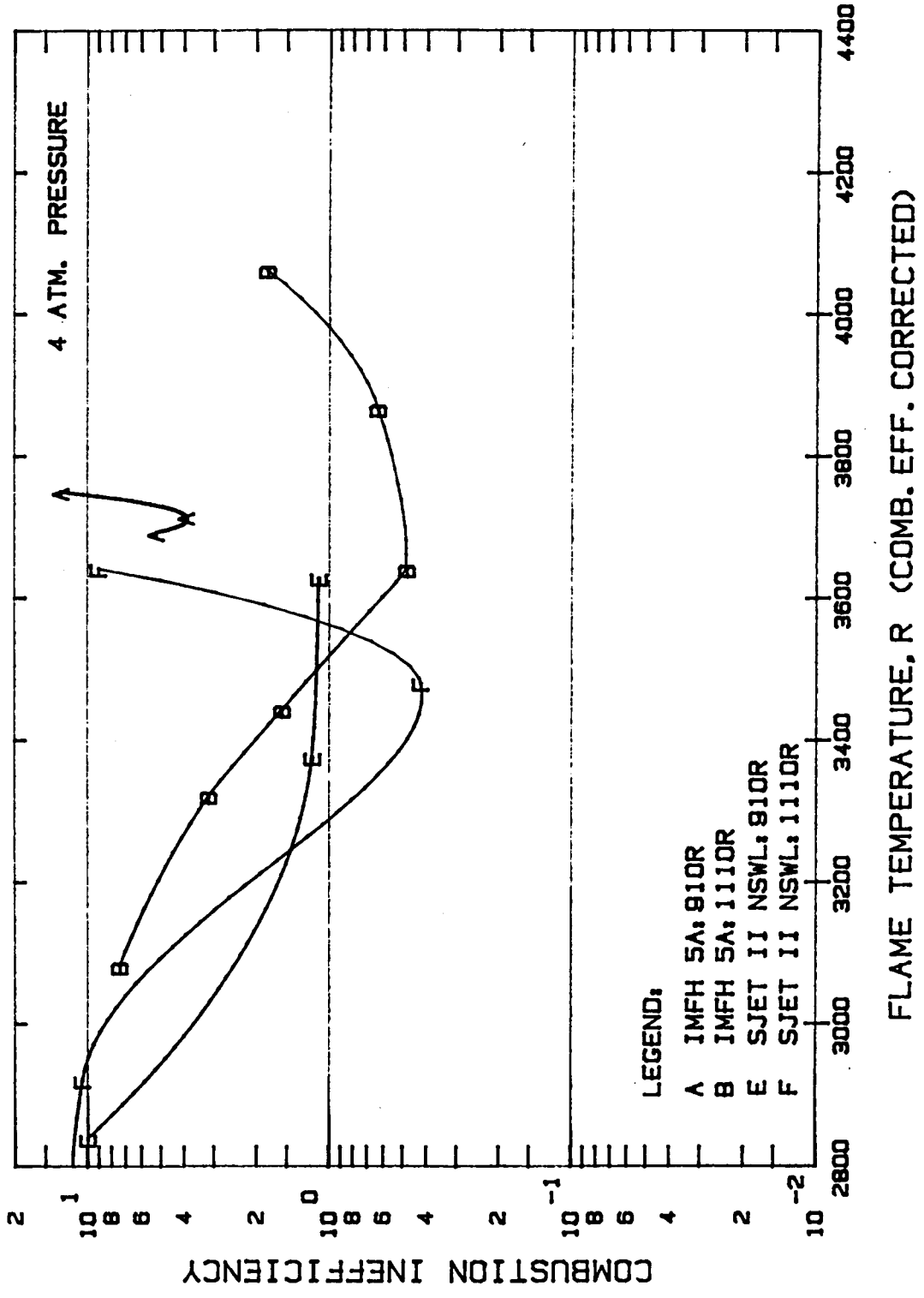


Figure 3.48 - Combustion inefficiency for Configuration 2 of the Swirl-Jet Gen II plotted versus flame temperature.

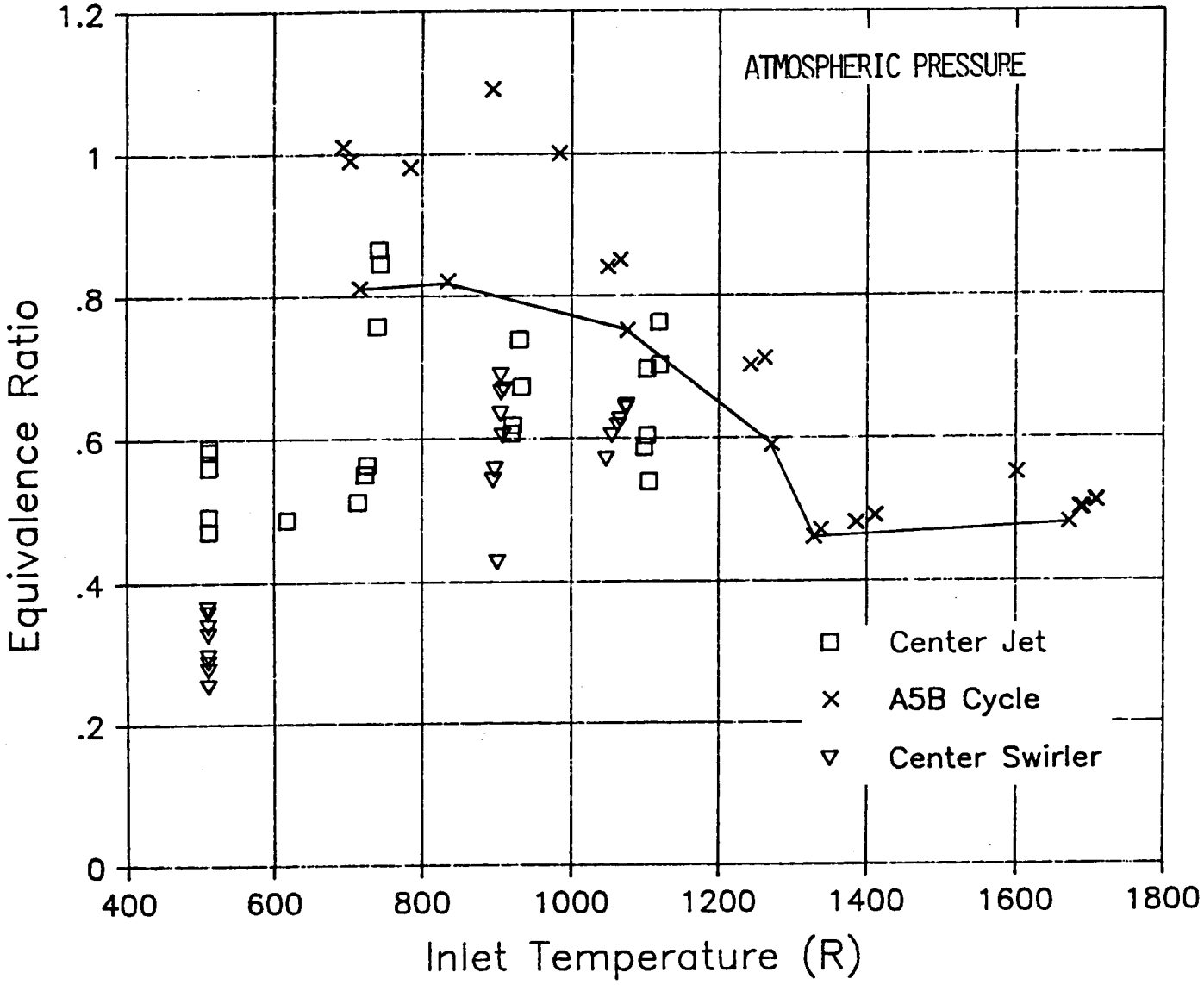


Figure 3.49 - Lean blow out equivalence ratio plotted versus inlet temperature of Configuration 1 (Center Swirler) and Configuration 2 (Center Jet) of the Swirl-Jet Gen II. Combustor conditions during the mission of the A5B cycle are shown for comparison.

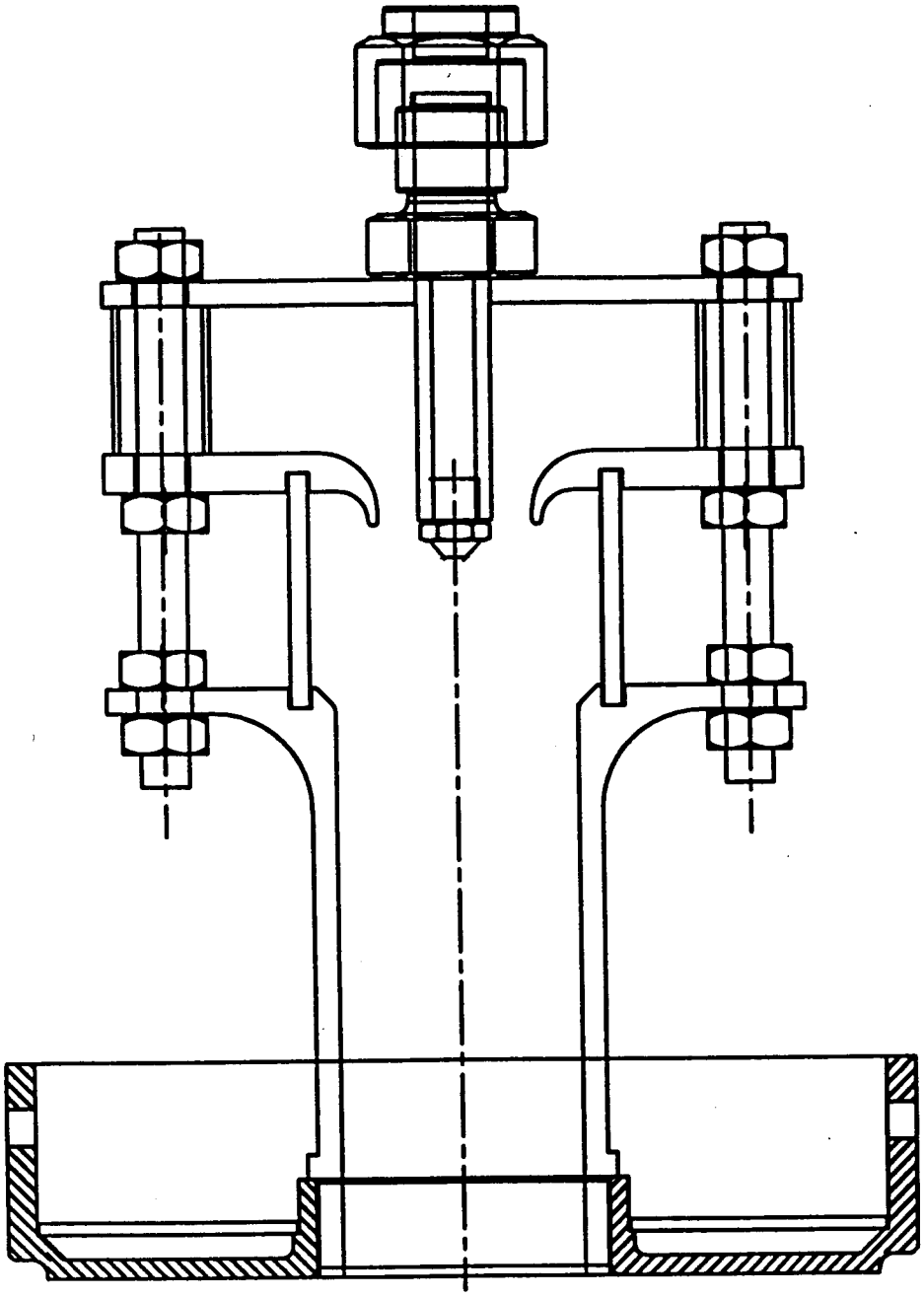


Figure 3.50 - Swirl-Jet Gen II, Configuration 3, single-cup test hardware. A radial swirler is used instead of an axial swirler. The fuel in injected with a simplex atomizer within a concentric air jet. The concentric air jet has a contoured inlet. The spent cooling air holes are not shown, but they are in the same location as are shown in Figure 3.42

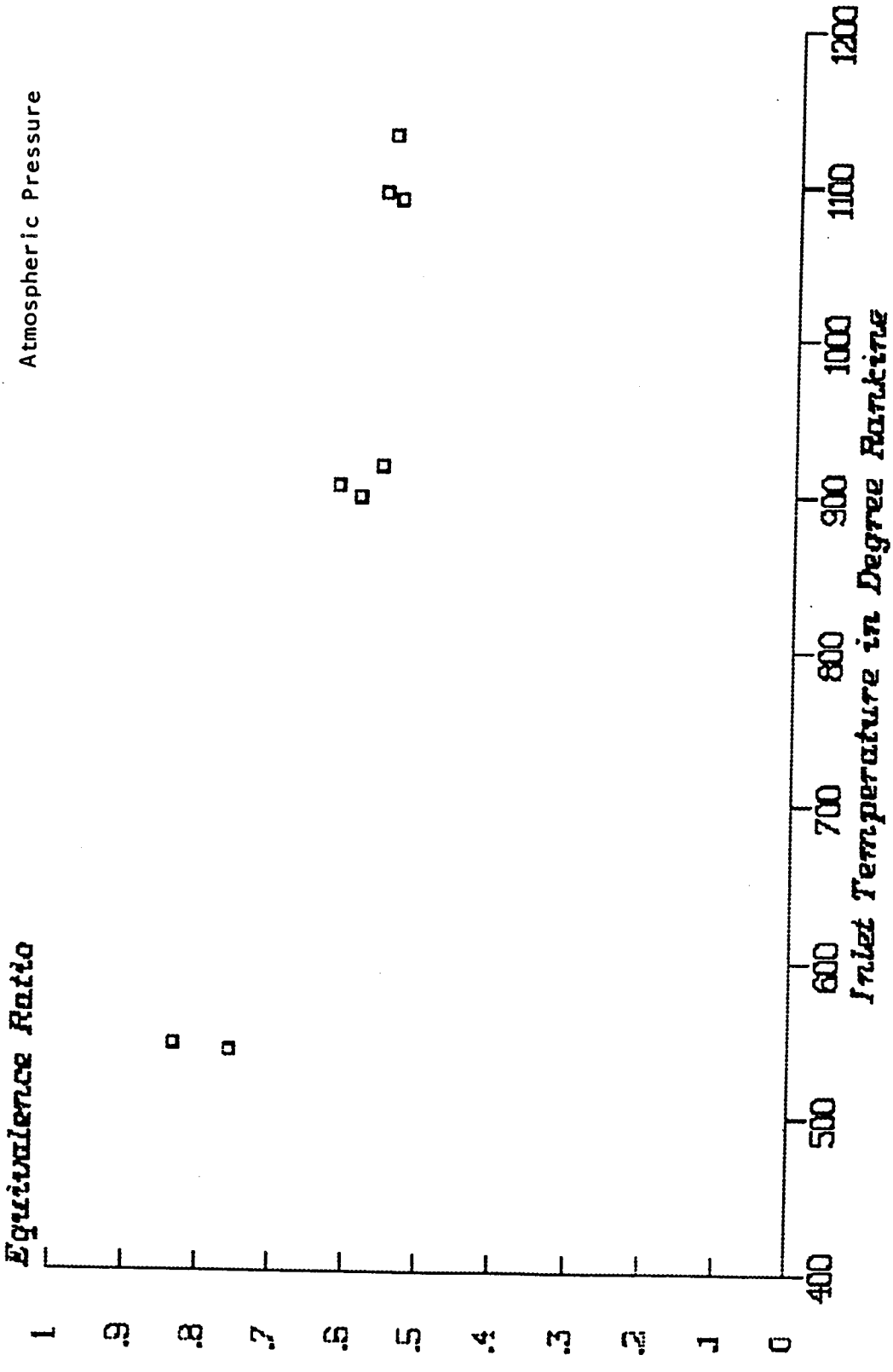


Figure 3.51 - Lean blow out equivalence ratio plotted versus inlet temperature of Configuration 3 of the Swirl-Jet Gen II.

carrying the fuel into the combustor before the droplets had time to vaporize. The initial results of these tests of Configurations 1, 2 and 3 of the Gen II Swirl-Jet were judged not very promising. The development of the Gen II Swirl-Jet was discontinued.

However, as the final part of this test series, a Configuration 4 was assembled using the available Gen II Swirl-Jet hardware. Configuration 4 used no swirler and was, in reality, a short IMFH with a concentric simplex fuel nozzle at the inlet of the tube. An atmospheric pressure test was run. The flame was about 2 feet long and was not firmly anchored to the dome. Based upon the observations in this test, the fuel almost certainly was not well mixed across the tube but was concentrated at the centerline.

3.6 Summary of Subcomponent Evaluations

Based on the results of the subcomponent testing in LET Task 10, the IMFH tube and Cyclone Swirler pilot mixer concepts were selected as the primary mixer concepts for future subscale sector combustor evaluations, confirming the conclusions of APT Task 5. The IMFH tube concept was selected for the main combustor stage. The Cyclone Swirler was selected for use in the pilot stage of the combustor. The other fuel-air mixer concepts (with the exception of the Multi-Venturi, an LDI concept [Lean-Direct-Injection] being tested at NASA-Lewis) were dropped from consideration for the subscale sector combustor tests because they did not meet the emissions performance requirements and/or stability requirements or, in the case of the curved tube IMFH, were inclined to flashback.

Section 4

Sector Combustor Design and Evaluation

Four tests of sector combustors were planned at GE Aircraft Engines in LET Task 10. The baseline hardware configuration was the sector combustor designed and fabricated in Task 5 of NASA Contract NAS3-25951. The sector combustor hardware is described in more detail in the final report for Task 5 [3-1]. A rectangular sector was chosen for the design rather than a sector of an annulus, in order to minimize costs and meet the schedule. The added design details (like the flowpath radii) of the curved sector would have been contrived, since the specific subscale demonstration engine had not been determined at the time the sector combustors basic layout had to be frozen.

The rectangular sector combustor's dome was divided into three sections; one central pilot dome, with five cyclone swirler pilots, and two main domes, each with 24 IMFH tubes. Each main dome had 4 separate fuel manifolds such that each manifold fueled six IMFH tubes. No isolation was provided between the four fueling regions on a main dome. This allowed evaluation of the effect of having no isolation between the fueled and unfueled IMFH stages. The length that the pilot dome was recessed relative to the main domes was adjustable, allowing evaluation of that design parameter. The liner and sidewalls were impingement and convectively cooled. No film cooling was used in the liners sidewalls in the baseline design. This was the conservative approach, since there was evidence in the open literature that LPP combustion suffered a significant penalty in combustion efficiency when film cooling is used. Not introducing film-cooling air into the combustor also simplified the interpretation of the emissions data, since all the air in the combustor flowed through one of the fuel-air premixers. Figure 4.1 shows the a sectional view of the rectangular sector combustor.

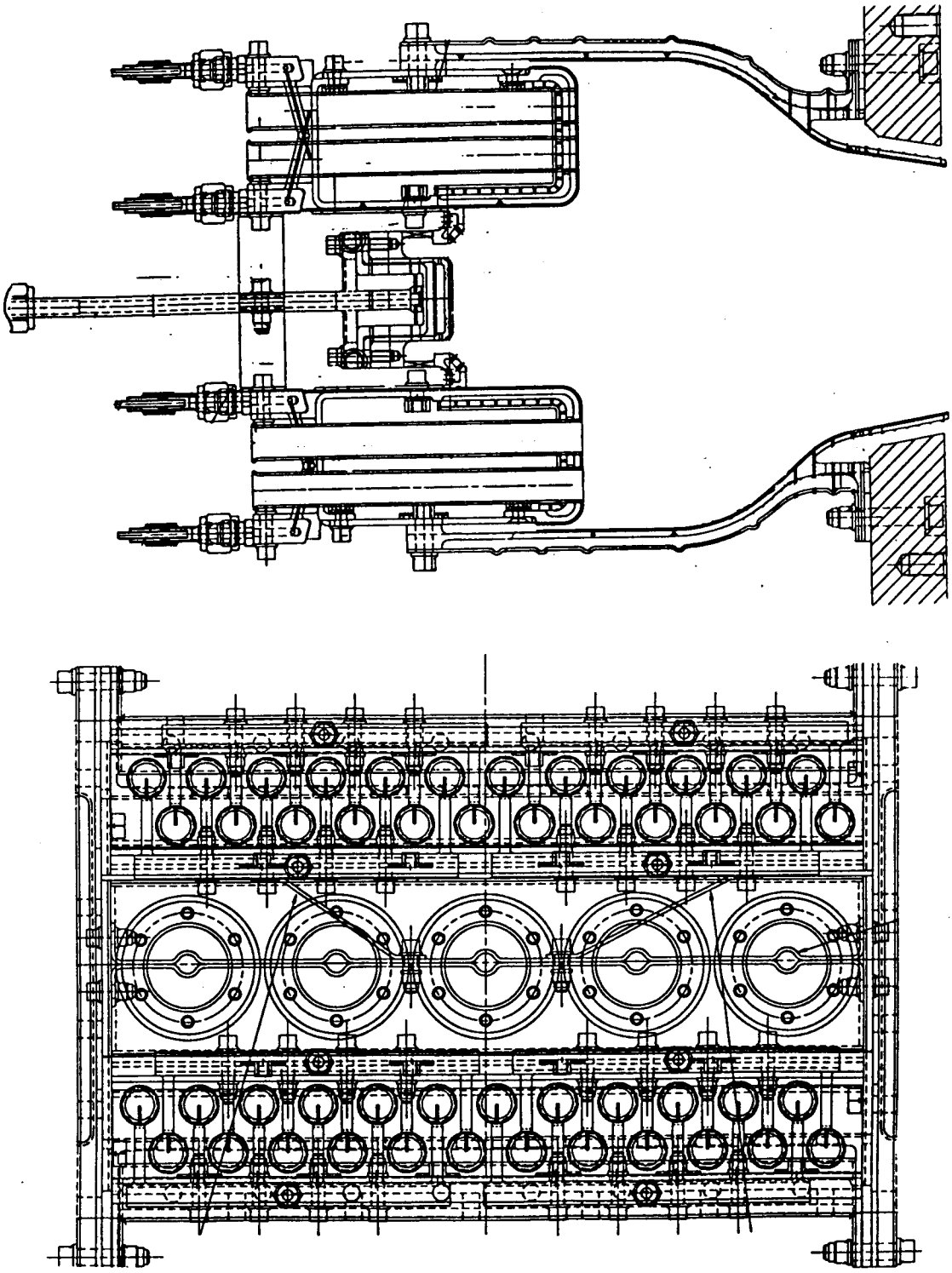


Figure 4.1 - Two views of the LPP rectangular sector combustor. The recessed center dome with the Cyclone Swirlers is the pilot stage. The two main domes with the IMFH tubes are the main stages. Each main dome has four separate fuel systems.

As a part of LET Task 10, a second rectangular sector combustor was designed and fabricated for testing at NASA-Lewis. The dome was a essentially identical to the 5-cup sector above, except that it had three Cyclone Swirler pilots on the central pilot dome and 14 IMFH tubes on each of the two main domes. The dome and the fuel injectors were supplied to NASA by GEAE. Instead of using convectively-cooled liners and sidewalls, the combustion zone walls were castable ceramic, similar to those used for single-cup tests at NASA-Lewis and GEAE. The 3-cup sector combustor would be used primarily for diagnostic studies.

At the time the planning was being done for the first tests of the HSCT 5-cup sector, there was no aero performance data on how the Cyclone Swirler pilot and the IMFH would operate together as a system. There were also a number of mechanical design and cooling design features in the sector combustor which were new and required evaluation. The preliminary list of requirements for the HSCT low emissions combustor (to be discussed in Section 6 of this report) led to a long list of test objectives. The highest priority test objectives were considered to be (in rough order of priority):

1. Establish that the combustor would operate.
2. Evaluation of emissions at inlet conditions comparable to the single-cup emissions data base for the Cyclone Swirler pilot and the IMFH. This would allow back-to-back comparisons of the effect of the installation of premixers in the combustor system.
3. Evaluation of emissions at Supersonic Cruise conditions. This is the primary metric for the HSCT low emissions combustor development program.
4. With maximum pilot stage isolation (maximum pilot recess), evaluation of CO emissions with one and both main domes turned off. This would establish with the largest recess, whether CO emissions would be acceptable during part staging.
5. With minimum pilot stage isolation (minimum pilot recess), evaluation of CO emissions and pilot stability with one and both main domes turned off

This would establish if the combustor can perform without isolation between the pilot and main stages. The isolation was believed to be mandatory for low CO emissions, but also is costly in terms added combustor complexity, weight, overall length, cooling air requirements, and fuel-system complexity.

6. Evaluation of main stage stability and CO emissions with adjacent rows of fired and unfired IMFH tubes. Isolation of IMFH main stages from each other raises the same issue of CO emissions performance versus design complexity as the pilot/main stage isolation.
7. Evaluation of the material temperatures and durability of the convectively cooled liners. At the time, there was very little experience with convectively-cooled liners at GEAE.
8. Evaluation of the effect of film-cooled liners (Lamilloy® liners supplied by Allison) on CO emissions.

The first objective may seem unwarranted, since the Cyclone Swirler pilot and IMFH had already been run in single-cup tests. However, some considered those tests inconclusive since the stability of the Cyclone Swirler and IMFH in the single-cup tests could have benefited from the hot castable ceramic walls used in the single-cup rigs. Also, there was a concern about stability during part-stage operation. Other possible objectives for the testing were also identified, but were considered to have a lower priority.

Emissions data from the sector combustor evaluations continue to be plotted versus fired dome flame temperature, as they were with the sub-component flametube results. Local flame temperature is the single most important parameter determining emissions from LPP combustors. The emissions data, thus presented, can easily be interpreted for new engine cycles as they evolve using the corresponding combustor system design to calculate the local fuel-air ratios and flame temperatures.

4.1 Sector Test 1 - Pressure Test of Baseline Sector Combustor

The first sector combustor test began on October 29, 1993 and was completed on November 4. The goals of the test were to demonstrate stable operation of the combustor system and obtain emissions data at conditions the data could be compared to single-cup data. A secondary goal was to reach supersonic cruise conditions, if the test went well. Stable operation of the IMFH/Cyclone Swirler dome system was demonstrated for inlet temperatures up to 1405 R (945° F), inlet pressures up to 8 atmospheres, and pressure drops ranging from 2.9% to 4.0%. Stable operation of the combustor was demonstrated with the pilot only operating at combustor conditions roughly corresponding to engine idle, an inlet temperature of 872 R (412° F) and inlet pressure of 47 psia. The test was terminated when inspection showed 13 of the 48 fuel injector tips had been clipped off by interference with the IMFH tube walls. The differential thermal expansion of the dome parts was greater than could be accommodated by the clearance hole in the walls of the IMFH tubes. The fuel from the clipped off fuel injectors apparently still went into the IMFH tubes or catastrophic damage would have occurred. The simple solution was to enlarge the clearance holes in the IMFH tube walls. Post-test hardware inspection indicated that the dome cooling design appeared to perform as intended. Minor TBC spalling occurred on the sector side walls near the pilot and at the ends of the main domes. The aft end of the liners warped. However these problems were not unexpected. In the interest of cost and simplicity, the sector combustor design had not entirely eliminated all the potential locations for thermal fight. This design simplicity, combined with the flat panels and simple curvature of the hot structures in this rectangular design, were expected to lead to some degree of warping and cracking.

A summary of the nominal combustor inlet conditions at which the combustor was operated in this first sector test is given in Table 4.1. The measurements for the NOx emissions index in the first sector test are plotted in Figure 4.2. The highest measured NOx emissions at the highest inlet temperature (1405 R or 945° F) was 4.3 EI NOx at a flame temperature of 3490 R. This would extrapolate to a NOx EI of about 5 to 6 g/kg at a flame temperature of 3530 R, the supersonic cruise design point flame temperature at that time. Combustion efficiencies were

99.9% or higher when all the fuel stages were on at the highest inlet temperature of 945° F (1405 R). The sector combustor's NOx data were slightly higher than the IMFH single cup test data, but followed the same trend.

Non-uniform temperature profiles were investigated. Reduction in the pilot dome flame temperature by 180° F relative to the main dome flame temperature reduced the NOx emissions by about 20% from the trendline flame temperature data (point 31, Appendix A), which confirmed predictions that the Cyclone Swirler pilot stage contributed proportionally more NOx than the IMFH stages. Increasing the outer main dome flame temperature by 130 and 190° F relative to the inner main dome, raised NOx emissions slightly from the trendline (points 32 and 33, Appendix A). The non-uniform points are shown as the shaded diamonds and solid circles, respectively, in Figure 4.2.

The pre-test flow check of the hardware indicated that the pilot dome flow split of rectangular stepped-dome sector combustor was significantly higher (27%) than the HSCT combustor system designs at that time (which had about a 20% pilot flow split). All else equal, the HSCT combustor (or the subscale demo engine combustor) with the correct pilot stage flow split would have lower emissions than measured in the 5-cup rectangular sector combustor. Adjusting the NOx emissions data for the correct pilot stage flow split indicated the program goal of a NOx EI of 5 g/kg would be met.

Table 4.1
Sector Test 1 Combustor Inlet Conditions, Nominal

T3 [R]	P_{INLET} [psia]	ΔP/P	Fuel Stages
1130	74	3.5%	All
872	47	2.9%	Pilot
1070	78	3.5%	All
1228	86	3.4%	All
1410	120	3.8%	All

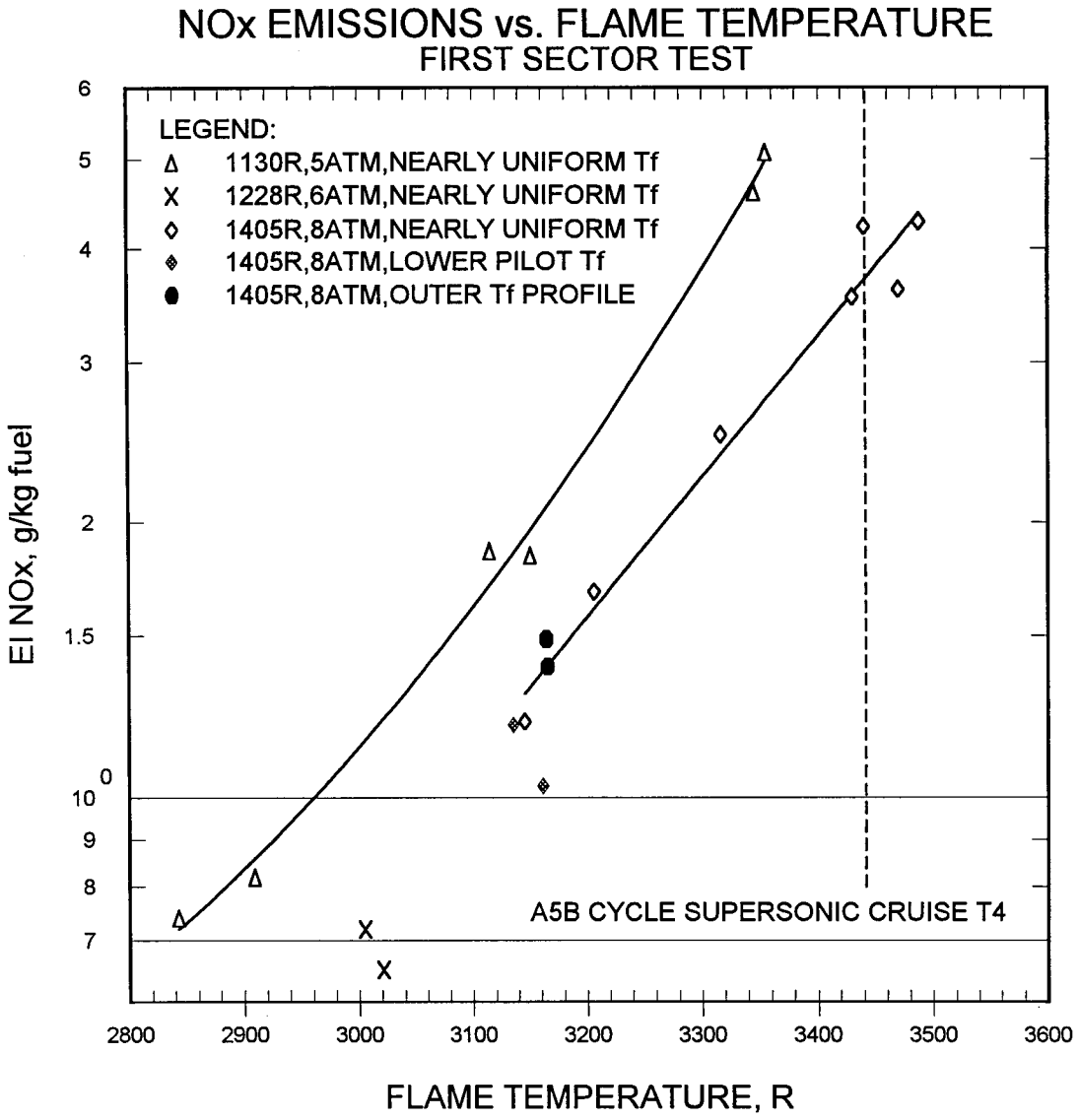


Figure 4.2 - NOx emissions index plotted versus flame temperature for the first rectangular sector test. All the fuel stages are fired. Flame temperature and combustor exit temperature are equivalent. Data from the first rectangular sector combustor test. The pilot flame temperatures reductions were 86° F and 183° F relative to the IMFH main stage (solid diamonds).

4.2 Sector Test 2 - Atmospheric Pressure Test of Baseline Sector

The second rectangular sector combustor test was performed at atmospheric pressure in the Advanced Combustor Laboratory at GEAE. The test began on April 6, 1994 and ended on April 8. The first day of the atmospheric pressure tests were run with the gas sampling rakes in place. The primary objectives were to obtain exit temperature profile factor results with the pilot stage only operating and to make visual observations of the combustion zone. The profiles were determined by gas sample analysis. The gas sampling rakes were then removed and LBO data obtained and visual observations made of the flame with different staging configurations.

The exit temperature profile factor is plotted in Figure 4.3. The profile factor is center-peaked, which is desirable. However, the peak value is higher than normal for a conventional turbine combustor, even if fuel-staged. The gas analyses used to obtain the sample fuel-air ratios also yielded emissions data. NOx and CO emissions at one atmosphere are not relevant to engine conditions so the data are not reproduced here.

The pilot stage lean blow out data is plotted in Figures 4.4. In Figure 4.5 the pilot stage lean blow out data is replotted along with single-cup Cyclone Swirler configuration 2 lean blow out data. Both sets of lean blow out data are very consistent over the inlet temperature range of 250° F to 600° F (710 R - 1060 R).

IMFH light-off and lean blow out equivalence ratios are plotted versus pilot equivalence ratios in Figure 4.6. The light-off data are labeled LO and the lean blow out data are labeled LBO. Light-off and lean blow out data were obtained for the inner (bottom) main dome when the outer (upper) main dome was fired and for the outer dome when the inner dome was not fired. There was little difference between the two sets of data. However, the pilot dome equivalence ration is seen to have a significant effect. Both the IMFH light-off and lean blow out equivalence ratios dropped with increased pilot dome equivalence ratio.

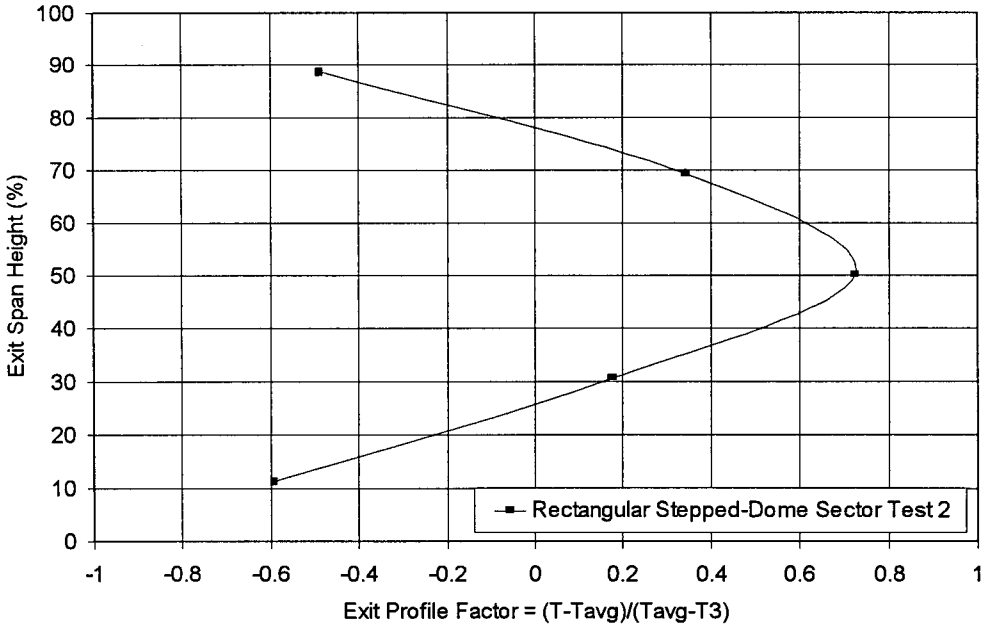


Figure 4.3 - Rectangular sector exit temperature profile factor with pilot stage only operating. Temperatures are calculated from analysis of gas samples. Atmospheric pressure. Inlet temperature was 861 R (402° F). Data from the second rectangular sector combustor test.

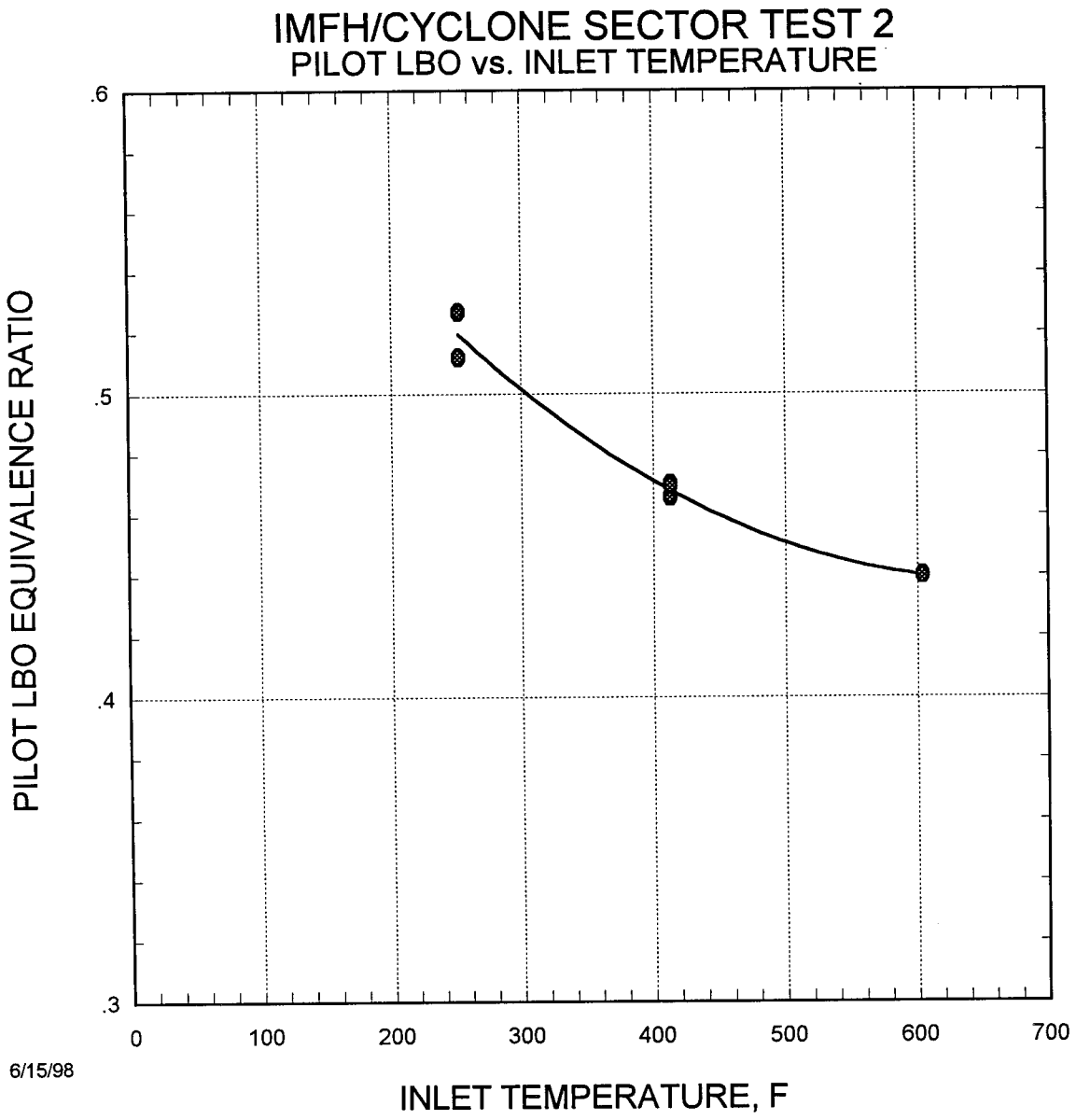


Figure 4.4 - Pilot lean blow out equivalence ratio plotted versus inlet temperature. Data from the second rectangular sector combustor test performed at atmospheric pressure.

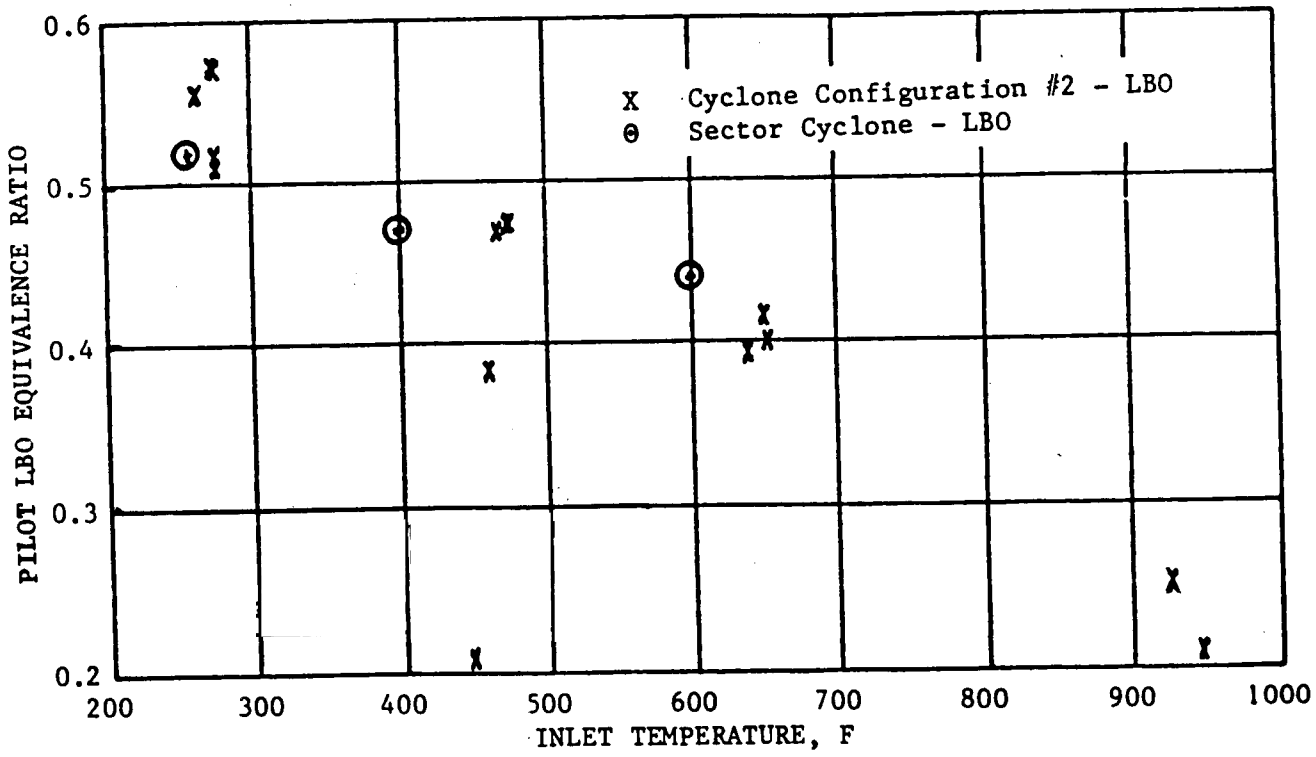


Figure 4.5 - Pilot lean blow out equivalence ratio plotted versus inlet temperature. Data from the second rectangular sector combustor test compared to single-cup data for Cyclone Swirler Configuration 2 obtained in APT Task 5 [3-1].

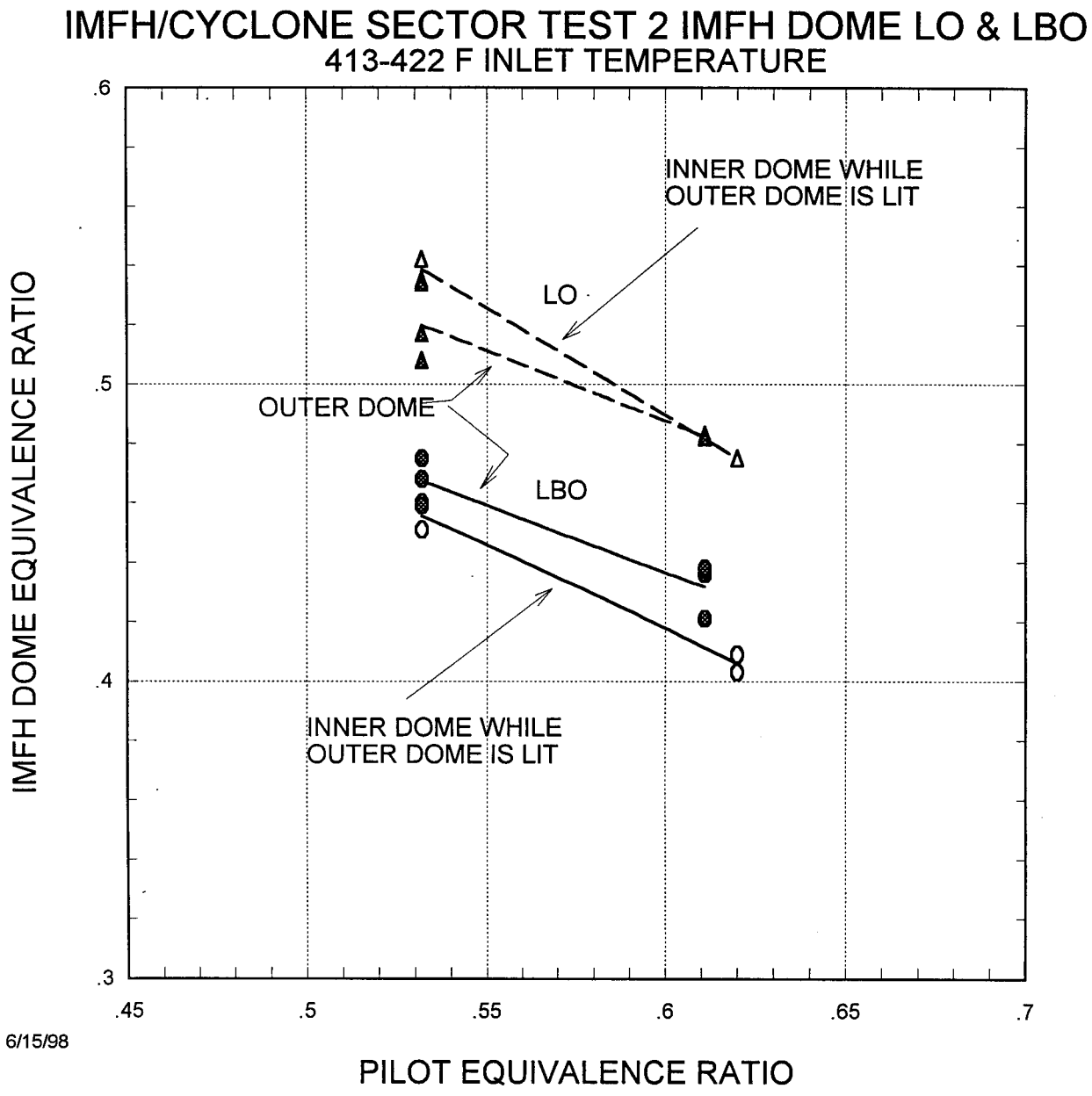


Figure 4.6 - IMFH light-off (labeled LO) and lean blow out (labeled LBO) equivalence ratio plotted versus pilot stage equivalence ratio. Data from the second rectangular sector combustor test performed at atmospheric pressure.

4.3 Sector Test 3 - Second Pressure Test of Baseline Sector Combustor

The third sector combustor test was run in GEAE's Cell A5 in June, 1994. The emphasis of the test was part-stage operation. With part stage operation, the sector combustor's NOx emissions are dominated by the Cyclone Swirler pilot stage, because the pilot is burning a greater proportion of the fuel. The NOx emissions during different staging configurations over a wide range of inlet conditions are shown in Figures 4.7 (with the pilot and outer dome fired), Figure 4.8 (with the pilot and the closest IMFH row in the outer dome fueled), and Figure 4.9 (with the pilot dome only fueled). The lowest NOx emissions are obtained with the pilot stage only fired. This is attributed to dilution of the pilot flame gases by the air from the unfired main stages. NOx emissions increase when one IMFH row is fired in addition to the pilot dome. This is attributed to the pilot being partially blanketed by the single row of fired IMFH tubes, so that the inherently higher NOx emissions of the Cyclone Swirler were not reduced by air entrainment or by large fractions of the fuel being burned by the IMFH. With the one IMFH row closest to pilot fired, the NOx emissions were the highest observed in the test. With that staging configuration, the NOx emissions increased with increasing inlet temperature. The trends with inlet temperature are consistent with the Cyclone Swirler single-cup test results in Section 3.

The same data are re-plotted in Figures 4.10 and 4.11 to clarify the effect of changes in staging configuration on NOx emissions at constant inlet conditions. In Figure 4.10, with an inlet temperature of 1410 R and a pressure of 8 atmospheres, turning on the last IMFH stages is shown to yield lower NOx emissions than with partial staging of the IMFH main domes. This is a result of the better NOx emissions characteristics of the IMFH relative to the Cyclone Swirler at the high inlet temperature. Figure 4.11 shows that at inlet temperatures near 1100 R, NOx emissions increase when more IMFH stages are turned on. At this lower inlet temperature, the Cyclone Swirler NOx emissions are nearly as low as the IMFH and the blanketing effect dominates. In general, NOx emissions were sensitive to the staging configuration, but the effect of changes in dome staging configurations on NOx depends on the combustor inlet conditions.

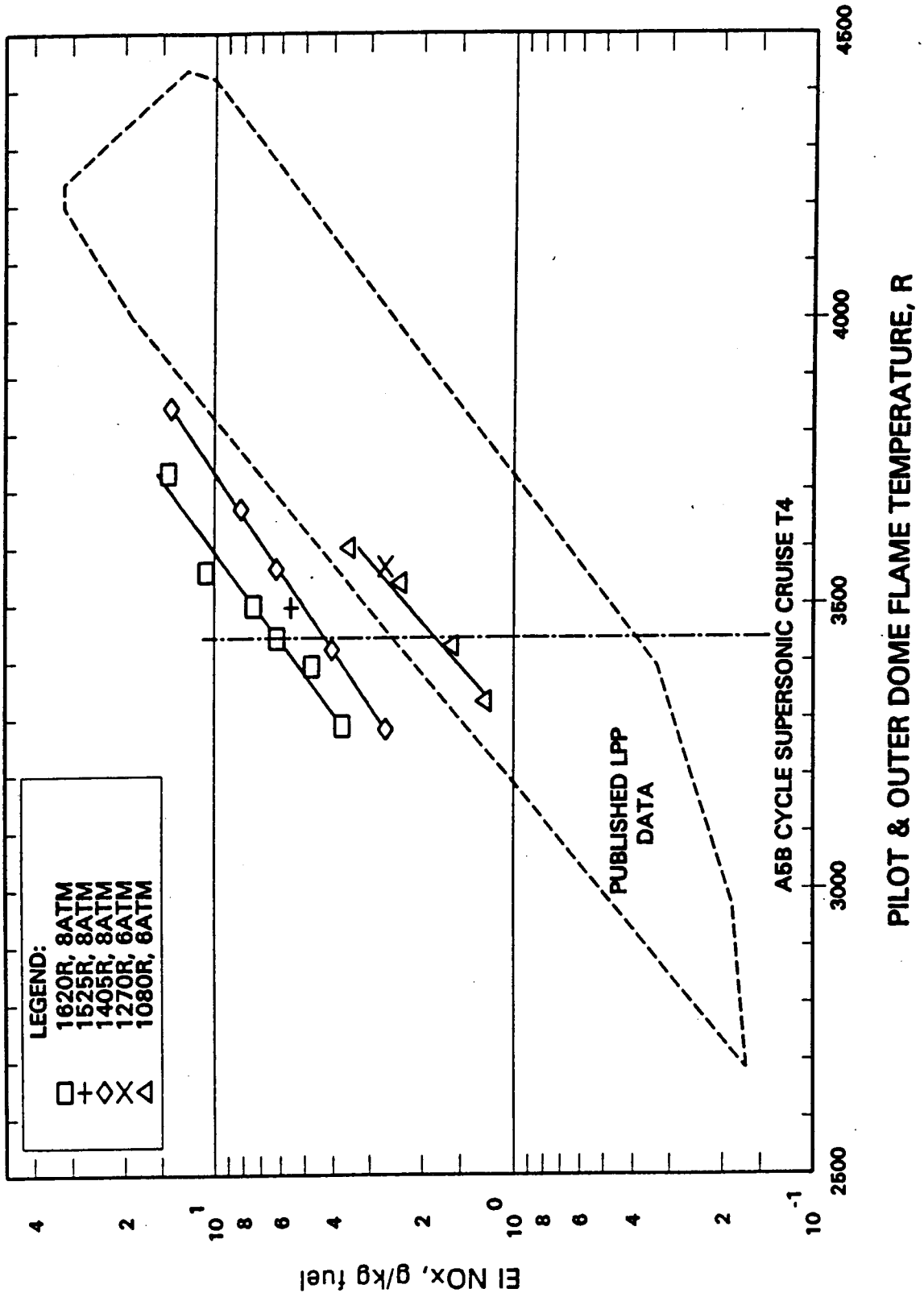


Figure 4.7 - NOx emissions index plotted versus flame temperature with the pilot and outer main dome fired. Data from the third rectangular sector combustor test.

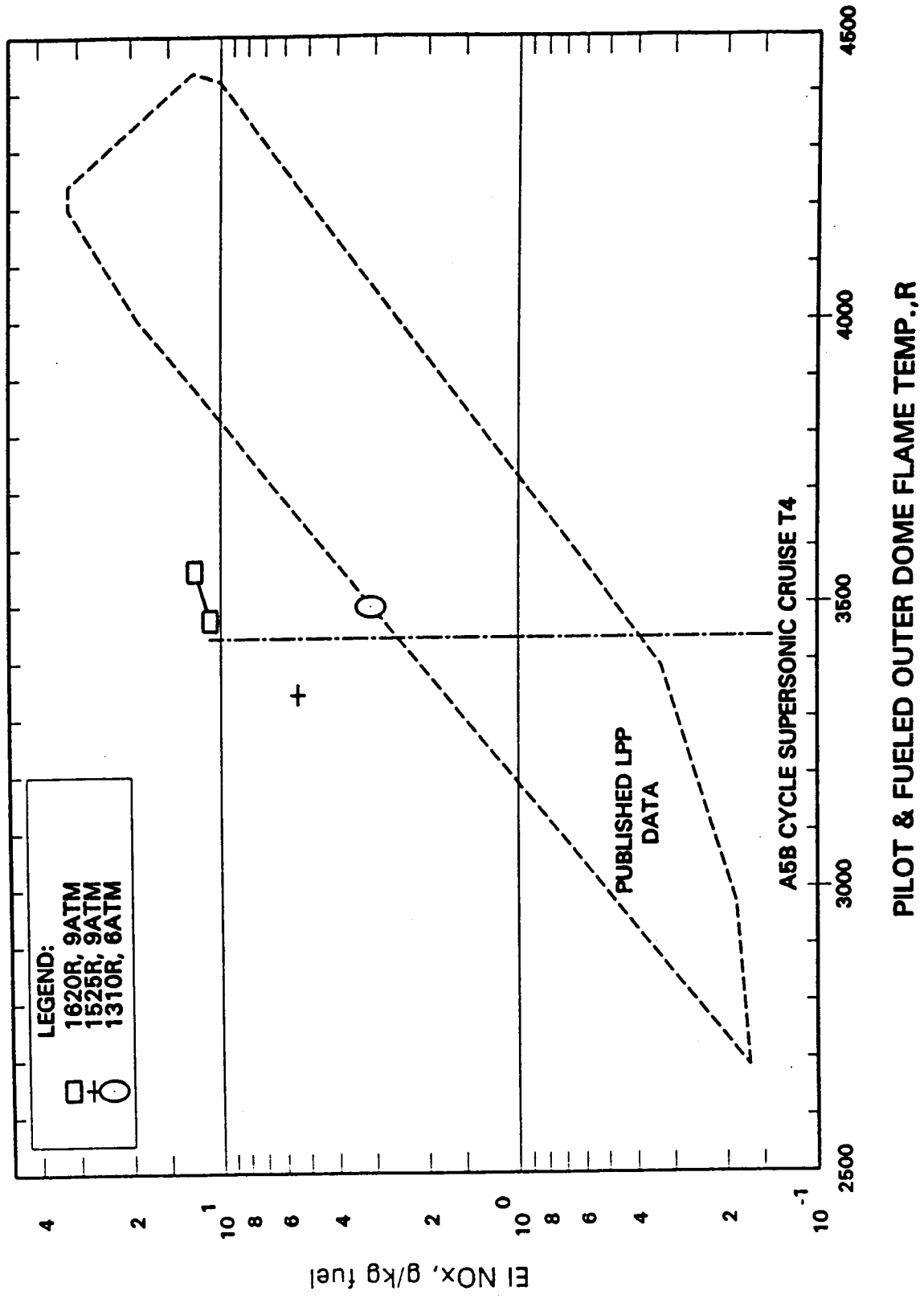


Figure 4.8 - NOx emissions index plotted versus flame temperature with the pilot and inner row of IMFH tubes on outer main dome fired. Data from the third rectangular sector combustor test.

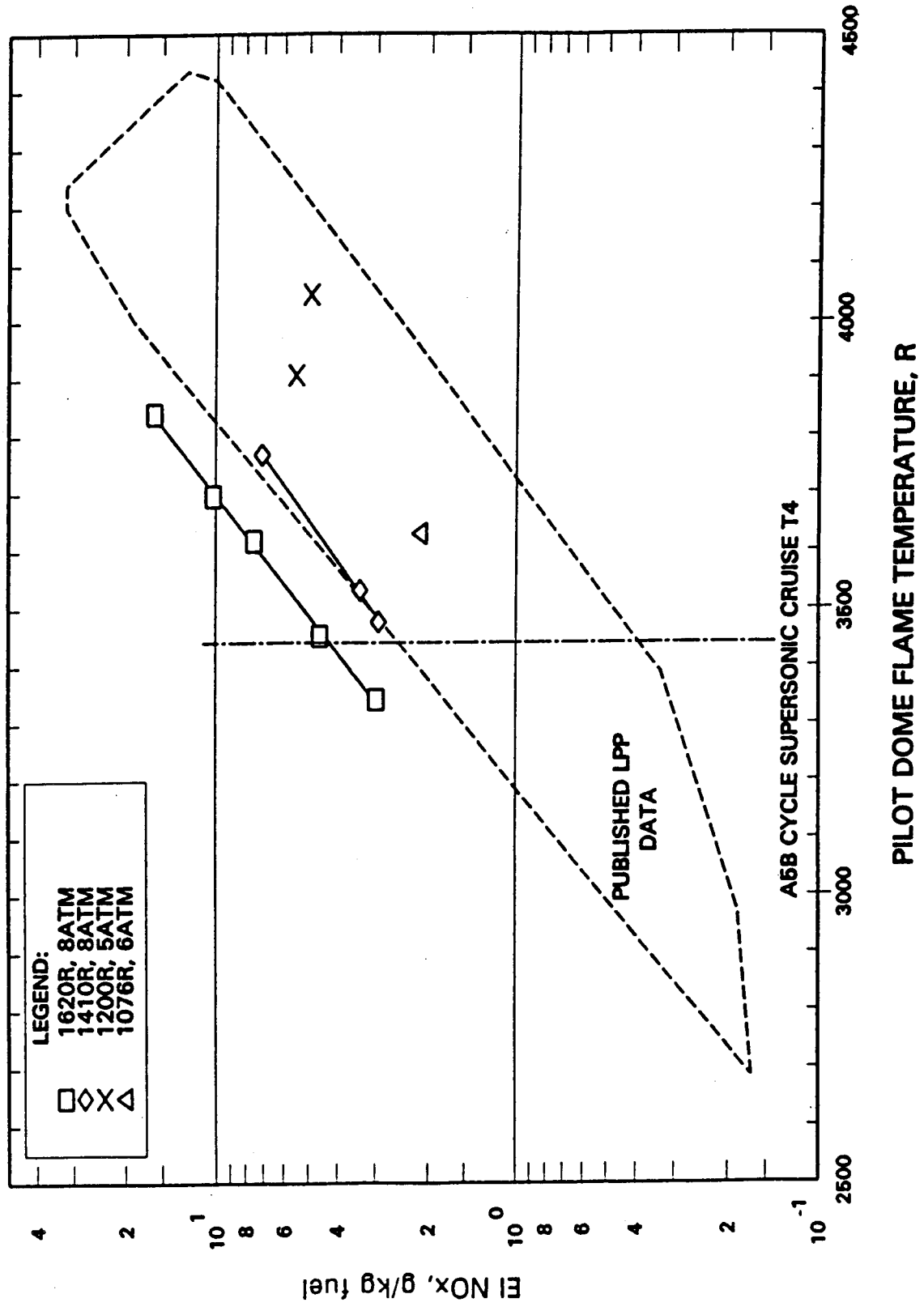


Figure 4.9 - NOx emissions index plotted versus flame temperature with the pilot stage only fired. Data from the third rectangular sector combustor test.

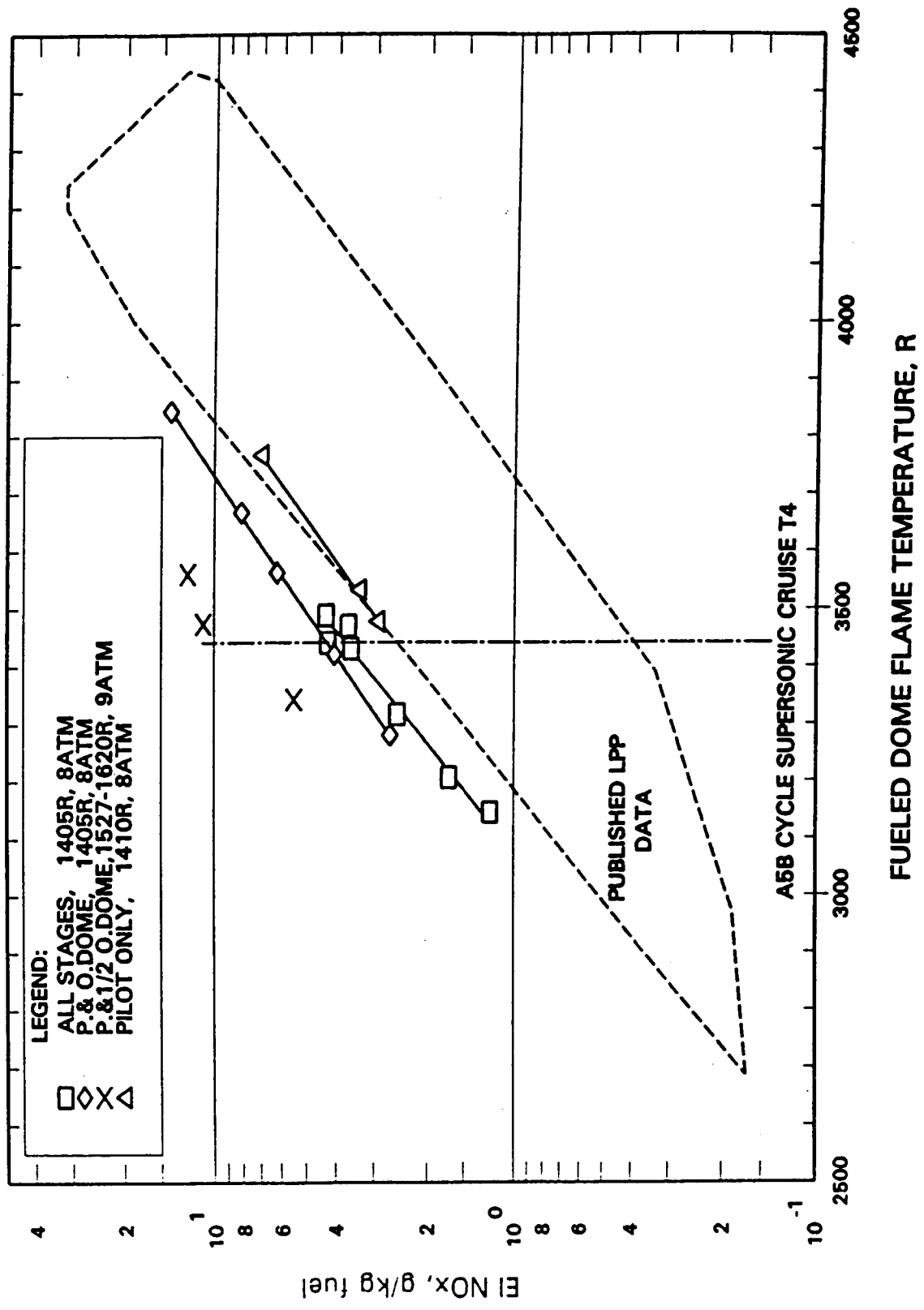


Figure 4.10 - NOx emissions index plotted versus flame temperature with various staging configurations compared. Combustor inlet temperature of approximately 1400 R and a pressure of 8 or 9 atmospheres. Data from the third rectangular sector combustor test.

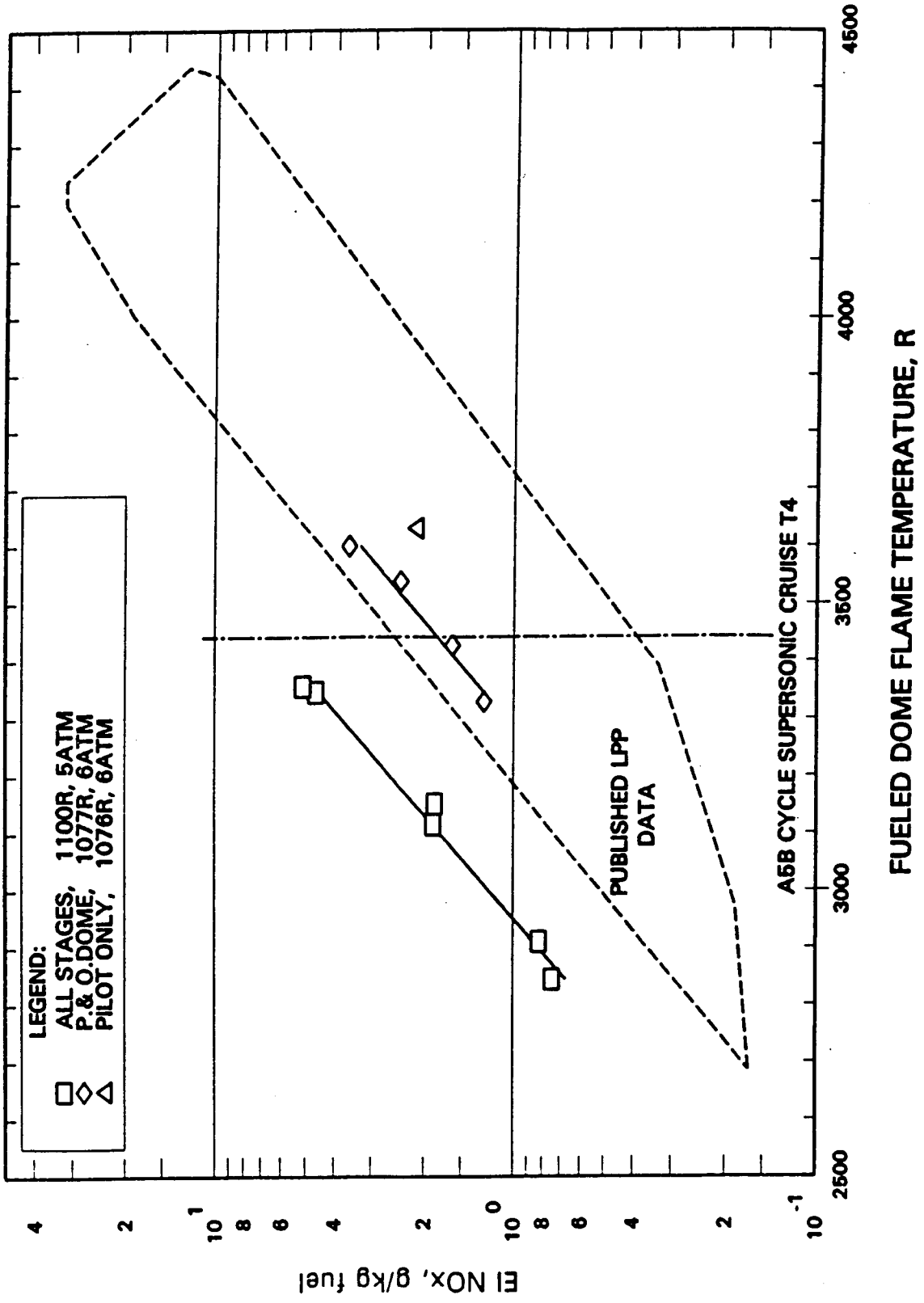


Figure 4.11 - NOx emissions index plotted versus flame temperature with various staging configurations compared. Combustor inlet temperature of approximately 1090 R and pressure of 5 or 6 atmospheres. Data from the third rectangular sector combustor test.

In Figures 4.10 and 4.11, with all the fuel stages fired, the sector combustor's emissions were dominated by the IMFH's emissions characteristics, because most of the fuel is burned by the main stages. Over the range of Inlet temperatures run in the test, the NOx emissions decreased with increasing inlet temperature, due to the more complete fuel evaporation and mixing in the IMFH. This is consistent with the IMFH single-cup data.

Before the third sector combustor test, there was a concern that partial fuel staging would result in low combustion efficiency due to the quenching of the CO combustion. However, the combustion efficiencies observed in this test during partial fuel staging, were very promising. Combustion inefficiency data for these tests is presented in Figures 4.12 through 4.14. All the inefficiency data are presented as a function of the fueled dome (local) flame temperature. At low inlet temperatures, combustion inefficiency was lowest for pilot-only operation, higher for pilot and one IMFH dome operation, and higher still for all domes fired. As inlet temperatures rose, the difference diminished between pilot-only and all domes fired combustion inefficiency. It was also evident that a small change in fueled dome flame temperature could result in a large increase in combustion efficiency for the pilot and one IMFH row operation. Overall, combustion efficiencies were greater than 99% for most of the test conditions. The fully fired points with higher combustion inefficiencies in Figures 4.12 and 4.13 are not a major concern. The points were run as part of the parametric test plan, but an actual combustor would not be run fully-staged at such low power inlet conditions.

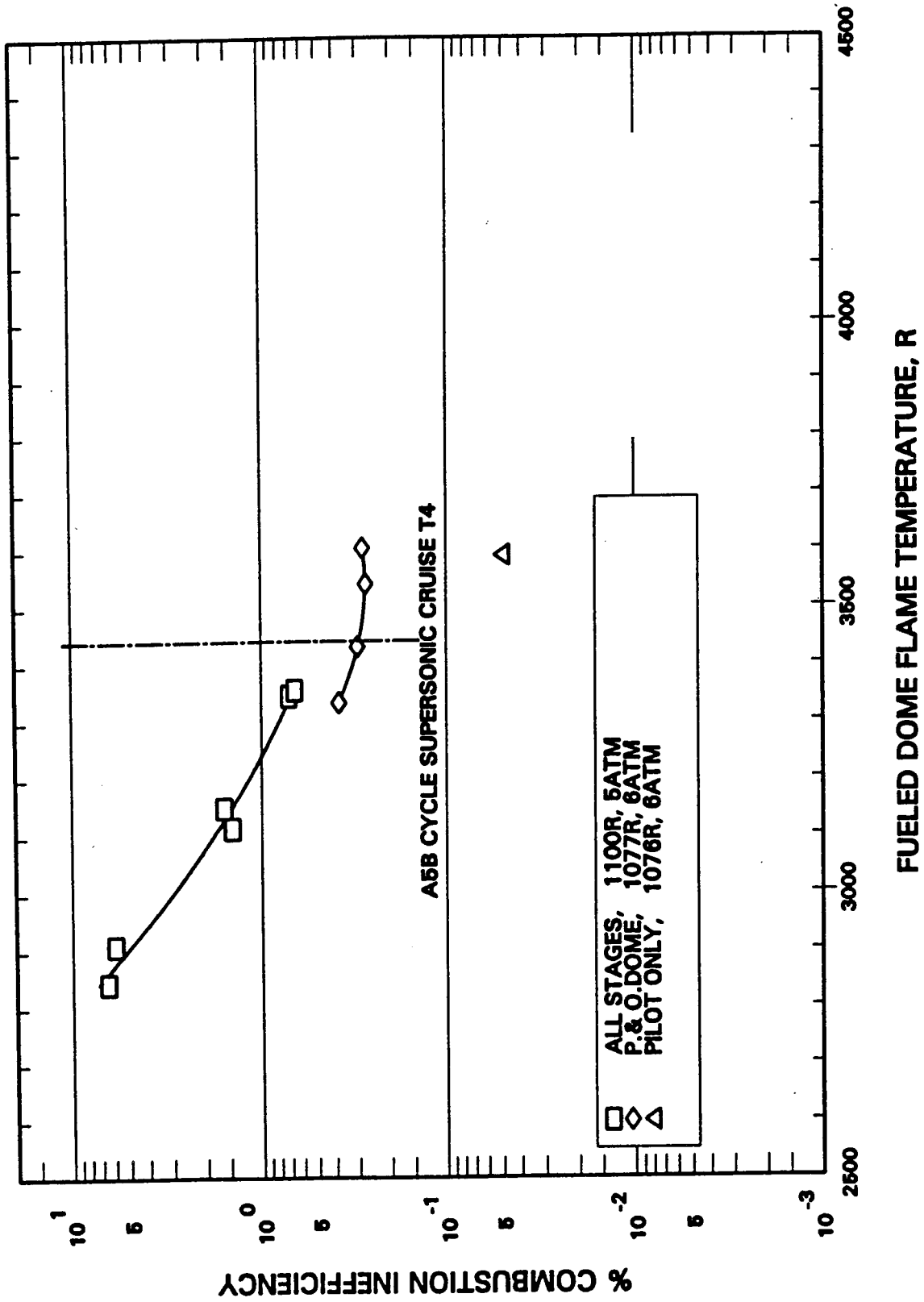


Figure 4.12 - Combustion inefficiency plotted versus flame temperature with various staging configurations compared. Combustor inlet temperature of approximately 1090 R and a pressure of 5 or 6 atmospheres. Data from the third rectangular sector combustor test.

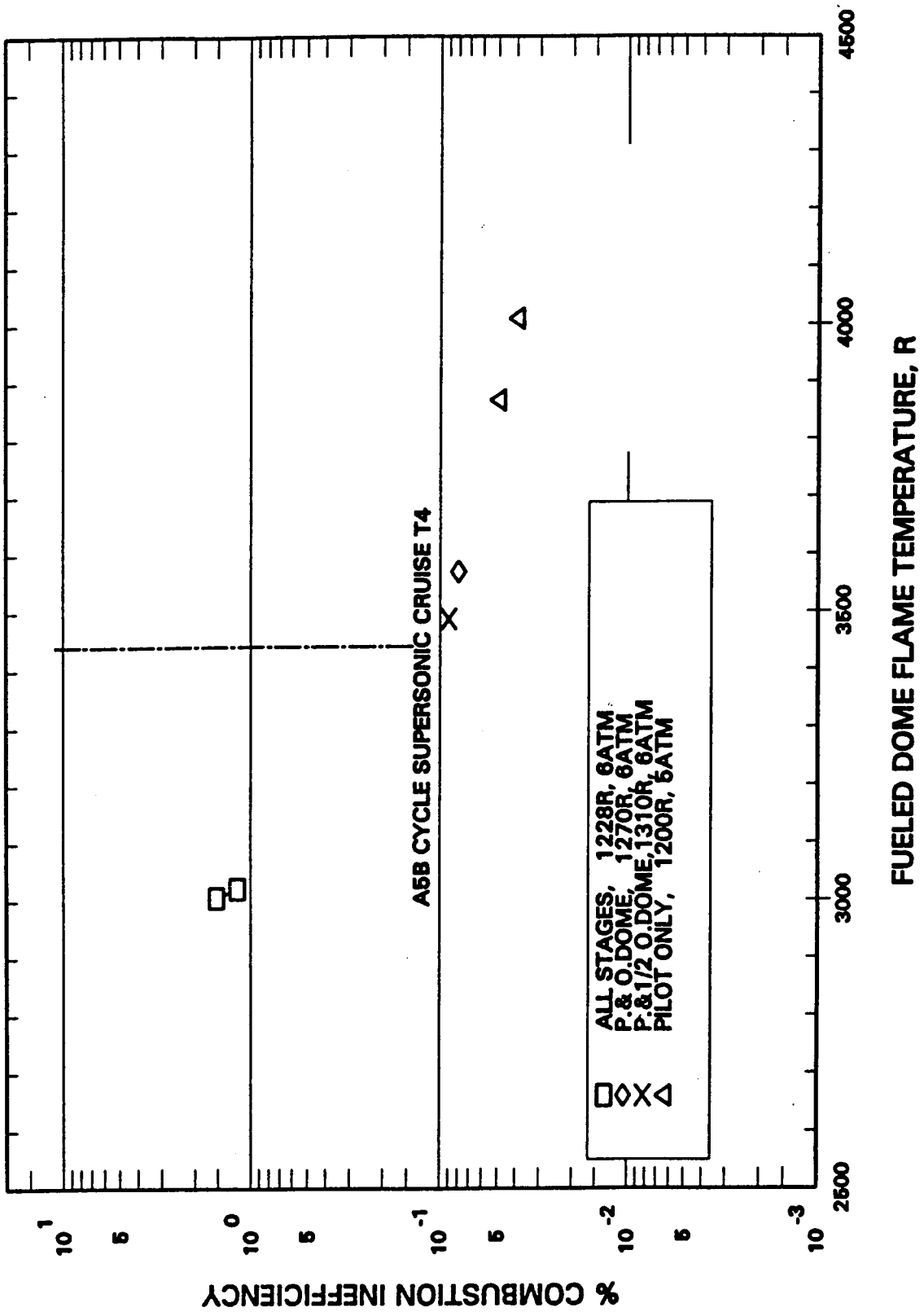


Figure 4.13 - Combustion inefficiency plotted versus flame temperature with various staging configurations compared. Combustor inlet temperature of 1200 R to 1310 R and a pressure of 5 or 6 atmospheres. Data from the third rectangular sector combustor test.

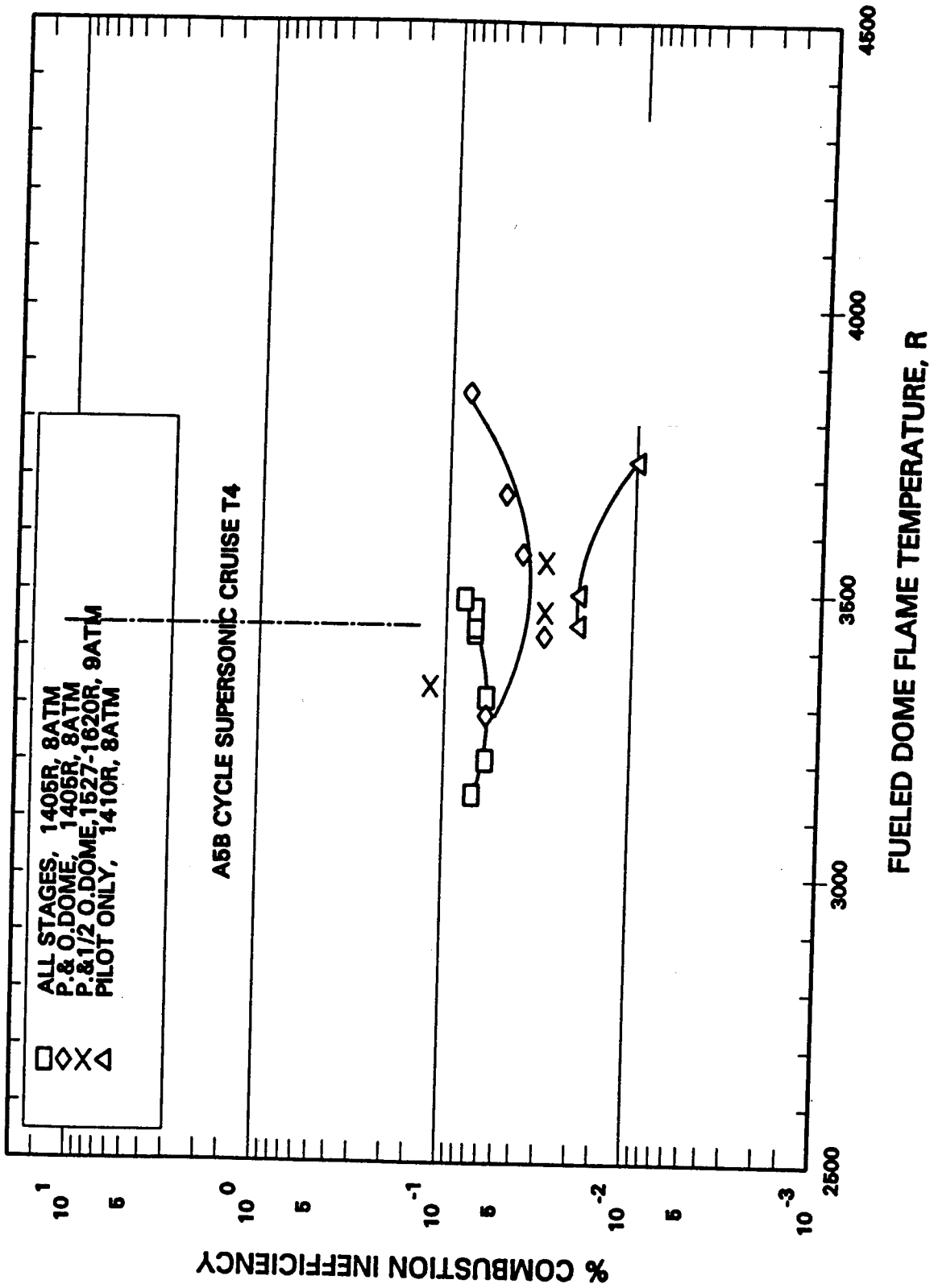


Figure 4.14 - Combustion inefficiency plotted versus flame temperature with various staging configurations compared. Combustor inlet temperature of 1410 R and a pressure of 8 atmospheres or inlet temperature of 1527 R to 1620 R and a pressure of 9 atmospheres. Data from the third rectangular sector combustor test.

4.4 Sector Test 4 - Lamilloy® Liner Sector CombustorTest

The fourth sector test used Lamilloy® liners designed and fabricated by Allison Gas Turbine specifically for the GEAE rectangular sector combustor. The rest of the sector combustor hardware (fuel system, pilot and main domes, side walls, and the rig hardware) was the same as used in the other LET Task 10 sector tests. The Lamilloy® sector test was funded by the EPM Program, so the results of the test are only summarized in this report. A complete set of the data is included in Appendix D.

The test was run in Evendale's Cell A5 in October, 1994. Over 60 data points were obtained. Emissions were measured at inlet temperatures from 1420 R to 1620 R and over a range of inlet pressures up to 132 psia. The test points very nearly encompassed the supersonic cruise conditions of the 3770 MFTF engine cycle. A recent Cell A5 enhancement, a servo-controlled sampling valve system, allowed single-point emissions sampling for the first time. This was timely because it allowed better understanding of the source of the CO emissions resulting from the film-cooling air.

The NOx emissions with all the domes fired at a uniform flame temperature are plotted versus the dome flame temperature in Figure 4.15. The NOx emissions obtained at an inlet temperature of 1620 R were the first obtained in the HSCT LPP combustor at close to supersonic cruise conditions. Those results were the first to clearly indicate that the LPP combustor is capable of meeting the HSR Program goal of a supersonic cruise NOx EI of 5 g NOx/kg of fuel: The usual qualification for the rectangular sector applies, that the pilot dome air split is high so that the pilot NOx is too heavily weighted. The NOx emissions at 1410 R inlet temperature are a little lower than the NOx emissions with the impingement cooled liner. This is interpreted as an effect of the flame temperature being reduced by the film-cooling air.

Of more significance, the film-cooling air from the Lamilloy® liners increased CO emissions relative to the impingement liners results. This quenching effect was not unexpected and was the reason the original rectangular sector design utilized impingement cooled liners.

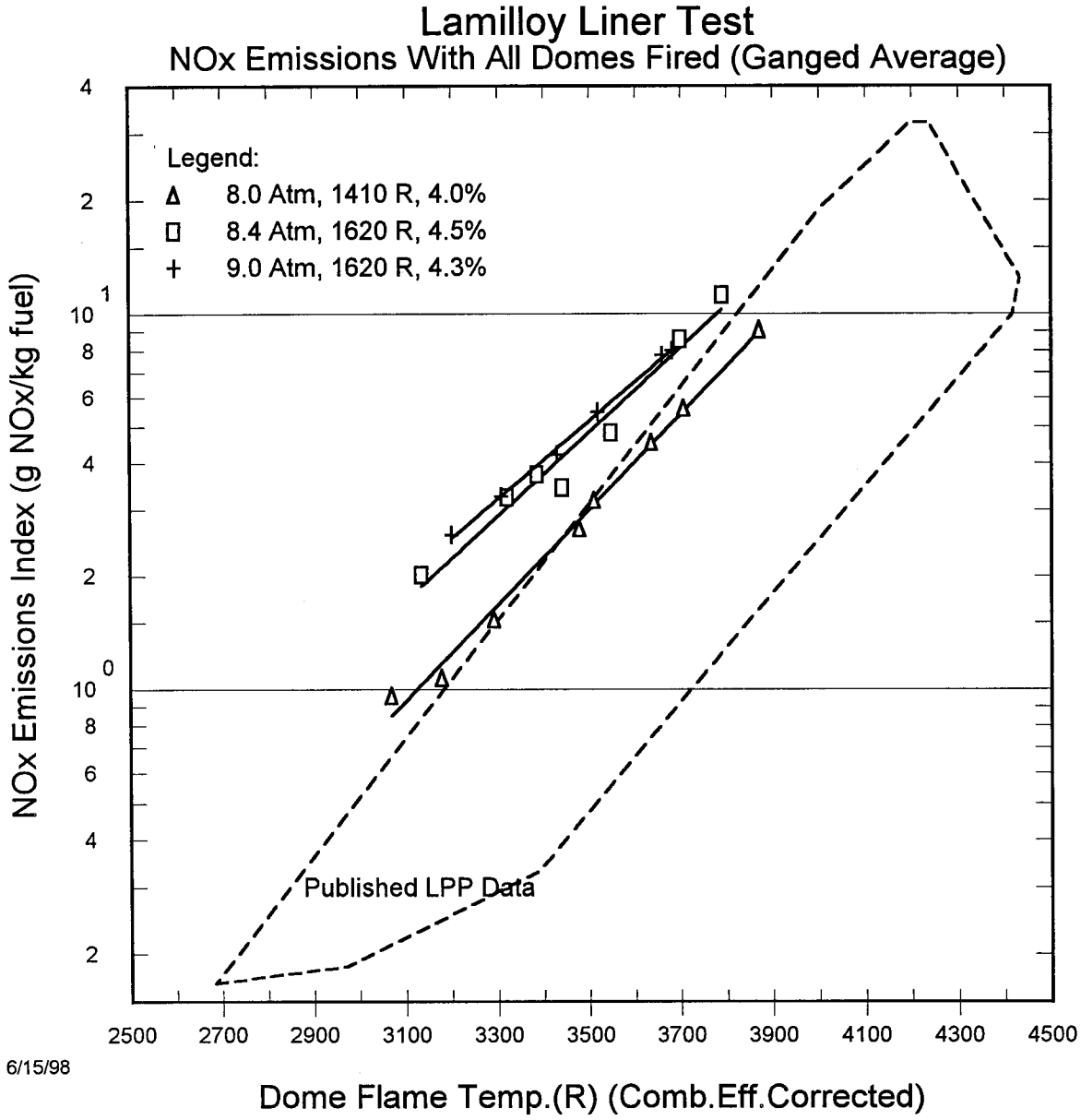


Figure 4.15 - NOx Emissions plotted versus dome flame temperature. Combustor inlet conditions as indicated in the legend. Data from the fourth rectangular sector combustor test using Lamilloy® liners.

At an inlet pressure of 8 atmospheres, an inlet temperature of 1410 R, a dome pressure drop of 4%, a flame temperature of 3160 R, and with the impingement-cooled liners; the combustion efficiency was 99.94% using ganged sample rakes (Point 31 of Sector Test 1). With the Lamilloy® liners at the same conditions, except the flame temperature was 3180 R (or slightly more favorable for low CO emissions), the combustion efficiency was 95.83% (Point 14 of Sector Test 4). These results are shown plotted versus flame temperature in Figure 4.16. The CO emissions for the same points are plotted versus flame temperature in Figure 4.17. At a flame temperature of 3200 R, the CO emissions using the Lamilloy® liners are more than 15 times higher than with the impingement cooled liners.

At conditions roughly corresponding to subsonic cruise combustor inlet conditions, for the two liner types, combustion inefficiencies are plotted in Figure 4.18 and CO emissions are plotted in Figure 4.19. Less of a difference is seen at these conditions. At a flame temperature of about 3100 R, the CO emissions using the Lamilloy® liners are about 2.5 times higher than with the impingement cooled liners.

These results confirmed the supposition that film-cooling air quenches the CO burnout reactions in an LPP combustor. This effect could be offset by maintaining higher flame temperatures, but this would narrow the operating range of the combustor requiring more fuel stages and would result in higher NOx emissions.

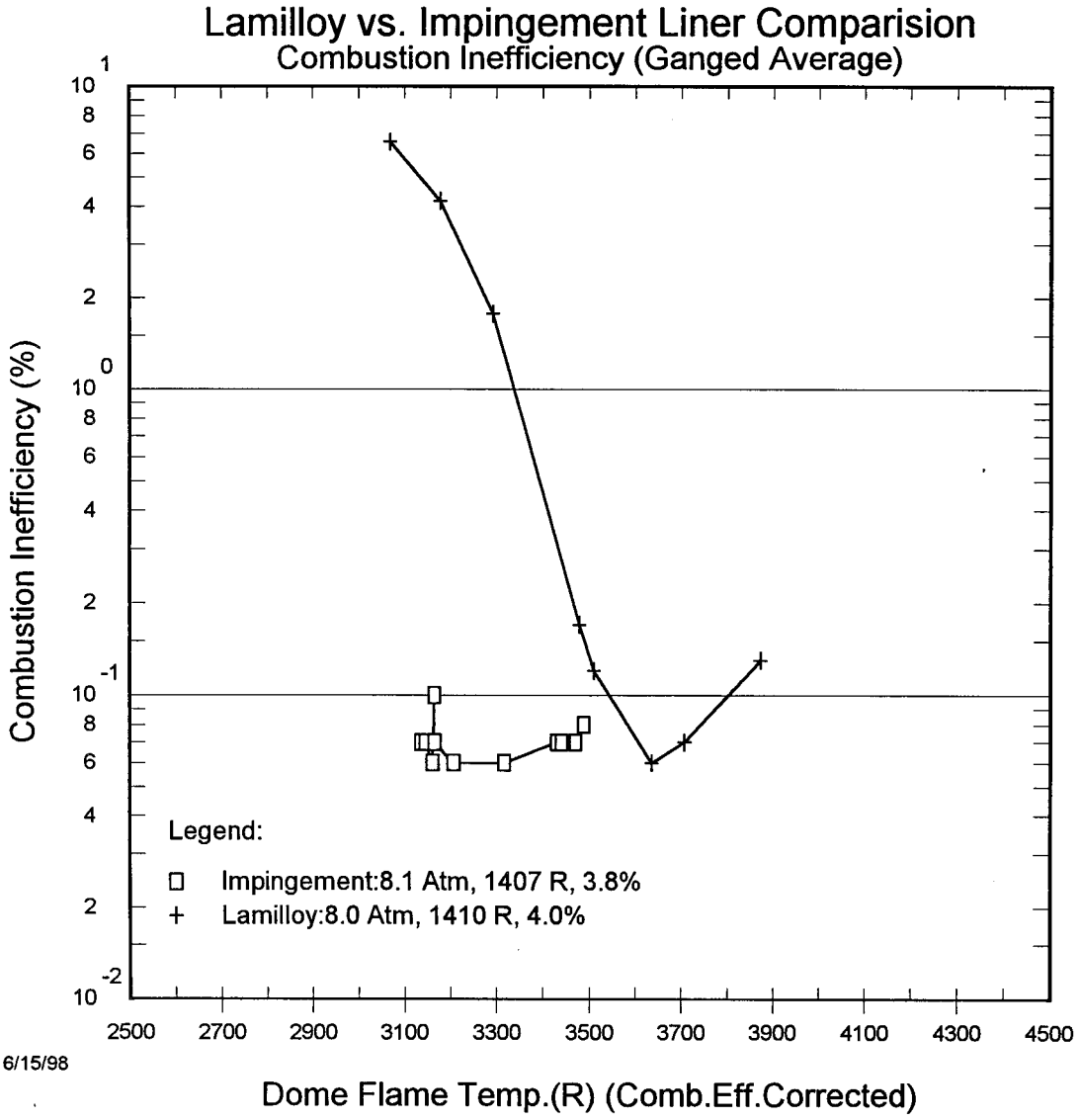


Figure 4.16 - Combustion inefficiency plotted versus flame temperature with Lamilloy® liners compared to impingement cooled liners. Combustor inlet temperature of 1410 R and a pressure of 8 atmospheres. Data from the fourth rectangular sector combustor test.

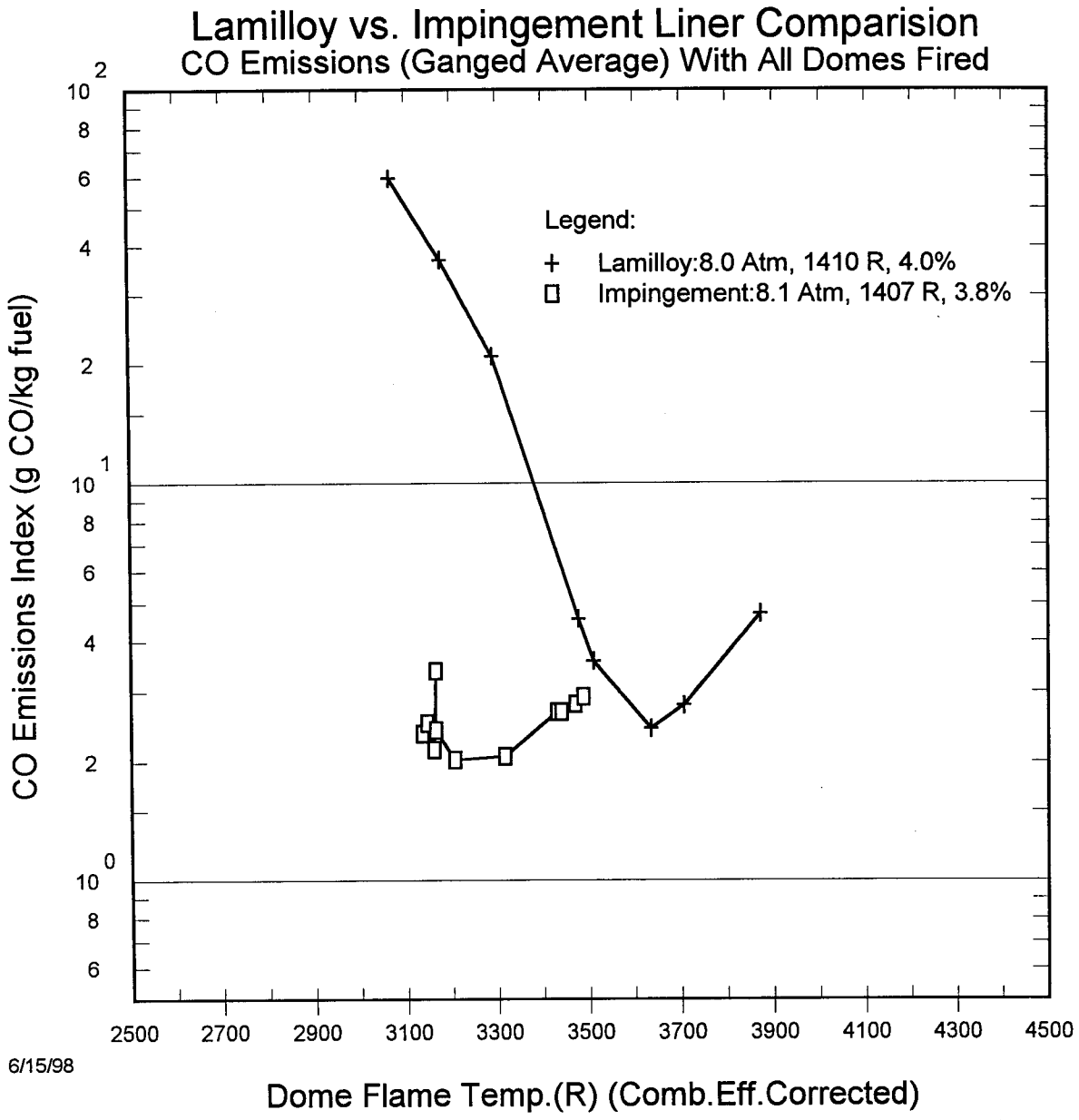


Figure 4.17 - CO emissions index plotted versus flame temperature with Lamilloy® liners compared to impingement cooled liners. Combustor inlet temperature of 1410 R and a pressure of 8 atmospheres. Data from the fourth rectangular sector combustor test.

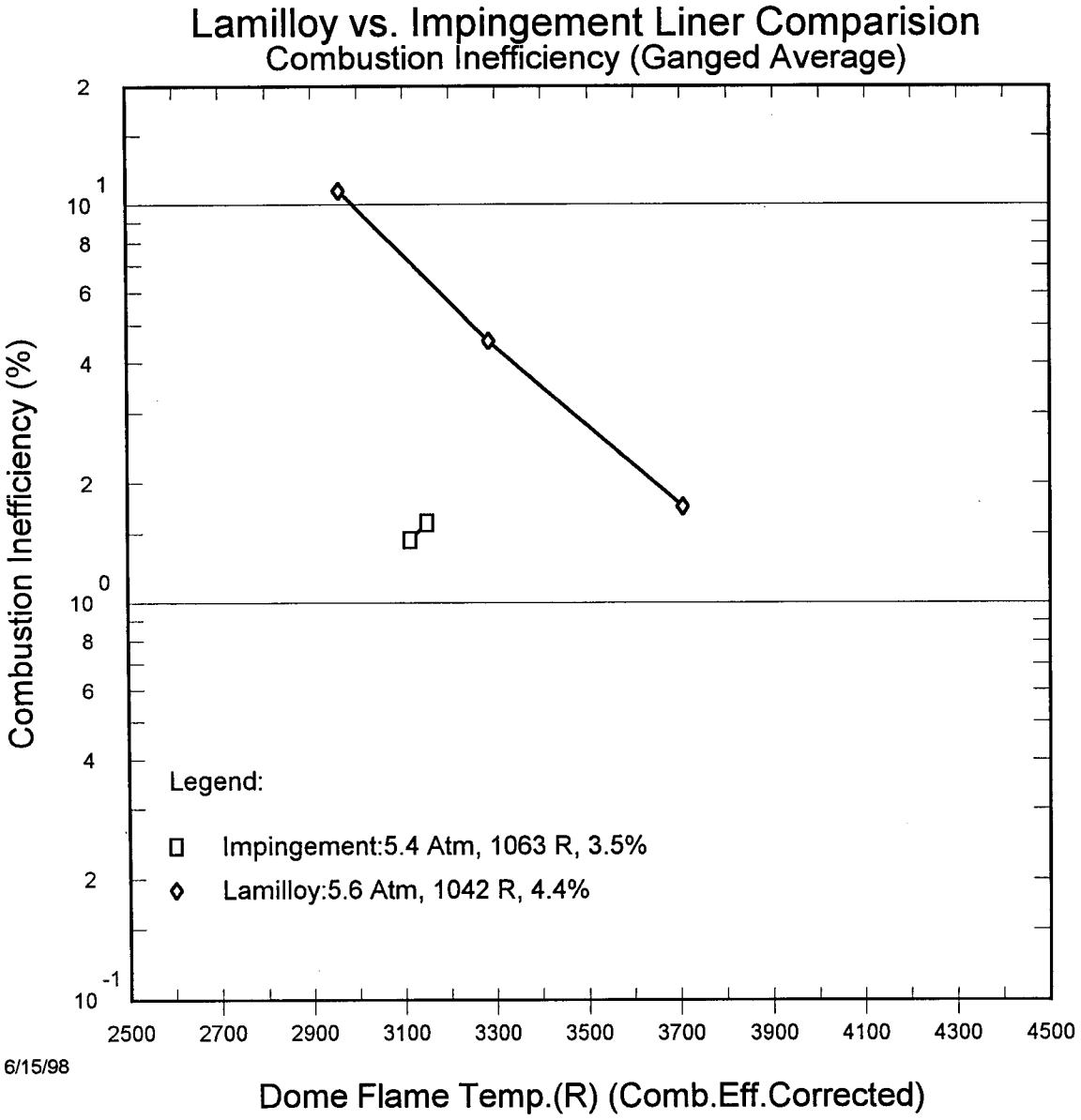


Figure 4.18 - Combustion inefficiency plotted versus flame temperature with Lamilloy® liners compared to impingement cooled liners at combustor inlet conditions roughly corresponding to subsonic cruise. Data from the fourth rectangular sector combustor test.

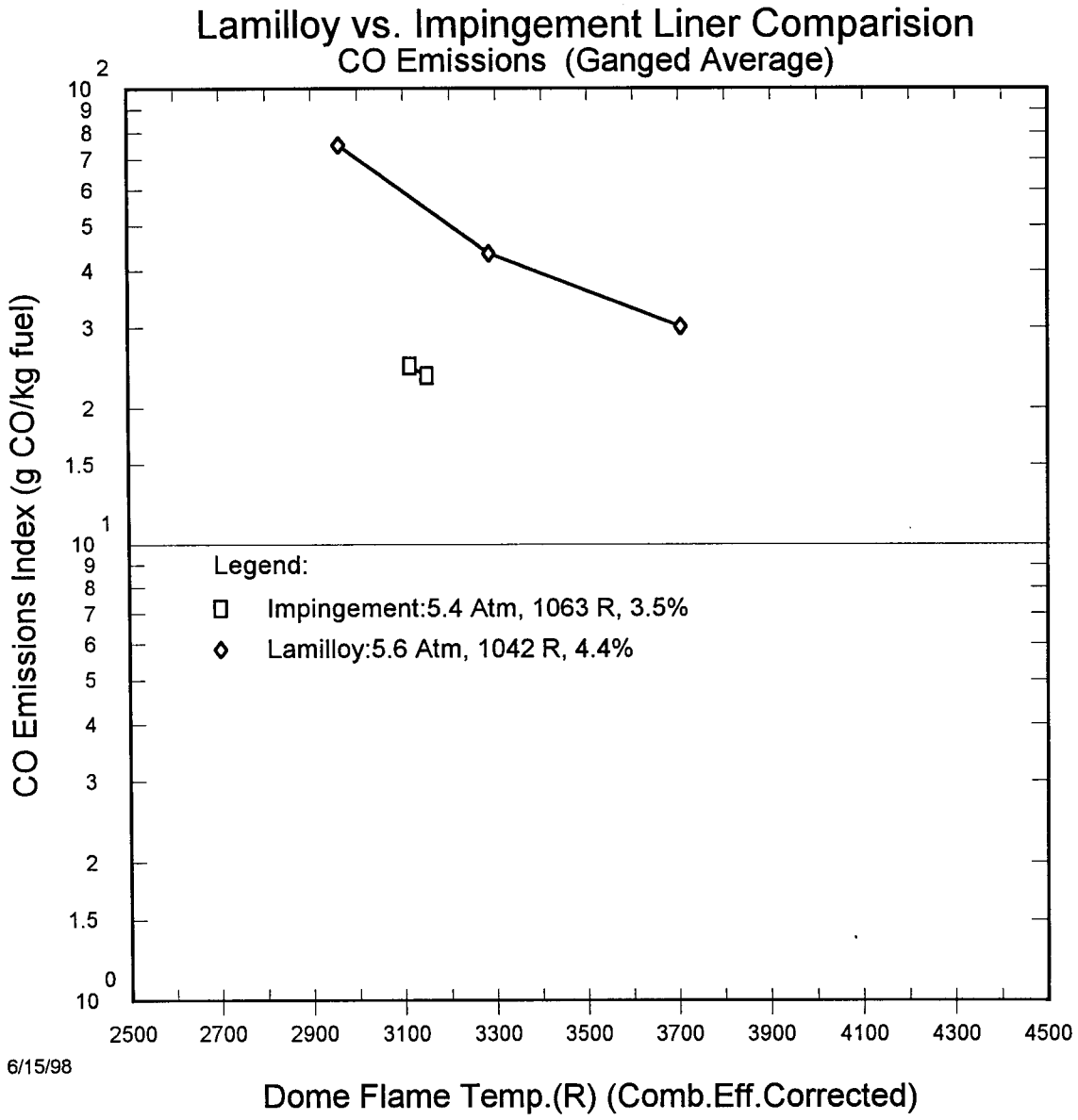


Figure 4.19 - CO emissions index plotted versus flame temperature with Lamilloy® liners compared to impingement cooled liners at combustor inlet conditions roughly corresponding to subsonic cruise. All the domes are fired. Data from the fourth rectangular sector combustor test.

4.5 Sector Test 5 - Pilot Aft and Heat Transfer Sector Test

The objective of this sector test was to obtain emissions data with the pilot dome adjusted to its full aft position (minimum isolation). Also, the impingement liners were heavily instrumented to obtain fundamental heat transfer data. The test was run in Test Cell A5. It began and ended on April 24, 1995. The test was shut down because of high indicated temperatures upstream of the dome. Inspection verified that extensive damage occurred when a fuel line broke that supplied the upper left bank of 6 IMFH injectors on the lower main dome (aft looking forward). The fuel line broke at a support bracket. The support bracket (and several of the others) were found to have a small ridge that put a crease around the fuel tube. The ridge was caused by a machining operation to place a chamfer at the ends of the clamping surfaces. The chamfer was included in the design of the clamp specifically to minimize stressing the fuel tube. The break occurred at the only location where the fuel line was single-wall (to accommodate a fitting). A factor that may have contributed to the failure was that the fuel line already had about 40 hours of test time prior to this test and may have been fatigued. Even with the fuel line failure, damage should have been minimal except that two safety systems were not working properly; the system for automatically calculating the fuel system flow numbers and an automatic trip on the safety thermocouples. No data was obtained in the fifth sector combustor test. However, the lessons learned were applied to the subsequent tests.

4.6 NASA 3-Cup Sector Design and Fabrication

The NASA 3-cup sector combustor is illustrated in Figures 4.20 through 4.22. The three domes and fuel injectors were designed and procured by GEAE. The Cyclone Swirler pilot and IMFH mixer tubes, as well as their respective fuel injectors, were of the same design as in the 5-cup sector combustor. The domes were very similar in design as the 5-cup sector, including the provisions for an adjustable pilot recess. Differences in the respective designs were that the NASA pilot dome had three Cyclone Swirler pilots instead of five and the main domes each had 14 IMFH tubes instead of 24. The rig's pressure vessel was designed and fabricated by NASA and their subcontractors. Its liners and sidewall were made of the same castable ceramic NASA-Lewis used in their flametube tests. There were four optical access windows installed in the rig to allow optical access to the combustion zone at different locations, depending how the rig parts were assembled.

Subsequently, two modified versions of the sector were design and procured. A new center dome was designed which used IMFH tubes. The purpose of the this dome was not to evaluate the effectiveness of the IMFH as a pilot, but rather to evaluate the effect of different step heights (length of the recess) isolating fired and unfired IMFH stages, on the emissions (primarily CO). The second design modification was to replace the two IMFH main domes with two new main domes with the multiple-venturi LDI (lean direct injection) fuel-air mixers.

All the tests of the 3-cup sector were done at NASA-Lewis. A GEAE engineer was in attendance for the earliest tests. The results of the laser diagnostics studies of the two versions of the sector combustor with IMFH tubes are documented in a NASA technical memorandum [3-3].

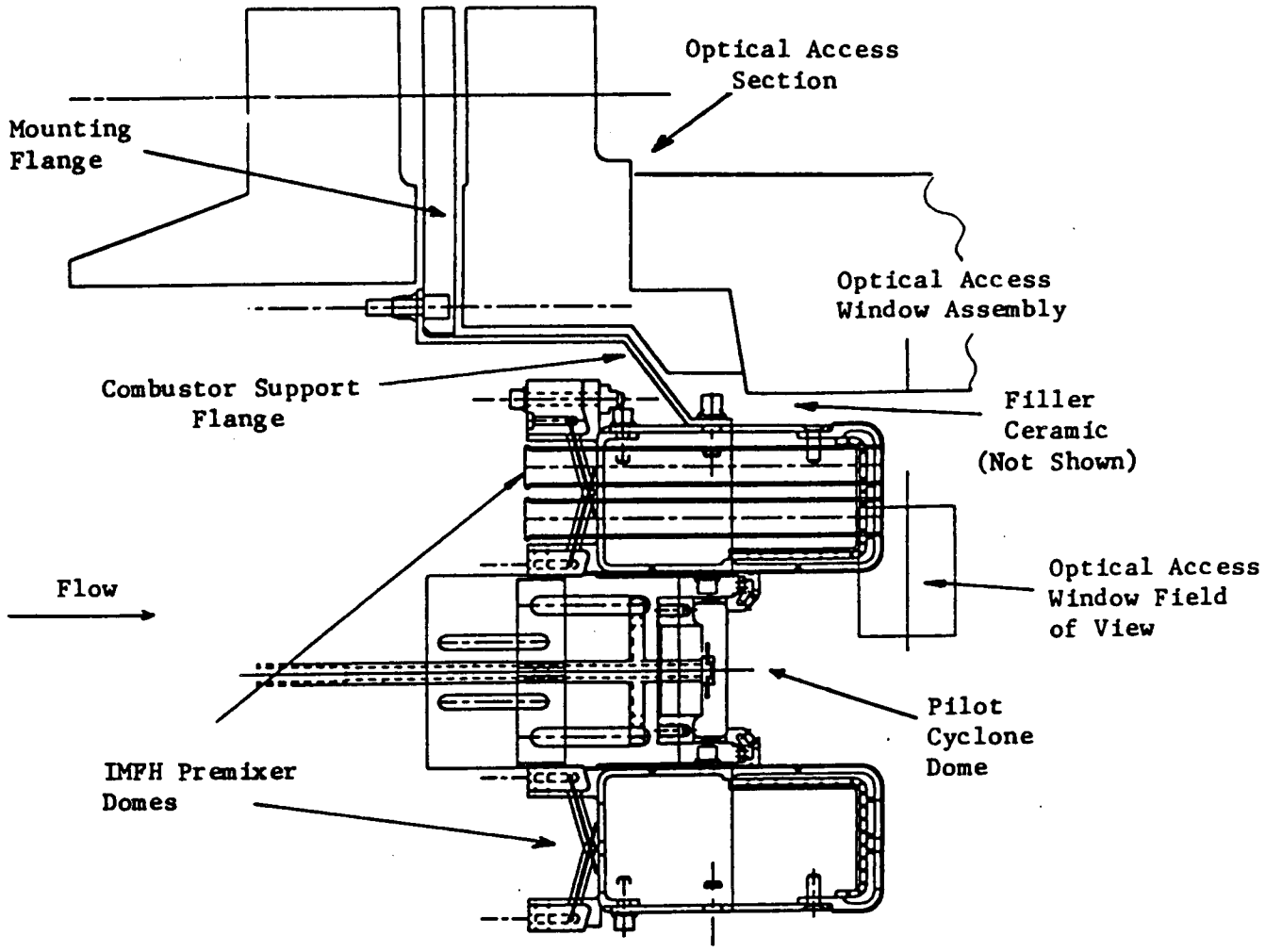


Figure 4.20 - Side view of the IMFH/Cyclone Swirler 3-cup sector combustor shown with a partial section of the NASA diagnostics rig to show the mounting interface.

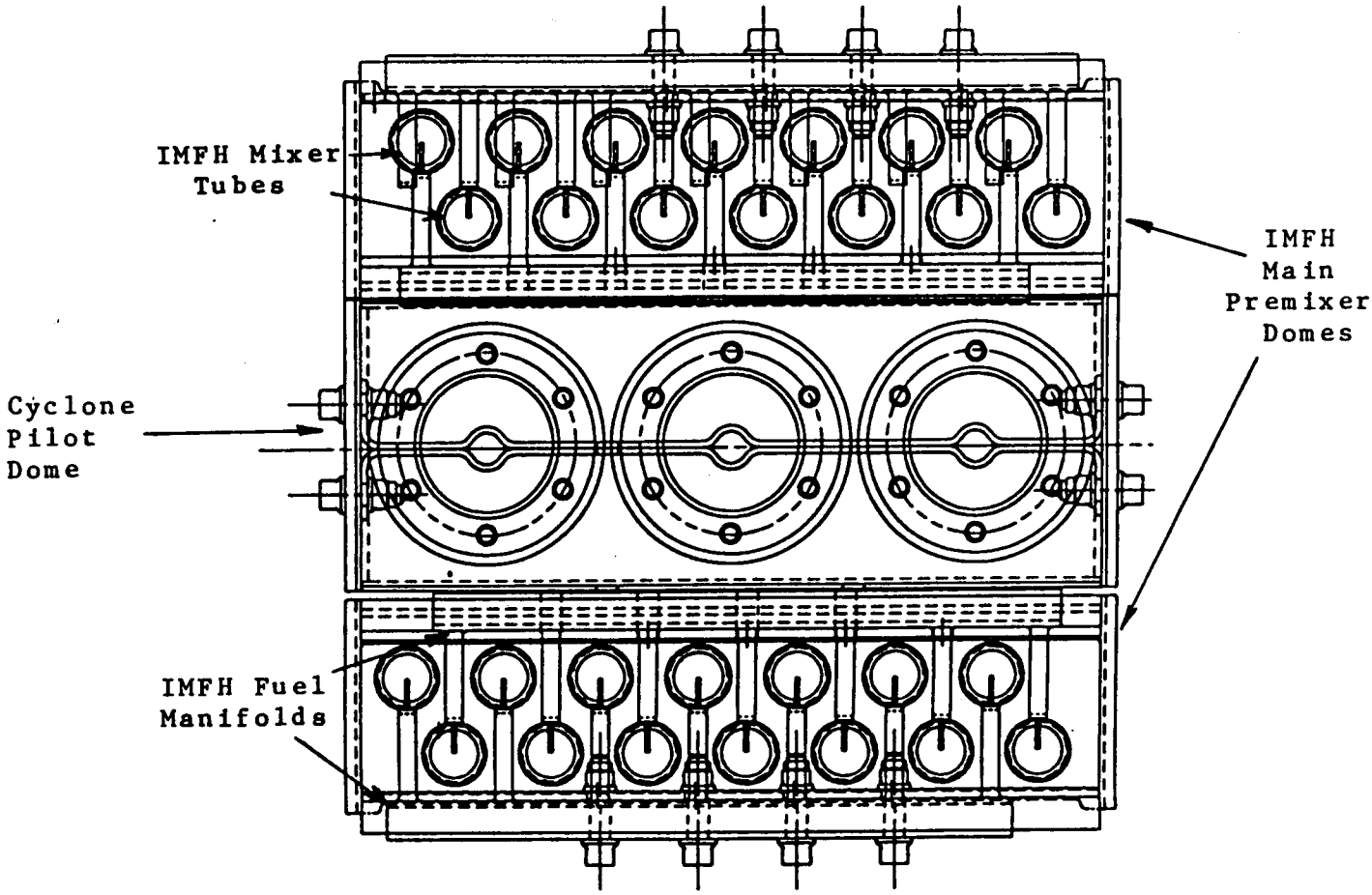


Figure 4.21 - View of the IMFH/Cyclone Swirler 3-cup sector combustor dome (aft looking forward).

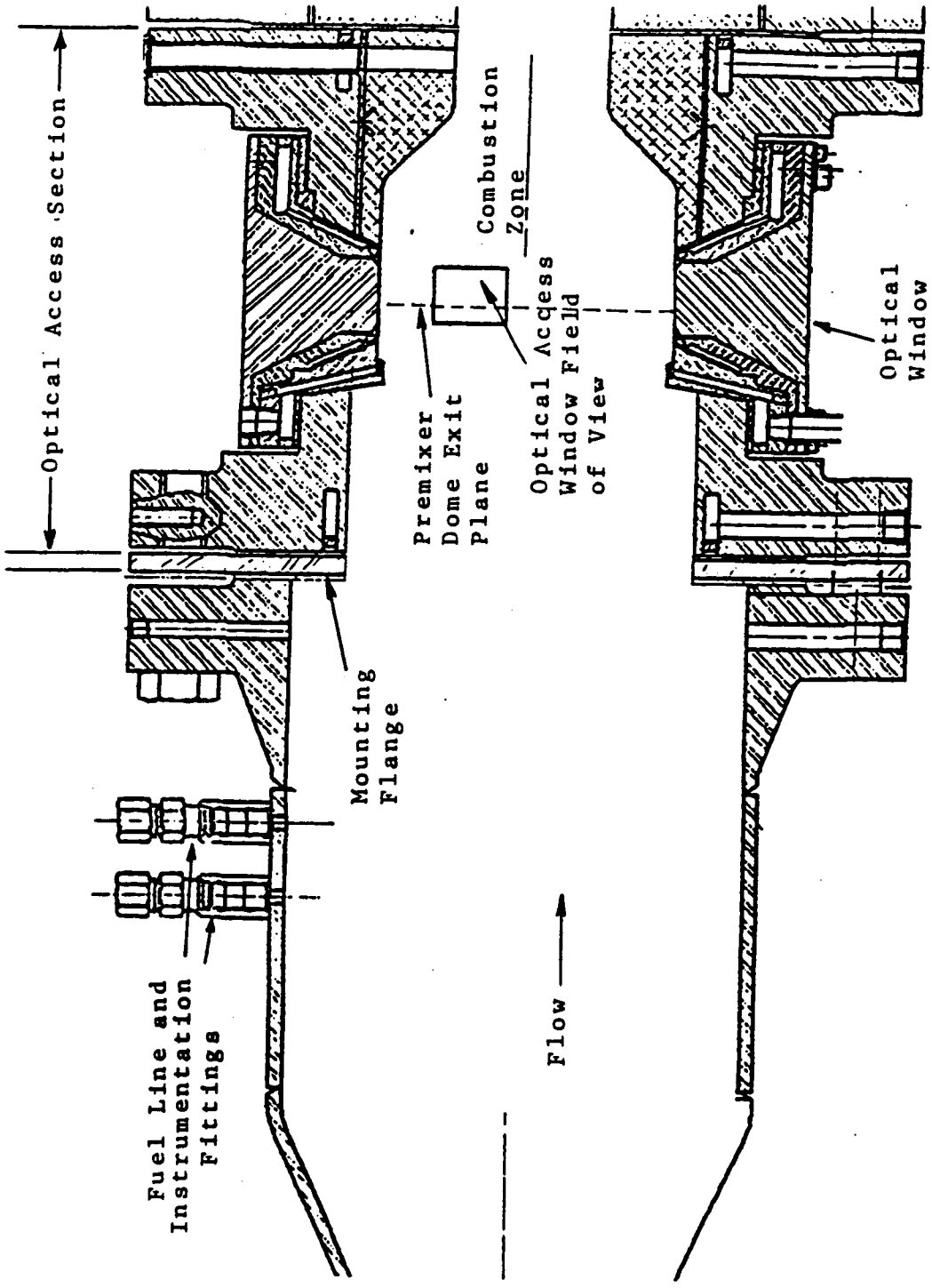


Figure 4.22 - Schematic of the NASA 3-cup sector combustor diagnostics rig.

4.7 Summary and Conclusions, LPP Sector Combustor Tests

The IMFH/Cyclone combustor sector tests successfully demonstrated the basic operation of the baseline IMFH/Cyclone Swirler combustor system under a wide range of conditions. Significant interactions between the stages were clearly evident, even in this parallel-staged configuration. These interactions affected both the NOx and CO emissions. The most significant result of the first five sector tests was that the combustion efficiency of the IMFH at mid-power inlet conditions was determined to be significantly better than indicated by the single-cup tests of the IMFH. Based on the single-cup IMFH test results, alone, there had been a concern that the IMFH operation would not meet efficiency requirements at subsonic cruise conditions. The high efficiencies while partially fuel staged observed in these tests indicated that it might be possible to reduce the isolation (the recess) of the pilot from the main stage, thereby reducing the cost and complexity of the combustor system. Another significant result was that the NOx emissions of the Cyclone Swirler were significantly reduced when some or all of the IMFH fuel stages were turned off. However, at high power, the sector test results demonstrated the need to improve the Cyclone Swirler pilot stage performance for high power NOx emissions.

The Lamilloy® liner test showed that combustion efficiency is compromised at lower flame temperatures when the liner cooling utilized film-cooling air. The conclusion from this test is that film-cooling air requires the use of higher flame temperatures. The higher flame temperatures will result in increased NOx emissions.

The fuel system failure which occurred in the fifth sector test indicates the need for careful review of all aspects of the fuel system. Although great care was taken in the design of the fuel system for the sector combustor, one mistake (the failure to detect the small ridge on the fuel clamps) caused an expensive failure.

A lesson-learned in the design of combustors was to keep the module size as small as possible. In this sector design there were 48 IMFH tubes per 5 pilots. Similarly the NASA 3-cup sector had 28 IMFH tubes per 3 pilots. The combustors could not be divided into a smaller module

with an integer number of tubes per pilot. This required compromises when comparing results of the 5-cup sector test, the 3-cup sector test and the 1-cup sector CFD model. Although only a minor problem, it was an unnecessary one. There was no reason not to have an integer number of IMFH tubes per pilot in the sector combustors. There are already an abundance of unavoidable difficulties in interpreting and comparing measured combustion data and CFD results. This particular difficulty was unnecessary.

Section 5

Variable Geometry Lean-Burn Fuel-Air Mixer

Control of the flame temperature within narrow limits is crucial to the emissions performance of Lean Premixed, Prevaporized (LPP) and Lean Direct Injection (LDI) gas turbine combustors. The systems used for controlling the flame temperature in LPP or LDI turbine combustors are fuel staging, air-scheduling, or a combination of the two methods.

Fuel staging involves turning on additional fuel injectors as the overall combustor fuel-air ratio increases. Each fuel injector has its own air supply, so that the additional fuel is mixed with an increasingly larger fraction of the combustor's total airflow. Modern diffusion flame turbine combustors, which because of their intense mixing, have some of the characteristics of a lean direct injection combustor, often rely upon fuel staging as a means to reduce emissions by maintaining the fuel-air ratio of the combustion zone between narrower limits than would otherwise be allowed by the engine cycle. Most production GEAE turbine combustors use some form of fuel staging. GEAE's LM6000 and LM2500 DLE premixed combustors use fuel staging to maintain the flame temperature between very narrow limits. This experience base with production fuel-staging systems led to the natural choice of fuel-staging as the baseline system for controlling flame temperature in the HSCT LPP and LDI low emissions combustors.

Air-scheduling involves redistributing the air to locations where the fuel is already being injected as the overall combustor fuel-air ratio increases. Fluidic devices aside, air-scheduling requires some form of variable geometry or moving parts within the combustor air flow. Placing moving parts in this environment has been the principle deterrent to the application of air-scheduling in production turbine combustors.

5.1 Fuel Staging Compared to Air-scheduling

As a method of controlling combustor fuel-air ratio, fuel staging has several advantages. The moving parts (the fuel valves) are immersed in the fuel which is generally kept under 300° F (760 R). In a fuel-staged combustor system, the moving parts are very small relative to air-scheduling valves because of the smaller volume flow of the fuel relative to the air (due to the fuel's smaller mass flow and its higher density than the air). An incidental advantage of a fuel staging system is that it automatically supplies turndown capability to the fuel injector system. Otherwise separate staging valves often have to be provided at the fuel injector tips to maintain the fuel injector pressure drop within a practical range.

The fundamental type of control system and valving required for fuel-staging is on-off. Air-scheduling systems generally involve continuous control. Continuous control is more complicated to implement, adjust and regulate. On-off control, while an advantage of fuel staging (because of its simplicity), is also responsible for one of the principle challenges of fuel-staging. Turning fuel systems off in a high temperature environment requires special design provisions to accommodate the resulting stagnant fuel in the manifolds and injectors and the loss of the cooling effect of the flowing fuel.

Controlling the fuel-air ratio and flame temperature by managing the air distribution instead of the fuel distribution also has advantages. A primary incentive for developing a variable-geometry lean-burn fuel/air mixer is to limit the use of fuel staging to low power conditions where it would be easier to manage the thermal effects of turning off the fuel flow in fuel passages. A second advantage, potentially, would be that combustor exit temperature profiles could be improved at low power, since fuel injectors would not be turned off. A third potential advantage of variable geometry would introduce a new continuous control mechanism into the combustor operation that could be used to meet specific performance requirements. This last advantage is a catch-all for the benefits are likely to be discovered as experience is gained with variable geometry.

The challenges of designing the variable-geometry system were recognized from the onset of the effort. As mentioned above, variable geometry requires moving parts that have to operate in the severe combustor environment. For the HSCT application, this would require materials, including bearings and lubricants, that would be reliable at temperatures up to at least 1200° F (1660 R). A second challenge is to integrate the variable geometry into the premixer design itself rather than add a separate valve placed in series upstream of the premixer. With the air valve integrated into the premixer, the premixer will have higher velocities in at least some locations. With a valve in series, the air velocities and pressure drop through the premixer would become very low at low power, reducing the fuel-air mixing. There might also be an increased risk of autoignition and/or flashback because of the lower air velocities.

5.2 Variable Geometry Premixer Design

The starting point for the conceptual designs for variable geometry premixers were the fixed geometry fuel-air mixer designs developed in NASA contracts NAS3-25552 and NAS3-25951. The Cyclone Swirler was quickly chosen as the baseline premixer for development of the variable geometry due to its acceptable emissions and operability performance at both high and low power. (The selection of the Cyclone Swirler presumed that its performance would be improved during the ongoing subcomponent development program.) Another reason for using the Cyclone Swirler was that its test results generally indicated that its performance is relatively insensitive to pressure drop variations. Depending on the specifics of the combustor system design, the effective flow area of the combustor and its pressure drop might change over its operating range.

An additional requirement imposed on the variable geometry Cyclone Swirler limited the types of variable geometry that would be considered. This requirement was that the swirl angle would be maintained constant as the effective area changed. That requirement was a consequence of a relationship that exists between the optimum diameter of the centerbody (that diameter can not easily be varied by variable geometry) and the swirl number. Another

requirement was that the premixer residence time would not exceed about 0.5 milliseconds when in the high power configuration.

The conceptual effort first concentrated on designs which incorporated a coarse screw thread into the radial swirler. In these designs, relatively large control movements would be required for small changes in the premixer's effective flow area. This would allow precise metering of the air irrespective of any sloppiness in the control linkage. The screw actuated designs ended up being very complicated. The effort was then redirected to designs involving a simple sliding mechanism. Figure 5.1 shows an axial section of the final design which resulted from this effort. Although this design was considered promising, a detailed mechanical design was never initiated due to considerations of the combustor system for the variable geometry premixer.

5.3 Conceptual Design of Combustor System

In parallel with the design of the variable geometry premixer, conceptual designs of the combustor system to use the variable geometry premixer were studied. The most promising system design was simulated with a spreadsheet analyses like those discussed in Section 1.2. Subcomponents were sized and the operation of the combustor system studied at key engine cycle points. The conceptual design effort resulted in a greater appreciation for one of the design challenges; moving a major fraction of the dome flow area from one location to another. Keeping the amount of air diverted within reasonable limits led to the chosen system design being a hybrid of variable geometry and fuel staging. This design allowed combustor operation with all burners fired down to engine cycle points corresponding to subsonic cruise. Fuel circuits were not turned off at combustor inlet temperatures above about 540° F (1000 R).

With the hybrid design and it's use of both methods of flame temperature control, came a realization that variable geometry designs would greatly add to the length of the list of combustor technologies needing development, not just change the technologies on the list. Meanwhile, the schedule for the HSR combustor development (at that time) called for a

definition of a workable concept for a lean low emissions combustor system in 1994. This combustor development schedule dictated that efforts be focused on the least risky design approaches. The variable geometry did not appear to meet this requirement. In April 1994, a Technical Redirection was agreed upon by GEAE and NASA. This Technical Redirection terminated the LPP variable geometry design effort. The subtask in Task 10 was replaced with a new subtask which provided funding for an engineer to be present at NASA during the tests at NASA-Lewis of the 3-cup sector combustor discussed in Section 4.6.

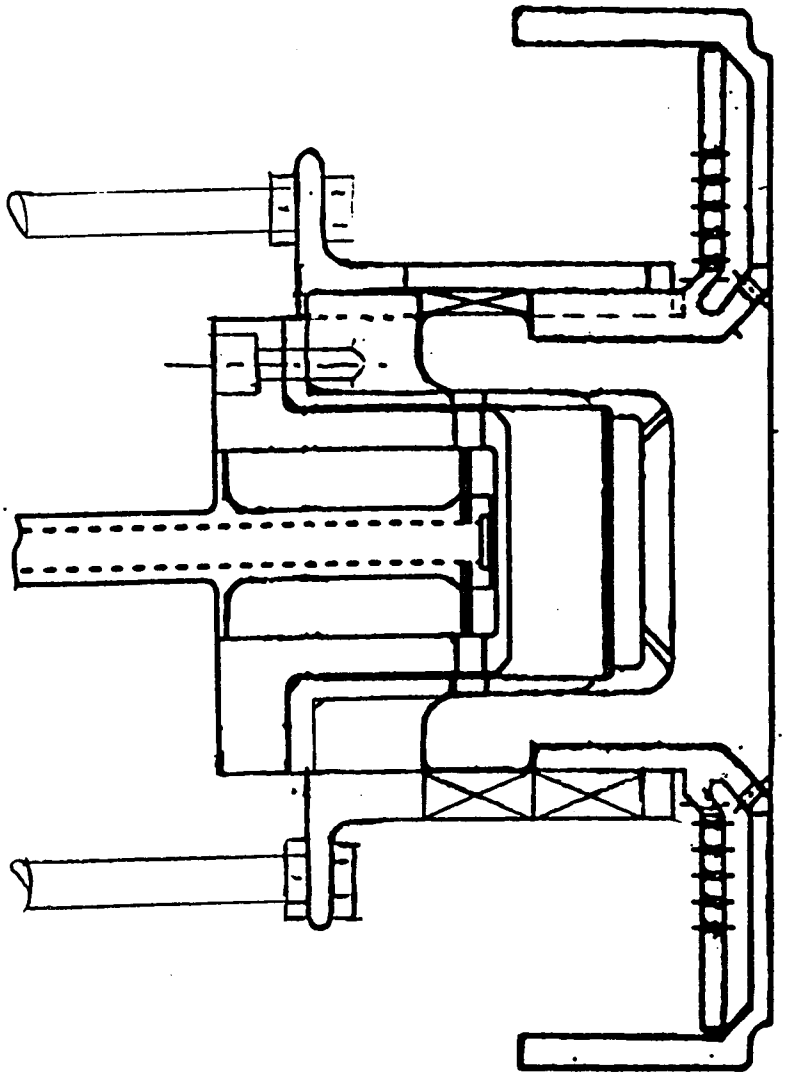


Figure 5.1 - Axial section of variable geometry Cyclone Swirler shown in an engineering sketch of rig hardware. In the actual combustor, the vanes would slide relative the position of the centerbody and the dome. Although the length of open vanes would be constant, the open area of the vanes per unit length would vary.

Section 6

Demonstration Engine Combustor Preliminary Design

In preparation for the HSR Phase II CPC Program, conceptual designs of annular combustor systems for the subscale HSCT demonstration engine were studied and several preliminary designs were generated. These preliminary designs consisted of the aero-thermal definition of the combustion system, including sizing of the premixers. For some of the designs, mechanical layouts were generated with basic flowpath dimensions. Some of these layouts were initially done for a full size engine so the features of the actual product design could be evaluated.

6.1 Design Requirements

An initial step in any design process is to define the requirements for the component or system being designed. The requirements for the HSCT low emissions combustor for the subscale engine demonstration originate from at least four sources: 1) general requirements for any combustor which operates in a gas turbine, 2) requirements specific to LPP/LDI gas turbine combustors, 3) requirements of the HSR program, and 4) interface requirements specific to the existing design of the demonstration engine for which the combustor was being designed.

A preliminary list of the HSCT combustor requirements from the first three sources had been compiled early in Phase I. They are discussed in the final report for Task 5 of NASA contract NAS3-25951. The requirement list for the HSCT low emissions combustor continued to be refined through Phase I and Phase II of the HSR program.

The only HSR program requirement for the HSCT combustor at the start of LET Task 10 was that the NOx EI at supersonic cruise would be less than 5 g/kg fuel. A second, unofficial, program requirement was that the liner cooling air budget for the lean combustors would be 5%

of the combustor air (W36) or less, including leakage. The premixers and the combustion zone would therefore be designed for 95% of the combustor air. The combustor system designs of LET Task 10 have the potential to meet the NOx EI of 5 g/kg as best can be determined with the existing data base. These data come from subcomponent tests in flametubes and tests of the rectangular sector performed in Task 10. The rectangular sector combustor data base did not include supersonic cruise conditions until the fourth sector combustor test performed in October, 1994. When first proposed, the 5% liner cooling goal was viewed as realistic only if the EPM Program developed a viable CMC liner material. Later, the 5% liner cooling budget became accepted as an attainable goal even for metallic liners. Until viable liners with a 5% cooling air budget were available, additional liner cooling air for the HSCT LPP combustors would be "borrowed" from the turbine cooling air budget. This allowed the size of the combustor premixers to remain constant as the liner cooling designs evolved. By the time the lean annular rig was to be run, the plan was to limit the liner cooling air budget to 10% of W36. Again, half of the 10% liner cooling would be borrowed, so that a 95% dome design was maintained. The demonstration engine combustor would, of course, not be allowed to borrow turbine cooling air and the liners (whether metallic or CMC) would have to be designed either to the 5% cooling air budget or the 95% dome air goal would have to be compromised.

The general gas turbine combustor requirements consist of the normal operability requirements for a combustor to operate in a gas turbine and the accepted design practices to meet those requirements. Some of these practices (which evolved for diffusion flame combustors) would be modified because of the special performance characteristics of LPP/LDI combustors. Examples of the latter would be main stage dome velocities, the combustor passage velocities and design practices relating the spacing of fuel-air mixers and dome heights to the combustor length.

The system requirements specific to LPP combustors refer primarily to the need to control the flame temperature within a narrow range. The narrow range of flame temperatures is bounded on the low side by the requirement to maintain acceptably low CO and unburned hydrocarbon emissions and, ultimately, maintain a margin on lean blowout. The flame

temperature range is bounded on the high side primarily by the NOx emissions, but it can also be bounded by material temperatures and the peak in the combustor exit temperature profiles. Together with the design of the fuel-air mixers themselves, the need to control fuel-air ratio or flame temperature within a narrow range are the two most significant features that differentiate LPP and LDI combustors from conventional diffusion flame combustors. This flame temperature control is a system attribute and generally requires the use of fuel staging and/or variable geometry for air scheduling.

A major milestone in the planning of the HSR low emissions combustor development program was the subscale engine demonstration test of the downselected lean or RQL combustor late in HSR Phase II. The decision was made to use a P&W engine for the engine demonstration test during the course of LET Task 10. The exact combustor interface requirements dictated by the choice of the demonstration engine were not made available to GE prior to completion of LET Task 10. These include the definition of the combustor envelope, the compressor exit velocity profile, the specific requirements for the combustor exit profile, and the engine cycle or operating lines over which the combustor would be required to operate. The normal procedures for designing a gas turbine combustor require this basic interface information. Instead, a few key parameters for the demonstration engine supplied by P&W allowed the HSCT A5B cycle conditions to be used for the combustor design with appropriate scaling factors. The parameters supplied by P&W were W3, T3 and P3 at the design point conditions (nominal supersonic cruise for the HSCT). These allowed the determination of the Mach number at the inlet to the diffuser at nominal supersonic cruise and the combustor flow function. For these preliminary designs, a realistic combustor envelope was defined by using the combustor envelope for a similar GE engine.

Since the detailed interface requirements for the demonstration engine were not available at the time the Task 10 preliminary design work was being done, GEAE followed the reverse procedure of supplying to P&W the layouts and the predictions of the LPP combustor operating parameters (e.g.; fuel-air ratio, T4, etc.) at approximately 50 key operating points over a mission and the flight envelope. These predictions were generated using the scaled A5B

Mixed Flow Turbofan (MFTF) cycle and a spreadsheet model of the LPP combustor system. These early projections of the LPP combustor operating parameters were reviewed by the P&W owners of the demonstration engine. The first review of these results by P&W quickly led to a joint meeting and further exchanges, until the apparent inconsistencies were resolved. The inconsistencies were determined, not unexpectedly, to be due to differences in the flight envelopes, the mission and the cycles of the two engines. This early communication was invaluable and led to a discussion and a better understanding of how the demonstration core engine would need to be operated in the test cell during the combustor's engine test (in HSR Phase II) to simulate the HSCT conditions.

6.2 Previous HSCT LPP/LDI Combustor System Designs

The preliminary designs of this subtask evolved from the conceptual designs developed in Task 5 of NASA Contract NAS3-25951, Aero Propulsion Technology (APT). A wide variety of conceptual designs were considered in APT Task 5. Those designs were documented in sketches, some of which are presented in the final report for Task 5. The more promising conceptual designs were brought to the next level of design. The combustor's subcomponents were sized and preliminary analyses of how the combustor system would operate over key engine cycle points were performed.

In APT Task 5, four conceptual designs were brought to the level of preliminary mechanical layouts. Two of those designs used the Swirl-Jet for the main stages. The Swirl-Jet was used because its large size required the fewest fuel injectors, allowing a relatively conventional fuel system design. A third mechanical layout utilized Jet-Mix LDI fuel-air mixers for the main stage. However, in subcomponent tests, the IMFH proved to have the best emissions performance of the fuel-air mixer designs tested. Therefore, in Task 5, the fourth mechanical layout was a stepped-dome combustor utilizing inner and outer IMFH main stages and a cyclone swirler pilot center-stage. The dome design was similar to the LPP rectangular sector combustor, however the fuel system in the stepped-dome combustor was not designed in APT Task 5.

6.3 Stepped Dome with Internal Fuel Manifolds

The challenges in designing a conventional fuel injection system for the IMFH main stages led to consideration of designs with internal fuel manifolds. Figure 6.1 shows a design with an internal fuel manifold for the IMFH main stages drawn for the full scale 3770 MFTF engine. This IMFH fuel system design was chosen for a more detailed design and thermal analysis in LET Task 42 [6-1]. The combustor system design with internal fuel manifolds was considered viable. However, a combustor with internal fuel manifolds was not developed further because of a perception at GEAE of customer resistance to internally manifolded combustors in civil aircraft. Thus, the subscale LPP combustor design using internal manifolds only reached the conceptual stage and a layout for the demonstration engine was never made. A ground rule requiring removable fuel injectors for the HSCT LPP and LDI combustors was adopted by GEAE for future designs, even though the installation of the engine in the HSCT would almost certainly preclude the removal of most of the fuel injectors while the engine is on the wing.

6.4 Stepped Dome with Removable Main Injectors

A mechanical design of a stepped dome with removable fuel injectors never evolved because of the challenge of accommodating the multiple fuel injection points. Figure 6.2 shows a very preliminary layout for a stepped-dome combustor in which the fuel injectors are not shown. The challenge of designing the fuel injection system for this combustor dome is apparent. This design placed the pilot outboard. This accomplished two goals. With the pilot near the outer casing, the design of the ignitor is simplified. Because the position of the dome changes gradually in one direction, it is possible to imagine a removable fuel injector design could be made to work. However, the design of the fuel injector for this dome was never accomplished. This design would probably have very poor combustor exit temperature profiles at low power.

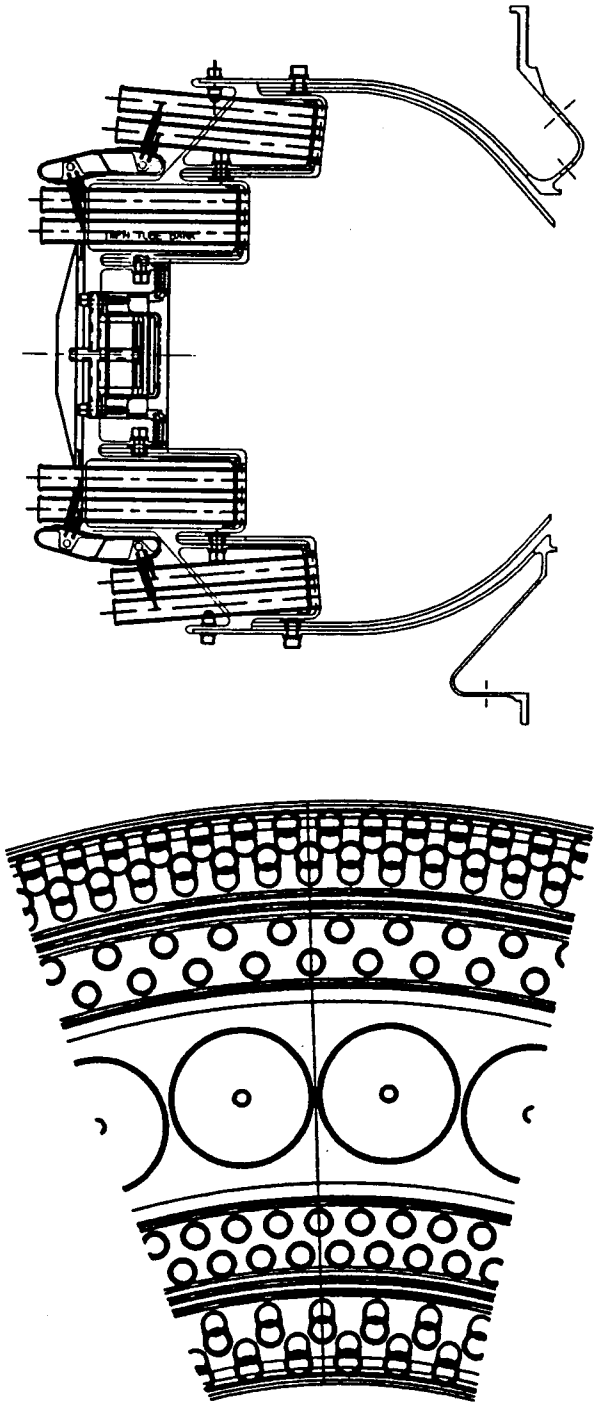


Figure 6.1 - Cyclone Swirler - IMFH combustor with stepped domes and internal fuel manifolds for the IMFH main stages. This layout is for a full size engine. The system design is a direct extension of the LPP rectangular sector layout. Side view shown on top. View of dome (aft looking forward) on the bottom.

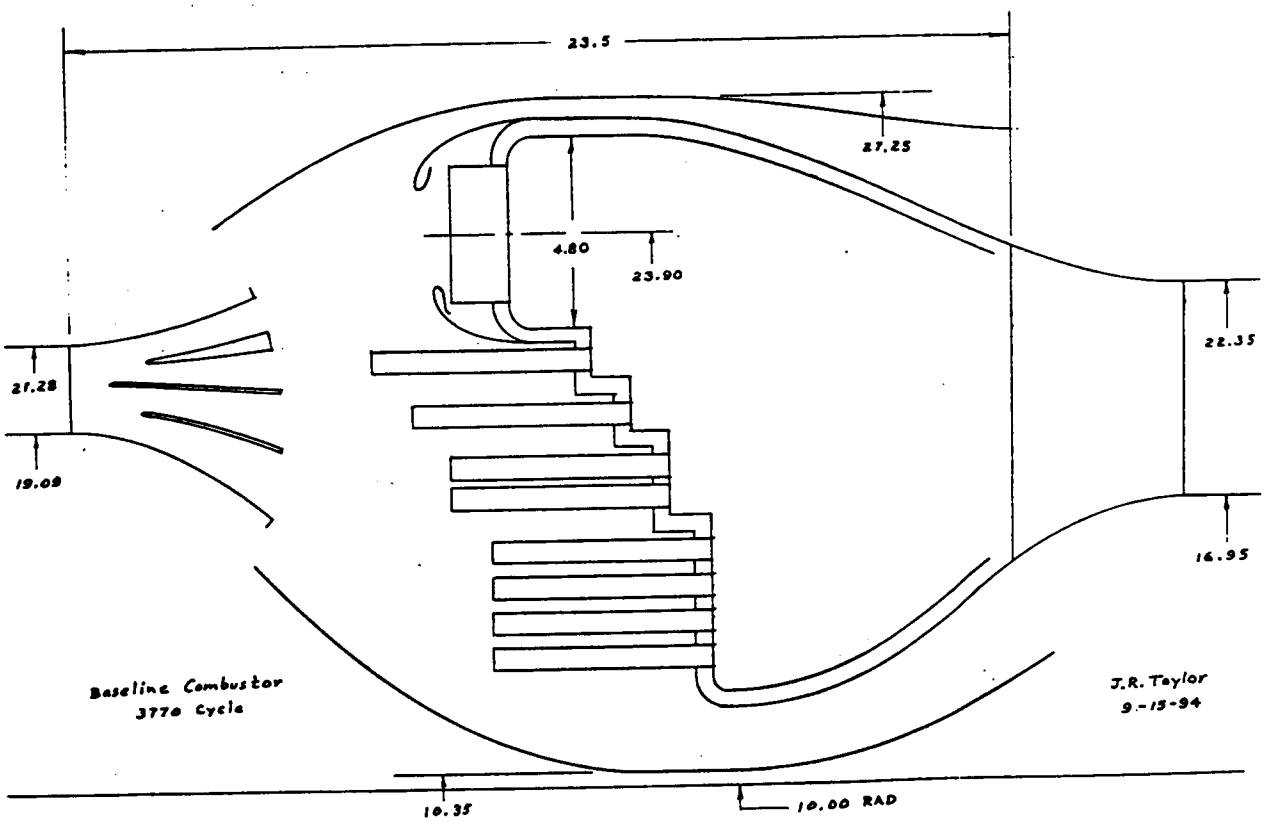


Figure 6.2 - Cyclone Swirler - IMFH combustor with stepped domes. The fuel injector design is not defined. This layout is for a full size engine.

6.5 Multistage Radial Axial System Design (Original MRA)

The original MRA combustor concept was first proposed in early 1994. It arranged the IMFH tubes in a pattern along the outer liner and placed the pilot in the front of the combustor in-line with the diffuser. An early engineering sketch of this conceptual design is shown in Figure 6.3. This design intent of the MRA was to promote better mixing between the fired fuel stages and the unfired IMFH fuel stages. This mixing of the fired and unfired stages would improve the exit temperature profiles when fuel stages were turned off. CONCERT CFD models verified the potential for nearly ideal exit profiles during subsonic cruise, despite the fact that roughly half the fuel injectors were off. This CFD modeling of the MRA combustor is discussed in Section 1.1.3 of this report.

A second goal of the MRA was to eliminate the use of steps to isolate the stages. This would simplify construction, reduce the cost, and reduce the cooling requirements. Instead, the isolation of the fuel stages would be attained by the forced convection of the burned gases from the fired stages towards the unfired stages.

The original MRA was thought to have advantages for the fuel injector design for the IMFH tubes, since the inlets to the IMFH tubes would all be very close to the outer casing. Thus, there was the potential for developing externally manifolded, removable injector designs. The MRA, as originally conceived, had straight IMFH tubes, but early mechanical layouts led to the conclusion that curved IMFH tubes were desirable to fit the combustor within the required engine envelope. A mechanical layout for the combustor showing the curved tubes is shown in Figure 6.4. Meanwhile, single-cup tests of curved IMFH tubes indicated, not unexpectedly, that they performed poorly and were prone to flashback or autoignite (discussed in Section 3). Further efforts on a straight tube design could have resolved the envelope issue (and the main injector design issue), but a new MRA concept evolved. Efforts to solve the main injectors design challenges for the original MRA were terminated and instead, development efforts were focused on the new MRA concept.

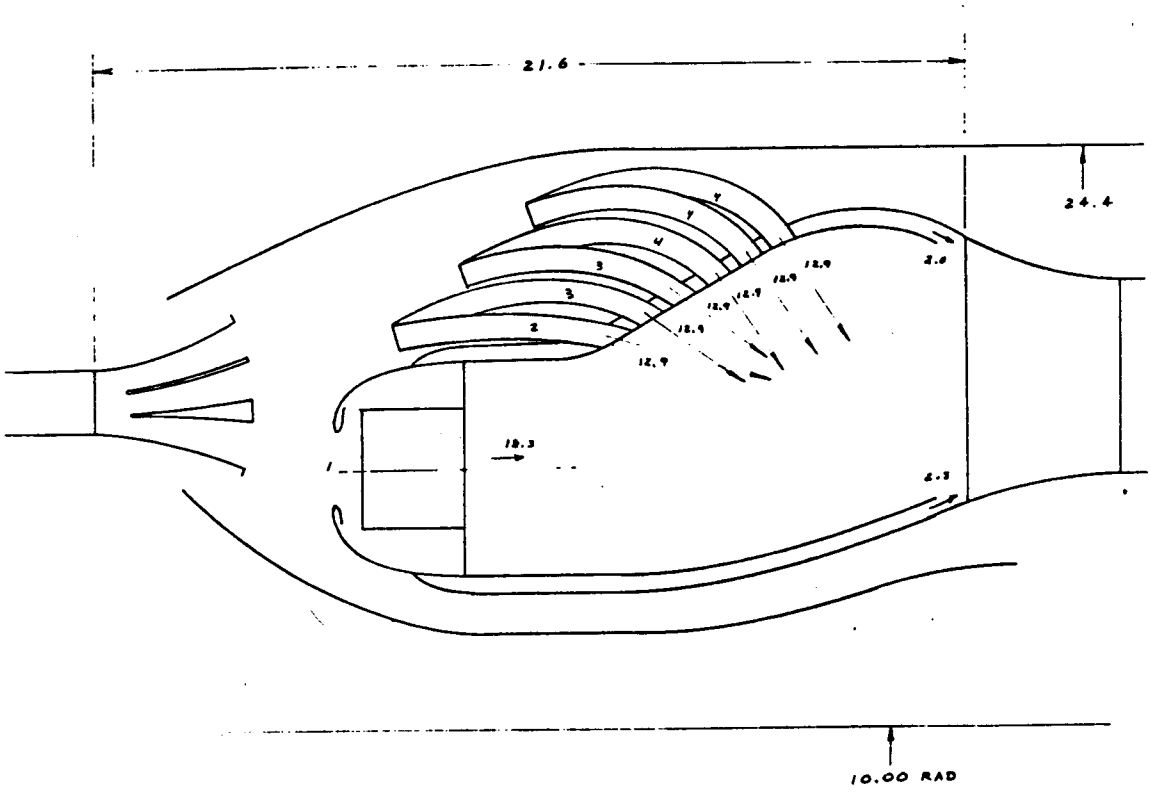


Figure 6.3 - Sketch of flowpath of the MRA (Multi-stage, radial, axial) combustor with curved tubes. Otherwise this design is equivalent to the design shown in Figure 1.25.

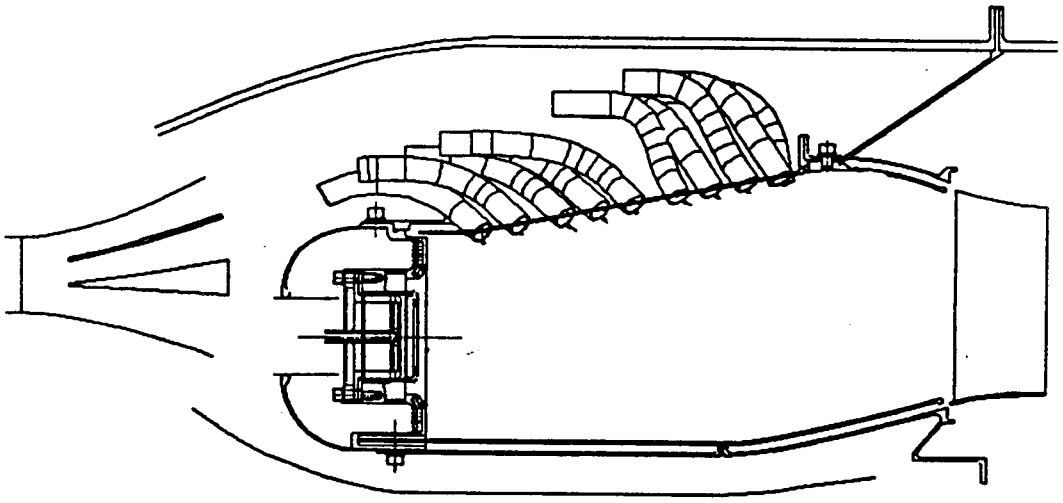


Figure 6.4 - Mechanical layout of the MRA combustor with curved tubes. The details of a practical fuel injector design for the IMFH tubes were never defined.

6.6 MRA Version II

In August, 1994, the concept of "flipping over" the MRA evolved. The new design concept placed straight IMFH tubes on the front dome and the pilot on the outside panel. This put the IMFH tubes inline with the diffuser, resulting in a very direct path for the passage of the main stage air (the largest fraction) through the combustor. An additional advantage of the new MRA concept over the stepped dome (with the normal pilot placement somewhere in the center of the dome) was better placement of the ignitor. The earliest layouts of this concept had the main dome at a 45 degree angle. One of those layouts is shown in Figure 6.5. The 45 degree design was expected to best retain the original feature of promoting mixing between fired and unfired stages, by forcing the burnt gases from the fired stages to flow towards the unfired stages, and also gave the large dome structure high rigidity. During the short time the 45 degree dome was being considered, the preliminary design of the first MRA sector design (which was rectangular) had to be frozen (to meet schedules). The detailed mechanical design and procurement of the rectangular MRA sector combustor (with the 45 degree main dome) proceeded under LET Task 43. The MRA sector combustor design is documented in the LET Task 43 final report.

The 45-degree main dome design quickly evolved to a main dome with a 75 degree angle to the engine centerline. This shortened the combustor and appeared to offer the potential of a relatively simple main fuel injector designs. The 75 degree dome retained the inherent rigidity of a dome which was a conical section, but raised concerns that the mixing characteristics of the original MRA (confirmed by CFD modeling) would be compromised. Cost, length, weight and complexity considerations resulted in vertical dome MRA (90 degrees to the engine centerline) layouts being considered by the end of August, 1994. Figure 6.6 shows an October, 1994 layout of a vertical dome MRA for the subscale demonstrator engine.

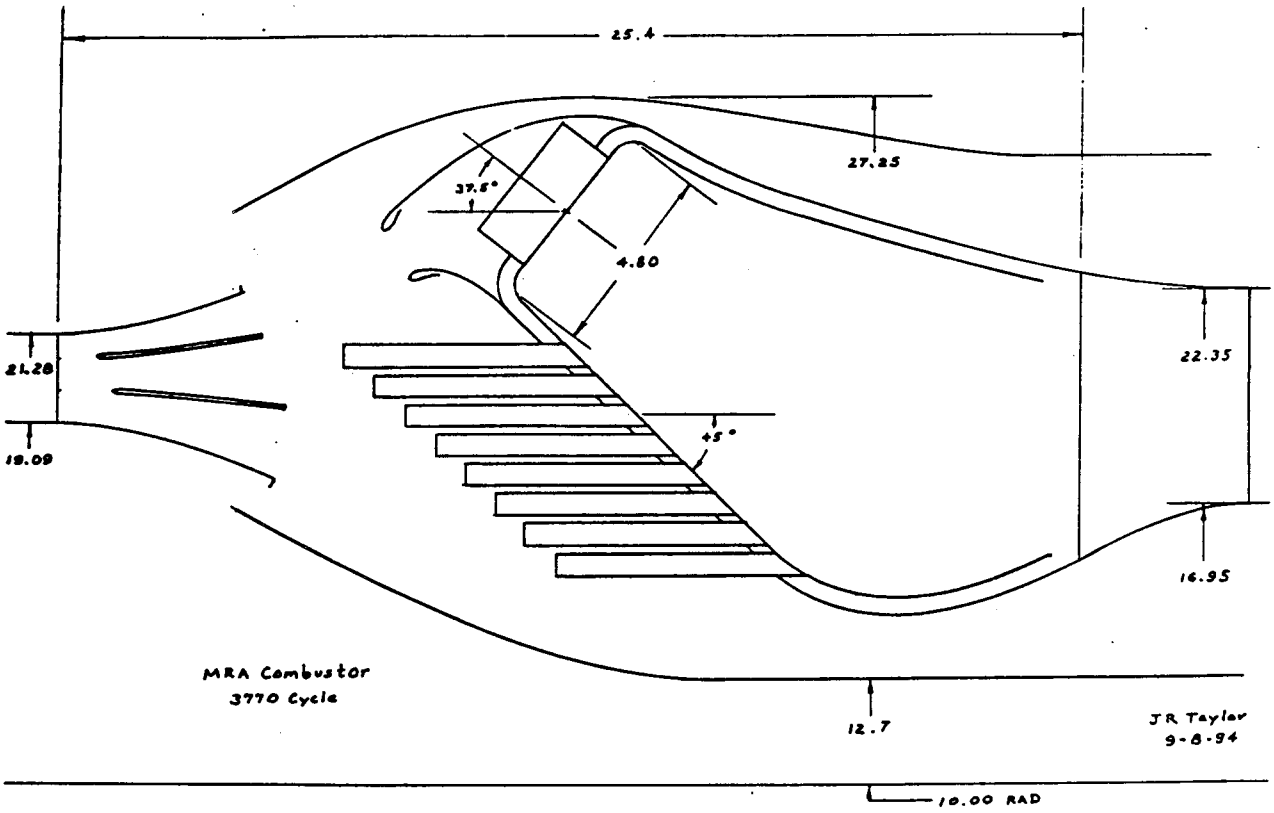


Figure 6.5 - MRA combustor after it was flipped over placing the IMFH tubes in-line with the diffuser. The main dome quickly evolved from 45 degrees to the radius (shown) to 75 degrees, and finally to vertical dome.

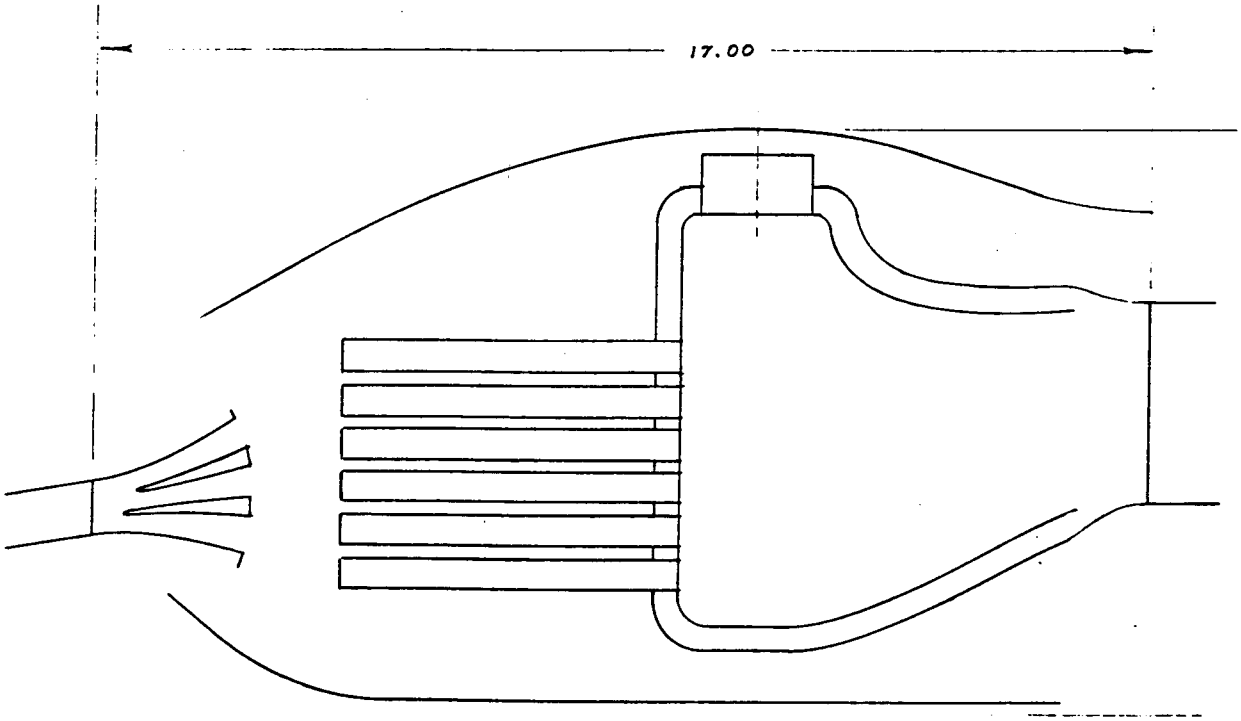


Figure 6.6 - Early layout of the MRA combustor with a vertical dome. This layout is sized for the subscale demonstrator engine.

6.7 Conclusion of Preliminary Combustor Designs

By mid-1995, the vertical dome MRA combustor design had been chosen for the LPP annular rig test in the Phase II CPC program (the LPP subscale annular rig test would later be changed to curved flowpath sector combustor test). The MRA design was chosen because a dome without steps would be inherently more durable than the stepped-dome designs. Also, the design of practical removable fuel injectors for the MRA appeared to be feasible. However, the design of those fuel injectors was to be very challenging. The preliminary design of the fuel injectors for the subscale MRA was not completed until September, 1996, under the Phase II CPC program. By that time, the rectangular MRA sector had been successfully tested (July and August of 1996). The results of that test indicated the MRA was capable of meeting its emissions and operability requirements.

Section 7

Summary and Conclusions

LET Task 10 efforts in the design, analysis, diagnostics, and subcomponent tests of combustor premixers continued similar efforts in APT Task 5. The Task 10 work supported the APT Task 5 conclusions that the Cyclone Swirler yielded the best overall performance in terms of operability and emissions for the pilot stage of the HSCT LPP low emissions combustor. Similarly, the IMFH yielded the best high power performance and was the best available choice for the main stage premixer. Tests of the stepped-dome rectangular LPP sector combustor using these premixers in this Task first confirmed their acceptable performance when integrated into a combustor system. However, significant interactions between the fuel stages were observed during low and mid-power operation. In the stepped-dome design, unfired IMFH stages appeared to degrade the stability of the adjacent fired IMFH stages. Other stage interactions were favorable, resulting in lower NOx and CO emissions. The flame temperature of fired stages are reduced by dilution by the air from unfired stages, in turn reducing the NOx emissions. CO emissions are reduced by further combustion of CO by the air from the unfired stages. During high power operation, with all the stages fired, the sector combustor emissions results are slightly lower than would be expected from the subcomponent test results.

Efforts to translate the stepped-dome LPP rig combustor into a practical subscale engine combustor met with significant challenges. Durability of the stepped dome and the development of a removable fuel injection system were the major barriers. During an eight-month period in 1994, the MRA (Multi-staged, Radial, Axial) combustor system design was conceived and evolved through several iterations to the vertical dome MRA design. The MRA was eventually chosen for the Phase II LPP subscale combustor testing. The advantages of the MRA in dome durability and removable fuel injectors were evident during the preliminary design of the combustor. However, the MRA combustor's satisfactory emissions and operability performance

were not confirmed until sector tests were performed in the HSR Phase II CPC Program in 1996 and 1997.

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Appendix A

5-Cup Rectangular Sector Combustor Test Data

Test 1

FIRST COMBUSTOR SECTOR, CELL 5
GAS SAMPLE PRESSURE TEST DATA

Test: 10/29 & 11/04/93

			INPUTS FROM CELL 5 DATA ACQUISITION SYSTEM PRINTOUT																					
			INPUTS FROM PAGE #3: CALCULATIONS													INPUTS FROM FRONT PAGE					INPUTS FROM GAS SAMPLE SHEET:				
			Main Airflow	Pilot Fuel Flow			Out.IMFH Dome Fuel Flow			Inn.IMFH Dome Fuel Flow														
			East	Pilot	Pilot											Pstrch		Pilot Manif.	Outer IMFH Manif.	Inner IMFH Manif.				Sample	Combust.
			Meter'd	Main	Verif.	Avg.			Avg.			Avg.	Pin,	Tin		(P4)	Pbaro	Pres.	Pres.	Pres.	EI	EI	EI	Fuel-Air	Efficiency
Rdg		Test Points	pps	pph	pph	pph	pph	pph	pph	pph	pph	pph	psia	F		psia	psia	psia	psia	psia	CO	HC	NOx	Ratio	%
Day 1		10/29/93				CALC			CALC			CALC													
16	500	All lit -ganged rakes	5.85	156.3	157.4	157	159.2	160.5	159.9	171.4	173.4	172.4	71.08	664		68.56	14.38	86.0	76.06	76.9	65.57	57.06	0.74	0.03032	93.50%
16	500	All lit -ganged rakes	5.85	156.3	157.4	157	159.2	160.5	159.9	171.4	173.4	172.4	71.08	664		68.56	14.38	86.0	76.06	76.9	60.28	52.04	0.82	0.03146	94.06%
17	500	All lit -ganged rakes	5.93	188.3	189.4	189	196.4	197.5	196.9	222.7	224.3	223.5	74.37	670		72.11	14.38	95.4	82.42	84.3	13.93	4.39	4.61	0.03807	99.29%
17	500	All lit -ganged rakes	5.93	188.3	189.4	189	196.4	197.5	196.9	222.7	224.3	223.5	74.37	670		72.11	14.38	95.4	82.42	84.3	14.26	3.78	5.09	0.03826	99.34%
Day 2		11/4/93																							
19	201	Pilot only - no sample	4.58	157.6	159.3	158	0.0	0.0	0.0	0.0	0.0	0.0	46.81	412		45.47	14.39	62.6	-	-	-	-	-	-	-
20	403	All lit - no sample	6.71	185.2	187.0	186	224.2	224.9	224.6	228.6	230.1	229.3	78.64	615		75.92	14.36	98.5	86.63	88.6	-	-	-	-	-
21	403	All lit -ganged rakes	6.72	185.5	187.3	186	226.1	226.9	226.5	228.8	230.4	229.6	78.76	603		76.02	14.36	98.9	86.86	88.8	24.71	9.92	1.86	0.03466	98.56%
21	403	All lit -ganged rakes	6.72	185.5	187.3	186	226.1	226.9	226.5	228.8	230.4	229.6	78.76	603		76.02	14.36	98.9	86.86	88.8	23.56	10.92	1.84	0.03545	98.41%
22	502	All lit -ganged rakes	7.05	190.8	192.6	192	237.6	238.1	237.8	235.7	237.1	236.4	85.56	768		82.65	14.35	106.6	94.48	96.1	26.69	10.34	0.72	0.03012	98.47%
22	502	All lit -ganged rakes	7.05	190.8	192.6	192	237.6	238.1	237.8	235.7	237.1	236.4	85.56	768		82.65	14.35	106.6	94.48	96.1	23.99	7.09	0.65	0.03030	98.82%
23	70	All lit -ganged rakes	9.74	255.6	257.7	257	339.1	338.5	338.8	340.3	341.2	340.7	121.18	946		116.70	14.34	158.2	140.83	142.9	2.66	0.11	4.23	0.03560	99.93%
		All lit rake A - ganged																			2.98	0.09	5.62	0.03640	99.92%
		All lit rake B - ganged																			1.92	0.09	3.49	0.03519	99.95%
		All lit rake C - ganged																			2.75	0.10	3.56	0.03660	99.93%
		All lit rake D - ganged																			3.69	0.18	5.58	0.03693	99.90%
24	53	All lit -ganged rakes	9.61	268.6	270.3	269	343.2	342.7	342.9	344.2	345.0	344.6	120.79	944		116.47	14.33	161.5	140.93	142.9	2.91	0.09	4.28	0.03661	99.92%
25	52	All lit -ganged rakes	9.58	264.2	266.1	265	337.8	337.3	337.5	338.6	339.4	339.0	121.68	945		117.22	14.33	161.1	141.02	143.2	2.66	0.09	3.54	0.03540	99.93%
		All lit rake A - ganged																			2.82	0.08	5.59	0.03580	99.93%
		All lit rake B - ganged																			1.82	0.05	4.09	0.03445	99.95%
26	51	All lit -ganged rakes	9.57	257.9	259.9	259	330.0	329.7	329.8	330.8	331.6	331.2	121.21	947		116.73	14.33	158.9	139.60	141.7	2.79	0.07	3.61	0.03620	99.93%
27	51	All lit -ganged rakes	9.61	241.9	244.0	243	316.8	316.5	316.6	317.2	318.2	317.7	119.07	947		114.66	14.33	152.5	135.83	137.9	2.06	0.10	2.50	0.03307	99.94%
28	99	All lit -ganged rakes	9.59	226.9	229.0	228	297.1	296.9	297.0	296.8	298.0	297.4	117.30	947		112.88	14.33	146.9	131.59	133.6	2.02	0.16	1.68	0.03086	99.94%
29	98	All lit -ganged rakes	9.62	217.1	219.2	218	282.0	281.9	281.9	284.1	285.3	284.7	116.07	948		111.44	14.33	143.0	128.35	128.4	2.50	0.18	1.21	0.02962	99.93%
30	97	All lit -ganged rakes	9.62	211.2	213.2	212	285.0	284.8	284.9	286.1	287.3	286.7	116.99	947		112.18	14.33	142.4	129.50	131.7	2.35	0.19	1.20	0.02944	99.93%
		All lit rake A - ganged																			3.25	0.25	1.64	0.02981	99.90%
		All lit rake B - ganged																			1.24	0.06	1.24	0.02873	99.97%
		All lit rake C - ganged																			2.29	0.24	1.15	0.03077	99.93%
		All lit rake D - ganged																			2.64	0.27	1.55	0.03007	99.91%
31	96	All lit -ganged rakes	9.74	201.8	203.8	203	292.1	291.9	292.0	291.0	292.2	291.6	117.46	949		112.80	14.33	141.0	131.07	133.0	2.14	0.16	1.03	0.02992	99.94%
32	75	All lit -ganged rakes	9.62	220.1	222.0	221	298.8	298.6	298.7	273.3	274.6	274.0	117.40	951		112.53	14.33	144.8	131.22	130.4	2.40	0.17	1.39	0.02997	99.93%
33	76	All lit -ganged rakes	9.59	220.2	222.1	221	313.4	313.3	313.4	258.3	259.5	258.9	117.18	949		112.71	14.33	145.2	133.26	129.0	3.38	0.26	1.49	0.02999	99.90%

FIRST COMBUSTOR SECTOR, CELL 5 GAS SAMPLE PRESSURE TEST DATA

		Sect.Tot.Aeff =	13.629	sq.in.						JP5 stoichiometric f/a =				0.06815															
		Out.IMFH Dome Aeff =	3.602	sq.in.	O.Dome In. =		3.202																						
		Pilot Dome Aeff =	2.834	sq.in.						At:		21 psid	100 psid																
		Inn.IMFH Dome Aeff =	3.607	sq.in.	I.Dome In. =		3.207			Out.Dome Flow #		66.5	68.8																
		Tot.Dome Aeff =	10.043	sq.in.						Pilot Dome Flow #		39.4	41.9																
		Dome/Sect.Tot. Air flow	73.68%							Inn.Dome Flow #		67.1	68.9						Test:	10/29 & 11/04/93									
		Left/Right.Out.&Inn.Dome	3.605																										
		(or inner/outer IMFH rows)		PRESSURES				TEMP'S		AIRFLOWS					FUEL FLOWS & PRESSURES														
																	Total	Outer	Inner									
																	IMFH	IMFH	IMFH		% IMFH			Outer	Inner			
			Sampling							Sector Airflow				Flow	Dome	Pilot	Domes	Dome	Dome		Fuel to	Pilot	IMFH	IMFH					
			G = ganged			Pres	%			Calc.		Calc.	Calc.	Function:	Fuel	Fuel	Fuel	Fuel	Fuel	% Fuel	IMFH	Manif.	Manif.	Manif.					
			I = individual	Pin,	P4	Drop,	Pres.	Tin		Total	Meter'd	Total	Dome	Wsqrt(T)	Flow,	Flow,	Flow	Flow,	Flow	to	Outer	Pres.	Pres.	Pres.					
Rdg	Test	Points	G & I = both	psia	psia	psid	Drop	F	R	pps	pps	Meter'd	Wa, pps	P	pph	pph	pph	pph	pph	Pilot	Dome	psia	psia	psia					
Day 1		10/29/93																											
		Pilot only:																											
16	500	All lit -ganged rakes	G rakes	71.08	68.56	2.52	3.55%	664	1124	5.97	5.85	1.02	4.40	2.82	489.1	156.8	332.3	159.9	172.4	32.1%	48.11%	85.95	76.06	76.9					
16	500	All lit -ganged rakes	G rakes	71.08	68.56	2.52	3.55%	664	1124	5.97	5.85	1.02	4.40	2.82	489.1	156.8	332.3	159.9	172.4	32.1%	48.11%	85.95	76.06	76.9					
17	500	All lit -ganged rakes	G rakes	74.37	72.11	2.26	3.04%	670	1130	5.77	5.93	0.97	4.25	2.61	609.3	188.8	420.5	196.9	223.5	31.0%	46.84%	95.41	82.42	84.3					
17	500	All lit -ganged rakes	G rakes	74.37	72.11	2.26	3.04%	670	1130	5.77	5.93	0.97	4.25	2.61	609.3	188.8	420.5	196.9	223.5	31.0%	46.84%	95.41	82.42	84.3					
Day 2		11/4/93																											
19	201	Pilot only - no sample	None	46.81	45.47	1.34	2.86%	412	872	4.01	4.58	0.88	2.96	2.53	158.4	158.4	0.0	0.0	0.0	100.0%	0.00%	62.55	-	-					
20	403	All lit - no sample	None	78.64	75.92	2.72	3.46%	615	1075	6.68	6.71	0.99	4.92	2.78	640.0	186.1	453.9	224.6	229.3	29.1%	49.47%	98.54	86.63	88.6					
21	403	All lit -ganged rakes	G rakes	78.76	76.02	2.74	3.48%	603	1063	6.74	6.72	1.00	4.97	2.79	642.5	186.4	456.1	226.5	229.6	29.0%	49.66%	98.94	86.86	88.8					
21	403	All lit -ganged rakes	G rakes	78.76	76.02	2.74	3.48%	603	1063	6.74	6.72	1.00	4.97	2.79	642.5	186.4	456.1	226.5	229.6	29.0%	49.66%	98.94	86.86	88.8					
22	502	All lit -ganged rakes	G rakes	85.56	82.65	2.91	3.40%	768	1228	6.74	7.05	0.96	4.96	2.76	666.0	191.7	474.3	237.8	236.4	28.8%	50.15%	106.55	94.48	96.1					
22	502	All lit -ganged rakes	G rakes	85.56	82.65	2.91	3.40%	768	1228	6.74	7.05	0.96	4.96	2.76	666.0	191.7	474.3	237.8	236.4	28.8%	50.15%	106.55	94.48	96.1					
23	70	All lit -ganged rakes	G rakes	121.18	116.70	4.48	3.70%	946	1406	9.30	9.74	0.95	6.85	2.88	936.3	256.7	679.6	338.8	340.7	27.4%	49.86%	158.23	140.83	142.9					
		All lit rake A - ganged	G elements																										
		All lit rake B - ganged	G elements																										
		All lit rake C - ganged	G elements																										
		All lit rake D - ganged	G elements																										
24	53	All lit -ganged rakes	G rakes	120.79	116.47	4.32	3.58%	944	1404	9.12	9.61	0.95	6.72	2.83	956.9	269.5	687.5	342.9	344.6	28.2%	49.88%	161.48	140.93	142.9					
25	52	All lit -ganged rakes	G rakes	121.68	117.22	4.46	3.67%	945	1405	9.30	9.58	0.97	6.85	2.86	941.7	265.2	676.5	337.5	339.0	28.2%	49.89%	161.10	141.02	143.2					
		All lit rake A - ganged	G elements																										
		All lit rake B - ganged	G elements																										
26	51	All lit -ganged rakes	G rakes	121.21	116.73	4.48	3.70%	947	1407	9.30	9.57	0.97	6.85	2.88	919.9	258.9	661.0	329.8	331.2	28.1%	49.90%	158.89	139.60	141.7					
27	51	All lit -ganged rakes	G rakes	119.07	114.66	4.41	3.70%	947	1407	9.14	9.61	0.95	6.74	2.88	877.3	242.9	634.3	316.6	317.7	27.7%	49.92%	152.47	135.83	137.9					
28	99	All lit -ganged rakes	G rakes	117.30	112.88	4.42	3.77%	947	1407	9.08	9.59	0.95	6.69	2.90	822.3	228.0	594.4	297.0	297.4	27.7%	49.97%	146.86	131.59	133.6					
29	98	All lit -ganged rakes	G rakes	116.07	111.44	4.63	3.99%	948	1408	9.25	9.62	0.96	6.81	2.99	784.8	218.2	566.6	281.9	284.7	27.8%	49.75%	143.04	128.35	128.4					
30	97	All lit -ganged rakes	G rakes	116.99	112.18	4.81	4.11%	947	1407	9.46	9.62	0.98	6.97	3.03	783.8	212.2	571.6	284.9	286.7	27.1%	49.84%	142.41	129.50	131.7					
		All lit rake A - ganged	G elements																										
		All lit rake B - ganged	G elements																										
		All lit rake C - ganged	G elements																										
		All lit rake D - ganged	G elements																										
31	96	All lit -ganged rakes	G rakes	117.46	112.80	4.66	3.97%	949	1409	9.33	9.74	0.96	6.87	2.98	786.4	202.8	583.6	292.0	291.6	25.8%	50.04%	140.98	131.07	133.0					
32	75	All lit -ganged rakes	G rakes	117.40	112.53	4.87	4.15%	951	1411	9.52	9.62	0.99	7.02	3.05	793.7	221.0	572.6	298.7	274.0	27.9%	52.16%	144.78	131.22	130.4					
33	76	All lit -ganged rakes	G rakes	117.18	112.71	4.47	3.81%	949	1409	9.12	9.59	0.95	6.72	2.92	793.4	221.2	572.3	313.4	258.9	27.9%	54.76%	145.15	133.26	129.0					

FIRST COMBUSTOR SECTOR, CELL 5 GAS SAMPLE PRESSURE TEST DATA

Test: 10/29 & 11/04/93

													Tflame	a0 =	166619100					a6 =	-462.556627							
													Coef's:	a1 =	222862300					a7 =	-280833.5							
														a2 =	-2921.308155					a8 =	1583.425649							
														a3 =	15972.29681					a9 =	-327760800							
														a4 =	-70493950					a10 =	14578990							
														a5 =	32214690					a11 =	7.938999							
								MEASURED FUEL-AIR RATIOS/ EQUIVALENCE RATIOS												UNCORRECTED CALCULATED EQUIV.RATIOS				
			FUEL FLOW NUMBERS						All Rakes (A,B,C,D)					Sample															
				Outer	Inner	Pilot	Outer IMFH	Inner IMFH			Sample	Sample	Airflow	Calc.	Calc.	Sample	Calc.				Total	Outer	Inner						
			Pilot	IMFH	IMFH	Test	Test	Test		Sample	Eq.R.i	Uncor.	Corr.	Sample	Sample	(Pilot&)	Sample				IMFH	IMFH	IMFH						
			Injector	Manif.	Manif.	Cal.	Cal.	Cal.	Sample	(Dome)	Sample	Dome	Dome	(Pilot)	(O.Dome)	(O.Dome)	(I.Dome)	Dome	Pilot	Domes	Dome	Dome						
			Flow	Flow	Flow	Flow	Flow	Flow	Fuel-Air	Equiv.	Eq.R.	Equiv.	Equiv.	Equiv.	Equiv.	Equiv.	Equiv.	Equiv.	Equiv.	Equiv.	Equiv.	Equiv.						
Rdg	Test Points		Number	Number	Number	Number	Number	Number	Ratio	Ratio	avg	Ratio	Ratio	Ratio	Ratio	Ratio	Ratio	Ratio	Ratio	Ratio	Ratio	Ratio						
Day 1		10/29/93																										
		Pilot only:																										
16	500	All lit -ganged rakes	37.61	58.37	59.66	0.95	0.88	0.89	0.03032	0.445	-	0.983	0.962	0.506	0.405	0.450	0.437	0.453	0.515	0.429	0.413	0.444						
16	500	All lit -ganged rakes	37.61	58.37	59.66	0.95	0.88	0.89	0.03146	0.462	-	1.019	0.998	0.525	0.421	0.466	0.453	0.453	0.515	0.429	0.413	0.444						
17	500	All lit -ganged rakes	39.12	61.33	63.97	0.99	0.92	0.95	0.03807	0.559	-	0.957	0.983	0.614	0.503	0.552	0.571	0.584	0.641	0.561	0.526	0.597						
17	500	All lit -ganged rakes	39.12	61.33	63.97	0.99	0.92	0.95	0.03826	0.561	-	0.961	0.988	0.617	0.506	0.555	0.573	0.584	0.641	0.561	0.526	0.597						
Day 2		11/4/93																										
19	201	Pilot only - no sample	38.33	NA	NA	0.97	NA	NA	-	-	-	-	-	-	-	-		0.218	0.774	0.000	0.000	0.000						
20	403	All lit - no sample	39.13	68.61	64.31	0.99	1.03	0.96	-	-	-	-	-	-	-	-		0.530	0.546	0.524	0.519	0.529						
21	403	All lit -ganged rakes	38.93	68.80	64.18	0.99	1.03	0.96	0.03466	0.509	-	0.965	0.962	0.523	0.500	0.510	0.506	0.527	0.542	0.521	0.518	0.525						
21	403	All lit -ganged rakes	38.93	68.80	64.18	0.99	1.03	0.96	0.03545	0.520	-	0.987	0.984	0.535	0.511	0.522	0.518	0.527	0.542	0.521	0.518	0.525						
22	502	All lit -ganged rakes	39.22	69.15	64.58	1.00	1.04	0.96	0.03012	0.442	-	0.808	0.846	0.451	0.440	0.445	0.437	0.547	0.558	0.542	0.544	0.540						
22	502	All lit -ganged rakes	39.22	69.15	64.58	1.00	1.04	0.96	0.03030	0.445	-	0.813	0.851	0.454	0.443	0.448	0.439	0.547	0.558	0.542	0.544	0.540						
23	70	All lit -ganged rakes	39.83	68.97	66.52	1.01	1.04	0.99	0.03560	0.522	-	0.938	0.982	0.508	0.527	0.518	0.529	0.557	0.541	0.563	0.562	0.564						
		All lit rake A - ganged							0.03640	0.534	1.022	-	-	0.519	0.539	0.530	0.541											
		All lit rake B - ganged							0.03519	0.516	0.988	-	-	0.502	0.521	0.513	0.523											
		All lit rake C - ganged							0.03660	0.537	1.028	-	-	0.522	0.542	0.533	0.544											
		All lit rake D - ganged							0.03693	0.542	1.037	-	-	0.527	0.547	0.538	0.549											
24	53	All lit -ganged rakes	40.16	69.33	67.00	1.02	1.04	1.00	0.03661	0.537	-	0.926	0.975	0.536	0.537	0.536	0.539	0.580	0.579	0.581	0.580	0.582						
25	52	All lit -ganged rakes	40.03	69.18	66.58	1.02	1.04	0.99	0.03540	0.519	-	0.927	0.955	0.518	0.519	0.519	0.521	0.560	0.559	0.561	0.560	0.561						
		All lit rake A - ganged							0.03580	0.525	1.011	-	-	0.524	0.525	0.525	0.527											
		All lit rake B - ganged							0.03445	0.506	0.973	-	-	0.505	0.505	0.505	0.507											
26	51	All lit -ganged rakes	39.87	68.97	66.24	1.01	1.04	0.99	0.03620	0.531	-	0.970	0.999	0.530	0.531	0.530	0.532	0.547	0.546	0.548	0.547	0.549						
27	51	All lit -ganged rakes	39.51	68.82	65.91	1.00	1.03	0.98	0.03307	0.485	-	0.914	0.961	0.476	0.488	0.483	0.489	0.531	0.521	0.535	0.534	0.535						
28	99	All lit -ganged rakes	39.11	68.66	65.33	0.99	1.03	0.97	0.03086	0.453	-	0.904	0.955	0.445	0.456	0.451	0.456	0.501	0.492	0.504	0.504	0.504						
29	98	All lit -ganged rakes	38.81	68.55	69.24	0.98	1.03	1.03	0.02962	0.435	-	0.926	0.963	0.428	0.435	0.432	0.439	0.470	0.463	0.472	0.470	0.474						
30	97	All lit -ganged rakes	38.60	68.47	64.88	0.98	1.03	0.97	0.02944	0.432	-	0.942	0.958	0.415	0.438	0.428	0.440	0.458	0.440	0.466	0.465	0.467						
		All lit rake A - ganged							0.02981	0.437	1.013	-	-	0.420	0.443	0.433	0.445											
		All lit rake B - ganged							0.02873	0.422	0.976	-	-	0.405	0.427	0.417	0.429											
		All lit rake C - ganged							0.03077	0.452	1.045	-	-	0.433	0.458	0.447	0.460											
		All lit rake D - ganged							0.03007	0.441	1.021	-	-	0.423	0.447	0.437	0.449											
31	96	All lit -ganged rakes	38.20	68.32	64.82	0.97	1.03	0.97	0.02992	0.439	-	0.942	0.983	0.401	0.455	0.431	0.453	0.466	0.426	0.482	0.483	0.481						
32	75	All lit -ganged rakes	38.92	69.09	64.81	0.99	1.04	0.97	0.02997	0.440	-	0.954	0.964	0.434	0.461	0.449	0.423	0.461	0.455	0.463	0.484	0.443						
33	76	All lit -ganged rakes	38.83	69.12	64.11	0.99	1.04	0.96	0.02999	0.440	-	0.915	0.962	0.435	0.485	0.463	0.400	0.481	0.475	0.483	0.530	0.437						

FIRST COMBUSTOR SECTOR, CELL 5 GAS SAMPLE PRESSURE TEST DATA

Test: 10/29 & 11/04/93

			AIRFLOW CORRECTED CALCULATED EQUIV.RATIOS					AIRFLOW UNCORRECTED,CALCULATED ADIABATIC FLAME TEMPERATURES					AIRFLOW CORRECTED ADIABATIC FLAME TEMPERATURES				
					Total IMFH	Outer IMFH	Inner IMFH			Total IMFH	Outer IMFH	Inner IMFH			Total IMFH	Outer IMFH	Inner IMFH
			Dome Equiv.	Pilot Equiv.	Domes Equiv.	Dome Equiv.	Dome Equiv.	Dome Flame	Pilot Flame	Domes Flame	Dome Flame	Dome Flame	Dome Flame	Pilot Flame	Domes Flame	Dome Flame	Dome Flame
Rdg	Test Points		Ratio	Ratio	Ratio	Ratio	Ratio	Temp.,R	Temp.,R	Temp.,R	Temp.,R	Temp.,R	Temp.,R	Temp.,R	Temp.,R	Temp.,R	Temp.,R
Day 1		10/29/93															
Day 1		Pilot only:															
16	500	All lit -ganged rakes	0.462	0.526	0.438	0.421	0.454	2991	3206	2905	2849	2961	3025	3244	2937	2880	2994
16	500	All lit -ganged rakes	0.462	0.526	0.438	0.421	0.454	2991	3206	2905	2849	2961	3025	3244	2937	2880	2994
17	500	All lit -ganged rakes	0.568	0.624	0.546	0.512	0.581	3445	3629	3370	3251	3486	3393	3575	3319	3203	3434
17	500	All lit -ganged rakes	0.568	0.624	0.546	0.512	0.581	3445	3629	3370	3251	3486	3393	3575	3319	3203	3434
Day 2		11/4/93															
19	201	Pilot only - no sample	0.191	0.678	0.000	0.000	0.000	1908	3837	872	872	872	1795	3568	872	872	872
20	403	All lit - no sample	0.528	0.544	0.521	0.516	0.526	3227	3282	3205	3187	3223	3218	3273	3196	3178	3213
21	403	All lit -ganged rakes	0.529	0.544	0.523	0.520	0.526	3208	3259	3188	3177	3199	3214	3265	3194	3183	3205
21	403	All lit -ganged rakes	0.529	0.544	0.523	0.520	0.526	3208	3259	3188	3177	3199	3214	3265	3194	3183	3205
22	502	All lit -ganged rakes	0.523	0.533	0.518	0.520	0.516	3392	3429	3377	3384	3370	3310	3346	3296	3302	3289
22	502	All lit -ganged rakes	0.523	0.533	0.518	0.520	0.516	3392	3429	3377	3384	3370	3310	3346	3296	3302	3289
23	70	All lit -ganged rakes	0.532	0.517	0.538	0.536	0.539	3555	3503	3575	3571	3579	3472	3422	3492	3488	3495
		All lit rake A - ganged															
		All lit rake B - ganged															
		All lit rake C - ganged															
		All lit rake D - ganged															
24	53	All lit -ganged rakes	0.551	0.550	0.551	0.551	0.552	3630	3626	3631	3628	3634	3535	3531	3536	3533	3539
25	52	All lit -ganged rakes	0.544	0.543	0.544	0.543	0.545	3565	3561	3566	3564	3569	3512	3508	3513	3510	3516
		All lit rake A - ganged															
		All lit rake B - ganged															
26	51	All lit -ganged rakes	0.532	0.530	0.532	0.532	0.533	3525	3520	3527	3524	3529	3473	3469	3475	3473	3477
27	51	All lit -ganged rakes	0.505	0.496	0.509	0.508	0.509	3469	3436	3482	3480	3484	3383	3352	3396	3394	3397
28	99	All lit -ganged rakes	0.474	0.466	0.478	0.478	0.478	3369	3340	3381	3381	3381	3280	3252	3291	3292	3291
29	98	All lit -ganged rakes	0.451	0.445	0.454	0.452	0.456	3265	3241	3274	3267	3281	3203	3180	3211	3205	3218
30	97	All lit -ganged rakes	0.451	0.433	0.458	0.457	0.459	3226	3163	3251	3247	3255	3201	3139	3225	3222	3229
		All lit rake A - ganged															
		All lit rake B - ganged															
		All lit rake C - ganged															
		All lit rake D - ganged															
31	96	All lit -ganged rakes	0.447	0.408	0.462	0.462	0.461	3254	3118	3308	3310	3305	3187	3056	3239	3241	3236
32	75	All lit -ganged rakes	0.456	0.450	0.459	0.479	0.439	3238	3218	3246	3315	3177	3223	3203	3231	3299	3162
33	76	All lit -ganged rakes	0.458	0.452	0.460	0.504	0.416	3304	3285	3312	3467	3155	3225	3206			3083

FIRST COMBUSTOR SECTOR, CELL 5 GAS SAMPLE PRESSURE TEST DATA

Test: 10/29 & 11/04/93

Rake emiss.norm.by all rake avg. for rakes
Element emiss.norm.by that rake avg.

MEASURED EMISSIONS

Rdg	Test Points		Uncorr. Sample (Dome) Flame Temp.,R	Uncorr. Sample (Pilot) Flame Temp.,R	Uncorr. Sample (O.Dome) Flame Temp.,R	Uncorr. Sample (Pilot&) (O.Dome) Flame Temp.,R	Uncorr. Sample (I.Dome) Flame Temp.,R	Combust. Efficiency %	Corr. Sample (Dome) Flame Temp.,R	Corr. Sample (Pilot) Flame Temp.,R	Corr. Sample (O.Dome) Flame Temp.,R	Corr. Sample (Pilot&) (O.Dome) Flame Temp.,R	Corr. Sample (I.Dome) Flame Temp.,R	EI NOx	EI NOx i NOx avg	EI CO	EI CO i CO avg	EI HC	EI HC i HC avg
Day 1		10/29/93																	
		Pilot only:																	
16	500	All lit -ganged rakes	2963	3175	2823	2979	2934	93.50%	2843	3042	2712	2859	2816	0.74	-	65.57	-	57.06	-
16	500	All lit -ganged rakes	3022	3240	2877	3039	2992	94.06%	2909	3115	2773	2925	2881	0.82	-	60.28	-	52.04	-
17	500	All lit -ganged rakes	3361	3541	3172	3338	3401	99.29%	3345	3524	3158	3322	3385	4.61	-	13.93	-	4.39	-
17	500	All lit -ganged rakes	3370	3551	3181	3347	3410	99.34%	3355	3535	3168	3333	3395	5.09	-	14.26	-	3.78	-
Day 2		11/4/93																	
19	201	Pilot only - no sample	-	-	-	-		-	-	-	-	-	-	-	-	-	-	-	-
20	403	All lit - no sample	-	-	-	-		-	-	-	-	-	-	-	-	-	-	-	-
21	403	All lit -ganged rakes	3144	3193	3113	3148	3135	98.56%	3114	3163	3084	3118	3105	1.86	-	24.71	-	9.92	-
21	403	All lit -ganged rakes	3184	3234	3153	3189	3175	98.41%	3150	3200	3120	3155	3141	1.84	-	23.56	-	10.92	-
22	502	All lit -ganged rakes	3033	3064	3026	3043	3015	98.47%	3005	3036	2999	3015	2987	0.72	-	26.69	-	10.34	-
22	502	All lit -ganged rakes	3042	3073	3035	3052	3024	98.82%	3021	3052	3014	3031	3003	0.65	-	23.99	-	7.09	-
23	70	All lit -ganged rakes	3441	3392	3457	3428	3464	99.93%	3440	3390	3455	3427	3463	4.23	-	2.66	-	0.11	-
		All lit rake A - ganged	3480	3430	3496	3467	3503	99.92%	3478	3428	3494	3465	3502	5.62	1.23	2.98	1.05	0.09	0.78
		All lit rake B - ganged	3421	3372	3437	3408	3444	99.95%	3420	3371	3436	3407	3443	3.49	0.76	1.92	0.68	0.09	0.78
		All lit rake C - ganged	3490	3439	3506	3477	3513	99.93%	3488	3438	3504	3475	3512	3.56	0.78	2.75	0.97	0.10	0.87
		All lit rake D - ganged	3506	3455	3522	3492	3529	99.90%	3504	3453	3520	3490	3527	5.58	1.22	3.69	1.30	0.18	1.57
24	53	All lit -ganged rakes	3489	3486	3488	3487	3494	99.92%	3488	3484	3486	3485	3492	4.28	-	2.91	-	0.09	-
25	52	All lit -ganged rakes	3431	3428	3430	3429	3435	99.93%	3430	3426	3428	3427	3434	3.54	-	2.66	-	0.09	-
		All lit rake A - ganged	3451	3447	3449	3448	3455	99.93%	3449	3446	3448	3447	3453	5.59	1.15	2.82	1.22	0.08	1.23
		All lit rake B - ganged	3385	3381	3383	3382	3388	99.95%	3384	3380	3382	3381	3387	4.09	0.85	1.82	0.78	0.05	0.77
26	51	All lit -ganged rakes	3471	3467	3471	3469	3476	99.93%	3470	3466	3469	3468	3474	3.61	-	2.79	-	0.07	-
27	51	All lit -ganged rakes	3317	3287	3327	3310	3331	99.94%	3316	3286	3326	3308	3329	2.5	-	2.06	-	0.10	-
28	99	All lit -ganged rakes	3207	3180	3218	3202	3218	99.94%	3206	3179	3217	3200	3217	1.68	-	2.02	-	0.16	-
29	98	All lit -ganged rakes	3146	3124	3148	3138	3161	99.93%	3145	3123	3147	3136	3160	1.21	-	2.50	-	0.18	-
30	97	All lit -ganged rakes	3136	3077	3156	3121	3163	99.93%	3135	3076	3155	3120	3162	1.2	-	2.35	-	0.19	-
		All lit rake A - ganged	3155	3095	3175	3140	3182	99.90%	3153	3093	3173	3138	3180	1.64	1.18	3.25	1.38	0.25	1.22
		All lit rake B - ganged	3101	3043	3120	3086	3127	99.97%	3100	3042	3120	3086	3127	1.24	0.89	1.24	0.53	0.06	0.29
		All lit rake C - ganged	3203	3141	3224	3187	3231	99.93%	3202	3140	3222	3186	3230	1.15	0.82	2.29	0.97	0.24	1.17
		All lit rake D - ganged	3168	3107	3188	3153	3195	99.91%	3166	3106	3187	3151	3194	1.55	1.11	2.64	1.12	0.27	1.32
31	96	All lit -ganged rakes	3162	3033	3215	3135	3210	99.94%	3161	3032	3214	3134	3209	1.03	-	2.14	-	0.16	-
32	75	All lit -ganged rakes	3166	3147	3240	3199	3108	99.93%	3165	3146	3238	3198	3107	1.39	-	2.40	-	0.17	-
33	76	All lit -ganged rakes	3165	3147	3316	3242	3028	99.90%	3164	3145	3314	3240	3026	1.49			-	0.26	-

FIRST COMBUSTOR SECTOR, CELL 5 GAS SAMPLE PRESSURE TEST DATA

Test: 10/29 & 11/04/93

Dimensions:

Width =	12.750	IMFH Diam. =	0.495
IMFH Dome Height =	2.300	IMFH Exit Aphys/Dome =	4.619
Pilot Dome Height =	3.000	Out.IMFH Dome Aeff =	3.602
IMFH Dome Aphys =	29.325	Pilot Dome Aeff =	2.834
Pilot Dome Aphys =	38.250	Inn.IMFH Dome Aeff =	3.607

			AIRFLOWS				AIR VELOCITIES													
							TOTAL DOME		PILOT DOME			OUTER DOME					INNER DOME				
														Vmixer					Vmixer		
					Outer	Inner	V total	V total		Vmixer		V outer	Vmixer	exit	Vmixer	V outer	V inner	Vmixer	exit	Vmixer	V outer
			Calc.	Pilot	Dome	Dome	dome	dome	V pilot	exit	V pilot	dome	exit	o.dome	@ inj.	dome	dome	exit	i.dome	@ inj.	dome
			Dome	Airflow	Airflow	Airflow	(cold)	(hot)	(cold)	pilot	(hot)	(cold)	o.dome	(bulk)	o.dome	(hot)	(cold)	i.dome	(bulk)	i.dome	(hot)
Rdg	Test Points		Wa, pps	pps	pps	pps	ft/s	ft/s	ft/s	ft/s	ft/s	ft/s	ft/s	ft/s	ft/s	ft/s	ft/s	ft/s	ft/s	ft/s	ft/s
16	500	All lit -ganged rakes	4.40	1.24	1.58	1.58	39.7	100.4	28.4	383	76.8	47.0	383	299	340	113.5	47.1	383	299	340	118.0
16	500	All lit -ganged rakes	4.40	1.24	1.58	1.58	39.7	102.7	28.4	383	78.6	47.0	383	299	340	116.1	47.1	383	299	340	120.8
17	500	All lit -ganged rakes	4.25	1.20	1.53	1.53	36.7	108.5	26.2	354	81.7	43.4	354	276	314	121.4	43.5	354	276	314	130.3
17	500	All lit -ganged rakes	4.25	1.20	1.53	1.53	36.7	108.8	26.2	354	82.0	43.4	354	276	314	121.8	43.5	354	276	314	130.7
19	201	Pilot only - no sample	2.96	0.83	1.06	1.06	31.2	-	22.3	301	-	37.0	301	235	268	-	37.0	301	235	268	-
20	403	All lit - no sample	4.92	1.39	1.76	1.77	38.3	-	27.4	370	-	45.4	370	288	329	-	45.5	370	289	329	-
21	403	All lit -ganged rakes	4.97	1.40	1.78	1.78	38.2	111.9	27.3	369	81.3	45.3	369	288	328	131.4	45.4	369	288	328	132.5
21	403	All lit -ganged rakes	4.97	1.40	1.78	1.78	38.2	113.2	27.3	369	82.2	45.3	369	288	328	132.9	45.4	369	288	328	134.0
22	502	All lit -ganged rakes	4.96	1.40	1.78	1.78	40.6	99.3	29.0	392	71.7	48.1	392	305	348	117.4	48.2	392	306	348	117.1
22	502	All lit -ganged rakes	4.96	1.40	1.78	1.78	40.6	99.8	29.0	392	72.1	48.1	392	305	348	118.0	48.2	392	306	348	117.7
23	70	All lit -ganged rakes	6.85	1.93	2.46	2.46	45.4	111.1	32.5	438	78.3	53.8	438	342	389	132.3	53.9	438	342	389	132.7
		All lit rake A - ganged																			
		All lit rake B - ganged																			
		All lit rake C - ganged																			
		All lit rake D - ganged																			
24	53	All lit -ganged rakes	6.72	1.90	2.41	2.41	44.6	110.7	31.9	430	79.1	52.8	430	335	382	131.1	52.9	430	336	382	131.6
25	52	All lit -ganged rakes	6.85	1.93	2.46	2.46	45.2	110.3	32.3	436	78.8	53.6	436	340	388	130.7	53.6	436	340	388	131.0
		All lit rake A - ganged																			
		All lit rake B - ganged																			
26	51	All lit -ganged rakes	6.85	1.93	2.46	2.46	45.4	112.0	32.5	438	80.0	53.8	438	342	390	132.7	53.9	438	342	390	133.1
27	51	All lit -ganged rakes	6.74	1.90	2.42	2.42	45.5	107.2	32.5	439	75.9	53.9	439	342	390	127.4	54.0	439	343	390	127.7
28	99	All lit -ganged rakes	6.69	1.89	2.40	2.40	45.9	104.6	32.8	443	74.1	54.4	443	345	394	124.4	54.5	443	346	394	124.5
29	98	All lit -ganged rakes	6.81	1.92	2.44	2.45	47.3	105.7	33.8	457	75.1	56.1	457	356	406	125.4	56.2	457	357	406	126.1
30	97	All lit -ganged rakes	6.97	1.97	2.50	2.50	48.1	107.1	34.4	464	75.1	57.0	464	362	412	127.8	57.1	464	362	413	128.3
		All lit rake A - ganged																			
		All lit rake B - ganged																			
		All lit rake C - ganged																			
		All lit rake D - ganged																			
31	96	All lit -ganged rakes	6.87	1.94	2.47	2.47	47.2	105.9	33.7	456	72.6	56.0	456	355	405	127.7	56.0	456	356	405	127.7
32	75	All lit -ganged rakes	7.02	1.98	2.52	2.52	48.4	108.6	34.6	467	77.1	57.4	467	364	415	131.7	57.5	467	365	415	126.5
33	76	All lit -ganged rakes	6.72	1.90	2.41	2.41	46.2	103.8	33.0	446	73.8	54.8	446	348	397	128.9	54.9	446	348	397	117.8

FIRST COMBUSTOR SECTOR, CELL 5 GAS SAMPLE PRESSURE TEST DATA

Test: 10/29 & 11/04/93

			PILOT DOME		OUTER DOME		INNER DOME	
			W/Amixer	W/Adome	W/Amixer	W/Adome	W/Amixer	W/Adome
Rdg	Test Points		lbm/s in2	lbm/s in2	lbm/s in2	lbm/s in2	lbm/s in2	lbm/s in2
16	500	All lit -ganged rakes	0.4384	0.03247	0.4384	0.05385	0.4384	0.05392
16	500	All lit -ganged rakes	0.4384	0.03247	0.4384	0.05385	0.4384	0.05392
17	500	All lit -ganged rakes	0.4235	0.03137	0.4235	0.05201	0.4235	0.05209
17	500	All lit -ganged rakes	0.4235	0.03137	0.4235	0.05201	0.4235	0.05209
19	201	Pilot only - no sample	0.2945	0.02182	0.2945	0.03618	0.2945	0.03623
20	403	All lit - no sample	0.4898	0.03629	0.4898	0.06017	0.4898	0.06025
21	403	All lit -ganged rakes	0.4947	0.03665	0.4947	0.06076	0.4947	0.06085
21	403	All lit -ganged rakes	0.4947	0.03665	0.4947	0.06076	0.4947	0.06085
22	502	All lit -ganged rakes	0.4943	0.03662	0.4943	0.06072	0.4943	0.06080
22	502	All lit -ganged rakes	0.4943	0.03662	0.4943	0.06072	0.4943	0.06080
23	70	All lit -ganged rakes	0.6824	0.05055	0.6824	0.08382	0.6824	0.08393
		All lit rake A - ganged						
		All lit rake B - ganged						
		All lit rake C - ganged						
		All lit rake D - ganged						
24	53	All lit -ganged rakes	0.6693	0.04958	0.6693	0.08221	0.6693	0.08232
25	52	All lit -ganged rakes	0.6824	0.05055	0.6824	0.08382	0.6824	0.08393
		All lit rake A - ganged						
		All lit rake B - ganged						
26	51	All lit -ganged rakes	0.6821	0.05053	0.6821	0.08378	0.6821	0.08390
27	51	All lit -ganged rakes	0.6709	0.04970	0.6709	0.08241	0.6709	0.08252
28	99	All lit -ganged rakes	0.6665	0.04937	0.6665	0.08187	0.6665	0.08198
29	98	All lit -ganged rakes	0.6784	0.05025	0.6784	0.08332	0.6784	0.08344
30	97	All lit -ganged rakes	0.6940	0.05141	0.6940	0.08525	0.6940	0.08537
		All lit rake A - ganged						
		All lit rake B - ganged						
		All lit rake C - ganged						
		All lit rake D - ganged						
31	96	All lit -ganged rakes	0.6844	0.05070	0.6844	0.08407	0.6844	0.08419
32	75	All lit -ganged rakes	0.6988	0.05177	0.6988	0.08584	0.6988	0.08595
33	76	All lit -ganged rakes	0.6695	0.04959	0.6695	0.08223	0.6695	0.08234

Appendix B

5-Cup Rectangular Sector Combustor Test Data

Test 2

Atmospheric Pressure Sector Test

SECOND COMBUSTOR SECTOR STABILITY TEST RESULTS

BUILDING 306 ATMOSPHERIC DISCHARGE TEST 4/25/94

Sect.Tot.Aeff =	14.136	sq.in.
Out.IMFH Dome Aeff=	3.674	sq.in.
Pilot Dome Aeff =	2.834	sq.in.
Inn.IMFH Dome Aeff=	3.679	sq.in.
Tot.Dome Aeff =	10.187	sq.in.
Dome/Sect.Tot. Air flow	72.06%	
Left/Right.Out.&Inn.Dome (or inner/outer IMFH rows)	3.677	

JP5 stoichiometric f/a = 0.06815

At:	25 psid	100 psid
Out.Dome Flow #	71.0	72.9
Pilot Dome Flow #	40.2	43.0
Inn.Dome Flow #	70.6	72.9

Test Points	Pin, psia	% Pres. Drop	P4 psia	Pbaro "Hg	Pbaro psia	Pres. Drop, psid	Pres. Drop, " H2O	Tin F	Tin R	Sector Airflow Total pps	Sector Airflow Metered pps	Dome Wa, pp	Flow Function: Wsqrt(T) P	Dome Fuel Flow, pph	% Fuel to Pilot	Pilot Fuel Flow, pph	Est. Pilot Injector Del.P psid	Total IMFH Domes Fuel Flow pph	% IMFH Fuel to IMFH Outer Dome	Outer IMFH Dome Fuel Flow, pph	Est. Outer IMFH Dome Injector Del.P psid	Inner IMFH Dom Fuel Flow pph
1 Checkout reading	15.26	5.90%	14.36	29.49	14.48	0.90	24.94	42	502	2.57	2.55	1.85	3.77	0.0	0.00%	0.0	0.0	0.0	0.00%	0.0	0.0	0.0
2 Pilot only with white smoke	15.31	3.46%	14.78	29.49	14.48	0.53	14.69	43	503		2.53	1.82	3.70	95.7	100.00%	95.7	5.7	0.0	0.00%	0.0	0.0	0.0
										^-- Error, use metered airflow												
3 Checkout reading	15.29	5.89%	14.39	29.51	14.49	0.90	24.94	214	674	2.22	2.15	1.60	3.77	0.0	0.00%	0.0	0.0	0.0	0.00%	0.0	0.0	0.0
4 Pilot only	15.33	5.61%	14.47	29.51	14.49	0.86	23.83	218	678	2.16	2.15	1.56	3.68	61.7	100.00%	61.7	2.4	0.0	0.00%	0.0	0.0	0.0
5 Pilot only	15.36	5.73%	14.48	29.51	14.49	0.88	24.38	220	680	2.19	2.16	1.58	3.72	73.9	100.00%	73.9	3.4	0.0	0.00%	0.0	0.0	0.0
6 Pilot only	15.41	6.04%	14.48	29.52	14.49	0.93	25.77	354	814	2.06	2.10	1.48	3.81	64.6	100.00%	64.6	2.6	0.0	0.00%	0.0	0.0	0.0
7 All stages lit	15.52	6.12%	14.57	29.53	14.50	0.95	26.32	363	823	2.08	2.07	1.50	3.84	225.5	30.55%	68.9	2.9	156.6	49.23%	77.1	1.2	79.5
8 All stages lit	15.48	5.81%	14.58	29.53	14.50	0.90	24.94	302	762	2.10	2.06	1.51	3.74	226.1	29.77%	67.3	2.8	158.8	49.75%	79.0	1.2	79.8
9 Pilot: only 3 cups fueled	15.34	5.35%	14.52	29.55	14.51	0.82	22.72	289	749	2.01	2.05	1.45	3.59	69.1	100.00%	69.1	8.2	0.0	0.00%	0.0	0.0	0.0
10 Pilot only	15.46	6.02%	14.53	29.57	14.52	0.93	25.77	252	712	2.21	2.18	1.59	3.81	83.2	100.00%	83.2	4.3	0.0	0.00%	0.0	0.0	0.0
10 Pilot only LBO	15.46	6.02%	14.53	29.57	14.52	0.93	25.77	252	712	2.21	2.18	1.59	3.81	57.2	100.00%	57.2	2.0	0.0	0.00%	0.0	0.0	0.0
10 Pilot only LBO	15.46	6.02%	14.53	29.57	14.52	0.93	25.77	252	712	2.21	2.18	1.59	3.81	55.5	100.00%	55.5	1.9	0.0	0.00%	0.0	0.0	0.0
11 Pilot only	15.42	5.97%	14.50	29.57	14.52	0.92	25.49	413	873	1.98	2.01	1.43	3.79	54.5	100.00%	54.5	1.8	0.0	0.00%	0.0	0.0	0.0
11 Pilot only LBO	15.42	5.97%	14.50	29.57	14.52	0.92	25.49	413	873	1.98	2.01	1.43	3.79	45.4	100.00%	45.4	1.3	0.0	0.00%	0.0	0.0	0.0
11 Pilot only LBO	15.42	5.97%	14.50	29.57	14.52	0.92	25.49	413	873	1.98	2.01	1.43	3.79	45.7	100.00%	45.7	1.3	0.0	0.00%	0.0	0.0	0.0
11 Pilot on, o.main LO	15.42	5.97%	14.50	29.57	14.52	0.92	25.49	413	873	1.98	2.01	1.43	3.79	117.1	44.24%	51.8	1.7	65.3	100.00%	65.3	0.8	0.0
11 Pilot on, o.main LO	15.42	5.97%	14.50	29.57	14.52	0.92	25.49	413	873	1.98	2.01	1.43	3.79	119.2	43.46%	51.8	1.7	67.4	100.00%	67.4	0.9	0.0
11 Pilot on, o.main LO	15.42	5.97%	14.50	29.57	14.52	0.92	25.49	413	873	1.98	2.01	1.43	3.79	115.9	44.69%	51.8	1.7	64.1	100.00%	64.1	0.8	0.0
11 Pilot on, o.main LBO	15.42	5.97%	14.50	29.57	14.52	0.92	25.49	413	873	1.98	2.01	1.43	3.79	109.7	47.22%	51.8	1.7	57.9	100.00%	57.9	0.7	0.0
11 Pilot on, o.main LBO	15.42	5.97%	14.50	29.57	14.52	0.92	25.49	413	873	1.98	2.01	1.43	3.79	111.7	46.37%	51.8	1.7	59.9	100.00%	59.9	0.7	0.0
11 Pilot on, o.main LBO	15.42	5.97%	14.50	29.57	14.52	0.92	25.49	413	873	1.98	2.01	1.43	3.79	110.9	46.71%	51.8	1.7	59.1	100.00%	59.1	0.7	0.0
11 Pilot & o.main on, i.main LO	15.42	5.97%	14.50	29.57	14.52	0.92	25.49	413	873	1.98	2.01	1.43	3.79	187.5	27.63%	51.8	1.7	135.7	49.52%	67.2	0.9	68.5
11 Pilot & o.main on, i.main LO	15.42	5.97%	14.50	29.57	14.52	0.92	25.49	413	873	1.98	2.01	1.43	3.79	186.6	27.76%	51.8	1.7	134.8	49.85%	67.2	0.9	67.6
11 Pilot & o.main on, i.main LB	15.42	5.97%	14.50	29.57	14.52	0.92	25.49	413	873	1.98	2.01	1.43	3.79	177.1	29.25%	51.8	1.7	125.3	53.63%	67.2	0.9	58.1
11 Pilot & o.main on, i.main LB	15.42	5.97%	14.50	29.57	14.52	0.92	25.49	413	873	1.98	2.01	1.43	3.79	176.0	29.43%	51.8	1.7	124.2	54.11%	67.2	0.9	57.0
12 Pilot only	15.43	5.96%	14.51	29.56	14.51	0.92	25.49	422	882	1.97	2.03	1.42	3.79	59.2	100.00%	59.2	2.2	0.0	0.00%	0.0	0.0	0.0
12 Pilot on, o.main LO	15.43	5.96%	14.51	29.56	14.51	0.92	25.49	422	882	1.97	2.03	1.42	3.79	119.8	49.42%	59.2	2.2	60.6	100.00%	60.6	0.7	0.0
12 Pilot on, o.main LO	15.43	5.96%	14.51	29.56	14.51	0.92	25.49	422	882	1.97	2.03	1.42	3.79	128.1	46.21%	59.2	2.2	68.9	100.00%	68.9	0.9	0.0
12 Pilot on, o.main LO	15.43	5.96%	14.51	29.56	14.51	0.92	25.49	422	882	1.97	2.03	1.42	3.79	119.7	49.46%	59.2	2.2	60.5	100.00%	60.5	0.7	0.0
12 Pilot on, o.main LBO	15.43	5.96%	14.51	29.56	14.51	0.92	25.49	422	882	1.97	2.03	1.42	3.79	112.0	52.86%	59.2	2.2	52.8	100.00%	52.8	0.6	0.0
12 Pilot on, o.main LBO	15.43	5.96%	14.51	29.56	14.51	0.92	25.49	422	882	1.97	2.03	1.42	3.79	114.0	51.93%	59.2	2.2	54.8	100.00%	54.8	0.6	0.0
12 Pilot on, o.main LBO	15.43	5.96%	14.51	29.56	14.51	0.92	25.49	422	882	1.97	2.03	1.42	3.79	114.2	51.84%	59.2	2.2	55.0	100.00%	55.0	0.6	0.0
13 Pilot & o.main on	15.46	5.89%	14.55	29.56	14.51	0.91	25.22	419	879	1.96	2.02	1.41	3.77	131.4	45.59%	59.9	2.2	71.5	100.00%	71.5	1.0	0.0
13 Pilot & o.main on, i.main LO	15.46	5.89%	14.55	29.56	14.51	0.91	25.22	419	879	1.96	2.02	1.41	3.77	182.5	32.82%	59.9	2.2	122.6	58.32%	71.5	1.0	51.1
13 Pilot & o.main on, i.main LO	15.46	5.89%	14.55	29.56	14.51	0.91	25.22	419	879	1.96	2.02	1.41	3.77	191.0	31.36%	59.9	2.2	131.1	54.54%	71.5	1.0	59.6
13 Pilot & o.main on, i.main LB	15.46	5.89%	14.55	29.56	14.51	0.91	25.22	419	879	1.96	2.02	1.41	3.77	182.7	32.79%	59.9	2.2	122.8	58.22%	71.5	1.0	51.3
13 Pilot & o.main on, i.main LB	15.46	5.89%	14.55	29.56	14.51	0.91	25.22	419	879	1.96	2.02	1.41	3.77	181.9	32.93%	59.9	2.2	122.0	58.61%	71.5	1.0	50.5
14 All stages lit	15.54	6.18%	14.58	29.56	14.51	0.96	26.60	496	956	1.94	1.95	1.40	3.86	198.7	30.45%	60.5	2.3	138.2	51.74%	71.5	1.0	66.7
15 Pilot only LBO	15.42	5.97%	14.50	29.56	14.51	0.92	25.49	604	1064	1.79	1.82	1.29	3.79	38.8	100.00%	38.8	0.9	0.0	0.00%	0.0	0.0	0.0
15 Pilot only LBO	15.42	5.97%	14.50	29.56	14.51	0.92	25.49	604	1064	1.79	1.82	1.29	3.79	38.8	100.00%	38.8	0.9	0.0	0.00%	0.0	0.0	0.0
16 Pilot only	15.44	6.15%	14.49	29.56	14.51	0.95	26.32	619	1079	1.81	1.85	1.30	3.85	44.5	100.00%	44.5	1.2	0.0	0.00%	0.0	0.0	0.0
4/6/94:																						
28 Inner main only LBO	15.29	6.28%	14.33	29.15	14.31	0.96	26.60	607	1067	1.82	1.80	1.31	3.89	53.6	0.00%	0.0	0.0	53.6	0.00%	0.0	0.0	53.6

SECOND COMBUSTOR SECTOR STABILITY TEST RESULTS BUILDING 306 ATMOSPHERIC DISCHARGE TEST 4/25/94

Tflame Coef's: a0= 1.7E+08 a1= 2.2E+08 a2= -2921.3 a3= 15972.3 a4= -7E+07 a5= 3.2E+07 a6= -462.56 a7= -280834 a8= 1583.4 a9= -3E+08 a10= 1E+07 a11= 7.939

IMFH DOMES: Tu (assumed)= 0.025; A IMFH dome, sq.in. 59.409; Mixer Tube Web,in. 0.473 = 0.012 meter; Blockage = 0.845

Est. Inner IMFH Dome Injector Del.P psid	Test Points	Dome Equiv. Ratio	Pilot Equiv. Ratio	Total IMFH Domes Equiv. Ratio	Outer IMFH Dome Equiv. Ratio	Inner IMFH Dome Equiv. Ratio	Average On Point Flame Temp.,R	Pilot Flame Temp.,R	Total IMFH Domes Flame Temp.,R	Outer IMFH Dome Flame Temp.,R	Inner IMFH Dome Flame Temp.,R	Pilot Vref ft/s	IMFH Vref ft/s	Comb. Vref ft/s	Pilot Vref R,ft,psi,s units Te^TP^0.25	Pilot LBO Equiv. Ratio	IMFH Vref R,ft,psi,s units Te^TP^0.25	IMFH PHI we K,m,Pa,s units	IMFH LBO Equiv. Ratio
0.0	1 Checkout reading	0.000	0.000	0.000	0.000	0.000	502	502	502	502	502	25.1	41.9	35.3	0.511	-	0.555	0.791	-
0.0	2 Pilot only with white smoke	0.214	0.771	0.000	0.000	0.000	1570	3608	503	503	503	24.0	40.1	33.8	0.508	-	0.552	0.786	-
0.0	3 Checkout reading	0.000	0.000	0.000	0.000	0.000	674	674	674	674	674	29.0	48.5	40.9	0.451	-	0.490	0.696	-
0.0	4 Pilot only	0.161	0.580	0.000	0.000	0.000	1484	3112	678	678	678	28.3	47.3	39.9	0.448	-	0.486	0.691	-
0.0	5 Pilot only	0.191	0.687	0.000	0.000	0.000	1622	3466	680	680	680	28.7	48.0	40.4	0.448	-	0.487	0.691	-
0.0	6 Pilot only	0.177	0.638	0.000	0.000	0.000	1681	3396	814	814	814	32.4	54.0	45.5	0.410	-	0.445	0.630	-
1.3	7 All stages lit	0.614	0.675	0.591	0.582	0.599	3325	3517	3247	3218	3276	32.8	54.8	46.2	0.408	-	0.443	0.627	-
1.3	8 All stages lit	0.609	0.652	0.593	0.590	0.596	3269	3409	3214	3205	3222	30.7	51.2	43.1	0.424	-	0.460	0.652	-
0.0	9 Pilot: only 3 cups fueled	0.194	0.699	0.000	0.000	0.000	1697	3544	749	749	749	29.0	48.4	40.8	0.424	-	0.461	0.654	-
0.0	10 Pilot only	0.213	0.767	0.000	0.000	0.000	1746	3715	712	712	712	30.2	50.4	42.5	0.440	-	0.478	0.678	-
0.0	10 Pilot only LBO	0.147	0.527	0.000	0.000	0.000	1446	2950	712	712	712	30.2	50.4	42.5	0.440	0.527	0.478	0.678	-
0.0	10 Pilot only LBO	0.142	0.512	0.000	0.000	0.000	1425	2893	712	712	712	30.2	50.4	42.5	0.440	0.512	0.478	0.678	-
0.0	11 Pilot only	0.156	0.560	0.000	0.000	0.000	1635	3175	873	873	873	33.3	55.6	46.9	0.393	-	0.427	0.605	-
0.0	11 Pilot only LBO	0.130	0.466	0.000	0.000	0.000	1512	2845	873	873	873	33.3	55.6	46.9	0.393	0.466	0.427	0.605	-
0.0	11 Pilot only LBO	0.131	0.470	0.000	0.000	0.000	1516	2856	873	873	873	33.3	55.6	46.9	0.393	0.470	0.427	0.605	-
0.0	11 Pilot on, o.main LO	0.335	0.532	0.259	0.517	0.000	2361	3079	2069	3027	873	33.3	55.6	46.9	0.393	-	0.427	0.605	-
0.0	11 Pilot on, o.main LO	0.341	0.532	0.267	0.534	0.000	2383	3079	2102	3085	873	33.3	55.6	46.9	0.393	-	0.427	0.605	-
0.0	11 Pilot on, o.main LO	0.331	0.532	0.254	0.508	0.000	2348	3079	2050	2993	873	33.3	55.6	46.9	0.393	-	0.427	0.605	-
0.0	11 Pilot on, o.main LBO	0.314	0.532	0.229	0.459	0.000	2281	3079	1952	2818	873	33.3	55.6	46.9	0.393	-	0.427	0.605	0.459
0.0	11 Pilot on, o.main LBO	0.319	0.532	0.237	0.475	0.000	2303	3079	1984	2875	873	33.3	55.6	46.9	0.393	-	0.427	0.605	0.475
0.0	11 Pilot on, o.main LBO	0.317	0.532	0.234	0.468	0.000	2294	3079	1971	2852	873	33.3	55.6	46.9	0.393	-	0.427	0.605	0.468
0.9	11 Pilot & o.main on, i.main LO	0.536	0.532	0.537	0.533	0.542	3092	3079	3097	3080	3113	33.3	55.6	46.9	0.393	-	0.427	0.605	-
0.9	11 Pilot & o.main on, i.main LO	0.533	0.532	0.534	0.533	0.535	3083	3079	3084	3080	3088	33.3	55.6	46.9	0.393	-	0.427	0.605	-
0.7	11 Pilot & o.main on, i.main LB	0.506	0.532	0.496	0.533	0.460	2987	3079	2951	3080	2821	33.3	55.6	46.9	0.393	-	0.427	0.605	0.460
0.7	11 Pilot & o.main on, i.main LB	0.503	0.532	0.492	0.533	0.451	2976	3079	2936	3080	2790	33.3	55.6	46.9	0.393	-	0.427	0.605	0.451
0.0	12 Pilot only	0.170	0.611	0.000	0.000	0.000	1709	3354	882	882	882	33.5	55.9	47.1	0.391	-	0.424	0.600	-
0.0	12 Pilot on, o.main LO	0.344	0.611	0.241	0.483	0.000	2404	3354	2008	2910	882	33.5	55.9	47.1	0.391	-	0.424	0.600	-
0.0	12 Pilot on, o.main LO	0.368	0.611	0.274	0.549	0.000	2493	3354	2138	3143	882	33.5	55.9	47.1	0.391	-	0.424	0.600	-
0.0	12 Pilot on, o.main LO	0.344	0.611	0.241	0.482	0.000	2403	3354	2006	2907	882	33.5	55.9	47.1	0.391	-	0.424	0.600	-
0.0	12 Pilot on, o.main LBO	0.322	0.611	0.210	0.421	0.000	2320	3354	1881	2686	882	33.5	55.9	47.1	0.391	-	0.424	0.600	0.421
0.0	12 Pilot on, o.main LBO	0.328	0.611	0.218	0.436	0.000	2341	3354	1914	2744	882	33.5	55.9	47.1	0.391	-	0.424	0.600	0.436
0.0	12 Pilot on, o.main LBO	0.328	0.611	0.219	0.438	0.000	2344	3354	1918	2750	882	33.5	55.9	47.1	0.391	-	0.424	0.600	0.438
0.0	13 Pilot & o.main on	0.379	0.620	0.285	0.571	0.000	2529	3382	2179	3218	879	33.2	55.4	46.7	0.391	-	0.425	0.601	-
0.5	13 Pilot & o.main on, i.main LO	0.526	0.620	0.489	0.571	0.408	3061	3382	2932	3218	2636	33.2	55.4	46.7	0.391	-	0.425	0.601	-
0.7	13 Pilot & o.main on, i.main LO	0.550	0.620	0.523	0.571	0.475	3146	3382	3052	3218	2882	33.2	55.4	46.7	0.391	-	0.425	0.601	-
0.5	13 Pilot & o.main on, i.main LB	0.526	0.620	0.490	0.571	0.409	3063	3382	2935	3218	2642	33.2	55.4	46.7	0.391	-	0.425	0.601	0.409
0.5	13 Pilot & o.main on, i.main LB	0.524	0.620	0.487	0.571	0.403	3055	3382	2923	3218	2619	33.2	55.4	46.7	0.391	-	0.425	0.601	0.403
0.9	14 All stages lit	0.580	0.634	0.558	0.578	0.539	3298	3477	3226	3293	3159	35.5	59.3	50.0	0.373	-	0.405	0.572	-
0.0	15 Pilot only LBO	0.122	0.440	0.000	0.000	0.000	1653	2891	1064	1064	1064	36.7	61.4	51.7	0.346	0.440	0.375	0.530	-
0.0	15 Pilot only LBO	0.122	0.440	0.000	0.000	0.000	1653	2891	1064	1064	1064	36.7	61.4	51.7	0.346	0.440	0.375	0.530	-
0.0	16 Pilot only	0.139	0.500	0.000	0.000	0.000	1747	3112	1079	1079	1079	37.7	62.9	53.0	0.343	-	0.373	0.526	-
0.6	28 Inner main only LBO	0.167	0.000	0.231	0.000	0.461	1860	1067	2125	1067	2968	37.9	63.3	53.3	0.346	-	0.376	0.532	0.461

SECOND COMBUSTOR SECTOR, 306 GAS SAMPLE TEST DATA AT ATMOSPHERIC DISCHARGE

		Sect.Tot.Aeff =	14.136	sq.in.									JP5 stoichiometric f/a =		0.06815		Test Date:	4/6/94																	
		Out.IMFH Dome Aeff=	3.674	sq.in.													Print Date:	6/1/94																	
		Pilot Dome Aeff =	2.834	sq.in.									At:		25 psid	100 psid																			
		Inn.IMFH Dome Aeff=	3.679	sq.in.									Out.Dome Flow #		71.0	72.9																			
		Tot.Dome Aeff =	10.187	sq.in.									Pilot Dome Flow #		40.2	43.0																			
		Dome/Sect.Tot. Air flow	72.06%										Inn.Dome Flow #		70.6	72.9																			
		Left/Right.Out.&Inn.Dome (or inner/outer IMFH rows)	3.677																																
			Sampling G=ganged I=individua		%			Pbaro		Pres.		Tin		Sector Airflow			Flow Function:	Dome Fuel	% Fuel	Pilot Fuel	Est. Pilot Injector	Total IMFH Domes Fuel	% IMFH Fuel to IMFH	Outer IMFH Dome Fuel	Est. Outer IMFH Injector	Inner IMFH Dom Fuel	Est. Inner IMFH Injector		All Rakes (A,B,C,D)					
Rd		Test Points	G & I=both	Pin, psia	Pres. Drop	P4 psia	"Hg	psia	Drop, psid	" H2O	F	R	Total pps	Meter' pps	Dome Wa, pp	Wsqrt(T) P	Flow, pph	to Pilot	Flow, pph	Del.P psid	Flow pph	Outer Dome	Flow, pph	Del.P psid	Flow pph	Del.P psid	Dome Equiv. Ratio	Sample Fuel-Air Ratio	Sample Equiv. Ratio	Sample Eq.R.i Eq.R. avg	Sampl Dome Equiv. Ratio				
Day 1		Pilot only:																																	
18	22	Pilot only -individual rake avg.	G	15.23	6.04%	14.31	29.16	14.32	0.92	25.49	401	861	1.98	2.00	1.43	3.81	62.1	100.0%	62.1	2.4	0.0	0.00%	0.0	0.0	0.0	0.0	0.177	0.01493	0.219	-	0.648				
		Pilot only rake A - ganged																										0.00783	0.115	0.524	-				
		Pilot only rake B - ganged																										0.01513	0.222	1.013	-				
		Pilot only rake C - ganged																										0.01983	0.291	1.328	-				
		Pilot only rake D - ganged																										0.01692	0.248	1.133	-				
18	22	P.only-elem.avg rake B&D	I	15.23	6.04%	14.31	29.16	14.32	0.92	25.49	401	861	1.98	2.00	1.43	3.81	62.1	100.0%	62.1	2.4	0.0	0.00%	0.0	0.0	0.0	0.0	0.177	0.01572	0.231	-	1.300				
		P.only-elem.avg rake B																										0.01460	0.214	0.929	-				
		P.only-elem.avg rake D																										0.01713	0.251	1.089	-				
		Pilot only rake B - element 1																										0.00722	0.106	0.494	-				
		Pilot only rake B - element 2																										0.01962	0.288	1.344	-				
		Pilot only rake B - element 3																										0.02260	0.332	1.548	-				
		Pilot only rake B - element 4																										0.01735	0.255	1.188	-				
		Pilot only rake B - element 5																										0.00622	0.091	0.426	-				
		Pilot only rake D - element 6																										0.00876	0.129	0.512	-				
		Pilot only rake D - element 7																										NA	NA	NA	-				
		Pilot only rake D - element 8																										0.03448	0.506	2.013	-				
		Pilot only rake D - element 9																										0.01885	0.277	1.101	-				
		Pilot only rake D - element 10																										0.00641	0.094	0.374	-				
19	23	Pilot only -individual rake avg.	G	15.24	6.20%	14.29	29.15	14.31	0.95	26.19	413	873	1.99	2.01	1.44	3.87	56.5	100.0%	56.5	2.0	0.0	0.00%	0.0	0.0	0.0	0.0	0.160	0.01271	0.187	-	1.163				
		Pilot only rake A - ganged																										0.00714	0.105	0.562	-				
		Pilot only rake B - ganged																										0.01297	0.190	1.020	-				
		Pilot only rake C - ganged																										0.01362	0.200	1.072	-				
		Pilot only rake D - ganged																										0.01712	0.251	1.347	-				
		Uniform profile:																																	
20	30	All stages lit -indiv. rake avg.	G	15.32	6.01%	14.40	29.13	14.30	0.92	25.49	403	863	1.98	2.01	1.43	3.80	222.9	28.2%	62.9	2.4	160.0	49.75%	79.6	1.3	80.4	1.3	0.636	0.03687	0.541	-	0.851				
		All stages lit rake A - ganged																										0.01704	0.250	0.462	-				
		All stages lit rake B - ganged																										0.04785	0.702	1.298	-				
		All stages lit rake C - ganged																										0.04340	0.637	1.177	-				
		All stages lit rake D - ganged																										0.03916	0.575	1.062	-				
21	30	All lit-elem.avg rake B&D	I	15.30	6.01%	14.38	29.13	14.30	0.92	25.49	399	859	1.99	2.02	1.43	3.81	222.6	27.9%	62.1	2.4	160.5	50.16%	80.5	1.3	80.0	1.3	0.634	0.03870	0.568	-	0.896				
		All lit-elem.avg rake B																										0.04060	0.596	1.049	-				
		All lit-elem.avg rake D																										0.03681	0.540	0.951	-				
		All lit rake B - element 1																										0.04042	0.593	0.996	-				
		All lit rake B - element 2																										0.03727	0.547	0.918	-				
		All lit rake B - element 3																										0.03825	0.561	0.942	-				
		All lit rake B - element 4																										0.03713	0.545	0.915	-				
		All lit rake B - element 5																										0.04992	0.733	1.230	-				
		All lit rake D - element 6																										0.03479	0.510	0.945	-				
		All lit rake D - element 7																										0.03215	0.472	0.873	-				
		All lit rake D - element 8																										0.03826	0.561	1.039	-				
		All lit rake D - element 9																										0.03435	0.504	0.933	-				
		All lit rake D - element 10																										0.04449	0.653	1.209	-				

SECOND COMBUSTOR SECTOR, 306 GAS SAMPLE TEST DATA AT ATMOSPHERIC DISCHARGE

Rd	Test Points	Sampling G=ganged I=individua G & I=both	Pin, psia	% Pres. Drop	P4 psia	Pbaro "Hg	Pbaro psia	Pres. Drop, psid	Pres. Drop, " H2O	Tin F	Tin R	Sector Airflow Total pps	Sector Airflow Meter pps	Sector Airflow Dome Wa, pp	Flow Function: Wsqrt(T) P	Dome Fuel Flow, pph	% Fuel to Pilot	Pilot Fuel Flow, pph	Est. Pilot Injector Del.P psid	Total IMFH Domes Fuel Flow pph	% IMFH Fuel to IMFH Outer Dome	Outer IMFH Dome Fuel Flow, pph	Est. Outer IMFH Dome Injector Del.P psid	Inner IMFH Dom Fuel Flow pph	Est. Inner IMFH Dome Injector Del.P psid	Dome Equiv. Ratio	All Rakes (A,B,C,D) Sample Fuel-Air Ratio	All Rakes (A,B,C,D) Sample Equiv. Ratio	All Rakes (A,B,C,D) Sample Eq.R.i Eq.R. avg	All Rakes (A,B,C,D) Sampl Dome Equiv. Ratio
	Center lean profile:																													
22	35 All stages lit -indiv. rake avg.	G	15.32	6.01%	14.40	29.12	14.30	0.92	25.49	407	867	1.98	2.02	1.43	3.80	238.8	25.8%	61.7	2.4	177.1	50.03%	88.6	1.6	88.5	1.6	0.682	0.03976	0.583	-	0.855
	All stages lit rake A - ganged																										0.01763	0.259	0.443	-
	All stages lit rake B - ganged																										0.05185	0.761	1.304	-
	All stages lit rake C - ganged																										0.04691	0.688	1.180	-
	All stages lit rake D - ganged																										0.04266	0.626	1.073	-
	Uniform profile:																													
23	49 All stages lit -indiv. rake avg.	G	15.32	6.14%	14.38	29.13	14.30	0.94	26.05	502	962	1.90	1.95	1.37	3.84	203.1	27.8%	56.5	2.0	146.6	49.93%	73.2	1.1	73.4	1.1	0.605	0.03586	0.526	-	0.870
	All stages lit rake A - ganged																										0.01752	0.257	0.489	-
	All stages lit rake B - ganged																										0.04398	0.645	1.226	-
	All stages lit rake C - ganged																										0.04247	0.623	1.184	-
	All stages lit rake D - ganged																										0.03948	0.579	1.101	-
23	49 All lit-elem.avg rake B&D	I	15.32	6.14%	14.38	29.13	14.30	0.94	26.05	502	962	1.90	1.95	1.37	3.84	203.1	27.8%	56.5	2.0	146.6	49.93%	73.2	1.1	73.4	1.1	0.605	0.03862	0.567	-	0.937
	All lit-elem.avg rake B																										0.04007	0.588	1.037	-
	All lit-elem.avg rake D																										0.03718	0.546	0.963	-
	All lit rake B - element 1																										0.03915	0.574	0.977	-
	All lit rake B - element 2																										0.03768	0.553	0.940	-
	All lit rake B - element 3																										0.03842	0.564	0.959	-
	All lit rake B - element 4																										0.03884	0.570	0.969	-
	All lit rake B - element 5																										0.04624	0.679	1.154	-
	All lit rake D - element 6																										0.03686	0.541	0.991	-
	All lit rake D - element 7																										0.03503	0.514	0.942	-
	All lit rake D - element 8																										0.03685	0.541	0.991	-
	All lit rake D - element 9																										0.03460	0.508	0.931	-
	All lit rake D - element 10																										0.04254	0.624	1.144	-
25	48 All stages lit -indiv. rake avg.	G	15.28	6.02%	14.36	29.11	14.29	0.92	25.49	500	960	1.88	1.91	1.35	3.81	222.5	26.8%	59.7	2.2	162.8	49.94%	81.3	1.3	81.5	1.3	0.670	0.03877	0.569	-	0.849
	All stages lit rake A - ganged																										0.01784	0.262	0.460	-
	All stages lit rake B - ganged																										0.04873	0.715	1.257	-
	All stages lit rake C - ganged																										0.04581	0.672	1.182	-
	All stages lit rake D - ganged																										0.04272	0.627	1.102	-
26	69 All stages lit -indiv. rake avg.	G	15.28	6.09%	14.35	29.13	14.30	0.93	25.77	607	1067	1.79	1.81	1.29	3.83	188.1	27.7%	52.1	1.7	136.0	50.15%	68.2	0.9	67.8	0.9	0.594	0.0355	0.520	-	0.876
	All stages lit rake A - ganged																										0.01706	0.250	0.481	-
	All stages lit rake B - ganged																										0.04274	0.627	1.205	-
	All stages lit rake C - ganged																										0.04196	0.616	1.183	-
	All stages lit rake D - ganged																										0.04009	0.588	1.131	-
26	69 All lit-elem.avg rake B&D	I	15.28	6.09%	14.35	29.13	14.30	0.93	25.77	607	1067	1.79	1.81	1.29	3.83	188.1	27.7%	52.1	1.7	136.0	50.15%	68.2	0.9	67.8	0.9	0.594	0.04011	0.589	-	0.991
	All lit-elem.avg rake B																										0.04158	0.610	1.037	-
	All lit-elem.avg rake D																										0.03864	0.567	0.963	-
	All lit rake B - element 1																										0.04111	0.603	0.989	-
	All lit rake B - element 2																										0.04000	0.587	0.962	-
	All lit rake B - element 3																										0.03985	0.585	0.958	-
	All lit rake B - element 4																										0.04103	0.602	0.987	-
	All lit rake B - element 5																										0.04592	0.674	1.104	-
	All lit rake D - element 6																										0.03914	0.574	1.013	-
	All lit rake D - element 7																										0.03694	0.542	0.956	-
	All lit rake D - element 8																										0.03846	0.564	0.995	-
	All lit rake D - element 9																										0.03632	0.533	0.940	-
	All lit rake D - element 10																										0.04235	0.621	1.096	-
27	68 All stages lit -indiv. rake avg.	G	15.31	6.21%	14.36	29.13	14.30	0.95	26.32	606	1066	1.81	1.83	1.31	3.87	206.7	27.2%	56.2	2.0	150.5	50.03%	75.3	1.1	75.2	1.1	0.645	0.03905	0.573	-	0.889
	All stages lit rake A - ganged																										0.01833	0.269	0.469	-
	All stages lit rake B - ganged																										0.04780	0.701	1.224	-
	All stages lit rake C - ganged																										0.04674	0.686	1.197	-
	All stages lit rake D - ganged																										0.04331	0.636	1.109	-

SECOND COMBUSTOR SECTOR, 306 GAS SAMPLE TEST DATA AT ATMOSPHERIC DISCHARGE

Rd	Test Points		Sampling G=ganged I=individua G & I=both	Pin, psia	% Pres. Drop	P4 psia	Pbaro "Hg	Pbaro psia	Pres. Drop, psid	Pres. Drop, " H2O	Tin F	Tin R	Sector Airflow Total pps	Airflow Meter' pps	Dome Wa, pp	Flow Function: Wsqrt(T) P	Dome Fuel Flow, pph	% Fuel to Pilot	Pilot Fuel Flow, pph	Est. Pilot Injector Del.P psid	Total IMFH Domes Fuel Flow pph	% IMFH Fuel to IMFH Outer Dome	Outer IMFH Fuel Flow, pph	Est. Outer IMFH Injector Del.P psid	Inner IMFH Dom Fuel Flow pph	Est. Inner IMFH Injector Del.P psid	Dome Equiv. Ratio	Sample Fuel-Air Ratio	Sample Equiv. Ratio	All Rake Sample Eq.R.i Eq.R. avg	All Rake Sampl Dome Equiv. Ratio
28	99	I.&O.Main only lit-ind.rake av	G	15.29	6.28%	14.33	29.15	14.31	0.96	26.60	607	1067	1.82	1.80	1.31	3.89	150.3	0.0%	0.0	0.0	150.3	49.83%	74.9	1.1	75.4	1.1	0.467	0.03068	0.450	-	0.964
		I.&O.Main only lit-rake A gang																										0.01582	0.232	0.516	-
		I.&O.Main only lit-rake B gang																										0.03898	0.572	1.271	-
		I.&O.Main only lit-rake C gang																										0.03760	0.552	1.226	-
		I.&O.Main only lit-rake D gang																										0.03031	0.445	0.988	-
Day 2																															
32	50	All stages lit -indiv. rake avg.	G	15.58	5.97%	14.65	29.68	14.57	0.93	25.77	504	964	1.90	1.91	1.37	3.79	183.9	27.5%	50.6	1.6	133.3	49.96%	66.6	0.9	66.7	0.9	0.547	0.03489	0.512		0.936
		All stages lit rake A - ganged																										0.01724	0.253	0.494	-
		All stages lit rake B - ganged																										0.04292	0.630	1.230	-
		All stages lit rake C - ganged																										0.04139	0.607	1.186	-
		All stages lit rake D - ganged																										0.03800	0.558	1.089	-
34	69	All stages lit -indiv. rake avg.	G	15.58	5.97%	14.65	29.69	14.58	0.93	25.77	600	1060	1.81	1.83	1.31	3.79	186.5	27.4%	51.1	1.6	135.4	49.93%	67.6	0.9	67.8	0.9	0.581	0.03763	0.552		0.950
		All stages lit rake A - ganged																										0.01878	0.276	0.499	
		All stages lit rake B - ganged																										0.04573	0.671	1.215	
		All stages lit rake C - ganged																										0.04424	0.649	1.176	
		All stages lit rake D - ganged																										0.04178	0.613	1.110	
34	69	All stages lit -ganged rakes	G	15.58	5.97%	14.65	29.69	14.58	0.93	25.77	600	1060	1.81	1.83	1.31	3.79	186.5	27.4%	51.1	1.6	135.4	49.93%	67.6	0.9	67.8	0.9	0.581	0.03626	0.532		0.915
34	69	All lit-elem.avg rake B&D	I	15.58	5.97%	14.65	29.69	14.58	0.93	25.77	600	1060	1.81	1.83	1.31	3.79	186.5	27.4%	51.1	1.6	135.4	49.93%	67.6	0.9	67.8	0.9	0.581	0.04022	0.590		1.015
		All lit-elem.avg rake B																										0.04194	0.615	1.043	
		All lit-elem.avg rake D																										0.03863	0.567	0.961	
		All lit rake B - element 1																										0.04177	0.613	0.996	
		All lit rake B - element 2																										0.04016	0.589	0.958	
		All lit rake B - element 3																										0.03972	0.583	0.947	
		All lit rake B - element 4																										0.04227	0.620	1.008	
		All lit rake B - element 5																										0.04577	0.672	1.091	
		All lit rake D - element 6																										0.03885	0.570	1.006	
		All lit rake D - element 7																										0.03424	0.502	0.886	
		All lit rake D - element 8																										0.03930	0.577	1.017	
		All lit rake D - element 9																										0.03708	0.544	0.960	
		All lit rake D - element 10																										0.04369	0.641	1.131	
35	62	Pilot only -individual rake avg.	I	15.55	6.43%	14.55	29.70	14.58	1.00	27.71	601	1061	1.88	1.84	1.35	3.94	49.9	100.0%	49.9	1.5	0.0	0.00%	0.0	0.0	0.0	0.0	0.150	0.01337	0.196		1.306
		Pilot only rake A - ganged																										0.00729	0.107	0.545	
		Pilot only rake B - ganged																										0.01425	0.209	1.066	
		Pilot only rake C - ganged																										0.01420	0.208	1.062	
		Pilot only rake D - ganged																										0.01772	0.260	1.325	
35	62	Pilot only -ganged rakes	G	15.55	6.43%	14.55	29.70	14.58	1.00	27.71	601	1061	1.88	1.84	1.35	3.94	49.9	100.0%	49.9	1.5	0.0	0.00%	0.0	0.0	0.0	0.0	0.150	0.01238	0.182		1.209
35	62	P.only-elem.avg rake B&D	I	15.55	6.43%	14.55	29.70	14.58	1.00	27.71	601	1061	1.88	1.84	1.35	3.94	49.9	100.0%	49.9	1.5	0.0	0.00%	0.0	0.0	0.0	0.0	0.150	0.01494	0.219		1.459
		P.only-elem.avg rake B																										0.01342	0.197	0.898	
		P.only-elem.avg rake D																										0.01654	0.243	1.107	
		Pilot only rake B - element 1																										0.00851	0.125	0.634	
		Pilot only rake B - element 2																										0.01666	0.244	1.241	
		Pilot only rake B - element 3																										0.01960	0.288	1.461	
		Pilot only rake B - element 4																										0.01556	0.228	1.159	
		Pilot only rake B - element 5																										0.00677	0.099	0.504	
		Pilot only rake D - element 6																										0.00990	0.145	0.598	
		Pilot only rake D - element 7																										0.01757	0.258	1.062	
		Pilot only rake D - element 8																										0.02780	0.408	1.681	
		Pilot only rake D - element 9																										0.02014	0.296	1.218	
		Pilot only rake D - element 10																										0.00730	0.107	0.441	

SECOND COMBUSTOR SECTOR, 306 GAS SAMPLE TEST DATA AT ATMOSPHERIC DISCHARGE

Rd		Test Points	Sampling G=ganged I=individua G & I=both	Pin, psia	% Pres. Drop	P4 psia	Pbaro "Hg	Pbaro psia	Pres. Drop, psid	Pres. Drop, " H2O	Tin F	Tin R	Sector Airflow Total pps	Sector Airflow Meter pps	Dome Wa, pp	Flow Function: Wsqrt(T) P	Dome Fuel Flow, pph	% Fuel to Pilot	Pilot Fuel Flow, pph	Est. Pilot Injector Del.P psid	Total IMFH Domes Fuel Flow pph	% IMFH Fuel to IMFH Outer Dome	Outer IMFH Dome Fuel Flow, pph	Est. Outer IMFH Dome Injector Del.P psid	Inner IMFH Dom Fuel Flow pph	Est. Inner IMFH Dome Injector Del.P psid	All Rakes (A,B,C,D) Dome Equiv. Ratio	Sample	All Rakes (A,B,C,D) Sample Eq.R.i Sample Equiv. Eq.R. avg	Sampl Dome Equiv. Ratio
	21	Pilot only -no sample	No Sample	15.25	6.16%	14.31	29.17	14.32	0.94	26.05	399	859	2.00	1.95	1.44	3.85	68.2	100.0%	68.2	2.9	0.0	0.00%	0.0	0.0	0.0	0.0	0.192		-	-	-
17	22	Pilot only -no sample	"	15.25	6.16%	14.31	29.17	14.32	0.94	26.05	399	859	2.00	2.02	1.44	3.85	62.6	100.0%	62.6	2.4	0.0	0.00%	0.0	0.0	0.0	0.0	0.177		-	-	-
24	48	All stages lit -no sample	No Sample	15.29	6.05%	14.36	29.12	14.30	0.93	25.63	504	964	1.88	1.91	1.35	3.82	226.2	27.7%	62.6	2.4	163.6	50.06%	81.9	1.3	81.7	1.3	0.681	-	-	-	-
28	99	I.Main only LBO	No Sample	15.29	6.28%	14.33	29.15	14.31	0.96	26.60	607	1067	1.82	1.80	1.31	3.89	53.6	0.0%	0.0	0.0	53.6	0.00%	0.0	0.0	53.6	0.6	0.167		-		-
Day 2		Pilot only:																													
29	40	P.only-4/ 5 cups lit no sample	No Sample -No Screech!	15.45	5.83%	14.55	29.65	14.56	0.90	24.94	598	1058	1.78	1.80	1.28	3.75	58.7	100.0%	58.7	2.1	0.0	0.00%	0.0	0.0	0.0	0.0	0.187		-		-
30	42	P.only-all cups lit no sample	No Sample	15.46	6.02%	14.53	29.67	14.57	0.93	25.77	487	947	1.91	1.90	1.38	3.81	51.6	100.0%	51.6	1.6	0.0	0.00%	0.0	0.0	0.0	0.0	0.153		-		-
31	50	All stages lit -no sample	No Sample	15.55	5.79%	14.65	29.68	14.57	0.90	24.94	505	965	1.87	1.88	1.35	3.73	183.6	27.4%	50.3	1.6	133.3	49.96%	66.6	0.9	66.7	0.9	0.556		-		-
33	69	All stages lit -no sample	No Sample	15.56	5.85%	14.65	29.69	14.58	0.91	25.22	603	1063	1.79	1.81	1.29	3.75	187.0	27.6%	51.6	1.6	135.4	49.93%	67.6	0.9	67.8	0.9	0.590		-		-
36	23	Pilot only -no sample	No Sample	15.50	5.81%	14.60	29.72	14.59	0.90	24.94	391	851	1.99	1.98	1.43	3.74	58.2	100.0%	58.2	2.1	0.0	0.00%	0.0	0.0	0.0	0.0	0.166		-		-

SECOND COMBUSTOR SECTOR, 306 HOWL TEST POINTS AT ATMOSPHERIC DISCHARGE

Test Date: 4/6/94

Rd		Test Points	Sampling G=ganged I=individua G & I=both	Pin, psia	% Pres. Drop	P4 psia	Pbaro "Hg	Pbaro psia	Pres. Drop, psid	Pres. Drop, " H2O	Tin F	Tin R	Sector Airflow Total pps	Sector Airflow etere pps	Dome Wa, pp	Flow Function: Wsqrt(T) P	Dome Fuel Flow, pph	% Fuel to Pilot	Pilot Fuel Flow, pph	Est. Pilot Injector Del.P psid	Total IMFH Domes Fuel Flow pph	% IMFH Fuel to IMFH Outer Dome	Outer IMFH Dome Fuel Flow, pph	Est. Outer IMFH Dome Injector Del.P psid	Inner IMFH Dom Fuel Flow pph	Est. Inner IMFH Dome Injector Del.P psid	Dome Equiv. Ratio	Sample	Sampl Dome Equiv. Ratio
		Howl Points:																											
23	49	All stages lit -howl! Day 1	Howl	15.32	6.14%	14.38	29.13	14.30	0.94	26.05	502	962	1.90	1.95	1.37	3.84	210.6	30.4%	64.0	2.5	146.6	49.93%	73.2	1.1	73.4	1.1	0.627		-		-
23	49	All stages lit -howl! Day 1	Howl	15.32	6.14%	14.38	29.13	14.30	0.94	26.05	502	962	1.90	1.95	1.37	3.84	209.6	30.1%	63.0	2.5	146.6	49.93%	73.2	1.1	73.4	1.1	0.624		-		-
30	42	Pilot only -howl! Day 2	Howl V1	15.46	6.02%	14.53	29.67	14.57	0.93	25.77	487	947	1.91	1.90	1.38	3.81	67.3	100.0%	67.3	2.8	0.0	0.00%	0.0	0.0	0.0	0.0	0.199		-		-
30	42	Pilot only -howl! Day 2	Howl V1	15.46	6.02%	14.53	29.67	14.57	0.93	25.77	487	947	1.91	1.90	1.38	3.81	67.8	100.0%	67.8	2.8	0.0	0.00%	0.0	0.0	0.0	0.0	0.201		-		-
31	50	All stages lit -howl! Day 2	No Sample	15.55	5.79%	14.65	29.68	14.57	0.90	24.94	505	965	1.87	1.88	1.35	3.73	201.1	33.7%	67.8	2.8	133.3	49.96%	66.6	0.9	66.7	0.9	0.609		-		-
33	69	All stages lit -howl! Day 2	No Sample	15.56	5.85%	14.65	29.69	14.58	0.91	25.22	603	1063	1.79	1.81	1.29	3.75	210.6	35.7%	75.2	3.5	135.4	49.93%	67.6	0.9	67.8	0.9	0.665		-		-
33	69	All stages lit -howl! Day 2	No Sample	15.56	5.85%	14.65	29.69	14.58	0.91	25.22	603	1063	1.79	1.81	1.29	3.75	217.0	37.6%	81.6	4.1	135.4	49.93%	67.6	0.9	67.8	0.9	0.685		-		-
35	62	Pilot only -howl! Day 2	I	15.55	6.43%	14.55	29.70	14.58	1.00	27.71	601	1061	1.88	1.84	1.35	3.94	75.2	100.0%	75.2	3.5	0.0	0.00%	0.0	0.0	0.0	0.0	0.226		-		-
Day 3		Howl films																											
37	22	Pilot only -no sample	No Sample	15.48	6.14%	14.53	29.76	14.61	0.95	26.32	417	877	2.01	1.98	1.45	3.85	54.5	100.0%	54.5	1.8	0.0	0.00%	0.0	0.0	0.0	0.0	0.153		-		-
38	30	All stages lit -no sample	"	15.59	6.03%	14.65	29.77	14.62	0.94	26.05	403	863	2.02	1.98	1.46	3.81	225.0	28.6%	64.4	2.6	160.6	49.69%	79.8	1.3	80.8	1.3	0.629		-		-
39	61	Pilot only -no sample	"	15.46	5.95%	14.54	29.77	14.62	0.92	25.49	591	1051	1.81	1.81	1.30	3.79	45.7	100.0%	45.7	1.3	0.0	0.00%	0.0	0.0	0.0	0.0	0.143		-		-
40	69	All stages lit -no sample	"	15.46	5.95%	14.54	29.77	14.62	0.92	25.49	612	1072	1.79	1.80	1.29	3.79	181.8	25.5%	46.4	1.3	135.4	49.93%	67.6	0.9	67.8	0.9	0.575		-		-
41		Inner Main only -no samples	"	15.50	6.32%	14.52	29.78	14.62	0.98	27.16	611	1071	1.85	1.81	1.33	3.90	67.8	0.0%	0.0	0.0	67.8	0.00%	0.0	0.0	67.8	0.9	0.207		-		-
41		Inner Main only -no samples	"	15.50	6.32%	14.52	29.78	14.62	0.98	27.16	611	1071	1.85	1.81	1.33	3.90	75.4	0.0%	0.0	0.0	75.4	0.00%	0.0	0.0	75.4	1.1	0.231		-		-
41		Inner Main only -no samples	"	15.50	6.32%	14.52	29.78	14.62	0.98	27.16	611	1071	1.85	1.81	1.33	3.90	84.6	0.0%	0.0	0.0	84.6	0.00%	0.0	0.0	84.6	1.4	0.259		-		-

SECOND COMBUSTOR SECTOR, 306 GAS SAMPLE TEST DATA AT ATMOSPHERIC DISCHARGE

Tflam Coef's			
a0=	166619100	a6=	-462.556627
a1=	222862300	a7=	-280833.5
a2=	-2921.308155	a8=	1583.425649
a3=	15972.29681	a9=	-327760800
a4=	-70493950	a10=	14578990
a5=	32214690	a11=	7.938999

Rake emiss.norm.by all rake avg. for rakes
Element emiss.norm.by that rake avg.

Rd		Test Points	Pilot Equiv. Ratio	Total IMFH Domes Equiv. Ratio	Outer IMFH Dome Equiv. Ratio	Inner IMFH Dome Equiv. Ratio	Adiabatic Flame Temperatures: Pilot Flame emp.,	Adiabatic Flame Temperatures: Total IMFH Domes Flame Temp.,R	Adiabatic Flame Temperatures: Outer IMFH Dome Flame Temp.,R	Adiabatic Flame Temperatures: Inner IMFH Dome Flame Temp.,R	Adiabatic Flame Temperatures: Average On Point Flame Temp.,R	Uncorr. Sample Flame Temp.,R	Combust. Efficiency %	Corr. Sample On Point Flame Temp.,R	Calc. Profile Factor	EI NOx	EI NOx i / NOx avg	Rake BCD EI NOx	EI NOx i / BCD NOx avg	EI CO	EI CO i / CO avg	Rake BCD EI CO	EI CO i / BCD CO avg	EI HC	EI HC i / HC avg	Rake BCD EI HC	EI HC i / BCD HC avg	Only Rakes B,C,D: Sampl Equiv. Ratio	Only Rakes B,C,D: Sample Eq.R.i / Sampl Eq.R. avg	Only Rakes B,C,D: Sampl Dome Equiv. Ratio
Day 1		Pilot only:																												
18	22	Pilot only -individual rake avg.	0.788	0.000	0.000	0.000	3853	861	861	861	1722	1900	98.17%	1881		1.54	-	1.60	-	59.4	-	56.45	-	5.01	-	5.09	-	0.254	-	1.431
		Pilot only rake A - ganged										1427	97.98%	1415	0.551	1.37	0.890	-	-	68.4	1.151	-	-	4.74	0.946	-	-	-	-	-
		Pilot only rake B - ganged										1912	97.53%	1886	1.018	1.32	0.857	-	0.827	75.3	1.266	-	1.333	8.10	1.617	-	1.590	0.222	0.875	-
		Pilot only rake C - ganged										2185	98.72%	2168	1.299	1.65	1.071	-	1.033	43.8	0.737	-	0.776	2.90	0.579	-	0.569	0.291	1.147	-
		Pilot only rake D - ganged										2018	98.45%	2000	1.132	1.82	1.182	-	1.140	50.3	0.846	-	0.891	4.28	0.854	-	0.840	0.248	0.978	-
18	22	P.only-elem.avg rake B&D	0.829	0.000	0.000	0.000	3949	861	861	861	1722	1947	96.58%	1910		1.34	-	-	-	95.0	-	-	-	13.67	-	-	-	-	-	-
		P.only-elem.avg rake B										1880	96.67%	1846		1.33	0.993	-	-	94.6	0.995	-	-	12.72	0.931	-	-	-	-	-
		P.only-elem.avg rake D										2030	96.46%	1989		1.35	1.004	-	-	95.6	1.006	-	-	14.86	1.087	-	-	-	-	-
		Pilot only rake B - element 1										1380	93.44%	1346	0.503	1.23	0.925	-	-	170.5	1.803	-	-	29.38	2.309	-	-	-	-	-
		Pilot only rake B - element 2										2173	98.77%	2157	1.343	1.32	0.992	-	-	45.7	0.484	-	-	1.80	0.141	-	-	-	-	-
		Pilot only rake B - element 3										2340	99.45%	2332	1.523	1.39	1.045	-	-	21.4	0.227	-	-	0.57	0.045	-	-	-	-	-
		Pilot only rake B - element 4										2043	98.44%	2025	1.205	1.28	0.962	-	-	58.5	0.619	-	-	2.13	0.167	-	-	-	-	-
		Pilot only rake B - element 5										1302	93.27%	1272	0.426	1.43	1.075	-	-	176.6	1.868	-	-	29.73	2.337	-	-	-	-	-
		Pilot only rake D - element 6										1495	93.33%	1453	0.540	1.13	0.840	-	-	168.3	1.761	-	-	31.22	2.102	-	-	-	-	-
		Pilot only rake D - element 7										NA	NA	NA	NA	NA	NA	-	-	NA	NA	-	-	NA	NA	-	-	-	-	-
		Pilot only rake D - element 8										2978	99.61%	2970	1.925	1.44	1.071	-	-	14.6	0.152	-	-	0.51	0.034	-	-	-	-	-
		Pilot only rake D - element 9										2129	98.71%	2113	1.143	1.42	1.056	-	-	46.1	0.482	-	-	2.38	0.160	-	-	-	-	-
		Pilot only rake D - element 10										1317	94.19%	1290	0.392	1.39	1.033	-	-	153.5	1.605	-	-	25.31	1.704	-	-	-	-	-
19	23	Pilot only -individual rake avg.	0.670	0.000	0.000	0.000	3536	873	873	873	1657	1773	95.31%	1731		0.89	-	0.86	-	97.7	-	94.20	-	27.56	-	26.82	-	0.214	-	1.333
		Pilot only rake A - ganged										1386	94.87%	1360	0.574	0.98	1.101	-	-	108.1	1.107	-	-	29.76	1.080	-	-	-	-	-
		Pilot only rake B - ganged										1790	96.10%	1754	1.040	0.86	0.966	-	1.000	93.6	0.958	-	0.994	19.52	0.708	-	0.728	0.190	0.890	-
		Pilot only rake C - ganged										1830	95.55%	1788	1.080	0.84	0.944	-	0.977	98.0	1.003	-	1.040	24.70	0.896	-	0.921	0.200	0.935	-
		Pilot only rake D - ganged										2040	94.71%	1979	1.306	0.88	0.989	-	1.023	91.0	0.932	-	0.966	36.25	1.315	-	1.351	0.251	1.175	-
		Uniform profile:																												
20	30	All stages lit -indiv. rake avg.	0.549	0.538	0.536	0.540	3130	3092	3084	3100	3420	3103	84.94%	2766		1.38	-	1.44	-	239.4	-	260.68	-	108.49	-	132.23	-	0.638		1.003
		All stages lit rake A - ganged										2027	92.64%	1941	0.583	1.22	0.884	-	-	175.6	0.734	-	-	37.26	0.343	-	-	-	-	-
		All stages lit rake B - ganged										3625	78.50%	3031	1.173	2.14	1.551	-	1.490	247.5	1.034	-	0.949	180.50	1.664	-	1.365	0.702	1.101	-
		All stages lit rake C - ganged										3424	85.89%	3063	1.190	1.19	0.862	-	0.828	274.6	1.147	-	1.053	88.12	0.812	-	0.666	0.637	0.998	-
		All stages lit rake D - ganged										3219	82.76%	2812	1.054	0.98	0.710	-	0.682	260.0	1.086	-	0.997	128.06	1.180	-	0.968	0.575	0.901	-
21	30	All lit-elem.avg rake B&D	0.570	0.567	0.569	0.565	3199	3191	3198	3184	3412	3193	87.18%	2894		1.03	-	-	-	252.3	-	-	-	79.32	-	-	-	-	-	-
		All lit-elem.avg rake B										3287	87.81%	2991		1.14	1.105	-	-	262.9	1.042	-	-	69.20	0.872	-	-	-	-	-
		All lit-elem.avg rake D										3097	86.55%	2796		0.91	0.887	-	-	241.7	0.958	-	-	89.43	1.127	-	-	-	-	-
		All lit rake B - element 1										3279	82.85%	2864	0.955	1.08	0.949	-	-	385.6	1.467	-	-	93.06	1.345	-	-	-	-	-
		All lit rake B - element 2										3121	93.99%	2985	1.012	1.26	1.107	-	-	125.8	0.479	-	-	35.12	0.507	-	-	-	-	-
		All lit rake B - element 3										3170	98.89%	3145	1.088	1.25	1.098	-	-	39.3	0.150	-	-	2.12	0.031	-	-	-	-	-
		All lit rake B - element 4										3114	95.71%	3017	1.028	1.29	1.134	-	-	159.5	0.607	-	-	6.22	0.090	-	-	-	-	-
		All lit rake B - element 5										3709	67.60%	2786	0.917	0.81	0.712	-	-	604.1	2.298	-	-	209.50	3.027	-	-	-	-	-
		All lit rake D - element 6										2993	75.69%	2474	0.843	0.85	0.930	-	-	433.2	1.792	-	-	162.57	1.818	-	-	-	-	-
		All lit rake D - element 7										2855	95.76%	2770	0.997	0.74	0.810	-	-	101.9	0.422	-	-	21.21	0.237	-	-	-	-	-
		All lit rake D - element 8										3171	98.68%	3140	1.191	1.14	1.247	-	-	37.0	0.153	-	-	5.13	0.057	-	-	-	-	-
		All lit rake D - element 9										2970	95.09%	2867	1.048	1.10	1.204	-	-	172.0	0.712	-	-	10.04	0.112	-	-	-	-	-
		All lit rake D - element 10										3473	67.51%	2624	0.921	0.74	0.810	-	-	464.5	1.922	-	-	248.19	2.775	-	-	-	-	-

		SECOND COMBUSTOR SECTOR, 306 GAS SAMPLE TEST DATA AT ATMOSPHERIC DISCHARGE						Adiabatic Flame Temperatures						Rake emiss.norm.by all rake avg. for rakes Element emiss.norm.by that rake avg.																	Only Rakes B,C,D		
				Total	Outer	Inner		Total	Outer	Inner					Corr.																Sample	
			Pilot	IMFH	IMFH	IMFH	Pilot	IMFH	IMFH	IMFH	Average	Uncorr.		Sample			EI	Rake	EI NOx i		EI	Rake	EI CO i		EI	Rake	EI HC i			Eq.R.i	Sampl
			Equiv.	Domes	Dome	Dome	Flame	Flame	Flame	Flame	On Point	Flame	Combust.	On Point	Calc.		NOx	EI	BCD	BCD		BCD	BCD		BCD	BCD	BCD	Sampl	Sampl	Dome
Rd		Test Points	Ratio	Ratio	Ratio	Ratio	emp.,	Temp.,R	Temp.,R	Temp.,R	Temp.,R	Temp.,R	Efficiency %	Flame Temp.,R	Profile Factor	EI NOx	avg	NOx	EI NOx	avg	EI CO	avg	EI CO	avg	EI HC	avg	EI HC	avg	Equiv. Ratio	Eq.R. avg	Equiv. Ratio
		Center lean profile:																													
22	35	All stages lit -indiv. rake avg.	0.542	0.599	0.600	0.599	3108	3304	3307	3302	3568	3251	84.68%	2886		1.52	-	1.60	-	268.2	-	292.55	-	103.73	-	127.72	-	0.692	-	1.014
		All stages lit rake A - ganged										2064	92.66%	1976	0.570	1.27	0.836	-	-	195.0	0.727	-	-	31.77	0.306	-	-	-	-	-
		All stages lit rake B - ganged										3789	76.97%	3116	1.154	0.87	0.572	-	0.543	286.4	1.068	-	0.979	187.55	1.808	-	1.468	0.761	1.100	-
		All stages lit rake C - ganged										3586	84.96%	3177	1.186	1.23	0.809	-	0.767	315.3	1.176	-	1.078	87.77	0.846	-	0.687	0.688	0.995	-
		All stages lit rake D - ganged										3392	84.14%	2991	1.090	2.71	1.783	-	1.690	276.0	1.029	-	0.943	107.84	1.040	-	0.844	0.626	0.905	-
		Uniform profile:																													
23	49	All stages lit -indiv. rake avg.	0.526	0.526	0.526	0.527	3120	3120	3119	3121	3386	3120	91.11%	2928		1.28	-	1.25	-	201.2	-	218.79	-	47.88	-	58.04	-	0.616	-	1.018
		All stages lit rake A - ganged										2139	95.00%	2080	0.578	1.36	1.063	-	-	148.3	0.737	-	-	17.39	0.363	-	-	-	-	-
		All stages lit rake B - ganged										3515	88.71%	3227	1.170	1.14	0.891	-	0.912	204.4	1.016	-	0.934	74.60	1.558	-	1.285	0.645	1.048	-
		All stages lit rake C - ganged										3445	91.53%	3235	1.174	1.48	1.156	-	1.184	226.3	1.125	-	1.034	36.33	0.759	-	0.626	0.623	1.012	-
		All stages lit rake D - ganged										3301	89.21%	3049	1.078	1.13	0.883	-	0.904	225.7	1.122	-	1.032	63.18	1.320	-	1.089	0.579	0.941	-
23	49	All lit-elem.avg rake B&D	0.567	0.567	0.566	0.567	3259	3259	3257	3260	3386	3259	90.69%	3045		1.18	-	-	-	215.0	-	-	-	48.96	-	-	-	-	-	-
		All lit-elem.avg rake B										3330	91.31%	3124		1.34	1.136	-	-	224.5	1.044	-	-	39.31	0.803	-	-	-	-	-
		All lit-elem.avg rake D										3187	90.08%	2966		1.02	0.861	-	-	205.6	0.956	-	-	58.60	1.197	-	-	-	-	-
		All lit rake B - element 1										3285	88.68%	3022	0.959	1.2	0.896	-	-	310.4	1.383	-	-	46.39	1.180	-	-	-	-	-
		All lit rake B - element 2										3212	96.10%	3124	1.007	1.55	1.157	-	-	124.7	0.556	-	-	11.11	0.283	-	-	-	-	-
		All lit rake B - element 3										3249	98.65%	3218	1.050	1.47	1.097	-	-	41.8	0.186	-	-	4.23	0.108	-	-	-	-	-
		All lit rake B - element 4										3270	96.26%	3183	1.034	1.49	1.112	-	-	141.4	0.630	-	-	4.77	0.121	-	-	-	-	-
		All lit rake B - element 5										3616	76.85%	3002	0.950	0.99	0.739	-	-	504.1	2.246	-	-	130.05	3.308	-	-	-	-	-
		All lit rake D - element 6										3171	83.09%	2797	0.921	0.92	0.906	-	-	364.2	1.772	-	-	96.06	1.639	-	-	-	-	-
		All lit rake D - element 7										3078	95.99%	2993	1.020	1.02	1.004	-	-	92.4	0.449	-	-	21.11	0.360	-	-	-	-	-
		All lit rake D - element 8										3170	98.75%	3143	1.095	1.16	1.142	-	-	34.9	0.170	-	-	4.97	0.085	-	-	-	-	-
		All lit rake D - element 9										3056	96.15%	2975	1.011	1.23	1.211	-	-	139.1	0.677	-	-	6.72	0.115	-	-	-	-	-
		All lit rake D - element 10	EST.									3448	76.40%	2861	0.954	0.75	0.738	-	-	397.3	1.932	-	-	164.14	2.801	-	-	-	-	-
25	48	All stages lit -indiv. rake avg.	0.549	0.577	0.576	0.577	3196	3291	3290	3292	3590	3265	89.03%	3012		1.63	-	1.59	-	250.5	-	275.40	-	58.51	-	71.88	-	0.671	-	1.002
		All stages lit rake A - ganged										2155	94.28%	2087	0.563	1.75	1.074	-	-	175.6	0.701	-	-	18.38	0.314	-	-	-	-	-
		All stages lit rake B - ganged										3721	85.01%	3307	1.172	1.41	0.865	-	0.889	261.7	1.045	-	0.950	101.70	1.738	-	1.415	0.715	1.065	-
		All stages lit rake C - ganged										3596	89.52%	3320	1.178	1.87	1.147	-	1.179	291.7	1.165	-	1.059	41.70	0.713	-	0.580	0.672	1.001	-
		All stages lit rake D - ganged										3455	87.31%	3139	1.088	1.48	0.908	-	0.933	272.8	1.089	-	0.990	72.25	1.235	-	1.005	0.627	0.934	-
26	69	All stages lit -indiv. rake avg.	0.518	0.521	0.523	0.519	3166	3176	3183	3170	3420	3173	94.08%	3049		1.85	-	1.76	-	174.2	-	189.64	-	21.07	-	26.36	-	0.610	-	1.028
		All stages lit rake A - ganged										2202	96.55%	2163	0.560	2.1	1.135	-	-	127.8	0.734	-	-	5.18	0.246	-	-	-	-	-
		All stages lit rake B - ganged										3526	93.14%	3357	1.171	1.77	0.957	-	1.004	179.3	1.029	-	0.945	30.52	1.449	-	1.158	0.627	1.027	-
		All stages lit rake C - ganged										3490	94.02%	3345	1.164	2.05	1.108	-	1.163	191.3	1.098	-	1.009	17.15	0.814	-	0.651	0.616	1.009	-
		All stages lit rake D - ganged										3401	92.61%	3229	1.105	1.47	0.795	-	0.834	198.4	1.139	-	1.046	31.41	1.491	-	1.192	0.588	0.964	-
26	69	All lit-elem.avg rake B&D	0.586	0.590	0.592	0.587	3394	3406	3412	3399	3420	3402	93.94%	3261		1.68	-	-	-	157.9	-	-	-	13.35	-	-	-	-	-	-
		All lit-elem.avg rake B										3472	94.23%	3333		1.79	1.064	-	-	184.9	-	-	-	16.45	-	-	-	-	-	-
		All lit-elem.avg rake D										3331	93.66%	3188		1.40	0.831	-	-	171.8	-	-	-	26.51	-	-	-	-	-	-
		All lit rake B - element 1										3450	92.79%	3278	0.978	1.4	0.783	-	-	248.4	1.343	-	-	15.87	0.965	-	-	-	-	-
		All lit rake B - element 2										3397	97.25%	3333	1.003	1.98	1.107	-	-	106.2	0.574	-	-	2.91	0.177	-	-	-	-	-
		All lit rake B - element 3										3390	98.93%	3365	1.017	2.46	1.376	-	-	41.7	0.226	-	-	1.05	0.064	-	-	-	-	-
		All lit rake B - element 4										3446	96.99%	3375	1.021	1.97	1.102	-	-	124.5	0.673	-	-	0.98	0.060	-	-	-	-	-
		All lit rake B - element 5										3669	85.17%	3283	0.981	1.13	0.632	-	-	403.8	2.183	-	-	61.44	3.735	-	-	-	-	-
		All lit rake D - element 6										3355	91.84%	3169	0.994	1.1	0.788	-	-	258.5	1.505	-	-	24.04	0.907	-	-	-	-	-
		All lit rake D - element 7										3247	97.32%	3189	1.004	1.53	1.096	-	-	81.0	0.472	-	-	8.96	0.338	-	-	-	-	-
		All lit rake D - element 8										3322	98.80%	3295	1.054	2.03	1.454	-	-	42.9	0.250	-	-	2.19	0.083	-	-	-	-	-
		All lit rake D - element 9										3217	96.89%	3150	0.985	1.49	1.067	-	-	122.3	0.712	-	-	2.71	0.102	-	-	-	-	-
		All lit rake D - element 10										3508	83.45%	3104	0.963	0.83	0.595	-	-	354.1	2.061	-	-	94.65	3.570	-	-	-	-	-
27	68	All stages lit -indiv. rake avg.	0.560	0.578	0.579	0.577	3307	3367	3369	3364	3581	3350	92.92%	3189		2.2	-	2.16	-	213.0	-	231.66	-	23.86	-	29.94	-	0.674	-	1.046
		All stages lit rake A - ganged										2272	95.83%	2222	0.555	2.32	1.055	-	-	156.9	0.737	-	-	5.60	0.235	-	-	-	-	-
		All stages lit rake B - ganged										3748	91.11%	3510	1.173	2.17	0.986	-	1.003	229.6	1.078	-	0.991	40.21	1.685	-	1.343	0.701	1.040	-
		All stages lit rake C - ganged										3704	93.17%	3524	1.180	2.47	1.123	-	1.142	235.2	1.104	-	1.015	15.00	0.629	-	0.501	0.686	1.017	-
		All stages lit rake D - ganged										3552	91.59%	3343	1.093	1.85	0.841	-	0.855	230.1	1.081	-	0.993	34.60	1.450	-	1.156	0.636	0.943	-

SECOND COMBUSTOR SECTOR, 306 GAS SAMPLE TEST DATA AT ATMOSPHERIC DISCHARGE

Rake emiss.norm.by all rake avg. for rakes
Element emiss.norm.by that rake avg.

				Adiabatic Flame Temperatures																										Only Rakes B,C,D		
				Total	Outer	Inner		Total	Outer	Inner																					Sample	
				IMFH	IMFH	IMFH		IMFH	IMFH	IMFH	Average	Uncorr.		Corr. Sample			EI	Rake	EI NOx i		EI	Rake	EI CO i		EI	Rake	HC i		EI	Eq.R.i	Sampl
			Pilot	Domes	Dome	Dome	Pilot	Domes	Dome	Dome	On Point	Sample	Combust.	On Point	Calc.		NOx i	BCD	BCD		CO i	BCD	BCD		HC i	BCD	BCD	Sampl	Equiv.	Sampl	Dome
			Equiv.	Equiv.	Equiv.	Equiv.	Flame	Flame	Flame	Flame	Flame	Flame	Efficiency	Flame	Profile	EI	NOx	EI	NOx	EI	CO	EI	CO	EI	HC	EI	HC	HC	Equiv.	Eq.R.	Equiv.
Rd	Test Points		Ratio	Ratio	Ratio	Ratio	emp.,	Temp.,R	Temp.,R	Temp.,R	Temp.,R	Temp.,R	%	Temp.,R	Factor	NOx	avg	NOx	avg	CO	avg	CO	avg	HC	avg	HC	avg	Ratio	avg	Ratio
28	99	I.&O.Main only lit-ind.rake av	0.000	0.624	0.622	0.625	1067	3515	3510	3520	2989	2929	86.35%	2675		1.3	-	1.21	-	245.4	-	253.90	-	90.73	-	112.52	-	0.523	-	1.120
		I.&O.Main only lit-rake A gang										2131	92.63%	2052	0.618	1.54	1.185	-	-	219.7	0.895	-	-	25.37	0.280	-	-	-	-	-
		I.&O.Main only lit-rake B gang										3348	90.36%	3128	1.292	1.36	1.046	-	1.121	243.1	0.991	-	0.957	45.15	0.498	-	0.401	0.572	1.094	-
		I.&O.Main only lit-rake C gang										3280	92.30%	3110	1.280	1.38	1.062	-	1.137	245.6	1.001	-	0.967	22.26	0.245	-	0.198	0.552	1.055	-
		I.&O.Main only lit-rake D gang										2910	70.10%	2359	0.810	0.9	0.692	-	0.742	273.1	1.113	-	1.076	270.15	2.978	-	2.401	0.445	0.851	-
Day 2																																
32	50	All stages lit -indiv. rake avg.	0.506	0.514	0.514	0.514	3053	3080	3080	3080	3193	3072	91.53%	2894		0.84	-	0.83	-	176.5	-	188.63	-	49.75	-	58.32	-	0.598	-	1.094
		All stages lit rake A - ganged										2125	94.62%	2062	0.577	0.85	1.012	-	-	139.9	0.793	-	-	24.07	0.484	-	-	-	-	-
		All stages lit rake B - ganged										3468	89.29%	3199	1.174	0.85	1.012	-	1.024	182.3	1.033	-	0.966	73.94	1.486	-	1.268	0.630	1.053	-
		All stages lit rake C - ganged										3395	92.96%	3224	1.187	0.9	1.071	-	1.084	176.7	1.002	-	0.937	33.24	0.668	-	0.570	0.607	1.015	-
		All stages lit rake D - ganged										3230	89.25%	2986	1.062	0.74	0.881	-	0.892	206.9	1.172	-	1.097	67.77	1.362	-	1.162	0.558	0.932	-
34	69	All stages lit -indiv. rake avg.	0.544	0.555	0.555	0.556	3249	3288	3286	3289	3374	3277	93.95%	3143		1.23	-	1.16	-	149.8	-	163.65	-	29.08	-	36.17	-	0.644	-	1.108
		All stages lit rake A - ganged										2292	96.78%	2252	0.581	1.42	1.154	-	-	108.1	0.722	-	-	7.80	0.268	-	-	-	-	-
		All stages lit rake B - ganged										3656	91.17%	3427	1.154	1.11	0.902	-	0.954	155.2	1.036	-	0.948	59.65	2.051	-	1.649	0.671	1.041	-
		All stages lit rake C - ganged										3590	94.67%	3455	1.167	1.35	1.098	-	1.160	159.1	1.063	-	0.972	18.28	0.629	-	0.505	0.649	1.007	-
		All stages lit rake D - ganged										3477	93.19%	3312	1.098	1.03	0.837	-	0.885	176.7	1.180	-	1.080	30.57	1.051	-	0.845	0.613	0.951	-
34	69	All stages lit -ganged rakes	0.524	0.535	0.535	0.536	3182	3219	3218	3221	3374	3209	93.19%	3063		0.96	-	-	-	157.5	-	-	-	35.78	-	-	-	-	-	-
34	69	All lit-elem.avg rake B&D	0.581	0.594	0.593	0.594	3374	3414	3413	3416	3374	3403	94.48%	3274		1.13	1.177	-	-	156.0	0.991	-	-	21.33	0.596	-	-	-	-	-
		All lit-elem.avg rake B										3484	94.85%	3360		1.24	1.099	-	-	159.2	1.020	-	-	16.18	0.758	-	-	-	-	-
		All lit-elem.avg rake D										3326	94.11%	3193		1.01	0.896	-	-	152.8	0.980	-	-	26.48	1.242	-	-	-	-	-
		All lit rake B - element 1										3477	93.16%	3311	0.981	1.08	0.870	-	-	220.1	1.383	-	-	19.18	1.186	-	-	-	-	-
		All lit rake B - element 2										3400	97.40%	3339	0.993	1.21	0.974	-	-	86.1	0.541	-	-	6.63	0.410	-	-	-	-	-
		All lit rake B - element 3										3379	99.03%	3356	1.001	1.52	1.224	-	-	29.6	0.186	-	-	3.13	0.193	-	-	-	-	-
		All lit rake B - element 4										3500	97.23%	3432	1.034	1.43	1.151	-	-	111.7	0.702	-	-	1.64	0.101	-	-	-	-	-
		All lit rake B - element 5										3658	87.44%	3332	0.990	0.97	0.781	-	-	348.5	2.189	-	-	50.30	3.110	-	-	-	-	-
		All lit rake D - element 6										3337	90.99%	3132	0.975	0.89	0.879	-	-	249.9	1.635	-	-	36.10	1.363	-	-	-	-	-
		All lit rake D - element 7										3107	97.53%	3056	0.940	0.8	0.791	-	-	67.9	0.444	-	-	10.10	0.381	-	-	-	-	-
		All lit rake D - element 8										3359	98.91%	3334	1.070	1.29	1.275	-	-	32.4	0.212	-	-	3.72	0.140	-	-	-	-	-
		All lit rake D - element 9										3250	97.22%	3189	1.002	1.22	1.206	-	-	104.0	0.681	-	-	3.92	0.148	-	-	-	-	-
		All lit rake D - element 10										3565	85.89%	3212	1.013	0.86	0.850	-	-	310.0	2.028	-	-	78.57	2.967	-	-	-	-	-
35	62	Pilot only -individual rake avg.	0.705	0.000	0.000	0.000	3757	1061	1061	1061	1782	1981	99.20%	1974		1.41	-	1.39	-	26.0	-	27.34	-	2.15	-	2.56	-	0.226	-	1.503
		Pilot only rake A - ganged										1573	99.40%	1570	0.566	1.47	1.043	-	-	22.1	0.849	-	-	0.90	0.419	-	-	-	-	-
		Pilot only rake B - ganged										2034	99.02%	2024	1.071	1.33	0.943	-	0.957	27.9	1.071	-	1.020	3.73	1.735	-	1.455	0.209	0.926	-
		Pilot only rake C - ganged										2031	99.31%	2024	1.071	1.37	0.972	-	0.986	24.5	0.941	-	0.896	1.32	0.614	-	0.515	0.208	0.923	-
		Pilot only rake D - ganged										2234	99.07%	2223	1.292	1.47	1.043	-	1.058	29.7	1.139	-	1.085	2.64	1.228	-	1.030	0.260	1.151	-
35	62	Pilot only -ganged rakes	0.653	0.000	0.000	0.000	3603	1061	1061	1061	1782	1920	99.13%	1912		1.35				28.5				2.28					-	-
35	62	P.only-elem.avg rake B&D	0.788	0.000	0.000	0.000	3972	1061	1061	1061	1782	2075	98.52%	2060		1.23	0.911	-	-	36.4	1.279	-	-	7.18	3.149	-	-	-	-	-
		P.only-elem.avg rake B										1984	98.96%	1974		1.22	0.990	-	-	28.2	0.776	-	-	4.38	0.610	-	-	-	-	-
		P.only-elem.avg rake D										2167	98.09%	2146		1.23	1.003	-	-	44.7	1.229	-	-	9.99	1.391	-	-	-	-	-
		Pilot only rake B - element 1										1662	98.47%	1653	0.661	0.54	0.443	-	-	43.9	1.553	-	-	5.80	1.324	-	-	-	-	-
		Pilot only rake B - element 2										2174	99.38%	2167	1.236	0.58	0.476	-	-	15.7	0.556	-	-	2.84	0.648	-	-	-	-	-
		Pilot only rake B - element 3										2338	99.60%	2333	1.421	1.71	1.404	-	-	9.8	0.345	-	-	1.95	0.445	-	-	-	-	-
		Pilot only rake B - element 4										2111	99.33%	2104	1.165	1.63	1.338	-	-	20.8	0.738	-	-	2.09	0.477	-	-	-	-	-
		Pilot only rake B - element 5										1534	98.00%	1524	0.517	1.63	1.338	-	-	51.1	1.809	-	-	9.22	2.105	-	-	-	-	-
		Pilot only rake D - element 6										1759	98.60%	1749	0.646	1.43	1.159	-	-	39.6	0.887	-	-	5.61	0.562	-	-	-	-	-
		Pilot only rake D - element 7										2226	99.50%	2220	1.087	0.95	0.770	-	-	16.7	0.374	-	-	1.18	0.118	-	-	-	-	-
		Pilot only rake D - element 8										2775	99.66%	2770	1.603	1.28	1.037	-	-	9.9	0.222	-	-	1.26	0.126	-	-	-	-	-
		Pilot only rake D - element 9										2368	98.87%	2353	1.212	1.17	0.948	-	-	37.5	0.839	-	-	2.90	0.290	-	-	-	-	-
		Pilot only rake D - element 10	EST.									1574	93.80%	1542	0.451	1.34	1.086	-	-	119.7	2.677	-	-	39.00	3.904	-	-	-	-	-

SECOND COMBUSTOR SECTOR, 306 GAS SAMPLE TEST DATA AT ATMOSPHERIC DISCHARGE

Rake emiss.norm.by all rake avg. for rakes
Element emiss.norm.by that rake avg.

Rd	Test	Points	Pilot Equiv. Ratio	Total IMFH Domes Equiv. Ratio	Outer IMFH Dome Equiv. Ratio	Inner IMFH Dome Equiv. Ratio	Pilot Flame emp.,	Adiabatic Flame Temperatures: Total IMFH Domes Flame Temp.,R	Outer IMFH Dome Flame Temp.,R	Inner IMFH Dome Flame Temp.,R	Average On Point Flame Temp.,R	Uncorr. Sample Flame Temp.,R	Combust. Efficiency %	Corr. Sample On Point Flame Temp.,R	Calc. Profile Factor	EI NOx	EI NOx i NOx avg	Rake BCD EI NOx	Rake BCD EI NOx avg	EI CO	EI CO i CO avg	Rake BCD EI CO	Rake BCD EI CO avg	EI HC	EI HC i HC avg	Rake BCD EI HC	Rake BCD EI HC avg	EI HC i HC avg	Only Rakes B,C,D Sample Sampl Equiv. Ratio	Eq.R.i Sampl Eq.R. avg	Sampl Dome Equiv. Ratio
	21	Pilot only -no sample	0.692	0.000	0.000	0.000	3592	859	859	859	1786	859		HOWL		-				-				-					-	-	-
17	22	Pilot only -no sample	0.635	0.000	0.000	0.000	3416	859	859	859	1717	859		No Sample		-				-				-					-	-	-
24	48	All stages lit -no sample	0.677	0.682	0.683	0.681	3614	3629	3633	3625	3625	964		No Sample		-	-	-	-	-	-	-	-	-	-	-	-				
28	99	I.Main only LBO	0.000	0.231	0.000	0.461	1067	2125	1067	2968	1860	1067		No Sample		-	-	-	-	-	-	-	-	-	-	-	-				
Day 2		Pilot only:																													
29	40	P.only-4/ 5 cups lit no sample	0.671	0.000	0.000	0.000	3654	1058	1058	1058	1938	1058		No Sample		-	-	-	-	-	-	-	-	-	-	-	-		-	-	-
30	42	P.only-all cups lit no sample	0.549	0.000	0.000	0.000	3187	947	947	947	1688	947		No Sample		-	-	-	-	-	-	-	-	-	-	-	-		-	-	-
31	50	All stages lit -no sample	0.547	0.559	0.559	0.559	3195	3235	3235	3235	3224	965		No Sample		-	-	-	-	-	-	-	-	-	-	-	-				
33	69	All stages lit -no sample	0.586	0.592	0.592	0.593	3390	3411	3409	3413	3405	1063		No Sample		-	-	-	-	-	-	-	-	-	-	-	-				
36	23	Pilot only -no sample	0.595	0.000	0.000	0.000	3281	851	851	851	1661	851		No Sample		-				-				-					-	-	-

SECOND COMBUSTOR SECTOR, 306 HOWL TEST POINTS AT ATMOSPHERIC DISCHARGE

Rd	Test	Points	Pilot Equiv. Ratio	Total IMFH Domes Equiv. Ratio	Outer IMFH Dome Equiv. Ratio	Inner IMFH Dome Equiv. Ratio	Pilot Flame emp.,	Adiabatic Flame Temperatures: Total IMFH Domes Flame Temp.,R	Outer IMFH Dome Flame Temp.,R	Inner IMFH Dome Flame Temp.,R	Average On Point Flame Temp.,R
		Howl Points:									
23	49	All stages lit -howl! Day 1	0.685	0.605	0.605	0.605	3637	3386	3384	3387	3458
23	49	All stages lit -howl! Day 1	0.675	0.605	0.605	0.605	3605	3386	3384	3387	3448
30	42	Pilot only -howl! Day 2	0.716	0.000	0.000	0.000	3715	947	947	947	1892
30	42	Pilot only -howl! Day 2	0.721	0.000	0.000	0.000	3730	947	947	947	1898
31	50	All stages lit -howl! Day 2	0.738	0.559	0.559	0.559	3787	3235	3235	3235	3400
33	69	All stages lit -howl! Day 2	0.853	0.592	0.592	0.593	4112	3411	3409	3413	3639
33	69	All stages lit -howl! Day 2	0.926	0.592	0.592	0.593	4230	3411	3409	3413	3699
35	62	Pilot only -howl! Day 2	0.814	0.000	0.000	0.000	4030	1061	1061	1061	2103
Day 3		Howl films									
37	22	Pilot only -no sample	0.551	0.000	0.000	0.000	3148	877	877	877	1628
38	30	All stages lit -no sample	0.647	0.622	0.619	0.626	3458	3377	3366	3388	3400
39	61	Pilot only -no sample	0.515	0.000	0.000	0.000	3142	1051	1051	1051	1739
40	69	All stages lit -no sample	0.528	0.593	0.593	0.594	3202	3422	3420	3423	3362
41		Inner Main only -no samples	0.000	0.287	0.000	0.574	1071	2345	1071	3358	2036
41		Inner Main only -no samples	0.000	0.320	0.000	0.639	1071	2464	1071	3565	2129
41		Inner Main only -no samples	0.000	0.359	0.000	0.717	1071	2606	1071	3794	2238

Appendix C

5-Cup Rectangular Sector Combustor Test Data

Test 3

THIRD COMBUSTOR SECTOR, CELL 5
GAS SAMPLE PRESSURE TEST DATA

Test: 6/8 & 13/1994
Print: 6/16/98

			INPUTS FROM CELL 5 DATA ACQUISITION SYSTEM PRINTOUT																					
			INPUTS FROM PAGE #3: CALCULATIONS												INPUTS FROM FRONT PAGE					INPUTS FROM GAS SAMPLE SHEET:				
			Main Airflow	Pilot Fuel Flow			Out.IMFH Dome Fuel Flow			Inn.IMFH Dome Fuel Flow														
			East Meter'd	Pilot Main	Pilot Verif.	Avg.			Avg.			Avg.	Pin,	Tin	Pstrch (P4)	Pbaro	Pilot Manif. Pres.	Outer IMFH Manif. Pres.	Inner IMFH Manif. Pres.	EI CO	EI HC	EI NOx	Sample Fuel-Air Ratio	Combust. Efficiency
Rd	t Points		pps	pph	pph	pph	pph	pph	pph	pph	pph	pph	psia	F	psia	psia	psia	psia	psia					
Day 1		6/8/94				CALC			CALC			CALC												
		Pilot only:																						
8	3	Pilot only -no sample(JP8)	4.52	215.1	208.8	212	0.0	0.0	0.0	0.0	0.0	0.0	47.27	608	45.19	14.41	72.3	-	-	-	-	-	-	-
9	4	All lit- howl	4.51	155.1	150.7	153	182.0	183.0	182.5	184.2	186.2	185.2	51.83	623	49.54	14.41	64.7	55.63	57.0	-	-	-	-	-
10	5	All lit -individual rake avg.	5.95	226.0	219.6	223	176.5	179.0	177.8	179.6	181.4	180.5	60.75	646	58.12	14.41	88.2	63.62	65.5	96.62	56.33	1.36	0.03135	92.83%
		All lit rake A - ganged																		108.57	111.83	1.31	0.03316	87.73%
		All lit rake B - ganged																		40.94	13.58	1.87	0.03468	97.86%
		All lit rake C - ganged																		73.49	61.47	1.92	0.03431	92.93%
		All lit rake D - ganged																		82.45	51.21	1.07	0.03166	93.61%
11	5	All lit	6.47	226.1	220.8	223	176.3	177.2	176.8	180.5	182.2	181.4	67.26	703	64.15	14.40	94.9	70.15	71.3	-	-	-	-	-
Day 2		6/13/94																						
17	100	Pilot only -no sample	7.12	227.9	208.7	218	0.0	0.0	0.0	0.0	0.0	0.0	83.96	664	80.78	14.41	107.8	-	-	-	-	-	-	-
18	100	Pilot -individual rake avg.	7.10	257.9	238.7	248	0.0	0.0	0.0	0.0	0.0	0.0	72.79	738	68.91	14.40	104.1	-	-	1.48	0.18	5.45	0.01390	99.95%
		Pilot only A - ganged																		1.36	0.22	2.94	0.01311	99.95%
		Pilot only B - ganged																		1.46	0.15	4.93	0.01381	99.95%
		Pilot only C - ganged																		1.37	0.11	5.00	0.01325	99.96%
		Pilot only D - ganged																		1.21	0.08	4.90	0.01580	99.96%
19	5	P&O.M. -individual rake avg.	7.20	220.5	202.7	212	293.8	293.8	293.8	0.0	0.0	0.0	84.75	812	81.34	14.40	107.3	98.57	-	2.88	0.15	2.65	0.02614	99.92%
		P.&O.M. lit rake A - ganged																		3.96	0.24	2.61	0.02686	99.89%
		P.&O.M. lit rake B - ganged																		3.12	0.12	2.89	0.02490	99.92%
		P.&O.M. lit rake C - ganged																		2.51	0.06	3.13	0.02256	99.94%
		P.&O.M. lit rake D - ganged																		2.86	0.08	3.07	0.02750	99.93%
20	602	Pilot & O.Main lit-no sample	10.15	262.7	243.8	253	340.2	340.2	340.2	0.0	0.0	0.0	122.09	1018	116.53	14.38	155.0	140.16	-	-	-	-	-	-
21	602	P&O.M. -individual rake avg.	10.00	270.6	251.7	261	351.9	351.9	351.9	0.0	0.0	0.0	123.46	1066	117.87	14.38	158.7	143.10	-	0.90	0.08	5.53	0.02265	99.97%
		P.&O.M. lit rake A - ganged																		1.23	0.11	3.97	0.02348	99.96%
		P.&O.M. lit rake B - ganged																		0.89	0.04	4.68	0.02083	99.98%
		P.&O.M. lit rake C - ganged																		1.12	0.04	6.42	0.02055	99.97%
		P.&O.M. lit rake D - ganged																		1.06	0.04	6.92	0.02379	99.97%
22	8	P&O.M. -individual rake avg.	9.75	276.1	257.3	267	350.3	350.3	350.3	0.0	0.0	0.0	123.97	1141	118.30	14.38	160.7	143.31	-	1.58	0.05	10.67	0.02296	99.96%
		P.&O.M. lit rake A - ganged																		2.97	0.10	11.24	0.02602	99.92%
		P.&O.M. lit rake B - ganged																		1.29	0.04	8.78	0.02144	99.97%
		P.&O.M. lit rake C - ganged																		1.46	0.04	9.65	0.02083	99.96%
		P.&O.M. lit rake D - ganged																		1.41	0.0			99.96%

THIRD COMBUSTOR SECTOR, CELL 5
GAS SAMPLE PRESSURE TEST DATA

Sect.Tot.Aeff =	12.694	sq.in.			
Out.IMFH Dome Aeff=	3.533	sq.in.	O.Dome In.=	3.125	
Pilot Dome Aeff =	2.834	sq.in.			
Inn.IMFH Dome Aeff=	3.473	sq.in.	I.Dome In.=	3.081	
Tot.Dome Aeff =	9.840	sq.in.			
Dome/Sect.Tot. Air flow	77.51%				
Left/Right.Out.&Inn.Dome (or inner/outer IMFH rows)	3.503				

JP5 stoichiometric f/a = 0.06815

At:	25 psid	00 psid
Out.Dome Flow #	71.0	72.9
Pilot Dome Flow #	40.2	43.0
Inn.Dome Flow #	70.6	72.9

Test: 6/8 & 13/1994
Print: 6/16/98

				PRESSURES				TEMP'S		AIRFLOWS					FUEL FLOWS & PRESSURES									
Rd		Test Points	Sampling G=ganged I=individual G & I=both	Pin, psia	P4 psia	Pres Drop psid	% Pres. Drop	Tin F	Tin R	Sector Airflow Calc. Total pps	Sector Airflow Meter' pps	Calc. Total Meter'd	Calc. Dome Wa, pp	Flow Function: Wsqrt(T) P	Dome Fuel Flow, pph	Pilot Fuel Flow, pph	Total IMFH Domes Fuel Flow pph	Outer IMFH Dome Fuel Flow, pph	Inner IMFH Dome Fuel Flow pph	% Fuel to Pilot	% IMFH Fuel to IMFH Outer Dome	Pilot Manif. Pres. psia	Outer IMFH Manif. Pres. psia	Inner IMFH Manif. Pres. psia
		Pilot only:																						
8	3	Pilot only -no sample(JP8)	No sample	47.27	45.19	2.08	4.40%	608	1068	4.23	4.52	0.94	3.28	2.92	212.0	212.0	0.0	0.0	0.0	100.0%	0.0%	72.27	-	-
9	4	All lit- howl	No sample	51.83	49.54	2.29	4.42%	623	1083	4.61	4.51	1.02	3.58	2.93	520.6	152.9	367.7	182.5	185.2	29.4%	49.6%	64.65	55.63	57.0
10	5	All lit -individual rake avg.	G rakes	60.75	58.12	2.63	4.33%	646	1106	5.30	5.95	0.89	4.11	2.90	581.1	222.8	358.3	177.8	180.5	38.3%	49.6%	88.16	63.62	65.5
		All lit rake A - ganged	G elements																					
		All lit rake B - ganged	G elements																					
		All lit rake C - ganged	G elements																					
		All lit rake D - ganged	G elements																					
11	5	All lit	No sample	67.26	64.15	3.11	4.62%	703	1163	5.91	6.47	0.91	4.58	3.00	581.6	223.5	358.1	176.8	181.4	38.4%	49.4%	94.85	70.15	71.3
17	100	Pilot only -no sample	G rakes	83.96	80.78	3.18	3.79%	664	1124	6.79	7.12	0.95	5.27	2.71	218.3	218.3	0.0	0.0	0.0	100.0%	0.0%	107.81	-	-
18	100	Pilot -individual rake avg.	G rakes	72.79	68.91	3.88	5.33%	738	1198	6.77	7.10	0.95	5.25	3.22	248.3	248.3	0.0	0.0	0.0	100.0%	0.0%	104.06	-	-
		Pilot only A - ganged	G elements																					
		Pilot only B - ganged	G elements																					
		Pilot only C - ganged	G elements																					
		Pilot only D - ganged	G elements																					
19	5	P&O.M. -individual rake avg.	G rakes	84.75	81.34	3.41	4.02%	812	1272	6.64	7.20	0.92	5.15	2.80	505.4	211.6	293.8	293.8	0.0	41.9%	100.0%	107.32	98.57	-
		P.&O.M. lit rake A - ganged	G elements																					
		P.&O.M. lit rake B - ganged	G elements																					
		P.&O.M. lit rake C - ganged	G elements																					
		P.&O.M. lit rake D - ganged	G elements																					
20	602	Pilot & O.Main lit-no sample	G rakes	122.09	116.53	5.56	4.55%	1018	1478	9.45	10.15	0.93	7.32	2.97	593.5	253.3	340.2	340.2	0.0	42.7%	100.0%	155.04	140.16	-
21	602	P&O.M. -individual rake avg.	G rakes	123.46	117.87	5.59	4.53%	1066	1526	9.37	10.00	0.94	7.26	2.97	613.1	261.2	351.9	351.9	0.0	42.6%	100.0%	158.67	143.10	-
		P.&O.M. lit rake A - ganged	G elements																					
		P.&O.M. lit rake B - ganged	G elements																					
		P.&O.M. lit rake C - ganged	G elements																					
		P.&O.M. lit rake D - ganged	G elements																					
22	8	P&O.M. -individual rake avg.	G rakes	123.97	118.30	5.67	4.57%	1141	1601	9.24	9.75	0.95	7.16	2.98	617.0	266.7	350.3	350.3	0.0	43.2%	100.0%	160.73	143.31	-
		P.&O.M. lit rake A - ganged	G elements																					
		P.&O.M. lit rake B - ganged	G elements																					
		P.&O.M. lit rake C - ganged	G elements																					
		P.&O.M. lit rake D - ganged	G elements																					

THIRD COMBUSTOR SECTOR, CELL 5
GAS SAMPLE PRESSURE TEST DATA

Tes est: 6/8 & 13/1994
Print: 6/16/98

Tflame Coef's:

a0=	166619100	a6=	-462.556627
a1=	222862300	a7=	-280833.5
a2=	-2921.308155	a8=	1583.425649
a3=	15972.29681	a9=	-327760800
a4=	-70493950	a10=	14578990
a5=	32214690	a11=	7.938999

Rd	Test Points		FUEL FLOW NUMBERS: Pilot Injector Flow Number	Outer IMFH Manif. Flow Number	Inner IMFH Manif. Flow Number	Pilot Test Cal. Flow Numbe	Outer IMFH Test Cal. Flow Numbe	Inner IMFH Test Cal. Flow Numbe	MEASURED FUEL-AIR RATIOS/ EQUIVALENCE RATIOS: All Rakes (A,B,C,D) Sample Fuel-Air Ratio	Sample (Dome) Equiv. Ratio	Sample Eq.R.i Sample Eq.R. avg	Sample Uncor. Dome Equiv. Ratio	Sample Airflow Corr. Dome Equiv. Ratio	Calc. Sample (Pilot) Equiv. Ratio	Calc. Sample (O.Dome) Equiv. Ratio	Calc. Sample (Pilot&) (O.Dome) Equiv. Ratio	UNCORRECTED CALCULATED EQUIV.RATIOS: Dome Equiv. Ratio	Pilot Equiv. Ratio	Total IMFH Domes Equiv. Ratio	Outer IMFH Dome Equiv. Ratio	Inner IMFH Dome Equiv. Ratio
		Pilot only:																			
8	3	Pilot only -no sample(JP8)	40.73	NA	NA	1.01	NA	NA	-	-	-	-					0.264	0.915	0.000	0.000	0.000
9	4	All lit- howl	39.33	73.95	67.85	0.98	1.04	0.96	-	-	-	-					0.593	0.605	0.589	0.579	0.598
10	5	All lit -individual rake avg.	40.65	75.79	66.67	1.01	1.07	0.94	0.03135	0.460	-	0.798	0.896	0.613	0.392	0.490	0.577	0.768	0.499	0.491	0.508
		All lit rake A - ganged							0.03316	0.487	1.058	-	-	0.648	0.415	0.518					
		All lit rake B - ganged							0.03468	0.509	1.106	-	-	0.678	0.434	0.542					
		All lit rake C - ganged							0.03431	0.503	1.094	-	-	0.670	0.429	0.536					
		All lit rake D - ganged							0.03166	0.465	1.010	-	-	0.619	0.396	0.495					
11	5	All lit	40.33	72.16	67.63	1.00	1.02	0.96	-	-	-	-	-	-	-	-	0.517	0.690	0.447	0.438	0.457
17	100	Pilot only -no sample	41.99	NA	NA	1.04	NA	NA	-	-	-	-					0.169	0.587	0.000	0.000	0.000
18	100	Pilot -individual rake avg.	41.88	NA	NA	1.04	NA	NA	0.01390	0.204	-	1.057	1.109	0.708	0.000	0.315	0.193	0.670	0.000	0.000	0.000
		Pilot only A - ganged							0.01311	0.192	0.943	-	-	0.668	0.000	0.297					
		Pilot only B - ganged							0.01381	0.203	0.994	-	-	0.704	0.000	0.313					
		Pilot only C - ganged							0.01325	0.194	0.953	-	-	0.675	0.000	0.300					
		Pilot only D - ganged							0.01580	0.232	1.137	-	-	0.805	0.000	0.358					
19	5	P&O.M. -individual rake avg.	41.51	70.78	NA	1.03	1.00	NA	0.02614	0.384	-	0.959	1.039	0.558	0.621	0.593	0.400	0.582	0.327	0.648	0.000
		P.&O.M. lit rake A - ganged							0.02686	0.394	1.028	-	-	0.573	0.638	0.609					
		P.&O.M. lit rake B - ganged							0.02490	0.365	0.953	-	-	0.531	0.592	0.565					
		P.&O.M. lit rake C - ganged							0.02256	0.331	0.863	-	-	0.481	0.536	0.512					
		P.&O.M. lit rake D - ganged							0.02750	0.404	1.052	-	-	0.587	0.653	0.624					
20	602	Pilot & O.Main lit-no sample	40.81	69.98	NA	1.02	0.99	NA	-	-	-	-	-	-	-	-	0.330	0.490	0.266	0.527	0.000
21	602	P&O.M. -individual rake avg.	40.88	70.06	NA	1.02	0.99	NA	0.02265	0.332	-	0.966	1.031	0.492	0.531	0.514	0.344	0.509	0.277	0.550	0.000
		P.&O.M. lit rake A - ganged							0.02348	0.345	1.037	-	-	0.510	0.551	0.532					
		P.&O.M. lit rake B - ganged							0.02083	0.306	0.920	-	-	0.452	0.489	0.472					
		P.&O.M. lit rake C - ganged							0.02055	0.302	0.907	-	-	0.446	0.482	0.466					
		P.&O.M. lit rake D - ganged							0.02379	0.349	1.050	-	-	0.516	0.558	0.540					
22	8	P&O.M. -individual rake avg.	40.94	70.05	NA	1.02	0.99	NA	0.02296	0.337	-	0.959	1.012	0.506	0.533	0.521	0.351	0.527	0.280	0.555	0.000
		P.&O.M. lit rake A - ganged							0.02602	0.382	1.133	-	-	0.573	0.604	0.590					
		P.&O.M. lit rake B - ganged							0.02144	0.315	0.934	-	-	0.472	0.497	0.486					
		P.&O.M. lit rake C - ganged							0.02083	0.306	0.907	-	-	0.459	0.483	0.472					
		P.&O.M. lit rake D - ganged							0.02445	0.359	1.065	-	-	0.539	0.567	0.554					

THIRD COMBUSTOR SECTOR, CELL 5
GAS SAMPLE PRESSURE TEST DATA

Test: 6/8 & 13/1994
Print: 6/16/98

Rd	Test Points		AIRFLOW CORRECTED CALCULATED EQUIV.RATIOS					AIRFLOW UNCORRECTED,CALCULATED ADIABATIC FLAME TEMPERATURES					AIRFLOW CORRECTED ADIABATIC FLAME TEMPERATURES				
			Dome Equiv. Ratio	Pilot Equiv. Ratio	Total IMFH Domes Equiv. Ratio	Outer IMFH Dome Equiv. Ratio	Inner IMFH Dome Equiv. Ratio	Dome Flame Temp.,R	Pilot Flame emp.,	Total IMFH Domes Flame Temp.,R	Outer IMFH Dome Flame Temp.,R	Inner IMFH Dome Flame Temp.,R	Dome Flame emp.,	Pilot Flame Temp.,R	Total IMFH Domes Flame emp.,	Outer IMFH Dome Flame emp.,	Inner IMFH Dome Flame Temp.,R
Day 1		Pilot only:															
8	3	Pilot only -no sample(JP8)	0.247	0.857	0.000	0.000	0.000	2256	4234	1068	1068	1068	2191	4136	1068	1068	1068
9	4	All lit- howl	0.608	0.620	0.603	0.593	0.612	3438	3477	3423	3392	3454	3485	3523	3469	3438	3500
10	5	All lit -individual rake avg.	0.514	0.684	0.445	0.438	0.452	3401	3967	3138	3110	3167	3187	3737	2947	2922	2973
		All lit rake A - ganged															
		All lit rake B - ganged															
		All lit rake C - ganged															
		All lit rake D - ganged															
11	5	All lit	0.473	0.631	0.409	0.400	0.418	3243	3795	3000	2967	3034	3088	3615	2864	2833	2895
17	100	Pilot only -no sample	0.161	0.560	0.000	0.000	0.000	1926	3452	1124	1124	1124	1891	3363	1124	1124	1124
18	100	Pilot -individual rake avg.	0.184	0.639	0.000	0.000	0.000	2092	3759	1198	1198	1198	2055	3665	1198	1198	1198
		Pilot only A - ganged															
		Pilot only B - ganged															
		Pilot only C - ganged															
		Pilot only D - ganged															
19	5	P&O.M. -individual rake avg.	0.369	0.537	0.301	0.598	0.000	2919	3536	2660	3743	1272	2811	3389	2570	3588	1272
		P.&O.M. lit rake A - ganged															
		P.&O.M. lit rake B - ganged															
		P.&O.M. lit rake C - ganged															
		P.&O.M. lit rake D - ganged															
20	602	Pilot & O.Main lit-no sample	0.308	0.456	0.248	0.491	0.000	2843	3383	2616	3509	1478	2764	3270	2550	3388	1478
21	602	P&O.M. -individual rake avg.	0.322	0.477	0.260	0.516	0.000	2929	3482	2698	3616	1526	2855	3377	2636	3504	1526
		P.&O.M. lit rake A - ganged															
		P.&O.M. lit rake B - ganged															
		P.&O.M. lit rake C - ganged															
		P.&O.M. lit rake D - ganged															
22	8	P&O.M. -individual rake avg.	0.333	0.499	0.265	0.526	0.000	3013	3595	2770	3686	1601	2950	3505	2718	3592	1601
		P.&O.M. lit rake A - ganged															
		P.&O.M. lit rake B - ganged															
		P.&O.M. lit rake C - ganged															
		P.&O.M. lit rake D - ganged															

THIRD COMBUSTOR SECTOR, CELL 5
GAS SAMPLE PRESSURE TEST DATA

Test: 6/8 & 13/1994
Print: 6/16/98

Rake emiss.norm.by all rake avg. for rakes
Element emiss.norm.by that rake avg.

			MEASURED EMISSIONS																		
			Uncorr. Sample (Dome) Flame	Uncorr. Sample (Pilot) Flame	Uncorr. Sample (O.Dome) Flame	Uncorr. Sample (Pilot&) (O.Dome) Flame	Combust. Efficiency	Corr. Sample (Dome) Flame	Corr. Sample (Pilot) Flame	Corr. Sample (O.Dome) Flame	Corr. Sample (Pilot&) (O.Dome) Flame		EI NOx i		EI CO i		EI HC i	Rake BCD	EI NOx i BCD	Rake BCD	EI CO i BCD
Rd	Test	Points	Temp.,R	Temp.,R	Temp.,R	Temp.,R	%	Temp.,R	Temp.,R	Temp.,R	Temp.,R	EI NOx	avg	EI CO	avg	EI HC	avg	NOx	avg	CO	avg
Day 1		Pilot only:																			
8	3	Pilot only -no sample(JP8)	-	-	-	-	-	-				-	-	-	-	-	-	-	-	-	-
9	4	All lit- howl	-	-	-	-	-	-				-	-	-	-	-	-	-	-	-	-
10	5	All lit -individual rake avg.	3001	3518	2759	3106	92.83%	2865	3345	2641	2963	1.36	-	96.62	-	56.33	-	1.62	-	65.63	-
		All lit rake A - ganged	3094	3629	2840	3204	87.73%	2850	3320	2627	2947	1.31	0.85	108.57	1.42	111.83	1.88	-	-	-	-
		All lit rake B - ganged	3171	3719	2908	3285	97.86%	3127	3663	2869	3239	1.87	1.21	40.94	0.54	13.58	0.23	-	1.15	-	0.62
		All lit rake C - ganged	3153	3698	2891	3266	92.93%	3008	3514	2765	3113	1.92	1.24	73.49	0.96	61.47	1.03	-	1.19	-	1.12
		All lit rake D - ganged	3017	3537	2773	3123	93.61%	2895	3382	2667	2994	1.07	0.69	82.45	1.08	51.21	0.86	-	0.66	-	1.26
11	5	All lit	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
17	100	Pilot only -no sample	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	4.29	-	1.40	-
18	100	Pilot -individual rake avg.	2137	3869	1198	2558	99.95%	2137	3868	1198	2557	5.45	-	1.48	-	0.18	-	4.94	-	1.35	-
		Pilot only A - ganged	2090	3753	1198	2493	99.95%	2089	3752	1198	2492	2.94	0.66	1.36	1.01	0.22	1.57	-	-	-	-
		Pilot only B - ganged	2132	3856	1198	2551	99.95%	2131	3855	1198	2550	4.93	1.11	1.46	1.08	0.15	1.07	-	1.00	-	1.08
		Pilot only C - ganged	2098	3774	1198	2505	99.96%	2098	3773	1198	2504	5	1.13	1.37	1.01	0.11	0.79	-	1.01	-	1.02
		Pilot only D - ganged	2247	4114	1198	2713	99.96%	2247	4113	1198	2712	4.9	1.10	1.21	0.90	0.08	0.57	-	0.99	-	0.90
19	5	P&O.M. -individual rake avg.	2862	3458	3661	3572	99.92%	2860	3456	3659	3570	2.65	-	2.88	-	0.15	-	3.03	-	2.83	-
		P.&O.M. lit rake A - ganged	2899	3508	3714	3624	99.89%	2897	3505	3712	3621	2.61	0.89	3.96	1.27	0.24	1.92	-	-	-	-
		P.&O.M. lit rake B - ganged	2798	3370	3568	3481	99.92%	2796	3368	3566	3479	2.89	0.99	3.12	1.00	0.12	0.96	-	0.95	-	1.10
		P.&O.M. lit rake C - ganged	2676	3200	3385	3304	99.94%	2675	3199	3384	3302	3.13	1.07	2.51	0.81	0.06	0.48	-	1.03	-	0.89
		P.&O.M. lit rake D - ganged	2931	3552	3761	3670	99.93%	2930	3551	3759	3668	3.07	1.05	2.86	0.92	0.08	0.64	-	1.01	-	1.01
20	602	Pilot & O.Main lit-no sample	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	5.02	-	1.08	-
21	602	P&O.M. -individual rake avg.	2889	3426	3556	3498	99.97%	2889	3425	3555	3498	5.53	-	0.90	-	0.08	-	6.01	-	1.02	-
		P.&O.M. lit rake A - ganged	2931	3485	3619	3560	99.96%	2930	3484	3618	3559	3.97	0.72	1.23	1.14	0.11	1.91	-	-	-	-
		P.&O.M. lit rake B - ganged	2797	3294	3416	3362	99.98%	2797	3294	3415	3361	4.68	0.85	0.89	0.83	0.04	0.70	-	0.78	-	0.87
		P.&O.M. lit rake C - ganged	2783	3274	3394	3341	99.97%	2782	3273	3393	3340	6.42	1.17	1.12	1.04	0.04	0.70	-	1.07	-	1.09
		P.&O.M. lit rake D - ganged	2946	3507	3642	3583	99.97%	2946	3507	3642	3582	6.92	1.26	1.06	0.99	0.04	0.70	-	1.15	-	1.04
22	8	P&O.M. -individual rake avg.	2964	3525	3613	3574	99.96%	2964	3524	3612	3573	10.67	-	1.58	-	0.05	-	9.41	-	1.39	-
		P.&O.M. lit rake A - ganged	3115	3741	3837	3795	99.92%	3114	3740	3835	3793	11.24	1.14	2.97	1.67	0.10	1.90	-	-	-	-
		P.&O.M. lit rake B - ganged	2888	3415	3498	3462	99.97%	2888	3415	3498	3461	8.78	0.89	1.29	0.72	0.04	0.76	-	0.93	-	0.93
		P.&O.M. lit rake C - ganged	2858	3371	3452	3416	99.96%	2857	3370	3451	3415	9.65	0.98	1.46	0.82	0.04	0.76	-	1.03	-	1.05
		P.&O.M. lit rake D - ganged	3038	3631	3723	3683	99.96%	3037	3631	3722	3682	9.8	0.99	1.41	0.79	0.03				-	1.02

3RD COMBUSTOR SECTOR, CELL 5 GAS SAMPLE PRES.TEST DATA			INPUTS FROM CELL 5 DATA ACQUISITION SYSTEM PRINTOUT																				
			INPUTS FROM PAGE #3: CALCULATIONS													INPUTS FROM FRONT PAGE					INPUT FROM GAS SAMPLE SHEET:				
			Main Airflow	Pilot Fuel Flow			Out.IMFH Dome Fuel Flow			Inn.IMFH Dome Fuel Flow														
			East	Pilot	Pilot											Pstrch		Pilot Manif.	Outer IMFH Manif.	Inner IMFH Manif.			Sample	Combust.
			Meter'd	Main	Verif.	Avg.			Avg.			Avg.	Pin,	Tin		(P4)	Pbaro	Pres.	Pres.	Pres.	EI	EI	EI	Fuel-Air	Efficiency
Rd	t Points		pps	pph	pph	pph	pph	pph	pph	pph	pph	pph	psia	F		psia	psia	psia	psia	psia	CO	HC	NOx	Ratio	%
Day 2		(6/13/94)				CALC			CALC			CALC													
23	7	P&O.M. -individual rake avg.	9.85	250.0	232.0	241	332.0	332.0	332.0	0.0	0.0	0.0	122.75	1151		116.89	14.38	152.7	139.55	-	0.93	0.04	6.16	0.02111	99.97%
		P.&O.M. lit rake A - ganged																			1.87	0.09	6.73	0.02395	99.95%
		P.&O.M. lit rake B - ganged																			0.71	0.02	4.72	0.01974	99.98%
		P.&O.M. lit rake C - ganged																			0.77	0.02	4.93	0.01875	99.98%
		P.&O.M. lit rake D - ganged																			0.68	0.02	5.19	0.02198	99.98%
24	7	P&O.M. -individual rake avg.	9.68	262.0	243.6	253	330.8	330.8	330.8	0.0	0.0	0.0	122.65	1156		116.81	14.38	155.7	139.33	-	1.02	0.04	7.39	0.02184	99.97%
		P.&O.M. lit rake A - ganged																			1.97	0.07	7.72	0.02442	99.95%
		P.&O.M. lit rake B - ganged																			0.82	0.02	6.77	0.01998	99.98%
		P.&O.M. lit rake D - ganged																			0.80	0.02	6.61	0.02246	99.98%
25	9	P&O.M. -individual rake avg.	9.88	243.4	225.7	235	307.5	307.5	307.5	0.0	0.0	0.0	121.48	1157		115.52	14.38	149.8	135.30	-	0.64	0.02	4.71	0.02040	99.98%
		P.&O.M. lit rake A - ganged																			1.19	0.05	5.52	0.02273	99.97%
		P.&O.M. lit rake B - ganged																			0.55	0.01	4.06	0.01861	99.99%
		P.&O.M. lit rake D - ganged																			0.46	0.02	3.92	0.02068	99.99%
26	10	P&O.M. -individual rake avg.	9.95	228.1	210.8	219	288.7	288.7	288.7	0.0	0.0	0.0	121.32	1154		115.15	14.38	146.1	132.93	-	0.53	0.02	3.71	0.01902	99.99%
		P.&O.M. lit rake A - ganged																			0.83	0.05	4.85	0.02162	99.98%
		P.&O.M. lit rake B - ganged																			0.62	0.02	2.19	0.01742	99.98%
		P.&O.M. lit rake D - ganged																			0.34	0.02	2.64	0.01984	99.99%
27	13	P&O.M. -individual rake avg.	9.44	290.3	271.4	281	374.3	374.3	374.3	0.0	0.0	0.0	124.18	1157		118.71	14.38	165.2	147.26	-	2.12	0.02	14.34	0.02504	99.95%
		P.&O.M. lit rake A - ganged																			3.80	0.04	15.88	0.02768	99.91%
		P.&O.M. lit rake B - ganged																			2.08	0.02	9.14	0.02274	99.95%
		P.&O.M. lit rake D - ganged																			2.11	0.02	10.97	0.02568	99.95%
28	213	Pilot -individual rake avg.	9.66	290.5	271.6	281	0.0	0.0	0.0	0.0	0.0	0.0	123.34	1161		117.63	14.38	164.3	-	-	0.45	0.07	15.98	0.01155	99.98%
		Pilot only A - ganged																			0.47	0.08	13.30	0.01070	99.98%
		Pilot only B - ganged																			0.40	0.04	14.28	0.01122	99.99%
		Pilot only D - ganged																			0.34	0.03	17.26	0.01395	99.99%
29	207	Pilot -individual rake avg.	9.66	259.9	241.7	251	0.0	0.0	0.0	0.0	0.0	0.0	122.07	1160		116.29	14.38	154.6	-	-	0.32	0.05	7.47	0.01020	99.99%
		Pilot only A - ganged																			0.16	0.09	5.13	0.00902	99.99%
		Pilot only B - ganged																			0.16	0.04	5.07	0.01004	99.99%
		Pilot only D - ganged																			0.18	0.04	8.08	0.01166	99.99%
30	208	Pilot -individual rake avg.	9.64	272.7	254.2	263	0.0	0.0	0.0	0.0	0.0	0.0	123.03	1158		117.27	14.39	158.9	-	-	0.26	0.04	10.17	0.01068	99.99%
		Pilot only A - ganged																			0.23	0.09	6.28	0.00951	99.99%
		Pilot only B - ganged																			0.19	0.04	7.64	0.01035	99.99%
		Pilot only D - ganged																			0.19	0.04	10.29	0.01255	99.99%
31	209	Pilot -individual rake avg.	9.73	240.5	222.9	232	0.0	0.0	0.0	0.0	0.0	0.0	121.73	1158		115.90	14.39	149.4	-	-	0.29	0.04	4.55	0.00923	99.99%
		Pilot only A - ganged																			0.23	0.05	3.42	0.00834	99.99%
		Pilot only B - ganged																			0.10	0.01	3.79	0.00941	100.00%
		Pilot only D - ganged																			0.09	0.00	4.64	0.01043	100.00%
32	210	Pilot -individual rake avg.	9.81	224.4	207.3	216	0.0	0.0	0.0	0.0	0.0	0.0	121.44	1159		115.54	14.39	145.3	-	-	0.22	0.11	2.97	0.00859	99.99%
		Pilot only A - ganged																			0.22	0.19	1.96	0.00750	99.98%
		Pilot only B - ganged																			0.12	0.05	1.92	0.00869	99.99%
		Pilot only D - ganged																			0.28	0.04	2.66	0.00941	99.99%

3RD COMBUSTOR SECTOR, CELL 5
GAS SAMPLE PRES.TEST DATA

				PRESSURES				TEMP'S		AIRFLOWS					FUEL FLOWS & PRESSURES									
																	Total	Outer	Inner		% IMFH		Outer	Inner
			Sampling											Flow	Dome	Pilot	IMFH	IMFH	IMFH		Fuel to	Pilot	IMFH	IMFH
			G=ganged			Pres	%			Sector Airflow				Function:	Fuel	Fuel	Domes	Dome	Dome		IMFH	Manif.	Manif.	Manif.
			I=individual	Pin,	P4	Drop	Pres.	Tin		Total	Meter'	Total	Dome	Wsqrt(T)	Flow,	Flow,	Fuel Flow	Fuel Flow,	Fuel Flow	% Fuel to	Outer	Pres.	Pres.	Pres.
Rd	Test Points		G & I=both	psia	psia	psid	Drop	F	R	pps	pps	Meter'd	Wa, pp	P	pph	pph	pph	pph	pph	Pilot	Dome	psia	psia	psia
		Pilot only:																						
23	7	P&O.M. -individual rake avg.	G rakes	122.75	116.89	5.86	4.77%	1151	1611	9.31	9.85	0.95	7.22	3.05	573.0	241.0	332.0	332.0	0.0	42.1%	100.0%	152.70	139.55	-
		P.&O.M. lit rake A - ganged	G elements																					
		P.&O.M. lit rake B - ganged	G elements																					
		P.&O.M. lit rake C - ganged	G elements																					
		P.&O.M. lit rake D - ganged	G elements																					
24	7	P&O.M. -individual rake avg.	G rakes	122.65	116.81	5.84	4.76%	1156	1616	9.28	9.68	0.96	7.19	3.04	583.6	252.8	330.8	330.8	0.0	43.3%	100.0%	155.66	139.33	-
		P.&O.M. lit rake A - ganged	G elements																					
		P.&O.M. lit rake B - ganged	G elements																					
		P.&O.M. lit rake D - ganged	G elements																					
25	9	P&O.M. -individual rake avg.	G rakes	121.48	115.52	5.96	4.91%	1157	1617	9.33	9.88	0.94	7.23	3.09	542.1	234.6	307.5	307.5	0.0	43.3%	100.0%	149.79	135.30	-
		P.&O.M. lit rake A - ganged	G elements																					
		P.&O.M. lit rake B - ganged	G elements																					
		P.&O.M. lit rake D - ganged	G elements																					
26	10	P&O.M. -individual rake avg.	G rakes	121.32	115.15	6.17	5.09%	1154	1614	9.49	9.95	0.95	7.36	3.14	508.2	219.5	288.7	288.7	0.0	43.2%	100.0%	146.06	132.93	-
		P.&O.M. lit rake A - ganged	G elements																					
		P.&O.M. lit rake B - ganged	G elements																					
		P.&O.M. lit rake D - ganged	G elements																					
27	13	P&O.M. -individual rake avg.	G rakes	124.18	118.71	5.47	4.40%	1157	1617	9.03	9.44	0.96	7.00	2.93	655.2	280.9	374.3	374.3	0.0	42.9%	100.0%	165.21	147.26	-
		P.&O.M. lit rake A - ganged	G elements																					
		P.&O.M. lit rake B - ganged	G elements																					
		P.&O.M. lit rake D - ganged	G elements																					
28	213	Pilot -individual rake avg.	G rakes	123.34	117.63	5.71	4.63%	1161	1621	9.19	9.66	0.95	7.12	3.00	281.1	281.1	0.0	0.0	0.0	100.0%	0.0%	164.32	-	-
		Pilot only A - ganged	G elements																					
		Pilot only B - ganged	G elements																					
		Pilot only D - ganged	G elements																					
29	207	Pilot -individual rake avg.	G rakes	122.07	116.29	5.78	4.73%	1160	1620	9.20	9.66	0.95	7.13	3.03	250.8	250.8	0.0	0.0	0.0	100.0%	0.0%	154.58	-	-
		Pilot only A - ganged	G elements																					
		Pilot only B - ganged	G elements																					
		Pilot only D - ganged	G elements																					
30	208	Pilot -individual rake avg.	G rakes	123.03	117.27	5.76	4.68%	1158	1618	9.23	9.64	0.96	7.15	3.02	263.5	263.5	0.0	0.0	0.0	100.0%	0.0%	158.92	-	-
		Pilot only A - ganged	G elements																					
		Pilot only B - ganged	G elements																					
		Pilot only D - ganged	G elements																					
31	209	Pilot -individual rake avg.	G rakes	121.73	115.90	5.83	4.79%	1158	1618	9.23	9.73	0.95	7.15	3.05	231.7	231.7	0.0	0.0	0.0	100.0%	0.0%	149.39	-	-
		Pilot only A - ganged	G elements																					
		Pilot only B - ganged	G elements																					
		Pilot only D - ganged	G elements																					
32	210	Pilot -individual rake avg.	G rakes	121.44	115.54	5.90	4.86%	1159	1619	9.27	9.81	0.95	7.19	3.07	215.9	215.9	0.0	0.0	0.0	100.0%	0.0%	145.34	-	-
		Pilot only A - ganged	G elements																					
		Pilot only B - ganged	G elements																					
		Pilot only D - ganged	G elements																					

3RD COMBUSTOR SECTOR, CELL 5 GAS SAMPLE PRES.TEST DATA			FUEL FLOW NUMBERS						MEASURED FUEL-AIR RATIOS/ EQUIVALENCE RATIOS								UNCORRECTED CALCULATED EQUIV.RATIOS				
							Outer	Inner	All Rakes (A,B,C,D)				Sample			Calc.					
				Outer	Inner	Pilot	IMFH	IMFH		Sample	Sample	Sample	Airflow	Calc.	Calc.	Sample			Total	Outer	Inner
			Pilot	IMFH	IMFH	Test	Test	Test		(Dome)	Eq.R.i	Uncor.	Corr.	Sample	Sample	(Pilot&)			IMFH	IMFH	IMFH
			Injector	Manif.	Manif.	Cal.	Cal.	Cal.	Sample	Equiv.	Sample	Dome	Dome	(Pilot)	(O.Dome)	(O.Dome)	Dome	Pilot	Domes	Dome	Dome
			Flow	Flow	Flow	Flow	Flow	Flow	Fuel-Air	Equiv.	Eq.R.	Equiv.	Equiv.	Equiv.	Equiv.	Equiv.	Equiv.	Equiv.	Equiv.	Equiv.	Equiv.
Rd		Test Points	Number	Number	Number	Numbe	Numbe	Numbe	Ratio	Ratio	avg	Ratio	Ratio	Ratio	Ratio	Ratio	Ratio	Ratio	Ratio	Ratio	Ratio
		Pilot only:																			
23	7	P&O.M. -individual rake avg.	40.27	69.74	NA	1.00	0.98	NA	0.02111	0.310	-	0.957	1.013	0.452	0.500	0.479	0.324	0.473	0.263	0.522	0.000
		P.&O.M. lit rake A - ganged							0.02395	0.351	1.135	-		0.513	0.567	0.543					
		P.&O.M. lit rake B - ganged							0.01974	0.290	0.935	-		0.423	0.467	0.448					
		P.&O.M. lit rake C - ganged							0.01875	0.275	0.888	-		0.402	0.444	0.425					
		P.&O.M. lit rake D - ganged							0.02198	0.323	1.041	-		0.471	0.520	0.498					
24	7	P&O.M. -individual rake avg.	40.56	69.71	NA	1.01	0.98	NA	0.02184	0.320	-	0.969	1.011	0.482	0.506	0.495	0.331	0.497	0.263	0.522	0.000
		P.&O.M. lit rake A - ganged							0.02442	0.358	1.118	-		0.539	0.566	0.554					
		P.&O.M. lit rake B - ganged							0.01998	0.293	0.915	-		0.441	0.463	0.453					
		P.&O.M. lit rake D - ganged							0.02246	0.330	1.028	-		0.496	0.520	0.509					
25	9	P&O.M. -individual rake avg.	40.07	69.14	NA	1.00	0.97	NA	0.02040	0.299	-	0.979	1.038	0.450	0.473	0.463	0.306	0.459	0.243	0.483	0.000
		P.&O.M. lit rake A - ganged							0.02273	0.334	1.114	-		0.501	0.527	0.515					
		P.&O.M. lit rake B - ganged							0.01861	0.273	0.912	-		0.410	0.431	0.422					
		P.&O.M. lit rake D - ganged							0.02068	0.303	1.014	-		0.456	0.479	0.469					
26	10	P&O.M. -individual rake avg.	39.47	68.47	NA	0.98	0.96	NA	0.01902	0.279	-	0.992	1.039	0.419	0.442	0.431	0.281	0.422	0.225	0.445	0.000
		P.&O.M. lit rake A - ganged							0.02162	0.317	1.137	-		0.476	0.502	0.490					
		P.&O.M. lit rake B - ganged							0.01742	0.256	0.916	-		0.383	0.404	0.395					
		P.&O.M. lit rake D - ganged							0.01984	0.291	1.043	-		0.437	0.461	0.450					
27	13	P&O.M. -individual rake avg.	41.19	70.05	NA	1.02	0.99	NA	0.02504	0.367	-	0.964	1.007	0.547	0.585	0.568	0.381	0.568	0.306	0.607	0.000
		P.&O.M. lit rake A - ganged							0.02768	0.406	1.105	-		0.605	0.646	0.628					
		P.&O.M. lit rake B - ganged							0.02274	0.334	0.908	-		0.497	0.531	0.516					
		P.&O.M. lit rake D - ganged							0.02568	0.377	1.026	-		0.561	0.600	0.582					
28	213	Pilot -individual rake avg.	41.13	NA	NA	1.02	NA	NA	0.01155	0.169	-	1.053	1.108	0.589	0.000	0.262	0.161	0.559	0.000	0.000	0.000
		Pilot only A - ganged							0.01070	0.157	0.926	-		0.545	0.000	0.243					
		Pilot only B - ganged							0.01122	0.165	0.971	-		0.572	0.000	0.254					
		Pilot only D - ganged							0.01395	0.205	1.208	-		0.711	0.000	0.316					
29	207	Pilot -individual rake avg.	40.53	NA	NA	1.01	NA	NA	0.01020	0.150	-	1.044	1.096	0.520	0.000	0.231	0.143	0.498	0.000	0.000	0.000
		Pilot only A - ganged							0.00902	0.132	0.884	-		0.460	0.000	0.205					
		Pilot only B - ganged							0.01004	0.147	0.984	-		0.512	0.000	0.228					
		Pilot only D - ganged							0.01166	0.171	1.143	-		0.594	0.000	0.264					
30	208	Pilot -individual rake avg.	40.82	NA	NA	1.02	NA	NA	0.01068	0.157	-	1.044	1.091	0.544	0.000	0.242	0.150	0.521	0.000	0.000	0.000
		Pilot only A - ganged							0.00951	0.140	0.890	-		0.485	0.000	0.216					
		Pilot only B - ganged							0.01035	0.152	0.969	-		0.527	0.000	0.235					
		Pilot only D - ganged							0.01255	0.184	1.175	-		0.639	0.000	0.285					
31	209	Pilot -individual rake avg.	40.04	NA	NA	1.00	NA	NA	0.00923	0.135	-	1.026	1.082	0.470	0.000	0.209	0.132	0.458	0.000	0.000	0.000
		Pilot only A - ganged							0.00834	0.122	0.904	-		0.425	0.000	0.189					
		Pilot only B - ganged							0.00941	0.138	1.020	-		0.479	0.000	0.213					
		Pilot only D - ganged							0.01043	0.153	1.130	-		0.531	0.000	0.237					
32	210	Pilot -individual rake avg.	39.54	NA	NA	0.98	NA	NA	0.00859	0.126	-	1.030	1.089	0.438	0.000	0.195	0.122	0.425	0.000	0.000	0.000
		Pilot only A - ganged							0.00750	0.110	0.873	-		0.382	0.000	0.170					
		Pilot only B - ganged							0.00869	0.128	1.012	-		0.443	0.000	0.197					
		Pilot only D - ganged							0.00941	0.138	1.095	-		0.479	0.000	0.213					

3RD COMBUSTOR SECTOR, CELL 5 GAS SAMPLE PRES.TEST DATA			AIRFLOW CORRECTED CALCULATED EQUIV.RATIOS					AIRFLOW UNCORRECTED,CALCULATED ADIABATIC FLAME TEMPERATURES					AIRFLOW CORRECTED ADIABATIC FLAME TEMPERATURES				
Rd	Test Points		Dome Equiv. Ratio	Pilot Equiv. Ratio	Total IMFH Domes Equiv. Ratio	Outer IMFH Dome Equiv. Ratio	Inner IMFH Dome Equiv. Ratio	Dome Flame Temp.,R	Pilot Flame emp.,	Total IMFH Domes Flame Temp.,R	Outer IMFH Dome Flame Temp.,R	Inner IMFH Dome Flame Temp.,R	Dome Flame emp.,	Pilot Flame Temp.,R	Total IMFH Domes Flame emp.,	Outer IMFH Dome Flame emp.,	Inner IMFH Dome Flame Temp.,R
Day 1		Pilot only:															
23	7	P&O.M. -individual rake avg.	0.306	0.447	0.249	0.494	0.000	2927	3424	2720	3586	1611	2867	3339	2669	3493	1611
		P.&O.M. lit rake A - ganged															
		P.&O.M. lit rake B - ganged															
		P.&O.M. lit rake C - ganged															
		P.&O.M. lit rake D - ganged															
24	7	P&O.M. -individual rake avg.	0.317	0.477	0.252	0.500	0.000	2955	3508	2723	3588	1616	2908	3441	2684	3518	1616
		P.&O.M. lit rake A - ganged															
		P.&O.M. lit rake B - ganged															
		P.&O.M. lit rake D - ganged															
25	9	P&O.M. -individual rake avg.	0.288	0.433	0.230	0.456	0.000	2871	3384	2654	3462	1617	2812	3299	2605	3373	1617
		P.&O.M. lit rake A - ganged															
		P.&O.M. lit rake B - ganged															
		P.&O.M. lit rake D - ganged															
26	10	P&O.M. -individual rake avg.	0.269	0.403	0.214	0.425	0.000	2785	3259	2582	3336	1614	2740	3194	2544	3268	1614
		P.&O.M. lit rake A - ganged															
		P.&O.M. lit rake B - ganged															
		P.&O.M. lit rake D - ganged															
27	13	P&O.M. -individual rake avg.	0.365	0.543	0.293	0.581	0.000	3126	3735	2872	3857	1617	3071	3658	2827	3776	1617
		P.&O.M. lit rake A - ganged															
		P.&O.M. lit rake B - ganged															
		P.&O.M. lit rake D - ganged															
28	213	Pilot -individual rake avg.	0.153	0.531	0.000	0.000	0.000	2341	3710	1621	1621	1621	2308	3622	1621	1621	1621
		Pilot only A - ganged															
		Pilot only B - ganged															
		Pilot only D - ganged															
29	207	Pilot -individual rake avg.	0.137	0.474	0.000	0.000	0.000	2266	3513	1620	1620	1620	2236	3435	1620	1620	1620
		Pilot only A - ganged															
		Pilot only B - ganged															
		Pilot only D - ganged															
30	208	Pilot -individual rake avg.	0.144	0.499	0.000	0.000	0.000	2293	3588	1618	1618	1618	2265	3515	1618	1618	1618
		Pilot only A - ganged															
		Pilot only B - ganged															
		Pilot only D - ganged															
31	209	Pilot -individual rake avg.	0.125	0.435	0.000	0.000	0.000	2214	3382	1618	1618	1618	2183	3305	1618	1618	1618
		Pilot only A - ganged															
		Pilot only B - ganged															
		Pilot only D - ganged															
32	210	Pilot -individual rake avg.	0.116	0.402	0.000	0.000	0.000	2170	3272	1619	1619	1619	2139	3195	1619	1619	1619
		Pilot only A - ganged															
		Pilot only B - ganged															
		Pilot only D - ganged															

3RD COMBUSTOR SECTOR, CELL 5																						
GAS SAMPLE PRES.TEST DATA			MEASURED EMISSIONS																			
			Uncorr. Sample (Dome) Flame	Uncorr. Sample (Pilot) Flame	Uncorr. Sample (O.Dome) Flame	Uncorr. Sample (Pilot&) (O.Dome) Flame	Combust. Efficiency	Corr. Sample (Dome) Flame	Corr. Sample (Pilot) Flame	Corr. Sample (O.Dome) Flame	Corr. Sample (Pilot&) (O.Dome) Flame	EI	EI NOx i NOx	EI	EI CO i CO	EI	EI HC i HC	Rake BCD EI	NOx i BCD NOx	Rake BCD EI	CO i BCD CO
Rd	Test Points		Temp.,R	Temp.,R	Temp.,R	Temp.,R	%	Temp.,R	Temp.,R	Temp.,R	Temp.,R	NOx	avg	CO	avg	HC	avg	NOx	avg	CO	avg
Day 1		Pilot only:																				
23	7	P&O.M. -individual rake avg.	2880	3358	3513	3444	99.97%	2880	3357	3513	3444	6.16	-	0.93	-	0.04	-	4.95	-	0.72	-
		P.&O.M. lit rake A - ganged	3021	3557	3729	3653	99.95%	3021	3556	3728	3652	6.73	1.25	1.87	1.86	0.09	2.40	-	-	-	-
		P.&O.M. lit rake B - ganged	2811	3260	3407	3342	99.98%	2811	3260	3407	3342	4.72	0.88	0.71	0.70	0.02	0.53	-	0.95	-	0.99
		P.&O.M. lit rake C - ganged	2761	3190	3330	3268	99.98%	2761	3190	3329	3267	4.93	0.91	0.77	0.76	0.02	0.53	-	1.00	-	1.07
		P.&O.M. lit rake D - ganged	2924	3419	3580	3509	99.98%	2923	3419	3580	3508	5.19	0.96	0.68	0.67	0.02	0.53	-	1.05	-	0.94
24	7	P&O.M. -individual rake avg.	2920	3458	3536	3502	99.97%	2920	3458	3536	3501	7.39	-	1.02	-	0.04	-	6.69	-	0.81	-
		P.&O.M. lit rake A - ganged	3048	3643	3728	3690	99.95%	3047	3642	3727	3689	7.72	1.10	1.97	1.65	0.07	1.91	-	-	-	-
		P.&O.M. lit rake B - ganged	2827	3323	3395	3363	99.98%	2827	3323	3395	3363	6.77	0.96	0.82	0.69	0.02	0.55	-	1.01	-	1.01
		P.&O.M. lit rake D - ganged	2951	3503	3583	3547	99.98%	2951	3503	3582	3547	6.61	0.94	0.80	0.67	0.02	0.55	-	0.99	-	0.99
25	9	P&O.M. -individual rake avg.	2849	3353	3429	3395	99.98%	2849	3353	3429	3395	4.71	-	0.64	-	0.02	-	3.99	-	0.51	-
		P.&O.M. lit rake A - ganged	2965	3522	3605	3568	99.97%	2965	3521	3604	3567	5.52	1.23	1.19	1.62	0.05	1.88	-	-	-	-
		P.&O.M. lit rake B - ganged	2759	3222	3292	3261	99.99%	2758	3222	3292	3261	4.06	0.90	0.55	0.75	0.01	0.38	-	1.02	-	1.09
		P.&O.M. lit rake D - ganged	2863	3373	3450	3416	99.99%	2863	3373	3450	3416	3.92	0.87	0.46	0.63	0.02	0.75	-	0.98	-	0.91
26	10	P&O.M. -individual rake avg.	2776	3247	3323	3289	99.99%	2776	3247	3323	3289	3.71	-	0.53	-	0.02	-	2.42	-	0.48	-
		P.&O.M. lit rake A - ganged	2907	3436	3522	3483	99.98%	2907	3435	3521	3483	4.85	1.50	0.83	1.39	0.05	1.67	-	-	-	-
		P.&O.M. lit rake B - ganged	2694	3130	3200	3169	99.98%	2694	3129	3200	3168	2.19	0.68	0.62	1.04	0.02	0.67	-	0.91	-	1.29
		P.&O.M. lit rake D - ganged	2818	3307	3386	3351	99.99%	2818	3307	3386	3351	2.64	0.82	0.34	0.57	0.02	0.67	-	1.09	-	0.71
27	13	P&O.M. -individual rake avg.	3079	3670	3788	3736	99.95%	3079	3669	3787	3735	14.34	-	2.12	-	0.02	-	10.06	-	2.10	-
		P.&O.M. lit rake A - ganged	3209	3850	3975	3920	99.91%	3207	3848	3973	3918	15.88	1.32	3.80	1.43	0.04	1.50	-	-	-	-
		P.&O.M. lit rake B - ganged	2966	3507	3618	3569	99.95%	2965	3506	3617	3568	9.14	0.76	2.08	0.78	0.02	0.75	-	0.91	-	0.99
		P.&O.M. lit rake D - ganged	3111	3714	3835	3781	99.95%	3110	3713	3833	3780	10.97	0.91	2.11	0.79	0.02	0.75	-	1.09	-	1.01
28	213	Pilot -individual rake avg.	2376	3803	1621	2723	99.98%	2376	3803	1621	2723	15.98	-	0.45	-	0.07	-	15.77	-	0.37	-
		Pilot only A - ganged	2325	3667	1621	2655	99.98%	2325	3667	1621	2654	13.3	0.89	0.47	1.17	0.08	1.60	-	-	-	-
		Pilot only B - ganged	2357	3751	1621	2697	99.99%	2357	3751	1621	2697	14.28	0.96	0.40	0.99	0.04	0.80	-	0.91	-	1.08
		Pilot only D - ganged	2515	4158	1621	2911	99.99%	2515	4158	1621	2911	17.26	1.15	0.34	0.84	0.03	0.60	-	1.09	-	0.92
29	207	Pilot -individual rake avg.	2293	3584	1620	2613	99.99%	2293	3584	1620	2612	7.47	-	0.32	-	0.05	-	6.58	-	0.17	-
		Pilot only A - ganged	2217	3388	1620	2513	99.99%	2217	3388	1620	2513	5.13	0.84	0.16	0.96	0.09	1.59	-	-	-	-
		Pilot only B - ganged	2283	3558	1620	2599	99.99%	2283	3558	1620	2599	5.07	0.83	0.16	0.96	0.04	0.71	-	0.77	-	0.94
		Pilot only D - ganged	2382	3820	1620	2731	99.99%	2382	3819	1620	2731	8.08	1.33	0.18	1.08	0.04	0.71	-	1.23	-	1.06
30	208	Pilot -individual rake avg.	2321	3661	1618	2650	99.99%	2320	3661	1618	2650	10.17	-	0.26	-	0.04	-	8.97	-	0.19	-
		Pilot only A - ganged	2247	3468	1618	2553	99.99%	2247	3468	1618	2553	6.28	0.78	0.23	1.13	0.09	1.59	-	-	-	-
		Pilot only B - ganged	2300	3607	1618	2623	99.99%	2300	3607	1618	2623	7.64	0.95	0.19	0.93	0.04	0.71	-	0.85	-	1.00
		Pilot only D - ganged	2432	3955	1618	2799	99.99%	2432	3955	1618	2799	10.29	1.28	0.19	0.93	0.04	0.71	-	1.15	-	1.00
31	209	Pilot -individual rake avg.	2229	3422	1618	2530	99.99%	2229	3421	1618	2529	4.55	-	0.29	-	0.04	-	4.22	-	0.10	-
		Pilot only A - ganged	2170	3272	1618	2452	99.99%	2170	3272	1618	2452	3.42	0.87	0.23	1.64	0.05	2.50	-	-	-	-
		Pilot only B - ganged	2241	3452	1618	2545	100.00%	2241	3452	1618	2545	3.79	0.96	0.10	0.71	0.01	0.50	-	0.90	-	1.05
		Pilot only D - ganged	2306	3621	1618	2630	100.00%	2306	3621	1618	2630	4.64	1.17	0.09	0.64	0.00	0.00	-	1.10	-	0.95
32	210	Pilot -individual rake avg.	2187	3314	1619	2474	99.99%	2187	3314	1619	2474	2.97	-	0.22	-	0.11	-	2.29	-	0.20	-
		Pilot only A - ganged	2112	3130	1619	2376	99.98%	2112	3129	1619	2376	1.96	0.90	0.22	1.06	0.19	2.04	-	-	-	-
		Pilot only B - ganged	2194	3331	1619	2483	99.99%	2194	3331	1619	2483	1.92	0.88	0.12	0.58	0.05	0.54	-	0.84	-	0.60
		Pilot only D - ganged	2241	3452	1619	2545	99.99%	2241	3451	1619	2545	2.66	1.22	0.28	1.35	0.04	0.43				1.40

3RD COMBUSTOR SECTOR, CELL 5 GAS SAMPLE PRES.TEST DATA			INPUTS FROM CELL 5 DATA ACQUISITION SYSTEM PRINTOUT																	INPUTS FROM GAS SAMPLE SHEET:				
			INPUTS FROM PAGE #3: CALCULATIONS												INPUTS FROM FRONT PAGE									
																				INPUT FROM GAS SAMPLE SHEET:				
			Main Airflow	Pilot Fuel Flow			Out.IMFH Dome Fuel Flow			Inn.IMFH Dome Fuel Flow					Pstrch		Pilot Manif.	Outer IMFH Manif.	Inner IMFH Manif.				Sample	Combust.
			East Meter'd	Pilot Main	Pilot Verif.	Avg.			Avg.			Avg.	Pin,	Tin	(P4)	Pbaro	Pres.	Pres.	Pres.	EI	EI	EI	Fuel-Air	Efficiency
Rd	t Points		pps	pph	pph	pph	pph	pph	pph	pph	pph	pph	psia	F	psia	psia	psia	psia	psia	CO	HC	NOx	Ratio	%
Day 2		(6/13/94)				CALC			CALC			CALC												
33	252	Pilot -individual rake avg.	10.22	272.9	254.3	264	0.0	0.0	0.0	0.0	0.0	0.0	123.16	949	117.61	14.39	158.9	-	-	0.35	0.09	2.92	0.01025	99.98%
		Pilot only A - ganged																		0.38	0.14	1.83	0.00900	99.98%
		Pilot only B - ganged																		0.15	0.04	2.15	0.01004	99.99%
		Pilot only D - ganged																		0.25	0.04	2.14	0.01166	99.99%
34	254	Pilot -individual rake avg.	10.34	283.8	265.0	274	0.0	0.0	0.0	0.0	0.0	0.0	124.28	949	118.73	14.40	163.1	-	-	0.33	0.11	3.36	0.01057	99.98%
		Pilot only A - ganged																		0.36	0.09	1.95	0.00931	99.98%
		Pilot only B - ganged																		0.23	0.07	2.35	0.01030	99.99%
		Pilot only D - ganged																		0.22	0.03	2.62	0.01244	99.99%
35	254	Pilot -individual rake avg.	10.11	309.0	290.1	300	0.0	0.0	0.0	0.0	0.0	0.0	124.12	949	118.74	14.40	170.7	-	-	0.27	0.03	7.04	0.01199	99.99%
		Pilot only A - ganged																		0.34	0.08	5.51	0.01078	99.99%
		Pilot only B - ganged																		0.33	0.04	4.95	0.01155	99.99%
		Pilot only D - ganged																		0.31	0.03	6.31	0.01418	99.99%
36	154	P&O.M. -individual rake avg.	10.27	308.0	289.1	299	395.6	395.6	395.6	0.0	0.0	0.0	123.27	945	117.80	14.41	169.6	153.35	-	2.05	0.02	8.14	0.02617	99.95%
		P.&O.M. lit rake A - ganged																		3.75	0.03	10.35	0.02871	99.91%
		P.&O.M. lit rake B - ganged																		2.31	0.02	4.93	0.02442	99.94%
		P.&O.M. lit rake D - ganged																		1.76	0.02	4.68	0.02621	99.96%
37	153	P&O.M. -individual rake avg.	10.31	292.1	273.4	283	377.6	377.6	377.6	0.0	0.0	0.0	122.68	947	117.02	14.41	164.1	149.35	-	1.54	0.03	6.19	0.02472	99.96%
		P.&O.M. lit rake A - ganged																		2.92	0.04	7.00	0.02734	99.93%
		P.&O.M. lit rake B - ganged																		1.70	0.02	3.51	0.02288	99.96%
		P.&O.M. lit rake D - ganged																		1.24	0.02	3.03	0.02488	99.97%
38	152	P&O.M. -individual rake avg.	10.34	272.6	254.2	263	344.4	344.4	344.4	0.0	0.0	0.0	119.98	948	114.21	14.41	155.8	141.34	-	1.24	0.05	4.02	0.02280	99.97%
		P.&O.M. lit rake A - ganged																		1.74	0.05	5.22	0.02481	99.96%
		P.&O.M. lit rake B - ganged																		1.55	0.04	2.46	0.02130	99.96%
		P.&O.M. lit rake D - ganged																		0.88	0.02	2.18	0.02348	99.98%
39	151	P&O.M. -individual rake avg.	10.25	245.9	228.2	237	323.1	323.1	323.1	0.0	0.0	0.0	117.39	946	111.53	14.41	146.3	135.74	-	2.28	0.12	2.64	0.02099	99.94%
		P.&O.M. lit rake A - ganged																		1.39	0.04	3.64	0.02269	99.96%
		P.&O.M. lit rake B - ganged																		3.66	0.19	1.33	0.01960	99.90%
		P.&O.M. lit rake D - ganged																		3.51	0.31	1.10	0.02129	99.89%
40	155	P&O.M. -individual rake avg.	9.75	326.6	307.1	317	414.8	414.8	414.8	0.0	0.0	0.0	124.98	946	120.13	14.41	177.4	158.88	-	3.19	0.04	13.99	0.02870	99.92%
		P.&O.M. lit rake A - ganged																		5.09	0.04	14.65	0.03031	99.88%
		P.&O.M. lit rake B - ganged																		3.90	0.02	9.05	0.02668	99.91%
		P.&O.M. lit rake D - ganged																		2.95	0.03	9.31	0.02822	99.93%

3RD COMBUSTOR SECTOR, CELL 5 GAS SAMPLE PRES.TEST DATA				PRESSURES				TEMP'S		AIRFLOWS					FUEL FLOWS & PRESSURES										
										Sector Airflow							Total	Outer	Inner		% IMFH		Outer	Inner
			Sampling			Pres	%							Flow	Dome	Pilot	IMFH	IMFH	IMFH		Fuel to	Pilot	IMFH	IMFH
			G=ganged			Drop	Pres.	Tin		Total	Meter'	Total	Dome	Function:	Fuel	Fuel	Domes	Dome	Dome	% Fuel	IMFH	Manif.	Manif.	Manif.
			I=individual	Pin,	P4							Meter'd	Wa, pp	Wsqrt(T)	Flow,	Flow,	Flow	Flow,	Flow	to	Outer	Pres.	Pres.	Pres.
Rd	Test Points		G & I=both	psia	psia	psid	Drop	F	R	pps	pps			P	pph	pph	pph	pph	pph	Pilot	Dome	psia	psia	psia
		Pilot only:																						
33	252	Pilot -individual rake avg.	G rakes	123.16	117.61	5.55	4.51%	949	1409	9.71	10.22	0.95	7.53	2.96	263.6	263.6	0.0	0.0	0.0	100.0%	0.0%	158.89	-	-
		Pilot only A - ganged	G elements																					
		Pilot only B - ganged	G elements																					
		Pilot only D - ganged	G elements																					
34	254	Pilot -individual rake avg.	G rakes	124.28	118.73	5.55	4.47%	949	1409	9.75	10.34	0.94	7.56	2.95	274.4	274.4	0.0	0.0	0.0	100.0%	0.0%	163.09	-	-
		Pilot only A - ganged	G elements																					
		Pilot only B - ganged	G elements																					
		Pilot only D - ganged	G elements																					
35	254	Pilot -individual rake avg.	G rakes	124.12	118.74	5.38	4.33%	949	1409	9.60	10.11	0.95	7.44	2.90	299.6	299.6	0.0	0.0	0.0	100.0%	0.0%	170.68	-	-
		Pilot only A - ganged	G elements																					
		Pilot only B - ganged	G elements																					
		Pilot only D - ganged	G elements																					
36	154	P&O.M. -individual rake avg.	G rakes	123.27	117.80	5.47	4.44%	945	1405	9.66	10.27	0.94	7.48	2.94	694.2	298.6	395.6	395.6	0.0	43.0%	100.0%	169.62	153.35	-
		P.&O.M. lit rake A - ganged	G elements																					
		P.&O.M. lit rake B - ganged	G elements																					
		P.&O.M. lit rake D - ganged	G elements																					
37	153	P&O.M. -individual rake avg.	G rakes	122.68	117.02	5.66	4.61%	947	1407	9.79	10.31	0.95	7.59	2.99	660.4	282.8	377.6	377.6	0.0	42.8%	100.0%	164.12	149.35	-
		P.&O.M. lit rake A - ganged	G elements																					
		P.&O.M. lit rake B - ganged	G elements																					
		P.&O.M. lit rake D - ganged	G elements																					
38	152	P&O.M. -individual rake avg.	G rakes	119.98	114.21	5.77	4.81%	948	1408	9.78	10.34	0.95	7.58	3.06	607.8	263.4	344.4	344.4	0.0	43.3%	100.0%	155.80	141.34	-
		P.&O.M. lit rake A - ganged	G elements																					
		P.&O.M. lit rake B - ganged	G elements																					
		P.&O.M. lit rake D - ganged	G elements																					
39	151	P&O.M. -individual rake avg.	G rakes	117.39	111.53	5.86	4.99%	946	1406	9.75	10.25	0.95	7.56	3.11	560.2	237.1	323.1	323.1	0.0	42.3%	100.0%	146.30	135.74	-
		P.&O.M. lit rake A - ganged	G elements																					
		P.&O.M. lit rake B - ganged	G elements																					
		P.&O.M. lit rake D - ganged	G elements																					
40	155	P&O.M. -individual rake avg.	G rakes	124.98	120.13	4.85	3.88%	946	1406	9.15	9.75	0.94	7.09	2.75	731.7	316.9	414.8	414.8	0.0	43.3%	100.0%	177.37	158.88	-
		P.&O.M. lit rake A - ganged	G elements																					
		P.&O.M. lit rake B - ganged	G elements																					
		P.&O.M. lit rake D - ganged	G elements																					

3RD COMBUSTOR SECTOR, CELL 5 GAS SAMPLE PRES.TEST DATA			FUEL FLOW NUMBERS						MEASURED FUEL-AIR RATIOS/ EQUIVALENCE RATIOS								UNCORRECTED CALCULATED EQUIV.RATIOS				
									All Rakes (A,B,C,D)				Sample								
Rd	Test Points		Pilot Injector Flow Number	Outer IMFH Manif. Flow Number	Inner IMFH Manif. Flow Number	Pilot Test Cal. Flow Numbe	Outer IMFH Test Cal. Flow Numbe	Inner IMFH Test Cal. Flow Numbe	Sample Fuel-Air Ratio	Sample (Dome) Equiv. Ratio	Sample Eq.R.i Sample Eq.R. avg	Sample Uncor. Dome Equiv. Ratio	Airflow Corr. Dome Equiv. Ratio	Calc. Sample (Pilot) Equiv. Ratio	Calc. Sample (O.Dome) Equiv. Ratio	Calc. Sample (Pilot&) (O.Dome) Equiv. Ratio	Dome Equiv. Ratio	Pilot Equiv. Ratio	Total IMFH Domes Equiv. Ratio	Outer IMFH Dome Equiv. Ratio	Inner IMFH Dome Equiv. Ratio
		Pilot only:																			
33	252	Pilot -individual rake avg.	41.03	NA	NA	1.02	NA	NA	0.01025	0.150	-	1.053	1.109	0.522	0.000	0.232	0.143	0.496	0.000	0.000	0.000
		Pilot only A - ganged							0.00900	0.132	0.878	-		0.459	0.000	0.204					
		Pilot only B - ganged							0.01004	0.147	0.980	-		0.512	0.000	0.228					
		Pilot only D - ganged							0.01166	0.171	1.138	-		0.594	0.000	0.264					
34	254	Pilot -individual rake avg.	41.20	NA	NA	1.02	NA	NA	0.01057	0.155	-	1.048	1.111	0.539	0.000	0.240	0.148	0.514	0.000	0.000	0.000
		Pilot only A - ganged							0.00931	0.137	0.881	-		0.474	0.000	0.211					
		Pilot only B - ganged							0.01030	0.151	0.974	-		0.525	0.000	0.234					
		Pilot only D - ganged							0.01244	0.183	1.177	-		0.634	0.000	0.282					
35	254	Pilot -individual rake avg.	41.56	NA	NA	1.03	NA	NA	0.01199	0.176	-	1.072	1.129	0.611	0.000	0.272	0.164	0.570	0.000	0.000	0.000
		Pilot only A - ganged							0.01078	0.158	0.899	-		0.549	0.000	0.244					
		Pilot only B - ganged							0.01155	0.169	0.963	-		0.589	0.000	0.262					
		Pilot only D - ganged							0.01418	0.208	1.183	-		0.723	0.000	0.322					
36	154	P&O.M. -individual rake avg.	41.47	66.35	NA	1.03	0.93	NA	0.02617	0.384	-	1.016	1.080	0.574	0.609	0.593	0.378	0.565	0.303	0.600	0.000
		P.&O.M. lit rake A - ganged							0.02871	0.421	1.097	-		0.629	0.669	0.651					
		P.&O.M. lit rake B - ganged							0.02442	0.358	0.933	-		0.535	0.569	0.554					
		P.&O.M. lit rake D - ganged							0.02621	0.385	1.002	-		0.574	0.610	0.594					
37	153	P&O.M. -individual rake avg.	41.20	66.41	NA	1.02	0.94	NA	0.02472	0.363	-	1.023	1.077	0.539	0.578	0.561	0.355	0.527	0.285	0.565	0.000
		P.&O.M. lit rake A - ganged							0.02734	0.401	1.106	-		0.597	0.639	0.620					
		P.&O.M. lit rake B - ganged							0.02288	0.336	0.926	-		0.499	0.535	0.519					
		P.&O.M. lit rake D - ganged							0.02488	0.365	1.006	-		0.543	0.581	0.564					
38	152	P&O.M. -individual rake avg.	40.84	66.12	NA	1.02	0.93	NA	0.02280	0.335	-	1.023	1.082	0.503	0.528	0.517	0.327	0.492	0.260	0.516	0.000
		P.&O.M. lit rake A - ganged							0.02481	0.364	1.088	-		0.548	0.575	0.563					
		P.&O.M. lit rake B - ganged							0.02130	0.313	0.934	-		0.470	0.493	0.483					
		P.&O.M. lit rake D - ganged							0.02348	0.345	1.030	-		0.518	0.544	0.532					
39	151	P&O.M. -individual rake avg.	40.20	65.67	NA	1.00	0.92	NA	0.02099	0.308	-	1.020	1.072	0.453	0.495	0.476	0.302	0.444	0.245	0.485	0.000
		P.&O.M. lit rake A - ganged							0.02269	0.333	1.081	-		0.489	0.535	0.515					
		P.&O.M. lit rake B - ganged							0.01960	0.288	0.934	-		0.423	0.462	0.444					
		P.&O.M. lit rake D - ganged							0.02129	0.312	1.014	-		0.459	0.502	0.483					
40	155	P&O.M. -individual rake avg.	41.88	66.64	NA	1.04	0.94	NA	0.02870	0.421	-	1.002	1.067	0.633	0.665	0.651	0.420	0.632	0.335	0.664	0.000
		P.&O.M. lit rake A - ganged							0.03031	0.445	1.056	-		0.669	0.702	0.687					
		P.&O.M. lit rake B - ganged							0.02668	0.391	0.930	-		0.589	0.618	0.605					
		P.&O.M. lit rake D - ganged							0.02822	0.414	0.983	-		0.623	0.654	0.640					

3RD COMBUSTOR SECTOR, CELL 5 GAS SAMPLE PRES.TEST DATA			AIRFLOW CORRECTED CALCULATED EQUIV.RATIOS					AIRFLOW UNCORRECTED,CALCULATED ADIABATIC FLAME TEMPERATURES					AIRFLOW CORRECTED ADIABATIC FLAME TEMPERATURES				
Rd	Test Points		Dome Equiv. Ratio	Pilot Equiv. Ratio	Total IMFH Domes Equiv. Ratio	Outer IMFH Dome Equiv. Ratio	Inner IMFH Dome Equiv. Ratio	Dome Flame Temp.,R	Pilot Flame emp.,	Total IMFH Domes Flame Temp.,R	Outer IMFH Dome Flame Temp.,R	Inner IMFH Dome Flame Temp.,R	Dome Flame emp.,	Pilot Flame Temp.,R	Total IMFH Domes Flame emp.,	Outer IMFH Dome Flame emp.,	Inner IMFH Dome Flame Temp.,R
Day 1		Pilot only:															
33	252	Pilot -individual rake avg.	0.136	0.471	0.000	0.000	0.000	2070	3355	1409	1409	1409	2038	3271	1409	1409	1409
		Pilot only A - ganged															
		Pilot only B - ganged															
		Pilot only D - ganged															
34	254	Pilot -individual rake avg.	0.140	0.485	0.000	0.000	0.000	2093	3415	1409	1409	1409	2055	3317	1409	1409	1409
		Pilot only A - ganged															
		Pilot only B - ganged															
		Pilot only D - ganged															
35	254	Pilot -individual rake avg.	0.156	0.541	0.000	0.000	0.000	2163	3600	1409	1409	1409	2127	3505	1409	1409	1409
		Pilot only A - ganged															
		Pilot only B - ganged															
		Pilot only D - ganged															
36	154	P&O.M. -individual rake avg.	0.355	0.531	0.284	0.564	0.000	2950	3579	2686	3693	1405	2872	3469	2622	3578	1405
		P.&O.M. lit rake A - ganged															
		P.&O.M. lit rake B - ganged															
		P.&O.M. lit rake D - ganged															
37	153	P&O.M. -individual rake avg.	0.337	0.501	0.270	0.536	0.000	2870	3458	2624	3581	1407	2808	3370	2573	3488	1407
		P.&O.M. lit rake A - ganged															
		P.&O.M. lit rake B - ganged															
		P.&O.M. lit rake D - ganged															
38	152	P&O.M. -individual rake avg.	0.309	0.465	0.246	0.488	0.000	2774	3341	2536	3421	1408	2711	3250	2484	3326	1408
		P.&O.M. lit rake A - ganged															
		P.&O.M. lit rake B - ganged															
		P.&O.M. lit rake D - ganged															
39	151	P&O.M. -individual rake avg.	0.287	0.422	0.233	0.462	0.000	2685	3176	2477	3316	1406	2633	3102	2433	3236	1406
		P.&O.M. lit rake A - ganged															
		P.&O.M. lit rake B - ganged															
		P.&O.M. lit rake D - ganged															
40	155	P&O.M. -individual rake avg.	0.395	0.593	0.314	0.623	0.000	3097	3795	2801	3890	1406	3009	3674	2729	3766	1406
		P.&O.M. lit rake A - ganged															
		P.&O.M. lit rake B - ganged															
		P.&O.M. lit rake D - ganged															

3RD COMBUSTOR SECTOR, CELL 5																					
GAS SAMPLE PRES.TEST DATA			MEASURED EMISSIONS																		
Rd	Test Points		Uncorr. Sample (Dome) Flame Temp.,R	Uncorr. Sample (Pilot) Flame Temp.,R	Uncorr. Sample (O.Dome) Flame Temp.,R	Uncorr. Sample (Pilot&) (O.Dome) Flame Temp.,R	Combust. Efficiency %	Corr. Sample (Dome) Flame Temp.,R	Corr. Sample (Pilot) Flame Temp.,R	Corr. Sample (O.Dome) Flame Temp.,R	Corr. Sample (Pilot&) (O.Dome) Flame Temp.,R	EI NOx	EI NOx i NOx avg	EI CO	EI CO i CO avg	EI HC	EI HC i HC avg	Rake BCD EI NOx	EI NOx i Rake BCD NOx avg	Rake BCD EI CO	EI CO i BCD CO avg
Day 1		Pilot only:																			
33	252	Pilot -individual rake avg.	2104	3443	1409	2435	99.98%	2104	3443	1409	2434	2.92	-	0.35	-	0.09	-	2.15	-	0.20	-
		Pilot only A - ganged	2021	3229	1409	2326	99.98%	2021	3229	1409	2326	1.83	0.90	0.38	1.46	0.14	1.91	-	-	-	-
		Pilot only B - ganged	2090	3408	1409	2417	99.99%	2090	3407	1409	2417	2.15	1.05	0.15	0.58	0.04	0.55	-	1.00	-	0.75
		Pilot only D - ganged	2192	3677	1409	2553	99.99%	2192	3677	1409	2553	2.14	1.05	0.25	0.96	0.04	0.55	-	1.00	-	1.25
34	254	Pilot -individual rake avg.	2124	3497	1409	2462	99.98%	2124	3497	1409	2462	3.36	-	0.33	-	0.11	-	2.49	-	0.23	-
		Pilot only A - ganged	2042	3283	1409	2353	99.98%	2042	3282	1409	2353	1.95	0.85	0.36	1.33	0.09	1.42	-	-	-	-
		Pilot only B - ganged	2107	3452	1409	2439	99.99%	2107	3452	1409	2439	2.35	1.02	0.23	0.85	0.07	1.11	-	0.95	-	1.02
		Pilot only D - ganged	2239	3801	1409	2617	99.99%	2239	3801	1409	2617	2.62	1.14	0.22	0.81	0.03	0.47	-	1.05	-	0.98
35	254	Pilot -individual rake avg.	2212	3730	1409	2580	99.99%	2212	3730	1409	2580	7.04	-	0.27	-	0.03	-	5.63	-	0.32	-
		Pilot only A - ganged	2137	3533	1409	2480	99.99%	2137	3532	1409	2479	5.51	0.99	0.34	1.04	0.08	1.60	-	-	-	-
		Pilot only B - ganged	2185	3659	1409	2544	99.99%	2185	3659	1409	2544	4.95	0.89	0.33	1.01	0.04	0.80	-	0.88	-	1.03
		Pilot only D - ganged	2341	4056	1409	2757	99.99%	2341	4056	1409	2757	6.31	1.13	0.31	0.95	0.03	0.60	-	1.12	-	0.97
36	154	P&O.M. -individual rake avg.	2971	3608	3723	3672	99.95%	2970	3607	3722	3671	8.14	-	2.05	-	0.02	-	4.81	-	2.04	-
		P.&O.M. lit rake A - ganged	3099	3784	3902	3850	99.91%	3097	3782	3900	3848	10.35	1.56	3.75	1.44	0.03	1.29	-	-	-	-
		P.&O.M. lit rake B - ganged	2882	3483	3593	3544	99.94%	2881	3482	3592	3543	4.93	0.74	2.31	0.89	0.02	0.86	-	1.03	-	1.14
		P.&O.M. lit rake D - ganged	2973	3611	3726	3675	99.96%	2972	3610	3725	3674	4.68	0.70	1.76	0.68	0.02	0.86	-	0.97	-	0.86
37	153	P&O.M. -individual rake avg.	2898	3498	3623	3568	99.96%	2898	3497	3622	3567	6.19	-	1.54	-	0.03	-	3.27	-	1.47	-
		P.&O.M. lit rake A - ganged	3031	3683	3814	3756	99.93%	3030	3681	3813	3755	7	1.55	2.92	1.49	0.04	1.50	-	-	-	-
		P.&O.M. lit rake B - ganged	2804	3364	3483	3430	99.96%	2804	3364	3482	3429	3.51	0.78	1.70	0.87	0.02	0.75	-	1.07	-	1.16
		P.&O.M. lit rake D - ganged	2906	3509	3635	3579	99.97%	2906	3509	3634	3579	3.03	0.67	1.24	0.63	0.02	0.75	-	0.93	-	0.84
38	152	P&O.M. -individual rake avg.	2801	3379	3461	3424	99.97%	2800	3378	3460	3424	4.02	-	1.24	-	0.05	-	2.32	-	1.22	-
		P.&O.M. lit rake A - ganged	2903	3526	3613	3574	99.96%	2903	3525	3612	3573	5.22	1.59	1.74	1.25	0.05	1.36	-	-	-	-
		P.&O.M. lit rake B - ganged	2724	3267	3345	3310	99.96%	2723	3267	3344	3310	2.46	0.75	1.55	1.12	0.04	1.09	-	1.06	-	1.28
		P.&O.M. lit rake D - ganged	2836	3429	3512	3476	99.98%	2835	3429	3512	3475	2.18	0.66	0.88	0.63	0.02	0.55	-	0.94	-	0.72
39	151	P&O.M. -individual rake avg.	2706	3206	3348	3285	99.94%	2705	3204	3347	3284	2.64	-	2.28	-	0.12	-	1.22	-	3.59	-
		P.&O.M. lit rake A - ganged	2793	3330	3482	3414	99.96%	2793	3329	3481	3413	3.64	1.80	1.39	0.49	0.04	0.22	-	-	-	-
		P.&O.M. lit rake B - ganged	2633	3103	3237	3178	99.90%	2632	3102	3236	3176	1.33	0.66	3.66	1.28	0.19	1.06	-	1.09	-	1.02
		P.&O.M. lit rake D - ganged	2721	3228	3372	3308	99.89%	2720	3226	3370	3306	1.1	0.54	3.51	1.23	0.31	1.72	-	0.91	-	0.98
40	155	P&O.M. -individual rake avg.	3100	3798	3893	3851	99.92%	3098	3796	3891	3849	13.99	-	3.19	-	0.04	-	9.18	-	3.43	-
		P.&O.M. lit rake A - ganged	3180	3904	3999	3958	99.88%	3178	3901	3996	3954	14.65	1.33	5.09	1.28	0.04	1.33	-	-	-	-
		P.&O.M. lit rake B - ganged	2998	3659	3751	3710	99.91%	2996	3657	3749	3708	9.05	0.82	3.90	0.98	0.02	0.67	-	0.99	-	1.14
		P.&O.M. lit rake D - ganged	3076	3765	3860	3818	99.93%	3074	3764	3858	3817	9.31	0.85	2.95	0.74	0.03	1.00	-	1.01	-	0.86

THIRD COMBUSTOR SECTOR, CELL 5

GAS SAMPLE PRESSURE TEST DATA

Test: 6/27/94

Print: 6/16/98

Using Posttest flow check data

			INPUTS FROM CELL 5 DATA ACQUISITION SYSTEM PRINTOUT																				
			INPUTS FROM PAGE #3: CALCULATIONS												INPUTS FROM FRONT PAGE					INPUTS FROM GAS SAMPLE SHEET:				
			Main Airflow	Pilot Fuel Flow			Out.IMFH Row Out.IMFH Dome Fuel Flow			Inn.IMFH Row Out.IMFH Dome Fuel Flow					Pstrch		Pilot Manif.	Outer IMFH Row Manif.	Inner IMFH Row Manif.				Sample	Combust.
			East Meter'd	Pilot Main	Pilot Verif.	Avg.			Avg.			Avg.	Pin,	Tin	(P4)	Pbaro	Pres.	Pres.	Pres.	EI	EI	EI	Fuel-Air	Efficiency
Rdg	Test	Points	pps	pph	pph	pph	pph	pph	pph	pph	pph	pph	psia	F	psia	psia	psia	psia	psia	CO	HC	NOx	Ratio	%
Day 3		6/27/94				CALC			CALC			CALC												
49	100	Pilot only-ganged rake sample	7.10	271.4	252.2	262	0.0	0.0	0.0	0.0	0.0	0.0	75.54	747	71.57	14.37	111.6	-	-	1.37	0.11	4.88	0.01490	99.96%
59	225	Pilot only ganged	8.38	284.0	281.1	283	0.0	0.0	0.0	0.0	0.0	0.0	91.08	616	87.10	14.36	136.4	120.96	132.5	1.46	0.13	2.15	0.01255	99.95%
		Pilot only rake A																		1.52	0.23	1.79	0.01255	99.94%
		Pilot only rake B																		1.33	0.13	2.30	0.01255	99.96%
		Pilot only rake C																		1.43	0.19	2.02	0.01099	99.95%
		Pilot only rake D																		1.49	0.15	2.86	0.01385	99.95%
50	5	Pilot&Inn.Row/O.Dome ganged	6.96	211.1	194.4	203	0.0	0.0	0.0	150.2	153.4	151.8	87.76	850	84.42	14.37	109.3	-	105.8	3.15	0.19	3.09	0.01782	99.91%
		Pilot&Inn.Row/O.Dome Rake A																		3.55	0.19	2.55	0.01740	99.90%
		Pilot&Inn.Row/O.Dome Rake B																		6.29	0.28	2.18	0.01636	99.83%
		Pilot&Inn.Row/O.Dome Rake C																		3.76	0.20	3.11	0.01666	99.89%
		Pilot&Inn.Row/O.Dome Rake D																		2.00	0.07	3.33	0.02018	99.95%
51	602	Pilot&Inn.Row/O.Dome ganged	10.07	272.8	253.0	263	0.0	0.0	0.0	174.4	177.7	176.0	132.47	1067	127.09	14.38	169.0	-	155.2	4.47	0.14	5.44	0.01480	99.88%
		Pilot&Inn.Row/O.Dome Rake A																		1.51	0.14	3.10	0.01478	99.95%
		Pilot&Inn.Row/O.Dome Rake B																		15.38	0.49	3.64	0.01369	99.60%
		Pilot&Inn.Row/O.Dome Rake C																		2.67	0.09	6.33	0.01430	99.93%
		Pilot&Inn.Row/O.Dome Rake D																		1.07	0.06	5.55	0.01585	99.97%
52	13	Pilot&Inn.Row/O.Dome ganged	9.52	287.2	267.1	277	0.0	0.0	0.0	185.2	188.5	186.9	131.75	1159	126.48	14.37	172.4	-	158.6	0.76	0.08	12.24	0.01625	99.97%
		Pilot&Inn.Row/O.Dome Rake A																		0.43	0.16	9.12	0.01625	99.98%
		Pilot&Inn.Row/O.Dome Rake B																		1.64	0.08	10.30	0.01514	99.95%
		Pilot&Inn.Row/O.Dome Rake C																		0.77	0.08	16.36	0.01587	99.97%
		Pilot&Inn.Row/O.Dome Rake D																		0.40	0.07	15.78	0.01779	99.98%
53	8	Pilot&Inn.Row/O.Dome ganged	9.67	278.3	258.7	269	0.0	0.0	0.0	175.3	178.7	177.0	130.74	1162	125.49	14.37	168.9	-	154.5	1.02	0.05	10.86	0.01538	99.97%
		Pilot&Inn.Row/O.Dome Rake A																		0.43	0.11	6.62	0.01538	99.98%
		Pilot&Inn.Row/O.Dome Rake B																		3.19	0.06	10.45	0.01431	99.92%
		Pilot&Inn.Row/O.Dome Rake C																		0.97	0.04	12.03	0.01489	99.97%
		Pilot&Inn.Row/O.Dome Rake D																		0.37	0.05	12.02	0.01688	99.99%

THIRD COMBUSTOR SECTOR, CELL 5 GAS SAMPLE PRESSURE TEST DATA

Sect.Tot.Aeff =	12.694	sq.in.	Mixer Tube Inlet Areas:		JP5 stoichiometric f/a =		0.06815		
Out.IMFH Dome Aeff=	3.533	sq.in.	O.D.Inlet =	3.152					
Pilot Dome Aeff =	2.834	sq.in.			At:	25 psid	00 psid		
Inn.IMFH Dome Aeff=	3.473	sq.in.	I.D.Inlet =	2.985	Out.Dome Flow #	71.0	72.9		
Tot.Dome Aeff =	9.840	sq.in.			Pilot Dome Flow #	40.2	43.0		
Dome/Sect.Tot. Air flow	77.52%				Inn.Dome Flow #	70.6	72.9		
Left/Right.Out.&Inn.Dome	3.503								
(or inner/outer IMFH rows)									

Test: 6/27/94 Using Posttest flow check data

Print: 6/16/98

				PRESSURES				TEMP'S		AIRFLOWS					FUEL FLOWS & PRESSURES								
										Sector Airflow													
Rd	Test Points		Sampling G=ganged I=individual G & I=both	Pin, psia	P4 psia	Pres Drop psid	% Pres. Drop	Tin F	Tin R	Calc. Total pps	Meter' pps	Calc. Total Meter'd	Calc. Dome Wa, pp	Flow Function: Wsqrt(T) P	Dome Fuel Flow, pph	Pilot Fuel Flow, pph	Total IMFH O.Dome Fuel Flow pph	Outer IMFH Row Fuel Flow, pph	Inner IMFH Row Fuel Flow, pph	% Fuel to Pilot	% IMFH Dome Fuel to IMFH Outer Row	Pilot Manif. Pres. psia	Outer IMFH Row Manif. Pres. psia	Inner IMFH Row Manif. Pres. psia
49	100	Pilot only-ganged rake sample	G rakes	75.54	71.57	3.97	5.26%	747	1207	6.95	7.10	0.98	5.39	3.20	261.8	261.8	0.0	0.0	0.0	100.0%	0.00%	111.6	-	-
59	225	Pilot only ganged	G rakes	91.08	87.10	3.98	4.37%	616	1076	8.09	8.38	0.97	6.27	2.91	282.6	282.6	0.0	0.0	0.0	100.0%	0.00%	136.4	120.96	132.5
		Pilot only rake A	G elements																					
		Pilot only rake B	G elements																					
		Pilot only rake C	G elements																					
		Pilot only rake D	G elements																					
50	5	Pilot&Inn.Row/O.Dome ganged	G rakes	87.76	84.42	3.34	3.81%	850	1310	6.59	6.96	0.95	5.11	2.72	354.5	202.7	151.8	0.0	151.8	57.2%	0.00%	109.3	-	105.8
		Pilot&Inn.Row/O.Dome Rake A	G elements																					
		Pilot&Inn.Row/O.Dome Rake B	G elements																					
		Pilot&Inn.Row/O.Dome Rake C	G elements																					
		Pilot&Inn.Row/O.Dome Rake D	G elements																					
51	602	Pilot&Inn.Row/O.Dome ganged	G rakes	132.47	127.09	5.38	4.06%	1067	1527	9.52	10.07	0.95	7.38	2.81	439.0	262.9	176.0	0.0	176.0	59.9%	0.00%	169.0	-	155.2
		Pilot&Inn.Row/O.Dome Rake A	G elements																					
		Pilot&Inn.Row/O.Dome Rake B	G elements																					
		Pilot&Inn.Row/O.Dome Rake C	G elements																					
		Pilot&Inn.Row/O.Dome Rake D	G elements																					
52	13	Pilot&Inn.Row/O.Dome ganged	G rakes	131.75	126.48	5.27	4.00%	1159	1619	9.13	9.52	0.96	7.08	2.79	464.0	277.1	186.9	0.0	186.9	59.7%	0.00%	172.4	-	158.6
		Pilot&Inn.Row/O.Dome Rake A	G elements																					
		Pilot&Inn.Row/O.Dome Rake B	G elements																					
		Pilot&Inn.Row/O.Dome Rake C	G elements																					
		Pilot&Inn.Row/O.Dome Rake D	G elements																					
53	8	Pilot&Inn.Row/O.Dome ganged	G rakes	130.74	125.49	5.25	4.02%	1162	1622	9.07	9.67	0.94	7.03	2.79	445.5	268.5	177.0	0.0	177.0	60.3%	0.00%	168.9	-	154.5
		Pilot&Inn.Row/O.Dome Rake A	G elements																					
		Pilot&Inn.Row/O.Dome Rake B	G elements																					
		Pilot&Inn.Row/O.Dome Rake C	G elements																					
		Pilot&Inn.Row/O.Dome Rake D	G elements																					

THIRD COMBUSTOR SECTOR, CELL 5 GAS SAMPLE PRESSURE TEST DATA

Test: 6/27/94
Print: 6/16/98

Using Posttest flow check data

Tflame Coef's:	a0=	166619100	a6=	-462.556627
	a1=	222862300	a7=	-280833.5
	a2=	-2921.308155	a8=	1583.425649
	a3=	15972.29681	a9=	-327760800
	a4=	-70493950	a10=	14578990
	a5=	32214690	a11=	7.938999

			FUEL FLOW NUMBERS						MEASURED FUEL-AIR RATIOS/ EQUIVALENCE RATIOS									UNCORRECTED CALCULATED EQUIV.RATIOS				
									All Rakes (A,B,C,D)													
Rd	Test Points		Pilot Injector Flow Number	Outer IMFH Manif. Flow Number	Inner IMFH Manif. Flow Number	Pilot Test Cal. Flow Numbe	Outer IMFH Test Cal. Flow Numbe	Inner IMFH Test Cal. Flow Numbe	Sample Fuel-Air Ratio	Sample Equiv. Ratio	Sample Eq.R.i Sample Eq.R. avg	Sample Uncor. Dome Equiv. Ratio	Sample Airflow Corr. Dome Equiv. Ratio	Calc. Sample Pilot Equiv. Ratio	Calc. Sample I.Row O.Dome Equiv. Ratio	Calc. Sample Pilot & I.Row O.Dome Equiv. Ratio	Calc. Sample O.Dome Equiv. Ratio	Calc. Sample Pilot & O.Dome Equiv. Ratio	Dome Equiv. Ratio	Pilot Equiv. Ratio	Total IMFH Dome Equiv. Ratio	Outer IMFH Row Equiv. Ratio	Inner IMFH Row Equiv. Ratio
49	100	Pilot only-ganged rake sample	41.39	NA	NA	1.03	NA	NA	0.01490	0.219	-	1.103	1.128	0.759	0.000	0.468	0.000	0.338	0.198	0.688	0.000	0.000	0.000
59	225	Pilot only ganged	40.25	NA	NA	1.00	NA	NA	0.01255	0.184	-	1.002	1.039	0.639	0.000	0.394	0.000	0.285	0.184	0.638	0.000	0.000	0.000
		Pilot only rake A							0.01255	0.184	1.000	-	-	0.639	0.000	0.394	0.000	0.285					
		Pilot only rake B							0.01255	0.184	1.000	-	-	0.639	0.000	0.394	0.000	0.285					
		Pilot only rake C							0.01099	0.161	0.876	-	-	0.560	0.000	0.345	0.000	0.249					
		Pilot only rake D							0.01385	0.203	1.104	-	-	0.706	0.000	0.435	0.000	0.314					
50	5	Pilot&Inn.Row/O.Dome ganged	40.62	NA	32.85	1.01	NA	0.93	0.01782	0.261	-	0.925	0.976	0.519	0.624	0.559	0.312	0.404	0.283	0.561	0.337	0.000	0.674
		Pilot&Inn.Row/O.Dome Rake A							0.01740	0.255	0.976	-	-	0.507	0.609	0.546	0.304	0.395					
		Pilot&Inn.Row/O.Dome Rake B							0.01636	0.240	0.918	-	-	0.477	0.573	0.513	0.286	0.371					
		Pilot&Inn.Row/O.Dome Rake C							0.01666	0.244	0.935	-	-	0.485	0.583	0.523	0.292	0.378					
		Pilot&Inn.Row/O.Dome Rake D							0.02018	0.296	1.132	-	-	0.588	0.706	0.633	0.353	0.458					
51	602	Pilot&Inn.Row/O.Dome ganged	40.64	NA	33.20	1.01	NA	0.94	0.01480	0.217	-	0.896	0.947	0.452	0.485	0.465	0.243	0.336	0.242	0.504	0.271	0.000	0.541
		Pilot&Inn.Row/O.Dome Rake A							0.01478	0.217	0.999	-	-	0.451	0.484	0.464	0.242	0.335					
		Pilot&Inn.Row/O.Dome Rake B							0.01369	0.201	0.925	-	-	0.418	0.449	0.430	0.224	0.310					
		Pilot&Inn.Row/O.Dome Rake C							0.01430	0.210	0.966	-	-	0.436	0.469	0.449	0.234	0.324					
		Pilot&Inn.Row/O.Dome Rake D							0.01585	0.233	1.071	-	-	0.484	0.520	0.497	0.260	0.359					
52	13	Pilot&Inn.Row/O.Dome ganged	40.90	NA	32.96	1.02	NA	0.93	0.01625	0.238	-	0.892	0.930	0.495	0.535	0.510	0.267	0.369	0.267	0.554	0.300	0.000	0.600
		Pilot&Inn.Row/O.Dome Rake A							0.01625	0.238	1.000	-	-	0.495	0.535	0.510	0.267	0.369					
		Pilot&Inn.Row/O.Dome Rake B							0.01514	0.222	0.932	-	-	0.461	0.498	0.475	0.249	0.343					
		Pilot&Inn.Row/O.Dome Rake C							0.01587	0.233	0.977	-	-	0.483	0.522	0.498	0.261	0.360					
		Pilot&Inn.Row/O.Dome Rake D							0.01779	0.261	1.095	-	-	0.541	0.586	0.558	0.293	0.403					
53	8	Pilot&Inn.Row/O.Dome ganged	40.75	NA	32.86	1.01	NA	0.93	0.01538	0.226	-	0.874	0.932	0.472	0.499	0.483	0.250	0.349	0.258	0.541	0.286	0.000	0.572
		Pilot&Inn.Row/O.Dome Rake A							0.01538	0.226	1.000	-	-	0.472	0.499	0.483	0.250	0.349					
		Pilot&Inn.Row/O.Dome Rake B							0.01431	0.210	0.930	-	-	0.439	0.465	0.449	0.232	0.325					
		Pilot&Inn.Row/O.Dome Rake C							0.01489	0.218	0.968	-	-	0.457	0.483	0.467	0.242	0.338					
		Pilot&Inn.Row/O.Dome Rake D							0.01688	0.248	1.098	-	-	0.518	0.548	0.530	0.274	0.383					

THIRD COMBUSTOR SECTOR, CELL 5 GAS SAMPLE PRESSURE TEST DATA

Test: 6/27/94
Print: 6/16/98

Using Posttest flow check data

			AIRFLOW CORRECTED CALCULATED EQUIV.RATIOS					AIRFLOW UNCORRECTED,CALCULATED ADIABATIC FLAME TEMPERATURES					AIRFLOW CORRECTED ADIABATIC FLAME TEMPERATURES				
Rd	Test Points		Dome Equiv. Ratio	Pilot Equiv. Ratio	Total IMFH Domes Equiv. Ratio	Outer IMFH Dome Equiv. Ratio	Inner IMFH Dome Equiv. Ratio	Dome Flame Temp.,R	Pilot Flame emp.,	Total IMFH Domes Flame Temp.,R	Outer IMFH Dome Flame Temp.,R	Inner IMFH Dome Flame Temp.,R	Dome Flame emp.,	Pilot Flame Temp.,R	Total IMFH Domes Flame emp.,	Outer IMFH Dome Flame emp.,	Inner IMFH Dome Flame Temp.,R
49	100	Pilot only-ganged rake sample	0.194	0.673	0.000	0.000	0.000	2121	3818	1207	1207	1207	2104	3775	1207	1207	1207
59	225	Pilot only ganged	0.177	0.616	0.000	0.000	0.000	1946	3587	1076	1076	1076	1919	3516	1076	1076	1076
		Pilot only rake A															
		Pilot only rake B															
		Pilot only rake C															
		Pilot only rake D															
50	5	Pilot&Inn.Row/O.Dome ganged	0.268	0.532	0.319	0.000	0.639	2534	3497	2729	1310	3848	2479	3399	2666	1310	3742
		Pilot&Inn.Row/O.Dome Rake A															
		Pilot&Inn.Row/O.Dome Rake B															
		Pilot&Inn.Row/O.Dome Rake C															
		Pilot&Inn.Row/O.Dome Rake D															
51	602	Pilot&Inn.Row/O.Dome ganged	0.229	0.477	0.256	0.000	0.512	2574	3469	2676	1527	3591	2525	3378	2623	1527	3495
		Pilot&Inn.Row/O.Dome Rake A															
		Pilot&Inn.Row/O.Dome Rake B															
		Pilot&Inn.Row/O.Dome Rake C															
		Pilot&Inn.Row/O.Dome Rake D															
52	13	Pilot&Inn.Row/O.Dome ganged	0.256	0.532	0.287	0.000	0.575	2741	3697	2853	1619	3838	2702	3623	2811	1619	3761
		Pilot&Inn.Row/O.Dome Rake A															
		Pilot&Inn.Row/O.Dome Rake B															
		Pilot&Inn.Row/O.Dome Rake C															
		Pilot&Inn.Row/O.Dome Rake D															
53	8	Pilot&Inn.Row/O.Dome ganged	0.242	0.507	0.268	0.000	0.536	2712	3655	2808	1622	3753	2654	3546	2746	1622	3640
		Pilot&Inn.Row/O.Dome Rake A															
		Pilot&Inn.Row/O.Dome Rake B															
		Pilot&Inn.Row/O.Dome Rake C															
		Pilot&Inn.Row/O.Dome Rake D															

THIRD COMBUSTOR SECTOR, CELL 5 GAS SAMPLE PRESSURE TEST DATA

Test: 6/27/94
Print: 6/16/98

Using Posttest flow check data

Rake emiss.norm.by all rake avg. for rakes
Element emiss.norm.by that rake avg.

			MEASURED EMISSIONS																	
Rd	Test Points		Uncorr. Sample Dome Flame Temp.,R	Uncorr. Sample Pilot Flame Temp.,R	Uncorr. Sample I.Row Flame Temp.,R	Uncorr. Sample Pilot & I.Row Flame Temp.,R	Uncorr. Sample O.Dome Flame Temp.,R	Uncorr. Sample Pilot & O.Dome Flame Temp.,R	Combust. Efficiency %	Corr. Sample Dome Flame Temp.,R	Corr. Sample Pilot Flame Temp.,R	Corr. Sample I.Row Flame Temp.,R	Corr. Sample Pilot & I.Row Flame Temp.,R	Corr. Sample O.Dome Flame Temp.,R	Corr. Sample Pilot & O.Dome Flame Temp.,R	EI NOx	EI NOx i gang.	EI CO	EI CO i gang.	EI HC	EI HC i gang.
49	100	Pilot only-ganged rake sample	2203	4011	1207	3104	1207	2647	99.96%	2203	4010	1207	3103	1207	2647	4.88	-	1.37	-	0.11	-
59	225	Pilot only ganged	1948	3592	1076	2748	1076	2347	99.95%	1948	3590	1076	2747	1076	2346	2.15	-	1.46	-	0.13	-
		Pilot only rake A	1948	3592	1076	2748	1076	2347	99.94%	1948	3590	1076	2747	1076	2346	1.79	0.80	1.52	1.05	0.23	1.31
		Pilot only rake B	1948	3592	1076	2748	1076	2347	99.96%	1948	3591	1076	2747	1076	2346	2.30	1.03	1.33	0.92	0.13	0.74
		Pilot only rake C	1849	3332	1076	2570	1076	2212	99.95%	1848	3330	1076	2570	1076	2211	2.02	0.90	1.43	0.99	0.19	1.09
		Pilot only rake D	2028	3791	1076	2894	1076	2457	99.95%	2028	3790	1076	2893	1076	2456	2.86	1.28	1.49	1.03	0.15	0.86
50	5	Pilot&Inn.Row/O.Dome ganged	2456	3357	3696	3490	2639	2963	99.91%	2455	3355	3693	3488	2637	2961	3.09	-	3.15	-	0.19	-
		Pilot&Inn.Row/O.Dome Rake A	2433	3316	3650	3446	2612	2930	99.90%	2432	3314	3647	3444	2611	2928	2.55	0.91	3.55	0.91	0.19	1.03
		Pilot&Inn.Row/O.Dome Rake B	2376	3213	3533	3338	2547	2848	99.83%	2374	3210	3529	3334	2545	2845	2.18	0.78	6.29	1.61	0.28	1.51
		Pilot&Inn.Row/O.Dome Rake C	2393	3243	3567	3369	2566	2871	99.89%	2391	3240	3565	3367	2564	2870	3.11	1.11	3.76	0.96	0.20	1.08
		Pilot&Inn.Row/O.Dome Rake D	2582	3583	3939	3726	2785	3148	99.95%	2582	3582	3938	3724	2784	3147	3.33	1.19	2.00	0.51	0.07	0.38
51	602	Pilot&Inn.Row/O.Dome ganged	2480	3295	3406	3337	2574	2902	99.88%	2479	3292	3404	3335	2573	2900	5.44	-	4.47	-	0.14	-
		Pilot&Inn.Row/O.Dome Rake A	2479	3292	3404	3335	2573	2900	99.95%	2478	3292	3403	3334	2573	2899	3.10	0.67	1.51	0.29	0.14	0.72
		Pilot&Inn.Row/O.Dome Rake B	2418	3181	3285	3221	2507	2815	99.60%	2414	3174	3277	3214	2503	2810	3.64	0.78	15.38	2.98	0.49	2.51
		Pilot&Inn.Row/O.Dome Rake C	2452	3243	3351	3285	2544	2863	99.93%	2452	3242	3350	3284	2543	2862	6.33	1.36	2.67	0.52	0.09	0.46
		Pilot&Inn.Row/O.Dome Rake D	2538	3401	3520	3447	2637	2983	99.97%	2537	3401	3519	3446	2636	2983	5.55	1.19	1.07	0.21	0.06	0.31
52	13	Pilot&Inn.Row/O.Dome ganged	2638	3503	3634	3554	2741	3086	99.97%	2638	3503	3633	3553	2741	3085	12.24	-	0.76	-	0.08	-
		Pilot&Inn.Row/O.Dome Rake A	2638	3503	3634	3554	2741	3086	99.98%	2638	3503	3634	3553	2741	3085	9.12	0.71	0.43	0.53	0.16	1.64
		Pilot&Inn.Row/O.Dome Rake B	2579	3392	3516	3440	2677	3001	99.95%	2578	3391	3515	3439	2676	3000	10.30	0.80	1.64	2.02	0.08	0.82
		Pilot&Inn.Row/O.Dome Rake C	2618	3465	3594	3515	2719	3057	99.97%	2618	3465	3593	3514	2719	3056	16.36	1.27	0.77	0.95	0.08	0.82
		Pilot&Inn.Row/O.Dome Rake D	2719	3655	3795	3709	2829	3202	99.98%	2718	3655	3794	3709	2829	3202	15.78	1.22	0.40	0.49	0.07	0.72
53	8	Pilot&Inn.Row/O.Dome ganged	2594	3433	3521	3467	2681	3022	99.97%	2594	3432	3521	3466	2681	3021	10.86	-	1.02	-	0.05	-
		Pilot&Inn.Row/O.Dome Rake A	2594	3433	3521	3467	2681	3022	99.98%	2594	3432	3521	3466	2681	3022	6.62	0.64	0.43	0.35	0.11	1.69
		Pilot&Inn.Row/O.Dome Rake B	2536	3324	3407	3356	2619	2940	99.92%	2535	3323	3406	3355	2618	2939	10.45	1.02	3.19	2.57	0.06	0.92
		Pilot&Inn.Row/O.Dome Rake C	2568	3383	3469	3416	2653	2984	99.97%	2567	3382	3469	3416	2652	2984	12.03	1.17	0.97	0.78	0.04	0.62
		Pilot&Inn.Row/O.Dome Rake D	2674	3583	3678	3620	2767	3136	99.99%	2674	3583	3678	3620	2767	3136	12.02	1.17	0.37	0.30	0.05	0.77

THIRD COMBUSTOR SECTOR, CELL 5 GAS SAMPLE PRESSURE TEST DATA

Test: 6/27/94
Print: 6/16/98
Using Posttest flow check data

Dimensions:

Width =	12.750	IMFH Diam. =	0.495
IMFH Dome Height =	2.300	IMFH Exit Aphys/Dome =	4.619
Pilot Dome Height =	3.000	Out.IMFH Dome Aeff=	3.533
IMFH Dome Aphys =	29.325	Pilot Dome Aeff=	2.834
Pilot Dome Aphys =	38.250	Inn.IMFH Dome Aeff=	3.473

			AIRFLOWS				AIR VELOCITIES												
							TOTAL DOME		PILOT DOME			OUTER DOME					INNER DOME			
Rd	Test	Points	Calc. Dome Wa, pps	Pilot Airflow pps	Outer Dome Airflow pps	Inner Dome Airflow pps	V total dome (cold) ft/s	V total dome (hot) ft/s	V pilot (cold) ft/s	Vmixer exit pilot ft/s	V pilot (hot) ft/s	V outer dome (cold) ft/s	Vmixer exit o.dome ft/s	Vmixer exit o.dome (bulk) ft/s	Vmixer @ inj. o.dome ft/s	V outer dome (hot) ft/s	V inner dome (cold) ft/s	Vmixer exit i.dome ft/s	Vmixer exit i.dome (bulk) ft/s	Vmixer @ inj. i.dome ft/s
49	100	Pilot only-ganged rake sample	5.39	1.55	1.93	1.90	50.0	91.2	36.4	492	121.1	59.3	492	376	439	59.3	58.3	492	370	423
59	225	Pilot only ganged	6.27	1.81	2.25	2.21	42.6	77.1	31.1	420	103.7	50.6	420	321	375	50.6	49.7	420	316	361
		Pilot only rake A																		
		Pilot only rake B																		
		Pilot only rake C																		
		Pilot only rake D																		
50	5	Pilot&Inn.Row/O.Dome ganged	5.11	1.47	1.84	1.80	43.6	81.8	31.8	430	81.5	51.8	430	329	383	104.2	50.9	430	323	369
		Pilot&Inn.Row/O.Dome Rake A																		
		Pilot&Inn.Row/O.Dome Rake B																		
		Pilot&Inn.Row/O.Dome Rake C																		
		Pilot&Inn.Row/O.Dome Rake D																		
51	602	Pilot&Inn.Row/O.Dome ganged	7.38	2.13	2.65	2.61	48.8	79.2	35.6	480	76.7	57.9	480	368	429	97.5	56.9	480	361	413
		Pilot&Inn.Row/O.Dome Rake A																		
		Pilot&Inn.Row/O.Dome Rake B																		
		Pilot&Inn.Row/O.Dome Rake C																		
		Pilot&Inn.Row/O.Dome Rake D																		
52	13	Pilot&Inn.Row/O.Dome ganged	7.08	2.04	2.54	2.50	49.8	81.2	36.3	491	78.6	59.1	491	375	438	100.1	58.1	491	369	422
		Pilot&Inn.Row/O.Dome Rake A																		
		Pilot&Inn.Row/O.Dome Rake B																		
		Pilot&Inn.Row/O.Dome Rake C																		
		Pilot&Inn.Row/O.Dome Rake D																		
53	8	Pilot&Inn.Row/O.Dome ganged	7.03	2.02	2.52	2.48	50.0	79.9	36.5	492	77.1	59.3	492	377	439	98.0	58.3	492	370	423
		Pilot&Inn.Row/O.Dome Rake A																		
		Pilot&Inn.Row/O.Dome Rake B																		
		Pilot&Inn.Row/O.Dome Rake C																		
		Pilot&Inn.Row/O.Dome Rake D																		

3RD COMBUSTOR SECTOR, CELL 5 GAS SAMPLE PRE.TEST DATA			INPUTS FROM CELL 5 DATA ACQUISITION SYSTEM PRINTOUT																					
			INPUTS FROM PAGE #3: CALCULATIONS													INPUTS FROM FRONT PAGE					INPUTS FROM GAS SAMPLE SHEET:				
Test: 6/27/94			Main				Out.IMFH Row			Inn.IMFH Row									Outer	Inner					
Print: 6/16/98			Airflow	Pilot Fuel Flow			Out.IMFH Dome Fuel Flow			Out.IMFH Dome Fuel Flow								Pilot	IMFH Row	IMFH Row				Sample	Combust.
Using Posttest flow check data			East	Pilot	Pilot										Pstrch		Manif.	Manif.	Manif.				Sample	Combust.
			Meter'd	Main	Verif.	Avg.							Pin,	Tin	(P4)	Pbaro	Pres.	Pres.	Pres.	EI	EI	EI	Fuel-Air	Efficiency
Rdg	Test Points		pps	pph	pph	pph	pph	pph		pph	pph		psia	F	psia	psia	psia	psia	psia	CO	HC	NOx	Ratio	%
Day 3		6/27/94				CALC			CALC			CALC								-	-	-	-	-
54	200	Pilot&O.Dome ganged	8.59	303.7	300.6	302	193.8	194.0	193.9	191.3	195.0	193.2	105.32	750	101.25	14.36	156.6	132.65	134.6	-	-	-	-	-
55	217	Pilot&O.Dome ganged	8.51	300.6	297.6	299	196.8	196.8	196.8	197.4	201.0	199.2	94.49	618	90.56	14.36	145.0	123.01	125.9	9.77	0.56	3.57	0.02844	99.72%
		Pilot&O.Dome rake A																		10.39	0.80	2.97	0.02888	99.69%
		Pilot&O.Dome rake B																		9.26	0.34	2.66	0.03036	99.75%
		Pilot&O.Dome rake C																		11.10	0.20	3.12	0.02546	99.72%
		Pilot&O.Dome rake D																		10.78	0.53	2.89	0.02950	99.70%
56	218	Pilot&O.Dome ganged	8.59	284.3	281.4	283	187.1	187.2	187.1	189.5	193.2	191.4	92.92	617	88.85	14.36	138.3	118.41	121.7	8.67	0.77	2.39	0.02758	99.73%
		Pilot&O.Dome rake A																		10.35	1.03	2.29	0.02863	99.67%
		Pilot&O.Dome rake B																		8.59	0.91	2.05	0.02877	99.72%
		Pilot&O.Dome rake C																		8.39	0.23	2.40	0.02447	99.78%
		Pilot&O.Dome rake D																		8.75	0.72	2.10	0.02903	99.73%
57	219	Pilot&O.Dome ganged	8.62	270.2	267.2	269	177.4	177.6	177.5	179.1	182.8	181.0	92.01	617	87.93	14.36	133.1	114.70	117.5	8.63	1.13	1.61	0.02609	99.70%
		Pilot&O.Dome rake A																		10.38	1.56	1.81	0.02629	99.62%
		Pilot&O.Dome rake B																		9.25	1.80	1.45	0.02694	99.63%
		Pilot&O.Dome rake C																		6.97	0.39	1.85	0.02323	99.80%
		Pilot&O.Dome rake D																		8.77	1.10	1.58	0.02805	99.70%
58	220	Pilot&O.Dome ganged	8.63	257.3	254.4	256	168.7	168.9	168.8	169.9	173.7	171.8	90.74	615	86.57	14.36	128.1	110.97	113.3	9.66	1.77	1.26	0.02484	99.62%
		Pilot&O.Dome rake A																		11.15	1.94	1.32	0.02459	99.57%
		Pilot&O.Dome rake B																		11.70	3.25	1.10	0.02506	99.44%
		Pilot&O.Dome rake C																		6.83	0.71	1.27	0.02175	99.78%
		Pilot&O.Dome rake D																		9.61	1.65	1.23	0.02677	99.63%

3RD COMBUSTOR SECTOR, CELL 5
GAS SAMPLE PRE.TEST DATA

Test: 6/27/94
Print: 6/16/98
Using Posttest flow check data

Rd	Test Points	Sampling G=ganged I=individual G & I=both	PRESSURES Pin, psia	P4 psia	Pres Drop psid	% Pres. Drop	TEMP'S Tin F	Tin R	AIRFLOWS Sector Airflow Calc. Total pps	Meter' pps	Calc. Total Meter'd	Calc. Dome Wa, pp	Flow Function: Wsqrt(T) P	FUEL FLOWS & PRESSURES Dome Fuel Flow, pph	Pilot Fuel Flow, pph	Total IMFH O.Dome Fuel Flow pph	Outer IMFH Row Fuel Flow, pph	Inner IMFH Row Fuel Flow, pph	% Fuel to Pilot	% IMFH Dome Fuel to IMFH Outer Row	Pilot Manif. Pres. psia	Outer IMFH Row Manif. Pres. psia	Inner IMFH Row Manif. Pres. psia
54	200 Pilot&O.Dome ganged	G rakes	105.32	101.25	4.07	3.86%	750	1210	8.30	8.59	0.97	6.43	2.74	689.2	302.2	387.0	193.9	193.2	43.8%	50.09%	156.6	132.65	134.6
55	217 Pilot&O.Dome ganged	G rakes	94.49	90.56	3.93	4.16%	618	1078	8.18	8.51	0.96	6.34	2.84	695.1	299.1	396.0	196.8	199.2	43.0%	49.70%	145.0	123.01	125.9
	Pilot&O.Dome rake A	G elements																					
	Pilot&O.Dome rake B	G elements																					
	Pilot&O.Dome rake C	G elements																					
	Pilot&O.Dome rake D	G elements																					
56	218 Pilot&O.Dome ganged	G rakes	92.92	88.85	4.07	4.38%	617	1077	8.26	8.59	0.96	6.40	2.92	661.3	282.9	378.5	187.1	191.4	42.8%	49.44%	138.3	118.41	121.7
	Pilot&O.Dome rake A	G elements																					
	Pilot&O.Dome rake B	G elements																					
	Pilot&O.Dome rake C	G elements																					
	Pilot&O.Dome rake D	G elements																					
57	219 Pilot&O.Dome ganged	G rakes	92.01	87.93	4.08	4.43%	617	1077	8.23	8.62	0.95	6.38	2.93	627.1	268.7	358.5	177.5	181.0	42.8%	49.51%	133.1	114.70	117.5
	Pilot&O.Dome rake A	G elements																					
	Pilot&O.Dome rake B	G elements																					
	Pilot&O.Dome rake C	G elements																					
	Pilot&O.Dome rake D	G elements																					
58	220 Pilot&O.Dome ganged	G rakes	90.74	86.57	4.17	4.60%	615	1075	8.27	8.63	0.96	6.41	2.99	596.4	255.8	340.6	168.8	171.8	42.9%	49.56%	128.1	110.97	113.3
	Pilot&O.Dome rake A	G elements																					
	Pilot&O.Dome rake B	G elements																					
	Pilot&O.Dome rake C	G elements																					
	Pilot&O.Dome rake D	G elements																					

3RD COMBUSTOR SECTOR, CELL 5 GAS SAMPLE PRE.TEST DATA			FUEL FLOW NUMBERS						MEASURED FUEL-AIR RATIOS/ EQUIVALENCE RATIOS										UNCORRECTED CALCULATED EQUIV.RATIOS				
							Outer	Inner	All Rakes (A,B,C,D)				Sample		Calc.	Calc.		Calc.			Total		
Test:	6/27/94			Outer	Inner	Pilot	IMFH	IMFH			Sample	Sample	Airflow	Calc.	Sample	Sample	Calc.	Sample			IMFH	Outer	Inner
Print:	6/16/98	Pilot		IMFH	IMFH	Test	Test	Test			Eq.R.i	Uncor.	Corr.	Sample	I.Row	Pilot &	Sample	Pilot &			Outer	IMFH	IMFH
Using Posttest flow check data		Injector		Manif.	Manif.	Cal.	Cal.	Cal.	Sample	Sample	Sample	Dome	Dome	Pilot	O.Dome	I.Row	O.Dome	O.Dome	Dome	Pilot	Dome	Row	Row
		Flow		Flow	Flow	Flow	Flow	Flow	Fuel-Air	Equiv.	Eq.R.	Equiv.	Equiv.	Equiv.	Equiv.	Equiv.	Equiv.	Equiv.	Equiv.	Equiv.	Equiv.	Equiv.	Equiv.
Rd	Test Points	Number		Number	Number	Numbe	Numbe	Numbe	Ratio	Ratio	avg	Ratio	Ratio	Ratio	Ratio	Ratio	Ratio	Ratio	Ratio	Ratio	Ratio	Ratio	Ratio
54	200 Pilot&O.Dome ganged	40.63		34.60	33.46	1.01	0.97	0.95	-	-	-	-	-	-	-	-	-	-	0.437	0.665	0.683	0.684	0.682
55	217 Pilot&O.Dome ganged	40.54		34.55	33.49	1.01	0.97	0.95	0.02844	0.417	-	0.934	0.972	0.624	0.666	0.640	0.662	0.645	0.447	0.668	0.709	0.705	0.713
	Pilot&O.Dome rake A								0.02888	0.424	1.015	-	-	0.633	0.676	0.650	0.672	0.655					
	Pilot&O.Dome rake B								0.03036	0.445	1.068	-	-	0.666	0.711	0.683	0.707	0.688					
	Pilot&O.Dome rake C								0.02546	0.374	0.895	-	-	0.558	0.596	0.573	0.593	0.577					
	Pilot&O.Dome rake D								0.02950	0.433	1.037	-	-	0.647	0.691	0.664	0.687	0.669					
56	218 Pilot&O.Dome ganged	40.21		34.42	33.39	1.00	0.97	0.95	0.02758	0.405	-	0.961	1.000	0.601	0.652	0.621	0.645	0.625	0.421	0.625	0.671	0.664	0.679
	Pilot&O.Dome rake A								0.02863	0.420	1.038	-	-	0.624	0.677	0.644	0.670	0.649					
	Pilot&O.Dome rake B								0.02877	0.422	1.043	-	-	0.627	0.680	0.648	0.673	0.652					
	Pilot&O.Dome rake C								0.02447	0.359	0.887	-	-	0.533	0.579	0.551	0.572	0.555					
	Pilot&O.Dome rake D								0.02903	0.426	1.053	-	-	0.633	0.687	0.653	0.679	0.658					
57	219 Pilot&O.Dome ganged	39.99		34.30	33.30	0.99	0.97	0.94	0.02609	0.383	-	0.955	1.001	0.570	0.615	0.587	0.609	0.592	0.401	0.596	0.638	0.632	0.644
	Pilot&O.Dome rake A								0.02629	0.386	1.008	-	-	0.574	0.620	0.592	0.614	0.596					
	Pilot&O.Dome rake B								0.02694	0.395	1.033	-	-	0.588	0.635	0.606	0.629	0.611					
	Pilot&O.Dome rake C								0.02323	0.341	0.890	-	-	0.507	0.548	0.523	0.543	0.527					
	Pilot&O.Dome rake D								0.02805	0.412	1.075	-	-	0.612	0.662	0.631	0.655	0.636					
58	220 Pilot&O.Dome ganged	39.71		34.17	33.20	0.99	0.96	0.94	0.02484	0.364	-	0.961	1.003	0.543	0.585	0.559	0.580	0.563	0.379	0.565	0.603	0.598	0.608
	Pilot&O.Dome rake A								0.02459	0.361	0.990	-	-	0.537	0.579	0.553	0.574	0.558					
	Pilot&O.Dome rake B								0.02506	0.368	1.009	-	-	0.548	0.590	0.564	0.585	0.568					
	Pilot&O.Dome rake C								0.02175	0.319	0.876	-	-	0.475	0.512	0.489	0.508	0.493					
	Pilot&O.Dome rake D								0.02677	0.393	1.078	-	-	0.585	0.630	0.602	0.625	0.607					

3RD COMBUSTOR SECTOR, CELL 5 GAS SAMPLE PRE.TEST DATA			AIRFLOW CORRECTED CALCULATED EQUIV.RATIOS					AIRFLOW UNCORRECTED,CALCULATED ADIABATIC FLAME TEMPERATURES					AIRFLOW CORRECTED ADIABATIC FLAME TEMPERATURES				
Test: 6/27/94 Print: 6/16/98 Using Posttest flow check data			Dome Equiv. Ratio	Pilot Equiv. Ratio	Total IMFH Domes Equiv. Ratio	Outer IMFH Dome Equiv. Ratio	Inner IMFH Dome Equiv. Ratio	Dome Flame Temp.,R	Pilot Flame emp.,	Total IMFH Domes Flame Temp.,R	Outer IMFH Dome Flame Temp.,R	Inner IMFH Dome Flame Temp.,R	Dome Flame emp.,	Pilot Flame Temp.,R	Total IMFH Domes Flame emp.,	Outer IMFH Dome Flame emp.,	Inner IMFH Dome Flame Temp.,R
Rd	Test	Points															
54	200	Pilot&O.Dome ganged	0.422	0.642	0.660	0.661	0.659	3003	3760	3814	3818	3810	2951	3691	3745	3748	3741
55	217	Pilot&O.Dome ganged	0.429	0.642	0.681	0.677	0.686	2939	3681	3802	3790	3814	2877	3601	3722	3710	3734
		Pilot&O.Dome rake A															
		Pilot&O.Dome rake B															
		Pilot&O.Dome rake C															
		Pilot&O.Dome rake D															
56	218	Pilot&O.Dome ganged	0.405	0.601	0.645	0.638	0.652	2846	3548	3690	3667	3713	2788	3470	3610	3588	3633
		Pilot&O.Dome rake A															
		Pilot&O.Dome rake B															
		Pilot&O.Dome rake C															
		Pilot&O.Dome rake D															
57	219	Pilot&O.Dome ganged	0.383	0.569	0.609	0.603	0.615	2773	3453	3587	3567	3607	2707	3363	3494	3475	3514
		Pilot&O.Dome rake A															
		Pilot&O.Dome rake B															
		Pilot&O.Dome rake C															
		Pilot&O.Dome rake D															
58	220	Pilot&O.Dome ganged	0.363	0.541	0.578	0.573	0.583	2693	3346	3473	3456	3491	2636	3267	3390	3373	3407
		Pilot&O.Dome rake A															
		Pilot&O.Dome rake B															
		Pilot&O.Dome rake C															
		Pilot&O.Dome rake D															

3RD COMBUSTOR SECTOR, CELL 5 GAS SAMPLE PRE.TEST DATA			MEASURED EMISSIONS																		
Test: 6/27/94 Print: 6/16/98 Using Posttest flow check data			Uncorr. Sample Dome Flame	Uncorr. Sample Pilot Flame	Uncorr. Sample I.Row Flame	Uncorr. Sample Pilot & I.Row Flame	Uncorr. Sample O.Dome Flame	Uncorr. Sample Pilot & O.Dome Flame	Combust. Efficiency	Corr. Sample Dome Flame	Corr. Sample Pilot Flame	Corr. Sample I.Row Flame	Corr. Sample Pilot & I.Row Flame	Corr. Sample O.Dome Flame	Corr. Sample Pilot & O.Dome Flame	EI	EI NOx i NOx gang.	EI	EI CO i CO gang.	EI	EI HC i HC gang.
Rd	Test	Points	Temp.,R	Temp.,R	Temp.,R	Temp.,R	Temp.,R	Temp.,R	%	Temp.,R	Temp.,R	Temp.,R	Temp.,R	Temp.,R	Temp.,R	NOx		CO		HC	
54	200	Pilot&O.Dome ganged	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
55	217	Pilot&O.Dome ganged	2834	3543	3676	3595	3664	3611	99.72%	2829	3536	3669	3588	3656	3604	3.57	-	9.77	-	0.56	-
		Pilot&O.Dome rake A	2857	3574	3707	3626	3695	3642	99.69%	2851	3566	3699	3618	3687	3634	2.97	1.02	10.39	1.00	0.80	1.71
		Pilot&O.Dome rake B	2935	3675	3808	3727	3796	3743	99.75%	2930	3668	3801	3720	3789	3736	2.66	0.91	9.26	0.89	0.34	0.73
		Pilot&O.Dome rake C	2676	3327	3455	3377	3443	3392	99.72%	2672	3321	3448	3370	3436	3385	3.12	1.07	11.10	1.07	0.20	0.43
		Pilot&O.Dome rake D	2890	3617	3750	3669	3738	3685	99.70%	2884	3609	3742	3661	3730	3677	2.89	0.99	10.78	1.04	0.53	1.13
56	218	Pilot&O.Dome ganged	2788	3469	3632	3533	3610	3548	99.73%	2783	3463	3625	3526	3603	3541	2.39	-	8.67	-	0.77	-
		Pilot&O.Dome rake A	2843	3543	3708	3608	3685	3623	99.67%	2837	3535	3699	3599	3677	3615	2.29	1.04	10.35	1.15	1.03	1.43
		Pilot&O.Dome rake B	2850	3553	3718	3618	3695	3633	99.72%	2845	3546	3710	3610	3688	3626	2.05	0.93	8.59	0.95	0.91	1.26
		Pilot&O.Dome rake C	2623	3241	3395	3301	3374	3315	99.78%	2619	3237	3390	3296	3369	3310	2.40	1.09	8.39	0.93	0.23	0.32
		Pilot&O.Dome rake D	2864	3571	3736	3636	3713	3651	99.73%	2859	3564	3729	3629	3706	3644	2.10	0.95	8.75	0.97	0.72	1.00
57	219	Pilot&O.Dome ganged	2708	3364	3515	3423	3496	3438	99.70%	2703	3357	3508	3416	3489	3431	1.61	-	8.63	-	1.13	-
		Pilot&O.Dome rake A	2719	3379	3530	3438	3511	3453	99.62%	2713	3370	3521	3429	3502	3444	1.81	1.08	10.38	1.17	1.56	1.29
		Pilot&O.Dome rake B	2753	3426	3579	3486	3560	3501	99.63%	2747	3417	3570	3477	3551	3492	1.45	0.87	9.25	1.05	1.80	1.48
		Pilot&O.Dome rake C	2556	3150	3291	3205	3273	3219	99.80%	2553	3146	3287	3200	3268	3214	1.85	1.11	6.97	0.79	0.39	0.32
		Pilot&O.Dome rake D	2812	3505	3661	3566	3641	3581	99.70%	2807	3498	3653	3559	3633	3574	1.58	0.94	8.77	0.99	1.10	0.91
58	220	Pilot&O.Dome ganged	2640	3272	3413	3327	3396	3341	99.62%	2634	3264	3404	3318	3387	3333	1.26	-	9.66	-	1.77	-
		Pilot&O.Dome rake A	2627	3253	3393	3308	3377	3322	99.57%	2620	3244	3384	3298	3367	3313	1.32	1.07	11.15	1.14	1.94	1.03
		Pilot&O.Dome rake B	2652	3289	3430	3343	3413	3358	99.44%	2643	3276	3417	3331	3400	3345	1.10	0.89	11.70	1.19	3.25	1.72
		Pilot&O.Dome rake C	2474	3037	3165	3087	3150	3100	99.78%	2471	3033	3161	3082	3145	3096	1.27	1.03	6.83	0.70	0.71	0.38
		Pilot&O.Dome rake D	2742	3414	3561	3471	3543	3487	99.63%	2736	3406	3552	3462	3534	3478	1.23	1.00	9.61	0.98	1.65	0.87

3RD COMBUSTOR SECTOR, CELL 5 GAS SAMPLE PRE.TEST DATA			AIRFLOWS				AIR VELOCITIES													
							TOTAL DOME		PILOT DOME			OUTER DOME					INNER DOME			
Test: 6/27/94																				
Print: 6/16/98																				
Using Posttest flow check data			Calc. Dome	Pilot Airflow	Outer Dome Airflow	Inner Dome Airflow	V total dome (cold)	V total dome (hot)	V pilot (cold)	Vmixer exit pilot	V pilot (hot)	V outer dome (cold)	Vmixer exit o.dome	Vmixer exit o.dome (bulk)	Vmixer @ inj. o.dome	V outer dome (hot)	V inner dome (cold)	Vmixer exit i.dome	Vmixer exit i.dome (bulk)	Vmixer @ inj. i.dome
Rd	Test Points		Wa, pps	pps	pps	pps	ft/s	ft/s	ft/s	ft/s	ft/s	ft/s	ft/s	ft/s	ft/s	ft/s	ft/s	ft/s	ft/s	ft/s
54	200	Pilot&O.Dome ganged	6.43	1.85	2.31	2.27	42.3	-	30.8	416	-	50.1	416	318	371	-	49.3	416	313	358
55	217	Pilot&O.Dome ganged	6.34	1.83	2.28	2.24	41.5	108.9	30.3	409	99.3	49.3	409	313	365	167.1	48.4	409	307	351
		Pilot&O.Dome rake A																		
		Pilot&O.Dome rake B																		
		Pilot&O.Dome rake C																		
		Pilot&O.Dome rake D																		
56	218	Pilot&O.Dome ganged	6.40	1.84	2.30	2.26	42.7	110.3	31.1	420	100.1	50.7	420	322	375	169.4	49.8	420	316	361
		Pilot&O.Dome rake A																		
		Pilot&O.Dome rake B																		
		Pilot&O.Dome rake C																		
		Pilot&O.Dome rake D																		
57	219	Pilot&O.Dome ganged	6.38	1.84	2.29	2.25	43.0	107.9	31.3	423	97.7	51.0	423	324	378	165.2	50.1	423	318	364
		Pilot&O.Dome rake A																		
		Pilot&O.Dome rake B																		
		Pilot&O.Dome rake C																		
		Pilot&O.Dome rake D																		
58	220	Pilot&O.Dome ganged	6.41	1.85	2.30	2.26	43.8	107.3	31.9	431	97.0	51.9	431	330	385	163.7	51.1	431	324	371
		Pilot&O.Dome rake A																		
		Pilot&O.Dome rake B																		
		Pilot&O.Dome rake C																		
		Pilot&O.Dome rake D																		

Appendix D

5-Cup Rectangular Sector Combustor Test Data

Test 4

Lamilloy Liner Sector Test

FOURTH COMBUSTOR SECTOR, CELL 5 GAS SAMPLE PRESSURE DATA										Test:	10/18/94		Print:	6/8/98								
Flow check data:																						
Sect.Tot.Aeff =	13.174	sq.in.									Dimensions:											
Out.IMFH Dome Aeff=	3.533	sq.in.									Width =	12.750					IMFH Diam. =	0.495				
Pilot Dome Aeff =	2.801	sq.in.		Mixer Tube Inlet Areas:							IMFH Dome Height =	2.300					IMFH Exit Aphys/Dome =	4.618612				
Inn.IMFH Dome Aeff=	3.473	sq.in.				O.D.Inlet =	3.152	sq.in.			Pilot Dome Height =	3.000					Out.IMFH Dome Aeff=	3.533				
Tot.Dome Aeff =	9.807	sq.in.				I.D.Inlet =	2.985	sq.in.			IMFH Dome Aphys =	29.325					Pilot Dome Aeff=	2.801				
Dome/Sect.Tot. Air flow	74.4%										Pilot Dome Aphys =	38.250					Inn.IMFH Dome Aeff=	3.473				
Left/Right.Out.&Inn.Dome	3.503	sq.in.		JP5 stoichiometric f/a =			0.06815															
(or inner/outer IMFH rows)					At:	At:	25	100	psid													
O.Liner Aeff =	0.605	sq.in.		Out.Dome Flow #			71.0	72.9														
I.Liner Aeff =	0.621	sq.in.		Pilot Dome Flow #			40.2	43.0														
				Inn.Dome Flow #			70.6	72.9														

FOURTH COMBUSTOR SECTOR, CELL 5 GAS SAMPLE PRESSURE DATA Test: 10/18/94 Print: 6/8/98

			INPUTS FROM CELL 5 DATA ACQUISITION SYSTEM PRINTOUT																					
			INPUTS FROM PAGE #3: CALCULATIONS												INPUTS FROM FRONT PAGE					INPUTS FROM GAS SAMPLE SHEET:				
			Main				Out.IMFH Dome			Inn.IMFH Dome								Outer	Inner					
			Airflow	Pilot Fuel Flow			Fuel Flow			Fuel Flow							Pilot	IMFH	IMFH					
			East	Pilot	Pilot										Pstrch		Manif.	Manif.	Manif.				Sample	Combust.
			Meter'd	Main	Verif.	Avg.			Avg.			Avg.	Pin.	Tin	(P4)	Pbaro	Pres.	Pres.	Pres.	EI	EI	EI	Fuel-Air	Efficiency
Rdg	Test Points		pps	pph	pph	pph	pph	pph	pph	pph	pph	pph	psia	F	psia	psia	psia	psia	psia	CO	HC	NOx	Ratio	%
Day 1		10/18/94				CALC			CALC			CALC												
1	1	All lit -all rakes ganged	5.95	226.0	219.6	223	176.5	179.0	177.8	179.6	181.4	180.5	60.75	646	58.12	14.41	86.2	63.62	65.5	96.62	56.33	1.36	0.03135	92.83%
		All lit rake A - ganged																		108.57	111.83	1.31	0.03316	87.73%
		All lit rake B - ganged																		40.94	13.58	1.87	0.03468	97.86%
		All lit rake C - ganged																		73.49	61.47	1.92	0.03431	92.93%
		All lit rake D - ganged																		82.45	51.21	1.07	0.03166	93.61%
		All lit -individual rake avg.																		76.36	59.52	1.54	0.03345	93.03%
1	1	All lit rake A element 1																		96.62	56.33	1.36	0.03135	92.83%
		All lit rake A element 2																		108.57	111.83	1.31	0.03316	87.73%
		All lit rake A element 3																		40.94	13.58	1.87	0.03468	97.86%
		All lit rake A element 4																		73.49	61.47	1.92	0.03431	92.93%
		All lit rake A element 5																		82.45	51.21	1.07	0.03166	93.61%
1	1	All lit rake B element 6																		96.62	56.33	1.36	0.03135	92.83%
		All lit rake B element 7																		108.57	111.83	1.31	0.03316	87.73%
		All lit rake B element 8																		40.94	13.58	1.87	0.03468	97.86%
		All lit rake B element 9																		73.49	61.47	1.92	0.03431	92.93%
		All lit rake B element 10																		82.45	51.21	1.07	0.03166	93.61%
1	1	All lit rake C element 11																		96.62	56.33	1.36	0.03135	92.83%
		All lit rake C element 12																		108.57	111.83	1.31	0.03316	87.73%
		All lit rake C element 13																		40.94	13.58	1.87	0.03468	97.86%
		All lit rake C element 14																		73.49	61.47	1.92	0.03431	92.93%
		All lit rake C element 15																		82.45	51.21	1.07	0.03166	93.61%
1	1	All lit rake D element 16																		96.62	56.33	1.36	0.03135	92.83%
		All lit rake D element 17																		108.57	111.83	1.31	0.03316	87.73%
		All lit rake D element 18																		40.94	13.58	1.87	0.03468	97.86%
		All lit rake D element 19																		73.49	61.47	1.92	0.03431	92.93%
		All lit rake D element 20																		82.45	51.21	1.07	0.03166	93.61%

FOURTH COMBUSTOR SECTOR, CELL 5 GAS SAMPLE PRESSURE DATA — Test: 10/18/94 — Print: 6/8/98

				PRESSURES				TEMPS		AIRFLOWS					FUEL FLOWS & PRESSURES									
														Total Sector			Total IMFH	Outer IMFH	Inner IMFH		% IMFH		Outer	Inner
			Sampling							TotalSector Airflow				Flow	Dome	Pilot	Domes	Dome	Dome		Fuel to	Pilot	IMFH	IMFH
			G=ganged			Pres	%			Calc.		Calc.	Calc.	Function:	Fuel	Fuel	Fuel	Fuel	Fuel	% Fuel	IMFH	Manif.	Manif.	Manif.
			I=individual	Pin,	P4	Drop,	Pres.	Tin		Total	Meter'd	Total	Dome	Wsqrt(T)	Flow,	Flow,	Flow	Flow,	Flow	to	Outer	Pres.	Pres.	Pres.
Rdg		Test Points	G & I=both	psia	psia	psid	Drop	F	R	pps	pps	Meter'd	Wa, pps	P	pph	pph	pph	pph	pph	Pilot	Dome	psia	psia	psia
1	1	All lit -all rakes ganged	all ganged	60.75	58.12	2.63	4.33%	646	1106	5.50	5.95	0.92	4.09	3.01	581.1	222.8	358.3	177.8	180.5	38.3%	49.62%	88.16	63.62	65.5
		All lit rake A - ganged	G rake																					
		All lit rake B - ganged	G rake																					
		All lit rake C - ganged	G rake																					
		All lit rake D - ganged	G rake																					
		All lit -individual rake avg.	G rake avg.																					
1	1	All lit rake A element 1	Indiv.																					
		All lit rake A element 2	Indiv.																					
		All lit rake A element 3	Indiv.																					
		All lit rake A element 4	Indiv.																					
		All lit rake A element 5	Indiv.																					
1	1	All lit rake B element 6	Indiv.																					
		All lit rake B element 7	Indiv.																					
		All lit rake B element 8	Indiv.																					
		All lit rake B element 9	Indiv.																					
		All lit rake B element 10	Indiv.																					
1	1	All lit rake C element 11	Indiv.																					
		All lit rake C element 12	Indiv.																					
		All lit rake C element 13	Indiv.																					
		All lit rake C element 14	Indiv.																					
		All lit rake C element 15	Indiv.																					
1	1	All lit rake D element 16	Indiv.																					
		All lit rake D element 17	Indiv.																					
		All lit rake D element 18	Indiv.																					
		All lit rake D element 19	Indiv.																					
		All lit rake D element 20	Indiv.																					

FOURTH COMBUSTOR SECTOR, CELL 5 GAS SAMPLE PRESSURE DATA

Test: 10/18/94 Print: 6/8/98

LIMITED EXCLUSIVE RIGHT NOTICE THESE DATA ARE SUBJECT TO LIMITED EXCLUSIVE RIGHTS UNDER GOVERNMENT CONTRACT NUMBER NAS3-26617 OR NAS3-27235			FUEL FLOW NUMBERS						SAMPLE BASED EQUIVALENCE RATIOS SAMPLE EQUIV. RATIOS & FLOW AREAS All Rakes (A,B,C,D)						DEL.P.BASED EQUIV.RATIOS				
			Pilot Injector Flow Number	Outer IMFH Manif. Flow Number	Inner IMFH Manif. Flow Number	Pilot Test Flochk Number Ratio	Outer Test IMFH Flochk Ratio	Inner Test IMFH Flochk Ratio	Sample Fuel-Air Ratio	Sample Equiv. Ratio	Sample Eq.R.i Sample Eq.R. avg	Calc. Sample (Pilot) Equiv. Ratio	Calc. Sample (O.Dome) Equiv. Ratio	Calc. Sample (I.Dome) Equiv. Ratio	Dome Equiv. Ratio	Pilot Equiv. Ratio	Total IMFH Domes Equiv. Ratio	Outer IMFH Dome Equiv. Ratio	Inner IMFH Dome Equiv. Ratio
Rdg	Test	Points																	
1	1	All IH -all rakes ganged	40.65	75.79	66.67	1.01	1.07	0.94	0.03135	0.460	0.937	0.618	0.391	0.404	0.579	0.777	0.499	0.491	0.508
		All IH rake A - ganged							0.03316	0.487	0.991	0.653	0.413	0.427					
		All IH rake B - ganged							0.03468	0.509	1.037	0.683	0.432	0.446					
		All IH rake C - ganged							0.03431	0.503	1.026	0.676	0.427	0.442					
		All IH rake D - ganged							0.03166	0.465	0.946	0.624	0.394	0.407					
		All IH -individual rake avg.							0.03345	0.491	-	0.659	0.417	0.431					
1	1	All IH rake A element 1							0.03135	0.460	0.949	0.618	0.391	0.404					
		All IH rake A element 2							0.03316	0.487	1.004	0.653	0.413	0.427					
		All IH rake A element 3							0.03468	0.509	1.050	0.683	0.432	0.446					
		All IH rake A element 4							0.03431	0.503	1.039	0.676	0.427	0.442					
		All IH rake A element 5							0.03166	0.465	0.958	0.624	0.394	0.407					
1	1	All IH rake B element 6							0.03135	0.460	0.949	0.618	0.391	0.404					
		All IH rake B element 7							0.03316	0.487	1.004	0.653	0.413	0.427					
		All IH rake B element 8							0.03468	0.509	1.050	0.683	0.432	0.446					
		All IH rake B element 9							0.03431	0.503	1.039	0.676	0.427	0.442					
		All IH rake B element 10							0.03166	0.465	0.958	0.624	0.394	0.407					
1	1	All IH rake C element 11							0.03135	0.460	0.949	0.618	0.391	0.404					
		All IH rake C element 12							0.03316	0.487	1.004	0.653	0.413	0.427					
		All IH rake C element 13							0.03468	0.509	1.050	0.683	0.432	0.446					
		All IH rake C element 14							0.03431	0.503	1.039	0.676	0.427	0.442					
		All IH rake C element 15							0.03166	0.465	0.958	0.624	0.394	0.407					
1	1	All IH rake D element 16							0.03135	0.460	0.949	0.618	0.391	0.404					
		All IH rake D element 17							0.03316	0.487	1.004	0.653	0.413	0.427					
		All IH rake D element 18							0.03468	0.509	1.050	0.683	0.432	0.446					
		All IH rake D element 19							0.03431	0.503	1.039	0.676	0.427	0.442					
		All IH rake D element 20							0.03166	0.465	0.958	0.624	0.394	0.407					

FOURTH COMBUSTOR SECTOR, CELL 5 GAS SAMPLE PRESSURE DATA — Test: 10/18/94 — Print: 6/8/98

Rdg	Test Points	MAIN AIRFLOW BASED CALCULATED EQUIV.RATIOS					DEL.P.BASED, CALC. ADIABATIC FLAME TEMPERATURES					MAIN AIRFLOW BASED ADIABATIC FLAME TEMPERATURES				
				Total IMFH	Outer IMFH	Inner IMFH			Total IMFH	Outer IMFH	Inner IMFH			Total IMFH	Outer IMFH	Inner IMFH
		Dome Equiv. Ratio	Pilot Equiv. Ratio	Domes Equiv. Ratio	Dome Equiv. Ratio	Dome Equiv. Ratio	Dome Flame Temp.,R	Pilot Flame Temp.,R	Domes Flame Temp.,R	Dome Flame Temp.,R	Dome Flame Temp.,R	Dome Flame Temp.,R	Pilot Flame Temp.,R	Domes Flame Temp.,R	Dome Flame Temp.,R	Dome Flame Temp.,R
1	1 All lit -all rakes ganged	0.535	0.718	0.461	0.454	0.469	3407	3989	3138	3110	3167	3260	3835	3006	2980	3033
	All lit rake A - ganged															
	All lit rake B - ganged															
	All lit rake C - ganged															
	All lit rake D - ganged															
	All lit -individual rake avg.															
1	1 All lit rake A element 1															
	All lit rake A element 2															
	All lit rake A element 3															
	All lit rake A element 4															
	All lit rake A element 5															
1	1 All lit rake B element 6															
	All lit rake B element 7															
	All lit rake B element 8															
	All lit rake B element 9															
	All lit rake B element 10															
1	1 All lit rake C element 11															
	All lit rake C element 12															
	All lit rake C element 13															
	All lit rake C element 14															
	All lit rake C element 15															
1	1 All lit rake D element 16															
	All lit rake D element 17															
	All lit rake D element 18															
	All lit rake D element 19															
	All lit rake D element 20															

FOURTH COMBUSTOR SECTOR, CELL 5 GAS SAMPLE PRESSURE DATA — Test: 10/18/94 — Print: 6/8/98

Normalized rake emissions = rake I emission/average (rake A-D)

Normalized element emissions = element i emission/average (elements a,b,c,d,e of a selected rake)

MEASURED EMISSIONS

Rdg	Test Points	Uncorr. Sample Flame Temp.,R	Uncorr. Sample (Pilot) Flame Temp.,R	Uncorr. Sample (O.Dome) Flame Temp.,R	Uncorr. Sample (I.Dome) Flame Temp.,R	Combust. Efficiency %	Corr. Sample Flame Temp.,R	Corr. Sample (Pilot) Flame Temp.,R	Corr. Sample (O.Dome) Flame Temp.,R	Corr. Sample (I.Dome) Flame Temp.,R	EI NOx	EI NOx avg	EI CO	EI CO avg	EI HC	EI HC avg
1	1 All lit -all rakes ganged	3001	3534	2755	2801	92.83%	2865	3360	2636	2679	1.36	0.88	96.62	1.27	56.33	0.95
	All lit rake A - ganged	3094	3646	2835	2884	87.73%	2850	3334	2623	2666	1.31	0.85	108.57	1.42	111.83	1.88
	All lit rake B - ganged	3171	3736	2902	2953	97.86%	3127	3680	2864	2913	1.87	1.21	40.94	0.54	13.58	0.23
	All lit rake C - ganged	3153	3714	2886	2936	92.93%	3008	3530	2760	2807	1.92	1.24	73.49	0.96	61.47	1.03
	All lit rake D - ganged	3017	3554	2768	2815	93.61%	2895	3397	2662	2706	1.07	0.69	82.45	1.08	51.21	0.86
	All lit -individual rake avg.	3109	3662	2848	2897	93.03%	2970	3485	2727	2773	1.54	-	76.36	-	59.52	-
1	1 All lit rake A element 1	3001	3534	2755	2801	92.83%	2865	3360	2636	2679	1.36	0.90	96.62	1.20	56.33	0.96
	All lit rake A element 2	3094	3646	2835	2884	87.73%	2850	3334	2623	2666	1.31	0.87	108.57	1.35	111.83	1.90
	All lit rake A element 3	3171	3736	2902	2953	97.86%	3127	3680	2864	2913	1.87	1.24	40.94	0.51	13.58	0.23
	All lit rake A element 4	3153	3714	2886	2936	92.93%	3008	3530	2760	2807	1.92	1.27	73.49	0.91	61.47	1.04
	All lit rake A element 5	3017	3554	2768	2815	93.61%	2895	3397	2662	2706	1.07	0.71	82.45	1.03	51.21	0.87
1	1 All lit rake B element 6	3001	3534	2755	2801	92.83%	2865	3360	2636	2679	1.36	0.90	96.62	1.20	56.33	0.96
	All lit rake B element 7	3094	3646	2835	2884	87.73%	2850	3334	2623	2666	1.31	0.87	108.57	1.35	111.83	1.90
	All lit rake B element 8	3171	3736	2902	2953	97.86%	3127	3680	2864	2913	1.87	1.24	40.94	0.51	13.58	0.23
	All lit rake B element 9	3153	3714	2886	2936	92.93%	3008	3530	2760	2807	1.92	1.27	73.49	0.91	61.47	1.04
	All lit rake B element 10	3017	3554	2768	2815	93.61%	2895	3397	2662	2706	1.07	0.71	82.45	1.03	51.21	0.87
1	1 All lit rake C element 11	3001	3534	2755	2801	92.83%	2865	3360	2636	2679	1.36	0.90	96.62	1.20	56.33	0.96
	All lit rake C element 12	3094	3646	2835	2884	87.73%	2850	3334	2623	2666	1.31	0.87	108.57	1.35	111.83	1.90
	All lit rake C element 13	3171	3736	2902	2953	97.86%	3127	3680	2864	2913	1.87	1.24	40.94	0.51	13.58	0.45
	All lit rake C element 14	3153	3714	2886	2936	92.93%	3008	3530	2760	2807	1.92	1.27	73.49	0.91	61.47	1.04
	All lit rake C element 15	3017	3554	2768	2815	93.61%	2895	3397	2662	2706	1.07	0.71	82.45	1.03	51.21	0.87
1	1 All lit rake D element 16	3001	3534	2755	2801	92.83%	2865	3360	2636	2679	1.36	0.90	96.62	1.20	56.33	0.96
	All lit rake D element 17	3094	3646	2835	2884	87.73%	2850	3334	2623	2666	1.31	0.87	108.57	1.35	111.83	1.90
	All lit rake D element 18	3171	3736	2902	2953	97.86%	3127	3680	2864	2913	1.87	1.24	40.94	0.51	13.58	0.23
	All lit rake D element 19	3153	3714	2886	2936	92.93%	3008	3530	2760	2807	1.92	1.27	73.49	0.91	61.47	1.04
	All lit rake D element 20	3017	3554	2768	2815	93.61%	2895	3397	2662	2706	1.07	0.71	82.45	1.03	51.21	0.87

FOURTH COMBUSTOR SECTOR, CELL 5 GAS SAMPLE PRESSURE DATA Test: 10/18/94 Print: 6/8/98

LIMITED EXCLUSIVE RIGHT NOTICE			AIRFLOWS								AIR VELOCITIES									
THESE DATA ARE SUBJECT TO						TOTAL DOME		PILOT DOME			OUTER DOME					INNER DOME				
LIMITED EXCLUSIVE RIGHTS UNDER																				
GOVERNMENT CONTRACT NUMBER																				
NAS3-26617 OR NAS3-27235				Outer	Inner	V total	V total		Vmixer		V outer	Vmixer	Vmixer exit	Vmixer	V outer	V inner	Vmixer	Vmixer exit	Vmixer	V inner
		Calc.	Pilot	Dome	Dome	dome	dome	V pilot	exit	V pilot	dome	exit	o.dome	@ inj.	dome	dome	exit	l.dome	@ inj.	dome
		Dome	Airflow	Airflow	Airflow	(cold)	(hot)	(cold)	pilot	(hot)	(cold)	o.dome	(bulk)	o.dome	(hot)	(cold)	l.dome	(bulk)	l.dome	(hot)
Rdg	Test Points	Wa, pps	pps	pps	pps	ft/s	ft/s	ft/s	ft/s	ft/s	ft/s	ft/s	ft/s	ft/s	ft/s	ft/s	ft/s	ft/s	ft/s	ft/s
1	1 All lit -all rakes ganged	4.09	1.17	1.47	1.45	42.8	111.0	31.0	423	94.2	51.0	423	324	378	121.6	50.1	423	318	364	121.5

4TH COMBUSTOR SECTOR, CELL 5			INPUTS FROM CELL 5 DATA ACQUISITION SYSTEM PRINTOUT																								
GAS SAMPLE PRES.TEST DATA			INPUTS FROM PAGE #3: CALCULATIONS														INPUTS FROM FRONT PAGE						INPUT FROM GAS SAMPLE SHEET:				
		Using Posttest flow check data					Out.IMFH Dome			Inn.IMFH Dome										Outer	Inner						
Test:		10/18/94		Pilot Fuel Flow			Fuel Flow			Fuel Flow									Pilot	IMFH	IMFH						
Print:		6/8/98	East	Pilot	Pilot												Patrch		Manif.	Manif.	Manif.				Sample	Combust.	
			Meter'd	Main	Verif.	Avg.			Avg.			Avg.	Pin.	Tin			(P4)	Pbaro	Pres.	Pres.	Pres.	EI	EI	EI	Fuel-Air	Efficiency	
Rdg		Test Points	pps	pph	pph	pph	pph	pph	pph	pph	pph	pph	psia	F			psia	psia	psia	psia	psia	CO	HC	NOx	Ratio	%	
						CALC			CALC			CALC															
1	1	All lit -all rakes ganged	5.95	226.0	219.6	223	176.5	179.0	177.8	179.6	181.4	180.5	60.75	646			58.12	14.41	88.2	63.62	65.5	96.62	56.33	1.36	0.03135	92.83%	
		All lit rake A - ganged																				108.57	111.83	1.31	0.03316	87.73%	
		All lit rake B - ganged																				40.94	13.58	1.87	0.03468	97.86%	
		All lit rake C - ganged																				73.49	61.47	1.92	0.03431	92.93%	
		All lit rake D - ganged																				82.45	51.21	1.07	0.03166	93.61%	
		All lit -individual rake avg.																				76.36	59.52	1.54	0.03345	93.03%	
1	1	All lit rake A element 1																				96.62	56.33	1.36	0.03135	92.83%	
		All lit rake A element 2																				108.57	111.83	1.31	0.03316	87.73%	
		All lit rake A element 3																				40.94	13.58	1.87	0.03468	97.86%	
		All lit rake A element 4																				73.49	61.47	1.92	0.03431	92.93%	
		All lit rake A element 5																				82.45	51.21	1.07	0.03166	93.61%	
1	1	All lit rake B element 6																				96.62	56.33	1.36	0.03135	92.83%	
		All lit rake B element 7																				108.57	111.83	1.31	0.03316	87.73%	
		All lit rake B element 8																				40.94	13.58	1.87	0.03468	97.86%	
		All lit rake B element 9																				73.49	61.47	1.92	0.03431	92.93%	
		All lit rake B element 10																				82.45	51.21	1.07	0.03166	93.61%	
1	1	All lit rake C element 11																				96.62	56.33	1.36	0.03135	92.83%	
		All lit rake C element 12																				108.57	111.83	1.31	0.03316	87.73%	
		All lit rake C element 13																				40.94	13.58	1.87	0.03468	97.86%	
		All lit rake C element 14																				73.49	61.47	1.92	0.03431	92.93%	
		All lit rake C element 15																				82.45	51.21	1.07	0.03166	93.61%	
1	1	All lit rake D element 16																				96.62	56.33	1.36	0.03135	92.83%	
		All lit rake D element 17																				108.57	111.83	1.31	0.03316	87.73%	
		All lit rake D element 18																				40.94	13.58	1.87	0.03468	97.86%	
		All lit rake D element 19																				73.49	61.47	1.92	0.03431	92.93%	
		All lit rake D element 20																				82.45	51.21	1.07	0.03166	93.61%	
2	1	All lit -all rakes ganged	5.95	226.0	219.6	223	176.5	179.0	177.8	179.6	181.4	180.5	60.75	646			58.12	14.41	88.2	63.62	65.5	96.62	56.33	1.36	0.03135	92.83%	
		All lit rake A - ganged																				108.57	111.83	1.31	0.03316	87.73%	
		All lit rake B - ganged																				40.94	13.58	1.87	0.03468	97.86%	
		All lit rake C - ganged																				73.49	61.47	1.92	0.03431	92.93%	
		All lit rake D - ganged																				82.45	51.21	1.07	0.03166	93.61%	
		All lit -individual rake avg.																				76.36	59.52	1.54	0.03345	93.03%	
2	1	All lit rake A element 1																				96.62	56.33	1.36	0.03135	92.83%	
		All lit rake A element 2																				108.57	111.83	1.31	0.03316	87.73%	
		All lit rake A element 3																				40.94	13.58	1.87	0.03468	97.86%	
		All lit rake A element 4																				73.49	61.47	1.92	0.03431	92.93%	
		All lit rake A element 5																				82.45	51.21	1.07	0.03166	93.61%	
2	1	All lit rake B element 6																				96.62	56.33	1.36	0.03135	92.83%	
		All lit rake B element 7																				108.57	111.83	1.31	0.03316	87.73%	
		All lit rake B element 8																				40.94	13.58	1.87	0.03468	97.86%	
		All lit rake B element 9																				73.49	61.47	1.92	0.03431	92.93%	
		All lit rake B element 10																				82.45	51.21	1.07	0.03166	93.61%	
2	1	All lit rake C element 11																				96.62	56.33	1.36	0.03135	92.83%	
		All lit rake C element 12																				108.57	111.83	1.31	0.03316	87.73%	
		All lit rake C element 13																				40.94	13.58	1.87	0.03468	97.86%	
		All lit rake C element 14																				73.49	61.47	1.92	0.03431	92.93%	
		All lit rake C element 15																				82.45	51.21	1.07	0.03166	93.61%	
2	1	All lit rake D element 16																				96.62	56.33	1.36	0.03135	92.83%	
		All lit rake D element 17																				108.57	111.83	1.31	0.03316	87.73%	
		All lit rake D element 18																				40.94	13.58	1.87	0.03468	97.86%	
		All lit rake D element 19																				73.49	61.47	1.92	0.03431	92.93%	
		All lit rake D element 20																				82.45	51.21	1.07	0.03166	93.61%	
1	1	All lit -all rakes ganged	5.95	226.0	219.6	223	176.5	179.0	177.8	179.6	181.4	180.5	60.75	646			58.12	14.41	88.2	63.62	65.5	96.62	56.33	1.36	0.03135	92.83%	
		All lit rake A - ganged																				108.57	111.83	1.31	0.03316	87.73%	
		All lit rake B - ganged																				40.94	13.58	1.87	0.03468	97.86%	
		All lit rake C - ganged																				73.49	61.47	1.92	0.03431	92.93%	
		All lit rake D - ganged																				82.45	51.21	1.07	0.03166	93.61%	
		All lit -individual rake avg.																				76.36	59.52	1.54	0.03345	93.03%	
1	1	All lit rake A element 1																				96.62	56.33	1.36	0.03135	92.83%	
		All lit rake A element 2																				108.57	111.83	1.31	0.03316	87.73%	
		All lit rake A element 3																				40.94	13.58	1.87	0.03468	97.86%	
		All lit rake A element 4																				73.49	61.47	1.92	0.03431	92.93%	
		All lit rake A element 5																				82.45	51.21	1.07	0.03166	93.61%	
1	1	All lit rake B element 6																				96.62	56.33	1.36	0.03135	92.83%	
		All lit rake B element 7																				108.57	111.83	1.31	0.03316	87.73%	
		All lit rake B element 8																				40.94	13.58	1.87	0.03468	97.86%	
		All lit rake B element 9																				73.49	61.47	1.92	0.03431	92.93%	
		All lit rake B element 10																				82.45	51.21	1.07	0.03166	93.61%	
1	1	All lit rake C element 11																				96.62	56.33	1.36	0.03135	92.83%	
		All lit rake C element 12																				108.57	111.83	1.31	0.03316	87.73%	
		All lit rake C element 13																				40.94	13.58	1.87	0.03468	97.86%	
		All lit rake C element 14																				73.49	61.47	1.92	0.03431	92.93%	
		All lit rake C element 15																				82.45	51.21	1.07	0.03166	93.61%	
1	1	All lit rake D element 16																				96.62	56.33	1.36	0.03135	92.83%	
		All lit rake D element 17																				108.57	111.83	1.31	0.03316	87.73%	
		All lit rake D element 18																				40.94	13.58	1.87	0.03468	97.86%	
		All lit rake D element 19																				73.49	61.47	1.92	0.03431	92.93%	
		All lit rake D element 20																				82.45	51.21	1.07	0.03166	93.61%	

4TH COMBUSTOR SECTOR, CELL 5				PRESSURES				TEMP'S		AIRFLOWS					FUEL FLOWS & PRESSURES									
GAS SAMPLE PRES.TEST DATA																								
		Using Posttest flow check data															Total	Outer	Inner				Outer	Inner
Test:		10/18/94															IMFH	IMFH	IMFH		% IMFH		IMFH	IMFH
Print:		6/8/98	Sampling											Flow	Dome	Pilot	Domes	Dome	Dome		Fuel to	Pilot	Manif.	Manif.
			G=ganged			Pres	%			Sector Airflow				Function:	Fuel	Fuel	Fuel	Fuel	Fuel	% Fuel	IMFH	Manif.	Pres.	Pres.
			I=individual	Pin,	P4	Drop,	Pres.	Tin		Total	Meter'd	Total	Dome	Wsqrt(T)	Flow,	Flow,	Flow	Flow,	Flow	to	Outer	Pres.	Pres.	Pres.
Rdg	Test Points		G & I=both	psia	psia	psid	Drop	F	R	pps	pps	Meter'd	Wa, pps	P	pph	pph	pph	pph	pph	Pilot	Dome	psia	psia	psia
1	1	All lit -all rakes ganged	all ganged	60.75	58.12	2.63	4.33%	646	1106	5.50	5.95	0.92	4.09	3.01	581.1	222.8	358.3	177.8	180.5	38.3%	49.62%	88.16	63.62	65.5
		All lit rake A - ganged	G rake																					
		All lit rake B - ganged	G rake																					
		All lit rake C - ganged	G rake																					
		All lit rake D - ganged	G rake																					
		All lit -individual rake avg.	G rake avg.																					
1	1	All lit rake A element 1	Indiv.																					
		All lit rake A element 2	Indiv.																					
		All lit rake A element 3	Indiv.																					
		All lit rake A element 4	Indiv.																					
		All lit rake A element 5	Indiv.																					
1	1	All lit rake B element 6	Indiv.																					
		All lit rake B element 7	Indiv.																					
		All lit rake B element 8	Indiv.																					
		All lit rake B element 9	Indiv.																					
		All lit rake B element 10	Indiv.																					
1	1	All lit rake C element 11	Indiv.																					
		All lit rake C element 12	Indiv.																					
		All lit rake C element 13	Indiv.																					
		All lit rake C element 14	Indiv.																					
		All lit rake C element 15	Indiv.																					
1	1	All lit rake D element 16	Indiv.																					
		All lit rake D element 17	Indiv.																					
		All lit rake D element 18	Indiv.																					
		All lit rake D element 19	Indiv.																					
		All lit rake D element 20	Indiv.																					
2	1	All lit -all rakes ganged	all ganged	60.75	58.12	2.63	4.33%	646	1106	5.50	5.95	0.92	4.09	3.01	581.1	222.8	358.3	177.8	180.5	38.3%	49.62%	88.16	63.62	65.5
		All lit rake A - ganged	G rake																					
		All lit rake B - ganged	G rake																					
		All lit rake C - ganged	G rake																					
		All lit rake D - ganged	G rake																					
		All lit -individual rake avg.	G rake avg.																					
2	1	All lit rake A element 1	Indiv.																					
		All lit rake A element 2	Indiv.																					
		All lit rake A element 3	Indiv.																					
		All lit rake A element 4	Indiv.																					
		All lit rake A element 5	Indiv.																					
2	1	All lit rake B element 6	Indiv.																					
		All lit rake B element 7	Indiv.																					
		All lit rake B element 8	Indiv.																					
		All lit rake B element 9	Indiv.																					
		All lit rake B element 10	Indiv.																					
2	1	All lit rake C element 11	Indiv.																					
		All lit rake C element 12	Indiv.																					
		All lit rake C element 13	Indiv.																					
		All lit rake C element 14	Indiv.																					
		All lit rake C element 15	Indiv.																					
2	1	All lit rake D element 16	Indiv.																					
		All lit rake D element 17	Indiv.																					
		All lit rake D element 18	Indiv.																					
		All lit rake D element 19	Indiv.																					
		All lit rake D element 20	Indiv.																					
1	1	All lit -all rakes ganged	all ganged	60.75	58.12	2.63	4.33%	646	1106	5.50	5.95	0.92	4.09	3.01	581.1	222.8	358.3	177.8	180.5	38.3%	49.62%	88.16	63.62	65.5
		All lit rake A - ganged	G rake																					
		All lit rake B - ganged	G rake																					
		All lit rake C - ganged	G rake																					
		All lit rake D - ganged	G rake																					
		All lit -individual rake avg.	G rake avg.																					
1	1	All lit rake A element 1	Indiv.																					
		All lit rake A element 2	Indiv.																					
		All lit rake A element 3	Indiv.																					
		All lit rake A element 4	Indiv.																					
		All lit rake A element 5	Indiv.																					
1	1	All lit rake B element 6	Indiv.																					
		All lit rake B element 7	Indiv.																					
		All lit rake B element 8	Indiv.																					
		All lit rake B element 9	Indiv.																					
		All lit rake B element 10	Indiv.																					
1	1	All lit rake C element 11	Indiv.																					
		All lit rake C element 12	Indiv.																					
		All lit rake C element 13	Indiv.																					
		All lit rake C element 14	Indiv.																					
		All lit rake C element 15	Indiv.																					
1	1	All lit rake D element 16	Indiv.																					
		All lit rake D element 17	Indiv.																					
		All lit rake D element 18	Indiv.																					
		All lit rake D element 19	Indiv.																					
		All lit rake D element 20	Indiv.																					
1	1	All lit -all rakes ganged	all ganged	60.75	58.12	2.63	4.33%	646	1106	5.50	5.95	0.92	4.09	3.01	581.1	222.8	358.3	177.8	180.5	38.3%	49.62%	88.16	63.62	65.5
		All lit rake A - ganged	G rake																					
		All lit rake B - ganged	G rake																					
		All lit rake C - ganged	G rake																					
		All lit rake D - ganged	G rake																					
		All lit -individual rake avg.	G rake avg.																					
1	1	All lit rake A element 1	Indiv.																					
		All lit rake A element 2	Indiv.																					
		All lit rake A element 3	Indiv.																					
		All lit rake A element 4	Indiv.																					
		All lit rake A element 5	Indiv.																					
1	1	All lit rake B element 6	Indiv.																					
		All lit rake B element 7	Indiv.																					
		All lit rake B element 8	Indiv.																					
		All lit rake B element 9	Indiv.																					
		All lit rake B element 10	Indiv.																					
1	1	All lit rake C element 11	Indiv.																					
		All lit rake C element 12	Indiv.																					
		All lit rake C element 13	Indiv.																					
		All lit rake C element 14	Indiv.																					
		All lit rake C element 15	Indiv.																					
1	1	All lit rake D element 16	Indiv.																					
		All lit rake D element 17	Indiv.																					
		All lit rake D element 18	Indiv.																					
		All lit rake D element 19	Indiv.																					
		All lit rake D element 20	Indiv.																					

4TH COMBUSTOR SECTOR, CELL 5								MEASURED FUEL-AIR RATIOS/						UNCORRECTED				
GAS SAMPLE PRES.TEST DATA			FUEL FLOW NUMBERS					EQUIVALENCE RATIOS						CALCULATED EQUIV.RATIOS				
	Using Posttest flow check data					Outer	Inner	All Rakes (A,B,C,D)					Calc.					
Test:	10/16/94		Outer	Inner	Pilot	IMFH	IMFH			Sample	Calc.	Calc.	Sample			Total	Outer	Inner
Print:	6/8/98	Pilot	IMFH	IMFH	Test	Test	Test		Sample	Eq.R.I	Sample	(Pilot)	(Pilot&)			IMFH	IMFH	IMFH
		Injector	Manif.	Manif.	Cal.	Cal.	Cal.	Sample	(Dome)	Sample	(Pilot)	(O.Dome)	(O.Dome)	Dome	Pilot	Domes	Dome	Dome
		Flow	Flow	Flow	Flow	Flow	Flow	Fuel-Air	Equiv.	Eq.R.	Equiv.	Equiv.	Equiv.	Equiv.	Equiv.	Equiv.	Equiv.	Equiv.
Rdg	Test Points	Number	Number	Number	Number	Number	Number	Ratio	Ratio	avg	Ratio	Ratio	Ratio	Ratio	Ratio	Ratio	Ratio	Ratio
1	1 All lit -all rakes ganged	40.65	75.79	66.67	1.01	1.07	0.94	0.03135	0.460	0.937	0.618	0.391	0.404	0.579	0.777	0.499	0.491	0.508
	All lit rake A - ganged							0.03316	0.487	0.991	0.653	0.413	0.427					
	All lit rake B - ganged							0.03468	0.509	1.037	0.683	0.432	0.446					
	All lit rake C - ganged							0.03431	0.503	1.026	0.676	0.427	0.442					
	All lit rake D - ganged							0.03166	0.465	0.946	0.624	0.394	0.407					
	All lit -individual rake avg.							0.03345	0.491	-	0.659	0.417	0.431					
1	1 All lit rake A element 1							0.03135	0.460	0.949	0.618	0.391	0.404					
	All lit rake A element 2							0.03316	0.487	1.004	0.653	0.413	0.427					
	All lit rake A element 3							0.03468	0.509	1.050	0.683	0.432	0.446					
	All lit rake A element 4							0.03431	0.503	1.039	0.676	0.427	0.442					
	All lit rake A element 5							0.03166	0.465	0.958	0.624	0.394	0.407					
1	1 All lit rake B element 6							0.03135	0.460	0.949	0.618	0.391	0.404					
	All lit rake B element 7							0.03316	0.487	1.004	0.653	0.413	0.427					
	All lit rake B element 8							0.03468	0.509	1.050	0.683	0.432	0.446					
	All lit rake B element 9							0.03431	0.503	1.039	0.676	0.427	0.442					
	All lit rake B element 10							0.03166	0.465	0.958	0.624	0.394	0.407					
1	1 All lit rake C element 11							0.03135	0.460	0.949	0.618	0.391	0.404					
	All lit rake C element 12							0.03316	0.487	1.004	0.653	0.413	0.427					
	All lit rake C element 13							0.03468	0.509	1.050	0.683	0.432	0.446					
	All lit rake C element 14							0.03431	0.503	1.039	0.676	0.427	0.442					
	All lit rake C element 15							0.03166	0.465	0.958	0.624	0.394	0.407					
1	1 All lit rake D element 16							0.03135	0.460	0.949	0.618	0.391	0.404					
	All lit rake D element 17							0.03316	0.487	1.004	0.653	0.413	0.427					
	All lit rake D element 18							0.03468	0.509	1.050	0.683	0.432	0.446					
	All lit rake D element 19							0.03431	0.503	1.039	0.676	0.427	0.442					
	All lit rake D element 20							0.03166	0.465	0.958	0.624	0.394	0.407					
2	1 All lit -all rakes ganged	40.65	75.79	66.67	1.01	1.07	0.94	0.03135	0.460	0.937	0.618	0.391	0.404	0.579	0.777	0.499	0.491	0.508
	All lit rake A - ganged							0.03316	0.487	0.991	0.653	0.413	0.427					
	All lit rake B - ganged							0.03468	0.509	1.037	0.683	0.432	0.446					
	All lit rake C - ganged							0.03431	0.503	1.026	0.676	0.427	0.442					
	All lit rake D - ganged							0.03166	0.465	0.946	0.624	0.394	0.407					
	All lit -individual rake avg.							0.03345	0.491	-	0.659	0.417	0.431					
2	1 All lit rake A element 1							0.03135	0.460	0.949	0.618	0.391	0.404					
	All lit rake A element 2							0.03316	0.487	1.004	0.653	0.413	0.427					
	All lit rake A element 3							0.03468	0.509	1.050	0.683	0.432	0.446					
	All lit rake A element 4							0.03431	0.503	1.039	0.676	0.427	0.442					
	All lit rake A element 5							0.03166	0.465	0.958	0.624	0.394	0.407					
2	1 All lit rake B element 6							0.03135	0.460	0.949	0.618	0.391	0.404					
	All lit rake B element 7							0.03316	0.487	1.004	0.653	0.413	0.427					
	All lit rake B element 8							0.03468	0.509	1.050	0.683	0.432	0.446					
	All lit rake B element 9							0.03431	0.503	1.039	0.676	0.427	0.442					
	All lit rake B element 10							0.03166	0.465	0.958	0.624	0.394	0.407					
2	1 All lit rake C element 11							0.03135	0.460	0.949	0.618	0.391	0.404					
	All lit rake C element 12							0.03316	0.487	1.004	0.653	0.413	0.427					
	All lit rake C element 13							0.03468	0.509	1.050	0.683	0.432	0.446					
	All lit rake C element 14							0.03431	0.503	1.039	0.676	0.427	0.442					
	All lit rake C element 15							0.03166	0.465	0.958	0.624	0.394	0.407					
2	1 All lit rake D element 16							0.03135	0.460	0.949	0.618	0.391	0.404					
	All lit rake D element 17							0.03316	0.487	1.004	0.653	0.413	0.427					
	All lit rake D element 18							0.03468	0.509	1.050	0.683	0.432	0.446					
	All lit rake D element 19							0.03431	0.503	1.039	0.676	0.427	0.442					
	All lit rake D element 20							0.03166	0.465	0.958	0.624	0.394	0.407					
1	1 All lit -all rakes ganged	40.65	75.79	66.67	1.01	1.07	0.94	0.03135	0.460	0.937	0.618	0.391	0.404	0.579	0.777	0.499	0.491	0.508
	All lit rake A - ganged							0.03316	0.487	0.991	0.653	0.413	0.427					
	All lit rake B - ganged							0.03468	0.509	1.037	0.683	0.432	0.446					
	All lit rake C - ganged							0.03431	0.503	1.026	0.676	0.427	0.442					
	All lit rake D - ganged							0.03166	0.465	0.946	0.624	0.394	0.407					
	All lit -individual rake avg.							0.03345	0.491	-	0.659	0.417	0.431					
1	1 All lit rake A element 1							0.03135	0.460	0.949	0.618	0.391	0.404					
	All lit rake A element 2							0.03316	0.487	1.004	0.653	0.413	0.427					
	All lit rake A element 3							0.03468	0.509	1.050	0.683	0.432	0.446					
	All lit rake A element 4							0.03431	0.503	1.039	0.676	0.427	0.442					
	All lit rake A element 5							0.03166	0.465	0.958	0.624	0.394	0.407					
1	1 All lit rake B element 6							0.03135	0.460	0.949	0.618	0.391	0.404					
	All lit rake B element 7							0.03316	0.487	1.004	0.653	0.413	0.427					
	All lit rake B element 8							0.03468	0.509	1.050	0.683	0.432	0.446					
	All lit rake B element 9							0.03431	0.503	1.039	0.676	0.427	0.442					
	All lit rake B element 10							0.03166	0.465	0.958	0.624	0.394	0.407					
1	1 All lit rake C element 11							0.03135	0.460	0.949	0.618	0.391	0.404					
	All lit rake C element 12							0.03316	0.487	1.004	0.653	0.413	0.427					
	All lit rake C element 13							0.03468	0.509	1.050	0.683	0.432	0.446					
	All lit rake C element 14							0.03431	0.503	1.039	0.676	0.427	0.442					
	All lit rake C element 15							0.03166	0.465	0.958	0.624	0.394	0.407					
1	1 All lit rake D element 16							0.03135	0.460	0.949	0.618	0.391	0.404					
	All lit rake D element 17							0.03316	0.487	1.004	0.653	0.413	0.427					
	All lit rake D element 18							0.03468	0.509	1.050	0.683	0.432	0.446					
	All lit rake D element 19							0.03431	0.503	1.039	0.676							
	All lit rake D element 20							0.03166	0.465	0.958	0.624							

4TH COMBUSTOR SECTOR, CELL 5			AIRFLOW CORRECTED					AIRFLOW UNCORRECTED,CALCULATED					AIRFLOW CORRECTED				
GAS SAMPLE PRES.TEST DATA			CALCULATED EQUIV.RATIOS					ADIABATIC FLAME TEMPERATURES					ADIABATIC FLAME TEMPERATURES				
		Using Posttest flow check data															
Test:		10/18/94			Total	Outer	Inner			Total	Outer	Inner			Total	Outer	Inner
Print:		6/8/98			IMFH	IMFH	IMFH			IMFH	IMFH	IMFH			IMFH	IMFH	IMFH
			Dome	Pilot	Domes	Dome	Dome	Dome	Pilot	Domes	Dome	Dome	Dome	Pilot	Domes	Dome	Dome
			Equiv.	Equiv.	Equiv.	Equiv.	Equiv.	Flame	Flame	Flame	Flame	Flame	Flame	Flame	Flame	Flame	Flame
Rdg		Test Points	Ratio	Ratio	Ratio	Ratio	Ratio	Temp.,R	Temp.,R	Temp.,R	Temp.,R	Temp.,R	Temp.,R	Temp.,R	Temp.,R	Temp.,R	Temp.,R
1	1	All lit -all rakes ganged	0.535	0.718	0.461	0.454	0.469	3407	3989	3138	3110	3167	3260	3835	3006	2980	3033
		All lit rake A - ganged															
		All lit rake B - ganged															
		All lit rake C - ganged															
		All lit rake D - ganged															
		All lit -individual rake avg.															
1	1	All lit rake A element 1															
		All lit rake A element 2															
		All lit rake A element 3															
		All lit rake A element 4															
		All lit rake A element 5															
1	1	All lit rake B element 6															
		All lit rake B element 7															
		All lit rake B element 8															
		All lit rake B element 9															
		All lit rake B element 10															
1	1	All lit rake C element 11															
		All lit rake C element 12															
		All lit rake C element 13															
		All lit rake C element 14															
		All lit rake C element 15															
1	1	All lit rake D element 16															
		All lit rake D element 17															
		All lit rake D element 18															
		All lit rake D element 19															
		All lit rake D element 20															
2	1	All lit -all rakes ganged	0.535	0.718	0.461	0.454	0.469	3407	3989	3138	3110	3167	3260	3835	3006	2980	3033
		All lit rake A - ganged															
		All lit rake B - ganged															
		All lit rake C - ganged															
		All lit rake D - ganged															
		All lit -individual rake avg.															
2	1	All lit rake A element 1															
		All lit rake A element 2															
		All lit rake A element 3															
		All lit rake A element 4															
		All lit rake A element 5															
2	1	All lit rake B element 6															
		All lit rake B element 7															
		All lit rake B element 8															
		All lit rake B element 9															
		All lit rake B element 10															
2	1	All lit rake C element 11															
		All lit rake C element 12															
		All lit rake C element 13															
		All lit rake C element 14															
		All lit rake C element 15															
2	1	All lit rake D element 16															
		All lit rake D element 17															
		All lit rake D element 18															
		All lit rake D element 19															
		All lit rake D element 20															
1	1	All lit -all rakes ganged	0.535	0.718	0.461	0.454	0.469	3407	3989	3138	3110	3167	3260	3835	3006	2980	3033
		All lit rake A - ganged															
		All lit rake B - ganged															
		All lit rake C - ganged															
		All lit rake D - ganged															
		All lit -individual rake avg.															
1	1	All lit rake A element 1															
		All lit rake A element 2															
		All lit rake A element 3															
		All lit rake A element 4															
		All lit rake A element 5															
1	1	All lit rake B element 6															
		All lit rake B element 7															
		All lit rake B element 8															
		All lit rake B element 9															
		All lit rake B element 10															
1	1	All lit rake C element 11															
		All lit rake C element 12															
		All lit rake C element 13															
		All lit rake C element 14															
		All lit rake C element 15															
1	1	All lit rake D element 16															
		All lit rake D element 17															
		All lit rake D element 18															
		All lit rake D element 19															
		All lit rake D element 20															
1	1	All lit -all rakes ganged	0.535	0.718	0.461	0.454	0.469	3407	3989	3138	3110	3167	3260	3835	3006	2980	3033
		All lit rake A - ganged															
		All lit rake B - ganged															
		All lit rake C - ganged															
		All lit rake D - ganged															
		All lit -individual rake avg.															
1	1	All lit rake A element 1															
		All lit rake A element 2															
		All lit rake A element 3															
		All lit rake A element 4															
		All lit rake A element 5															
1	1	All lit rake B element 6															
		All lit rake B element 7															
		All lit rake B element 8															
		All lit rake B element 9															
		All lit rake B element 10															
1	1	All lit rake C element 11															
		All lit rake C element 12															
		All lit rake C element 13															
		All lit rake C element 14															
		All lit rake C element 15															
1	1	All lit rake D element 16															
		All lit rake D element 17															
		All lit rake D element 18															
		All lit rake D element 19															
		All lit rake D element 20															

4TH COMBUSTOR SECTOR, CELL 5																	
GAS SAMPLE PRES.TEST DATA		MEASURED EMISSIONS															
	Using Posttest flow check data				Uncorr.					Corr.							
Test:	10/18/94	Uncorr.	Uncorr.	Uncorr.	Sample		Corr.	Corr.	Corr.	Sample		EI		EI		EI	
Print:	6/8/98	Sample	Sample	Sample	(Pilot&)		Sample	Sample	Sample	(Pilot&)		NOx		CO		HC	
		(Dome)	(Pilot)	(O.Dome)	(O.Dome)	Combust.	(Dome)	(Pilot)	(O.Dome)	(O.Dome)							
		Flame	Flame	Flame	Flame	Efficiency	Flame	Flame	Flame	Flame	EI	NOx	EI	CO	EI,	HC	
Rdg	Test Points	Temp.,R	Temp.,R	Temp.,R	Temp.,R	%	Temp.,R	Temp.,R	Temp.,R	Temp.,R	NOx	avg	CO	avg	HC	avg	
1	1 All lit -all rakes ganged	3001	3534	2755	2801	92.83%	2865	3360	2636	2679	1.36	0.88	96.62	1.27	56.33	0.95	
	All lit rake A - ganged	3094	3646	2835	2884	87.73%	2850	3334	2623	2666	1.31	0.85	108.57	1.42	111.83	1.88	
	All lit rake B - ganged	3171	3736	2902	2953	97.86%	3127	3680	2864	2913	1.87	1.21	40.94	0.54	13.58	0.23	
	All lit rake C - ganged	3153	3714	2886	2936	92.93%	3008	3530	2760	2807	1.92	1.24	73.49	0.96	61.47	1.03	
	All lit rake D - ganged	3017	3554	2768	2815	93.61%	2895	3397	2662	2706	1.07	0.69	82.45	1.08	51.21	0.86	
	All lit -individual rake avg.	3109	3662	2848	2897	93.03%	2970	3485	2727	2773	1.54	-	76.36	-	59.52	-	
1	1 All lit rake A element 1	3001	3534	2755	2801	92.83%	2865	3360	2636	2679	1.36	0.90	96.62	1.20	56.33	0.96	
	All lit rake A element 2	3094	3646	2835	2884	87.73%	2850	3334	2623	2666	1.31	0.87	108.57	1.35	111.83	1.90	
	All lit rake A element 3	3171	3736	2902	2953	97.86%	3127	3680	2864	2913	1.87	1.24	40.94	0.51	13.58	0.23	
	All lit rake A element 4	3153	3714	2886	2936	92.93%	3008	3530	2760	2807	1.92	1.27	73.49	0.91	61.47	1.04	
	All lit rake A element 5	3017	3554	2768	2815	93.61%	2895	3397	2662	2706	1.07	0.71	82.45	1.03	51.21	0.87	
1	1 All lit rake B element 6	3001	3534	2755	2801	92.83%	2865	3360	2636	2679	1.36	0.90	96.62	1.20	56.33	0.96	
	All lit rake B element 7	3094	3646	2835	2884	87.73%	2850	3334	2623	2666	1.31	0.87	108.57	1.35	111.83	1.90	
	All lit rake B element 8	3171	3736	2902	2953	97.86%	3127	3680	2864	2913	1.87	1.24	40.94	0.51	13.58	0.23	
	All lit rake B element 9	3153	3714	2886	2936	92.93%	3008	3530	2760	2807	1.92	1.27	73.49	0.91	61.47	1.04	
	All lit rake B element 10	3017	3554	2768	2815	93.61%	2895	3397	2662	2706	1.07	0.71	82.45	1.03	51.21	0.87	
1	1 All lit rake C element 11	3001	3534	2755	2801	92.83%	2865	3360	2636	2679	1.36	0.90	96.62	1.20	56.33	0.96	
	All lit rake C element 12	3094	3646	2835	2884	87.73%	2850	3334	2623	2666	1.31	0.87	108.57	1.35	111.83	1.90	
	All lit rake C element 13	3171	3736	2902	2953	97.86%	3127	3680	2864	2913	1.87	1.24	40.94	0.51	13.58	0.45	
	All lit rake C element 14	3153	3714	2886	2936	92.93%	3008	3530	2760	2807	1.92	1.27	73.49	0.91	61.47	1.04	
	All lit rake C element 15	3017	3554	2768	2815	93.61%	2895	3397	2662	2706	1.07	0.71	82.45	1.03	51.21	0.87	
1	1 All lit rake D element 16	3001	3534	2755	2801	92.83%	2865	3360	2636	2679	1.36	0.90	96.62	1.20	56.33	0.96	
	All lit rake D element 17	3094	3646	2835	2884	87.73%	2850	3334	2623	2666	1.31	0.87	108.57	1.35	111.83	1.90	
	All lit rake D element 18	3171	3736	2902	2953	97.86%	3127	3680	2864	2913	1.87	1.24	40.94	0.51	13.58	0.23	
	All lit rake D element 19	3153	3714	2886	2936	92.93%	3008	3530	2760	2807	1.92	1.27	73.49	0.91	61.47	1.04	
	All lit rake D element 20	3017	3554	2768	2815	93.61%	2895	3397	2662	2706	1.07	0.71	82.45	1.03	51.21	0.87	
2	1 All lit -all rakes ganged	3001	3534	2755	2801	92.83%	2865	3360	2636	2679	1.36	0.88	96.62	1.27	56.33	0.95	
	All lit rake A - ganged	3094	3646	2835	2884	87.73%	2850	3334	2623	2666	1.31	0.85	108.57	1.42	111.83	1.88	
	All lit rake B - ganged	3171	3736	2902	2953	97.86%	3127	3680	2864	2913	1.87	1.21	40.94	0.54	13.58	0.23	
	All lit rake C - ganged	3153	3714	2886	2936	92.93%	3008	3530	2760	2807	1.92	1.24	73.49	0.96	61.47	1.03	
	All lit rake D - ganged	3017	3554	2768	2815	93.61%	2895	3397	2662	2706	1.07	0.69	82.45	1.08	51.21	0.86	
	All lit -individual rake avg.	3109	3662	2848	2897	93.03%	2970	3485	2727	2773	1.54	-	76.36	-	59.52	-	
2	1 All lit rake A element 1	3001	3534	2755	2801	92.83%	2865	3360	2636	2679	1.36	0.90	96.62	1.20	56.33	0.96	
	All lit rake A element 2	3094	3646	2835	2884	87.73%	2850	3334	2623	2666	1.31	0.87	108.57	1.35	111.83	1.90	
	All lit rake A element 3	3171	3736	2902	2953	97.86%	3127	3680	2864	2913	1.87	1.24	40.94	0.51	13.58	0.23	
	All lit rake A element 4	3153	3714	2886	2936	92.93%	3008	3530	2760	2807	1.92	1.27	73.49	0.91	61.47	1.04	
	All lit rake A element 5	3017	3554	2768	2815	93.61%	2895	3397	2662	2706	1.07	0.71	82.45	1.03	51.21	0.87	
2	1 All lit rake B element 6	3001	3534	2755	2801	92.83%	2865	3360	2636	2679	1.36	0.90	96.62	1.20	56.33	0.96	
	All lit rake B element 7	3094	3646	2835	2884	87.73%	2850	3334	2623	2666	1.31	0.87	108.57	1.35	111.83	1.90	
	All lit rake B element 8	3171	3736	2902	2953	97.86%	3127	3680	2864	2913	1.87	1.24	40.94	0.51	13.58	0.23	
	All lit rake B element 9	3153	3714	2886	2936	92.93%	3008	3530	2760	2807	1.92	1.27	73.49	0.91	61.47	1.04	
	All lit rake B element 10	3017	3554	2768	2815	93.61%	2895	3397	2662	2706	1.07	0.71	82.45	1.03	51.21	0.87	
2	1 All lit rake C element 11	3001	3534	2755	2801	92.83%	2865	3360	2636	2679	1.36	0.90	96.62	1.20	56.33	0.96	
	All lit rake C element 12	3094	3646	2835	2884	87.73%	2850	3334	2623	2666	1.31	0.87	108.57	1.35	111.83	1.90	
	All lit rake C element 13	3171	3736	2902	2953	97.86%	3127	3680	2864	2913	1.87	1.24	40.94	0.51	13.58	0.45	
	All lit rake C element 14	3153	3714	2886	2936	92.93%	3008	3530	2760	2807	1.92	1.27	73.49	0.91	61.47	1.04	
	All lit rake C element 15	3017	3554	2768	2815	93.61%	2895	3397	2662	2706	1.07	0.71	82.45	1.03	51.21	0.87	
2	1 All lit rake D element 16	3001	3534	2755	2801	92.83%	2865	3360	2636	2679	1.36	0.90	96.62	1.20	56.33	0.96	
	All lit rake D element 17	3094	3646	2835	2884	87.73%	2850	3334	2623	2666	1.31	0.87	108.57	1.35	111.83	1.90	
	All lit rake D element 18	3171	3736	2902	2953	97.86%	3127	3680	2864	2913	1.87	1.24	40.94	0.51	13.58	0.23	
	All lit rake D element 19	3153	3714	2886	2936	92.93%	3008	3530	2760	2807	1.92	1.27	73.49	0.91	61.47	1.04	
	All lit rake D element 20	3017	3554	2768	2815	93.61%	2895	3397	2662	2706	1.07	0.71	82.45	1.03	51.21	0.87	
1	1 All lit -all rakes ganged	3001	3534	2755	2801	92.83%	2865	3360	2636	2679	1.36	0.88	96.62	1.27	56.33	0.95	
	All lit rake A - ganged	3094	3646	2835	2884	87.73%	2850	3334	2623	2666	1.31	0.85	108.57	1.42	111.83	1.88	
	All lit rake B - ganged	3171	3736	2902	2953	97.86%	3127	3680	2864	2913	1.87	1.21	40.94	0.54	13.58	0.23	
	All lit rake C - ganged	3153	3714	2886	2936	92.93%	3008	3530	2760	2807	1.92	1.24	73.49	0.96	61.47	1.03	
	All lit rake D - ganged	3017	3554	2768	2815	93.61%	2895	3397	2662	2706	1.07	0.69	82.45	1.08	51.21	0.86	
	All lit -individual rake avg.	3109	3662	2848	2897	93.03%	2970	3485	2727	2773	1.54	-	76.36	-	59.52	-	
1	1 All lit rake A element 1	3001	3534	2755	2801	92.83%	2865	3360	2636	2679	1.36	0.90	96.62	1.20	56.33	0.96	
	All lit rake A element 2	3094	3646	2835	2884	87.73%	2850	3334	2623	2666	1.31	0.87	108.57	1.35	111.83	1.90	
	All lit rake A element 3	3171	3736	2902	2953	97.86%	3127	3680	2864	2913	1.87	1.24	40.94	0.51	13.58	0.23	
	All lit rake A element 4	3153	3714	2886	2936	92.93%	3008	3530	2760	2807	1.92	1.27	73.49	0.91	61.47	1.04	
	All lit rake A element 5	3017	3554	2768	2815	93.61%	2895	3397	2662	2706	1.07	0.71	82.45	1.03	51.21	0.87	
1	1 All lit rake B element 6	3001	3534	2755	2801	92.83%	2865	3360	2636	2679	1.36	0.90	96.62	1.20	56.33	0.96	
	All lit rake B element 7	3094	3646	2835	2884	87.73%	2850	3334	2623	2666	1.31	0.87	108.57	1.35	111.83	1.90	
	All lit rake B element 8	3171	3736	2902	2953	97.86%	3127	3680	2864	2913	1.87	1.24	40.94	0.51	13.58	0.23	
	All lit rake B element 9	3153	3714	2886	2936	92.93%	3008	3530	2760	2807	1.92	1.27	73.49	0.91	61.47	1.04	
	All lit rake B element 10	3017	3554	2768	2815	93.61%	2895	3397	2662	2706	1.07	0.71	82.45	1.03	51.21	0.87	
1	1 All lit rake C element 11	3001	3534	2755	2801	92.83%	2865	3360	2636	2679	1.36	0.90	96.62	1.20	56.33	0.96	
	All lit rake C element 12	3094	3646	2835	2884	87.73%	2850	3334	2623	2666	1.31	0.87	108.57	1.35	111.83	1.90	
	All lit rake C element 13	3171	3736	2902	2953	97.86%	3127	3680	2864	2913	1.87	1.24	40.94	0.51	13.58	0.45	
	All lit rake C element 14	3153	3714	2886	2936	92.93%	3008	3530	2760	2807	1.92	1.27	73.49	0.91	61.47	1.04	
	All lit rake C element 15	3017	3554	2768	2815	93.61%	2895	3397	2662	2706	1.07	0.71	82.45	1.03	51.21	0.87	
1	1 All lit rake D element 16	3001	3534	2755	2801	92.83%	2865	3360	2636	2679	1.36	0.90	96.62	1.20	56.33	0.96	
	All lit rake D element 17	3094	3646	2835	2884	87.73%	2850	3334	2623	2666	1.31	0.87	108.57	1.35	111.83	1.90	
	All lit rake D element 18	3171	3736	2902	2953	97.86%	3127	3680	2864	2913	1.87	1.24	40.94	0.51	13.58	0.23	
	All lit rake D element 19	3153	3714	2886	2936	92.93%	3008	3530	2760	2807	1.92	1.27	7				
	All lit rake D element 20	3017	3554	2768	2815	93.61%	2895	3397	2662	2706	1.07	0.71	8				

1	1	All lit -all rakes ganged	4.09	1.17	1.47	1.45	42.8	111.0	31.0	423	94.2	51.0	423	324	378	121.6	50.1	423	318	364	121.5
1	1	All lit -all rakes ganged	4.09	1.17	1.47	1.45	42.8	111.0	31.0	423	94.2	51.0	423	324	378	121.6	50.1	423	318	364	121.5
1	1	All lit -all rakes ganged	4.09	1.17	1.47	1.45	42.8	111.0	31.0	423	94.2	51.0	423	324	378	121.6	50.1	423	318	364	121.5
1	1	All lit -all rakes ganged	4.09	1.17	1.47	1.45	42.8	111.0	31.0	423	94.2	51.0	423	324	378	121.6	50.1	423	318	364	121.5

Appendix E

Pennsylvania State University Laser Diagnostics Study

Final Report

Mixing and Vaporization Evaluation of Integrated Injector Mixer Flame Holder (IMFH) Configurations

by

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September, 1994

I. INTRODUCTION

This report documents experimental work done at Penn State intended to define an injector geometry for optimized fuel-air mixing and vaporization for the integrated injector mixer flame holder (IMFH) configuration. The experiments were carried out in the high pressure, high temperature flow apparatus described in the previous final report (dated September, 1993). A schematic diagram of the overall facility is shown in Figure 1. All the experiments employed 2-D laser-induced exciplex fluorescence which allows instantaneous and separate visualization of the liquid and vapor distributions in an operating liquid fuel-injected high speed flow.

The main objective of these tests was to determine a fuel injector type and geometry and length of mixing section for optimized fuel vaporization and fuel-air mixing at the mixing section outlet.

This overall goal was divided into four tasks, each of which will be described in detail:

Task 1: Fuel Injector Modifications

Task 2: Mixer Tube Length Reduction

Task 3: Mixer Tube Diameter Modifications

Task 4: Air Injection at the Mixer Tube Exit

Tasks 1 and 2 were completed as posed. The equipment was designed and built for Tasks 3 and 4. However, because of changed priorities and the desire to have more information about new injector geometries, experimental work in tasks 3 and 4 was deferred, and Tasks 1 and 2 were expanded to include these new geometries.

II. APPARATUS AND PROCEDURE

The Penn State high temperature high pressure continuous flow system described in a previous report is capable of operation at inlet temperatures to about 1300°F and pressures to 10 atm. As shown in Figure 1, the heated air flows into a stainless steel entrance section about 5" long, proceeds through a rounded inlet section, and flows through a smaller diameter (13 mm

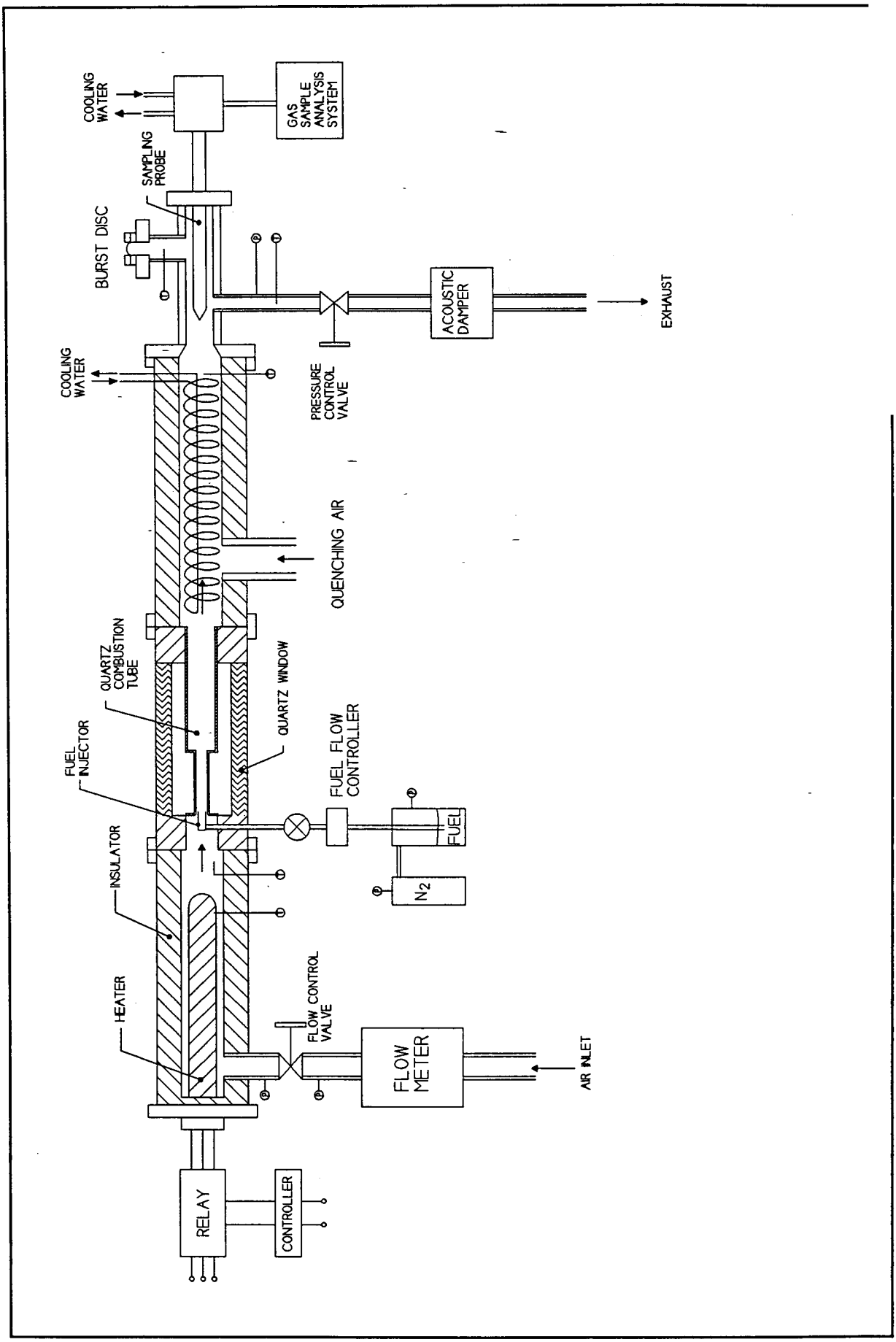


Figure 1 High Pressure / High Temperature Combustion Test Facility

(0.52") i.d. in this case) quartz mixing tube. A short, specially designed stainless steel adapter joins the mixing section to the larger diameter [28 mm i.d. (1.10")] quartz flame tube. The two quartz sections are sealed with loose ceramic fiber insulation and a compression-type fitting. The flow then exits through a longer section of stainless steel tube into the exhaust region. The system is designed to accommodate a variety of fuel injector types and locations.

Fuel was supplied from a nitrogen pressurized steel tank. In all of the visualization tests reported here, the fuel simulant was a mixture of 84% Tetradecane (from Humphrey Chemical Co.), 15% 1-Methylnapthalene and 1% N N N'-N' Tetramethyl p-phenylenediamine (TMPD) (From Spectrum Chemical Co.) by mass. The chemicals were used and mixed as received. All controls and instrumentation were the same as those reported previously.

The fuel was usually prepared in a 1-2 liter batch. Because oxygen rapidly degrades the TMPD, the fuel tank was always purged with nitrogen prior to filling. Nitrogen was also bubbled through the mixture for 15-30 minutes prior to use.

Since the exciplex fluorescence process is very susceptible to oxygen quenching, it must be carried out in an oxygen-free environment. During any given test, steady state inlet conditions were achieved using air flow. Then, the air flow was stopped and nitrogen flow commenced. The entire system was then purged of air by flowing nitrogen for 2-3 minutes before recording any data.

The fluorescence images were recorded using a Princeton Instruments image intensifying camera employing a 578 x 384 pixel CCD. Exciplex fluorescence was stimulated by 355 nm light pulses from an Nd:YAG laser with a frequency tripling crystal, operating at 10 Hz with a pulse duration of $\sim$8 ns. Light pulses from the laser were passed through an iris to try to eliminate as much of the stray, second harmonic green (532 nm) light as possible, then through a 610 mm focal length quartz spherical lens and a 65 mm focal length quartz cylindrical lens to spread the beam into a sheet and to focus it down to $<$ 0.5 mm width in the test section.

For these experiments, the camera was always positioned to view the test section from the side. The camera and laser sheet were always at right angles. A Nikon 60 mm f/2.8 lens was used to image the test section on the camera CCD. A schematic of this setup is shown in Figure 2.

The vapor and liquid fluorescence signals were separated using a Corion P1-500-R-1952, 500 nm center/10 nm FWHM band pass filter for the green (liquid) signal and a Corion S25-400-R-0008, 400 nm center/25 mm FWHM band pass filter for the blue (vapor) signal. The procedure in a typical exciplex experiment was as follows:

1. Set up the directory structure for storing images on the computer.
2. Set the air flow to the desired value and adjust the inlet temperature set point.
3. Allow air to flow while the system heats up and reaches equilibrium.
4. View images with the CCD camera in real-time in order to focus and adjust its position.
5. Once the system is at equilibrium, position the green filter on the camera lens, and switch to nitrogen flow.
6. Having purged air from the system, begin spraying exciplex liquid.
7. Record a set of liquid images.
8. Switch the filter on the camera and record a set of vapor images.

Included in each set of liquid and vapor images was an image under the same conditions but with no liquid flow, which provided background data. All exciplex images were recorded with the room lights off.

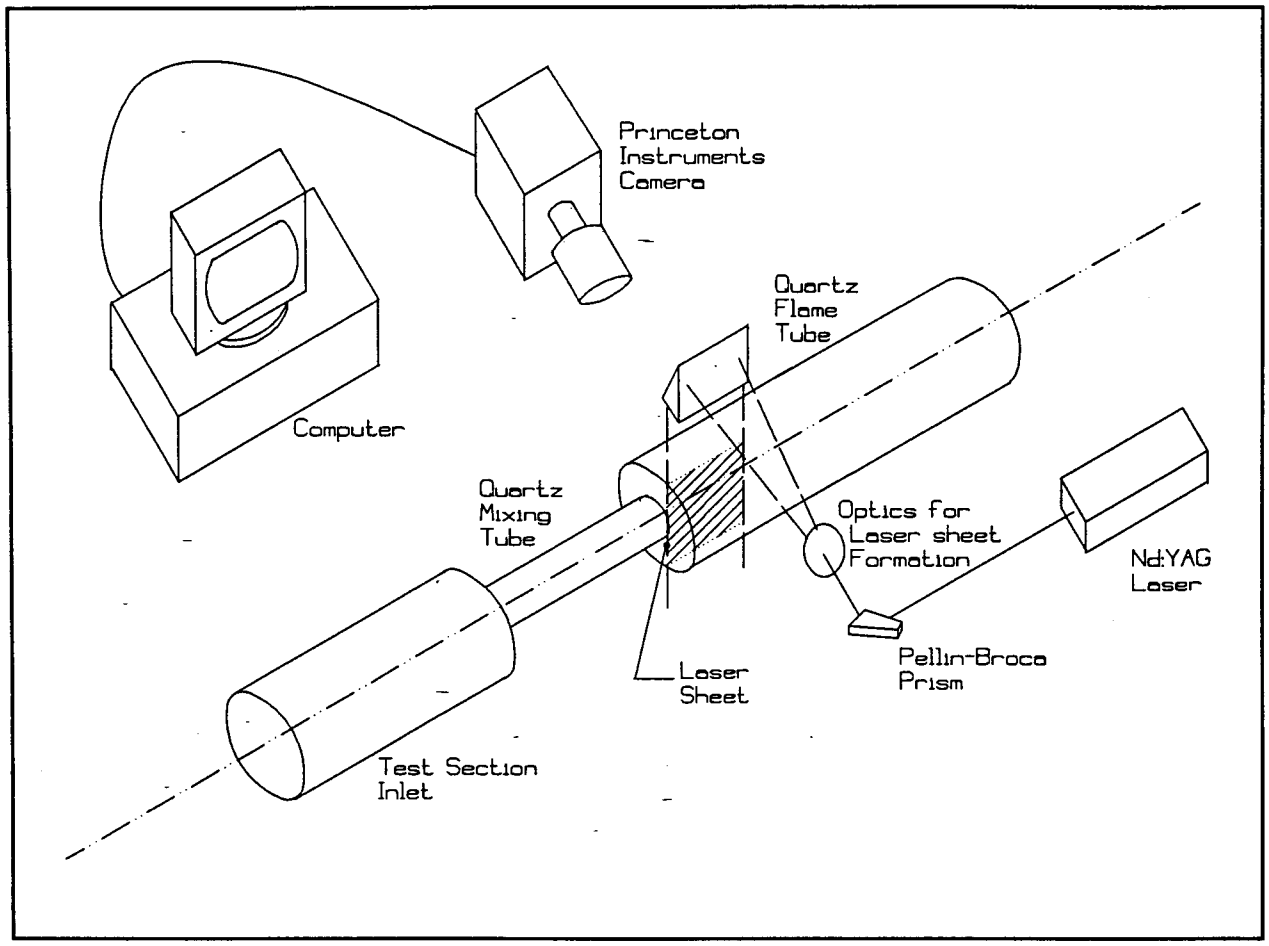


Figure 2 Experimental Setup

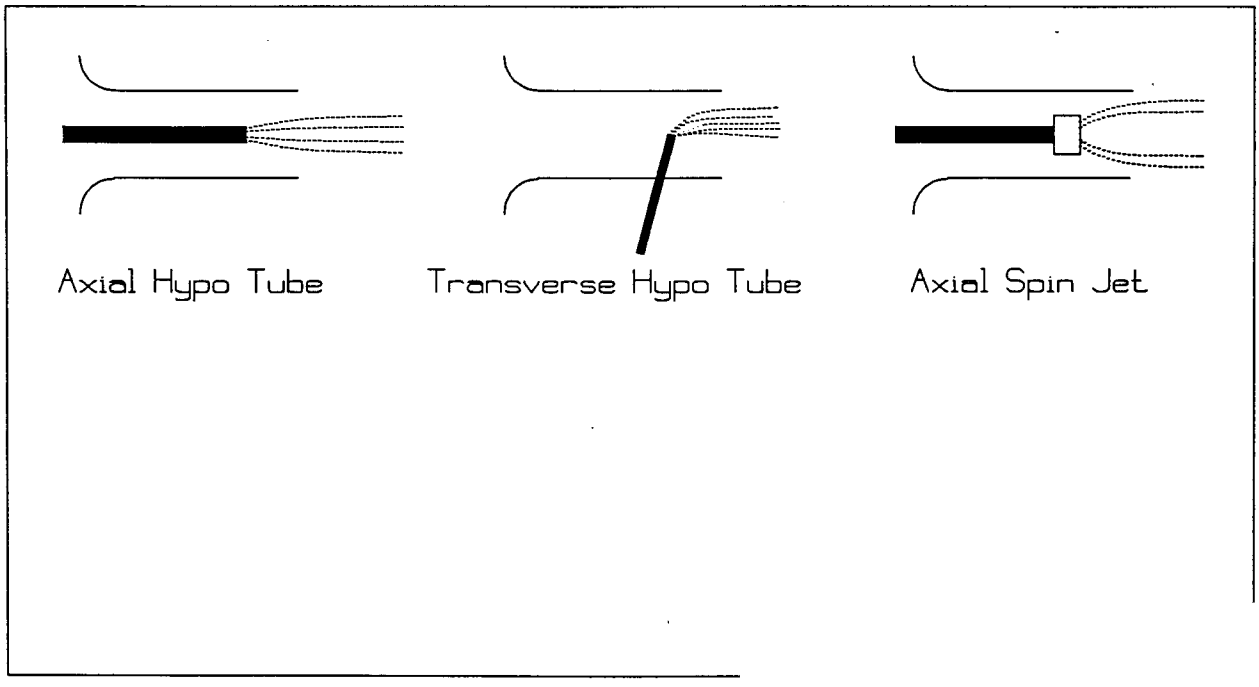


Figure 3 Fuel Injector Configurations

TABLE 1: Test Conditions

Case	Inlet Temp (°F)	System Pressure (psia)	Air(N_2) Flow Rate (lb/s)	Mixing Tube Air Speed (m/s)	Liquid Flow Rate (lb/hr) for Equivalence Ratios of:				
					0.4	0.5	0.6	0.7	0.8
A (High Inlet Temp)	950	64-66	0.049	100	4.84	605	7.26	\	\
B (Low Inlet Temp)	650	64-66	0.063	100	\	\	9.22	10.8	12.3

The above table summarizes test conditions for all experiments reported herein. Images recorded with the CCD camera are stored on disk and are later viewed and analyzed with the Princeton Instruments CCD Spectrometric Multichannel Analysis Software. Generally, a set of five liquid or vapor images was averaged. The background image was then subtracted to produce a final image. The software can assign colors to the various intensity levels in the image and display a false color image on the video screen. Eventually, a 35 mm color print of this image was made and a set of these prints was given to GE for most of the cases discussed in this report. A recently acquired color printer now enables direct production of a hard copy of the computer image; for most cases, such prints are included with this report.

III. TASK 1 - FUEL INJECTOR MODIFICATIONS

Using the 0.5" i.d. mixing tube and an axially positioned hypo tube injector, as shown in Figure 3, a series of liquid and vapor images were recorded in the flame tube at the exit of the mixing tube. The injector tube had a 0.040" o.d. and a 0.020" i.d. Images were recorded at both the high and low temperature conditions of Table 1. Results are shown in Figures 4 and 5. All the images in Figure 4 were recorded at the same camera and lens settings and at the same laser power. The images in Figure 5 were also all recorded at the same settings but those

EFFECT OF EQUIVALENCE RATIO

- T = 650 F
- Axial Hypo Tube
- Combustor at Mixing Tube Exit

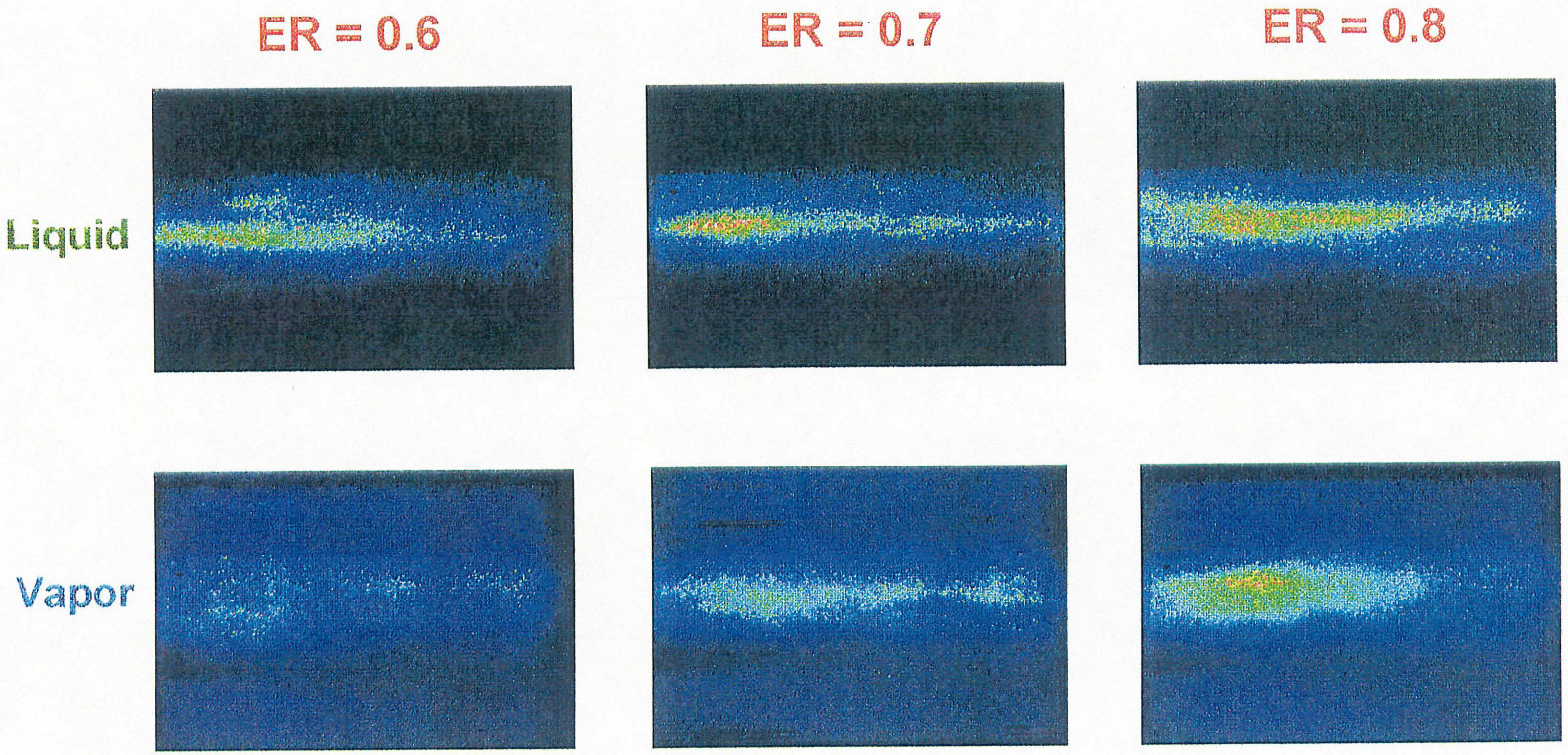


Figure 4 Axial Hypo Tube Images in the Flame Tube at the Mixing Tube Exit for 650 F Inlet and Three Equivalence Ratios

EFFECT OF EQUIVALENCE RATIO

- T = 950 F
- Axial Hypo Tube
- Combustor at Mixing Tube Exit

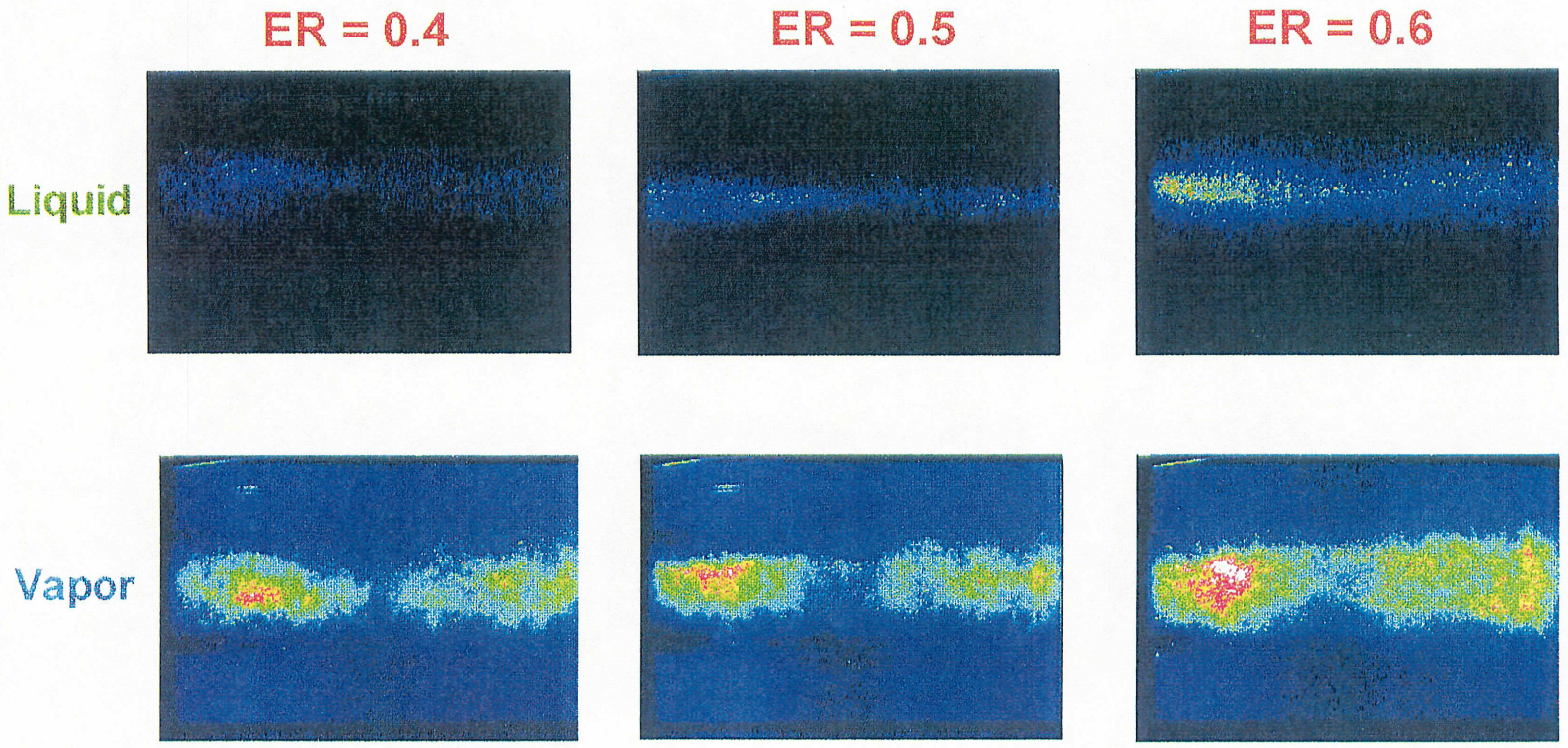


Figure 5 Axial Hypo Tube Images in the Flame Tube at the Mixing Tube Exit for 950 F Inlet and Three Equivalence Ratios

settings differed slightly from those used in Figure 4. In particular the camera gain used in Figure 5 is higher than that in Figure 4. Thus, no attempt to make quantitative comparisons between Figure 4 and 5 should be made.

With the axial hypo tube injector at the low inlet temperature (Figure 4), the liquid and vapor appear to be confined to a core region near the centerline. The liquid especially shows very little spreading, retaining a jet-like appearance after emerging from the mixing tube. At the high inlet temperature (Figure 5), the liquid and vapor are still heavily concentrated in a central core region, but the vapor shows some spreading to all portions of the flame tube.

In consultations with Paul Heberling and John Matulaitis at GE, it was decided to test an injector employing a Lee Spin Jet tip. This tip was fabricated onto a strut which adapted to the injector ring in the same way as did the axial hypo-tube. Liquid and vapor images were recorded at the mixing tube exit using this injector for the high temperature condition only, and the results are shown in Figure 6. In this case, because of differences in camera and lens settings, the original intensity values have been modified for direct comparison with Figure 5. With the spin jet injector under high inlet temperature conditions (Figure 6), there is more obvious spreading of vapor in the flame tube. Also, with the spin jet, there is much less liquid present, and, there is much more vapor present than there was in the hypo-tube injector case. The spin jet injector does a better job of producing a well-mixed, heavily vaporized region at the exit of the mixing tube.

A direct comparison of three injectors is shown in Figure 7 in which previously recorded images for a transversely mounted hypo tube injector are included. All images have been adjusted and scaled so quantitative comparisons are possible. Form this comparison, clearly the axial hypo tube performs worst, leaving much of the liquid unvaporized, and producing a very non-uniform vapor field. While the transverse hypo tube and the spin jet perform somewhat similarly, from the liquid images there is clearly less liquid remaining in the spin jet case. Non-uniformities in the spin jet vapor image were felt to be due more to laser sheet intensity

EFFECT OF EQUIVALENCE RATIO

- T = 950 F
- Lee Spin Jet
- Combustor at Mixing Tube Exit

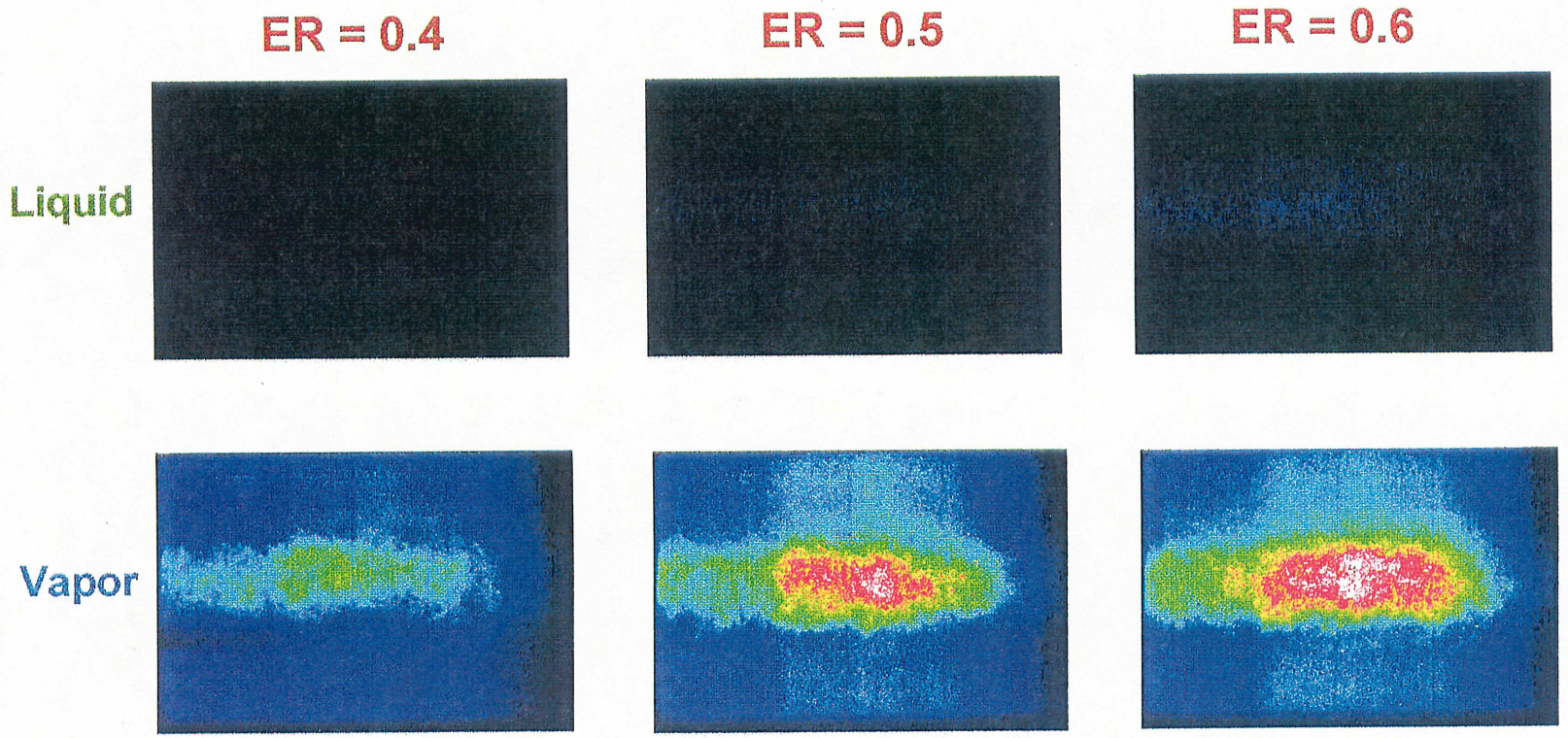


Figure 6 Lee Spin Jet Images in the Flame Tube at the Mixing Tube Exit for 950 F and Three Equivalence Ratios

FUEL INJECTOR COMPARISON

- T = 650 F
- ER = 0.6
- Combustor at Mixing Tube Exit

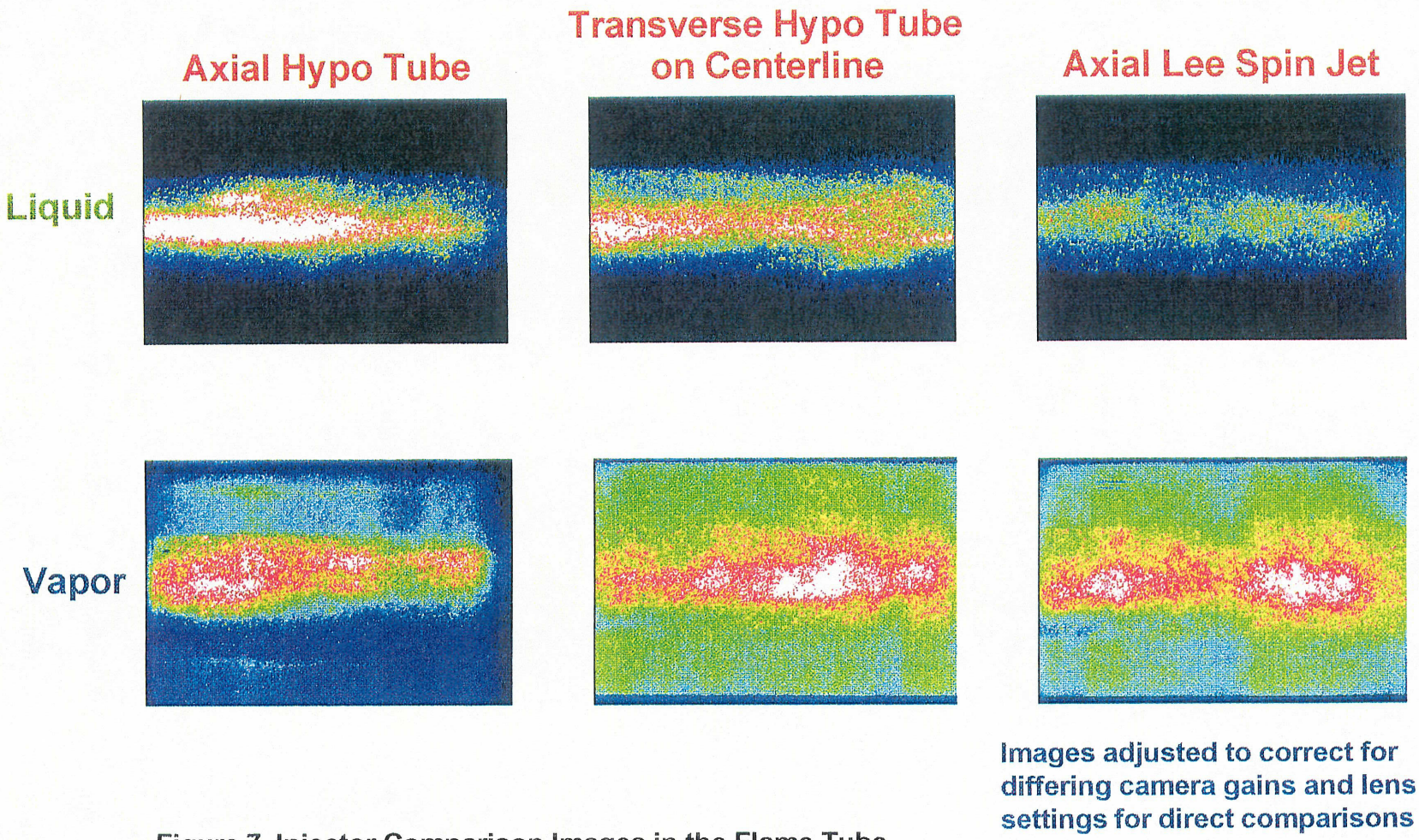


Figure 7 Injector Comparison Images in the Flame Tube at the Mixing Tube Exit for a 650 F Inlet and an Equivalence Ratio of 0.6

variations than to actual vapor non-uniformities. The spin jet was thus chosen for use in the mixing tube study of Task 2.

IV. TASK 2 - MIXER TUBE LENGTH REDUCTION

Having selected the Lee Spin Jet injector as providing the best mixing performance, experiments were conducted to record exciplex images along the length of the mixer tube, from the injector tip to approximately 0.5" upstream of the mixer tube exit. A schematic drawing of the image recording areas is shown in Figure 8. Liquid and vapor images were recorded for Positions A, B, C and D, each of which is about 24.5 mm (0.96") in extent. The laser sheet was set to extend over two of these regions at a time, thus minimizing the number of times the laser and optics would have to be moved. However, this introduced the problem that the laser sheet intensity variation is not the same over Region A as it is over Region B, and likewise for Regions C and D. The images though, with the exception of one or two cases, do not show large deficiencies due to this problem.

In a given test, the camera would be set to record images over Position A, with the laser sheet covering A and B. A set of liquid and vapor images would then be recorded for A, and with the system still operating (fuel flow off), the camera moved to record at Position B. Once the liquid and vapor images were recorded at Position B, the system would be shut down and allowed to cool, since positioning the laser sheet requires opening the test section. Then, the laser and optics would be moved and aligned to cover Positions C and D, and the camera moved on a traverse to Position C. Finally, the system would be re-started, brought to operating temperature as previously described, and liquid and vapor images recorded for Positions C and D.

Mixing tube images were recorded using the Lee Spin Jet injector at both the low and high temperature conditions, at the single equivalence ratio of 0.6, which is common to both inlet temperature conditions. These spin jet images, which were recorded under identical camera, lens and laser conditions, are shown in Figures 9 and 10. Also, mixing tube images

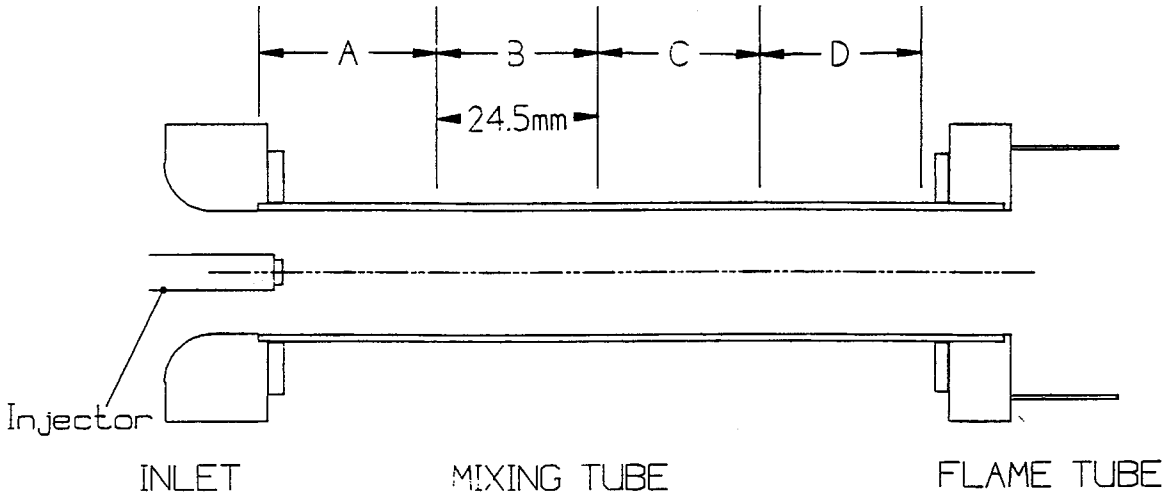


Figure 8 View Locations and Extent for Mixing Tube Images

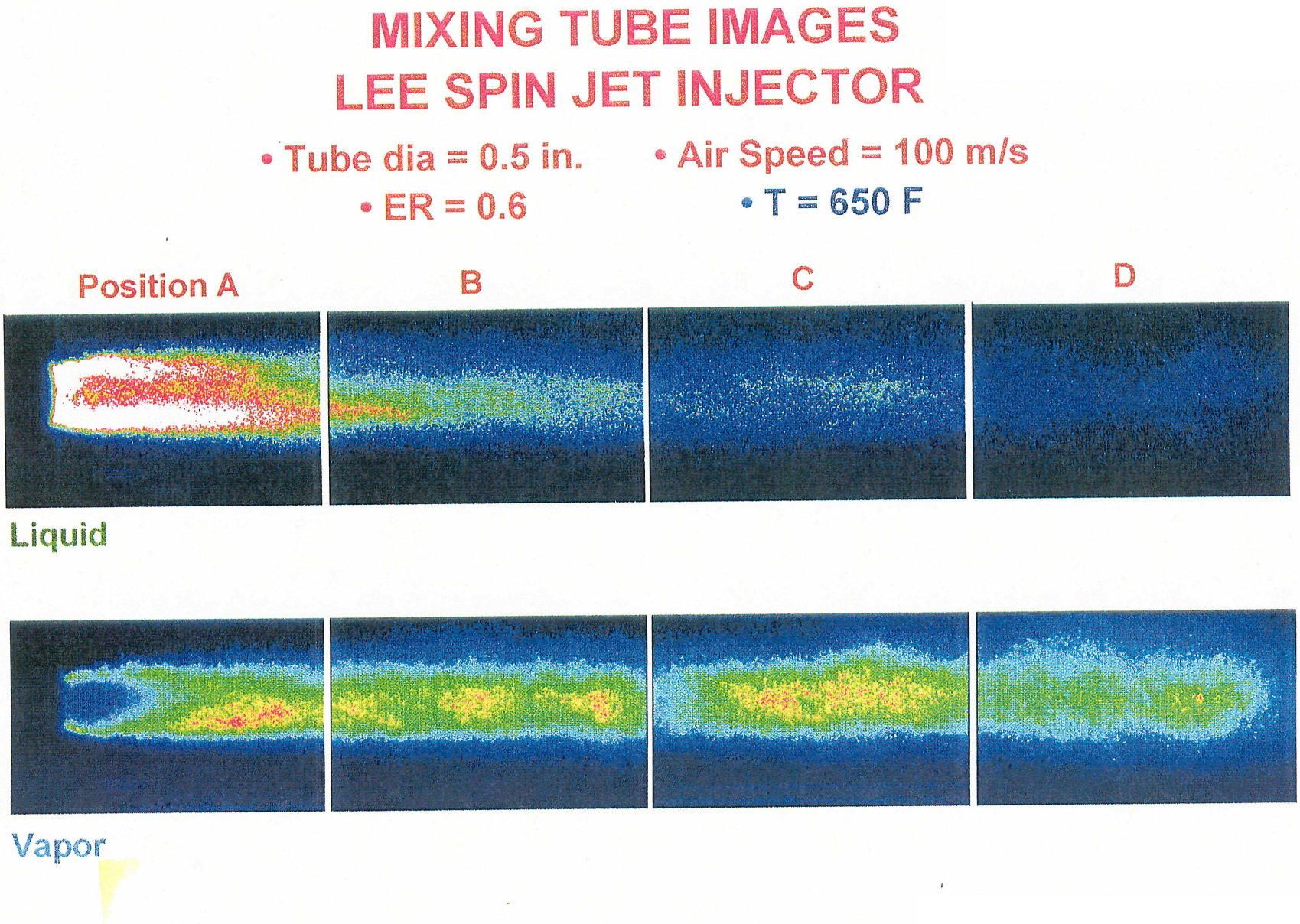


Figure 9 Mixing Tube Images with the Lee Spin Jet Injector for 650 F Inlet and an Equivalence Ratio of 0.6

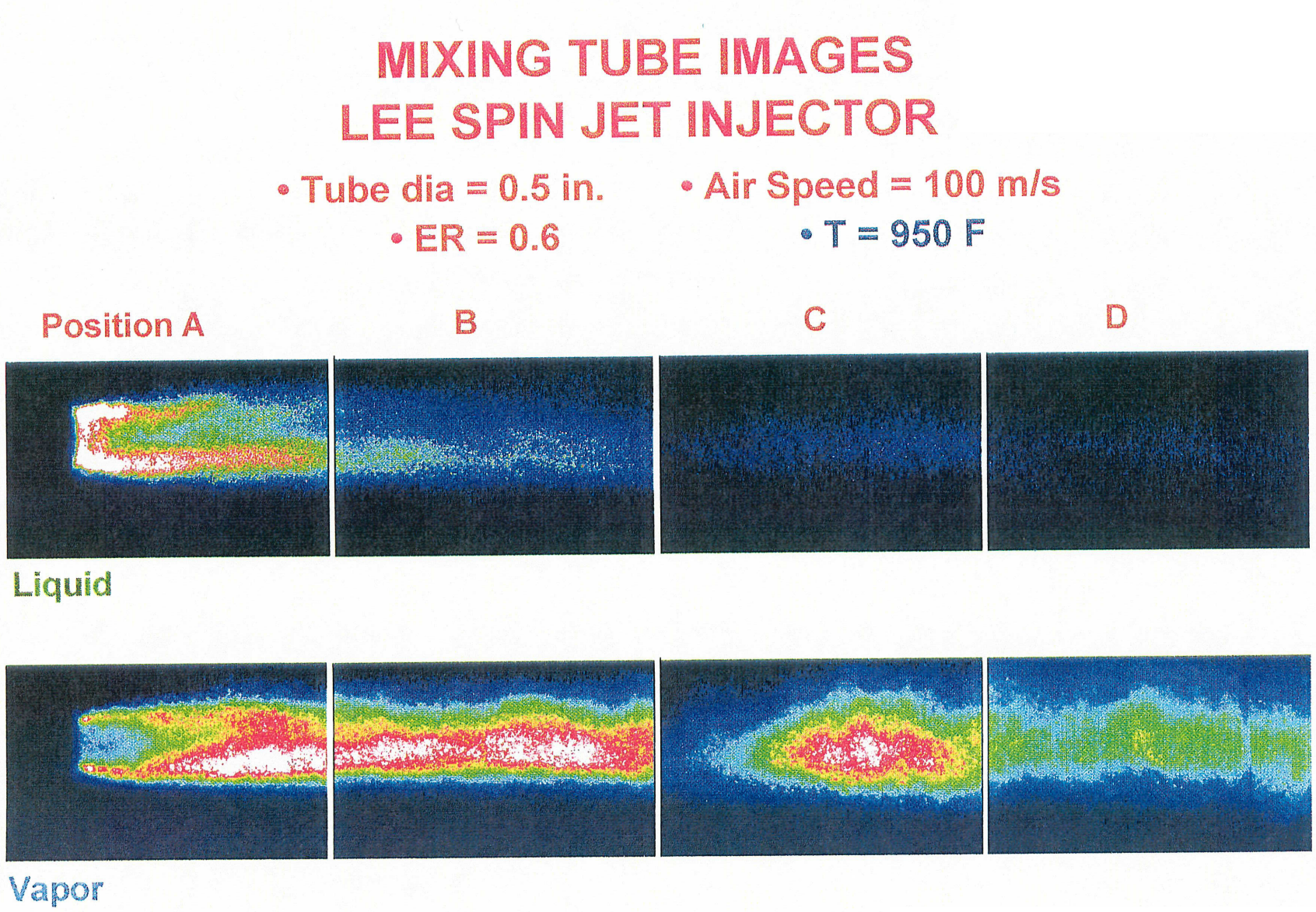


Figure 10 Mixing Tube Images with the Lee Spin Jet Injector for 950 F Inlet and an Equivalence Ratio of 0.6

were recorded for the transversely mounted hypo tube injector positioned with its tip on the flow centerline for the low temperature case, as shown in Figure 11, for comparison purposes.

Comparing Figures 9 and 10, one can see that there is more vapor present at each location at the higher temperature inlet condition than at the lower, as would be expected. There is also some indication of vapor hitting the upper wall of the mixer tube (Figure 9, Positions C and D), but this may have been due to a slight asymmetry in the construction of the nozzle support strut itself. It can be seen that very little liquid remains at the end of the mixing tube in the high temperature case. Note that there is a clear discontinuity in the vapor sequence of Figure 10 at Position C. While great care is exercised in aligning the laser sheet with the field of view of the camera, apparently in this case, there was poor alignment; the low intensity region at the upstream end of Figure 10C (vapor) was due to the alignment of the field of view with the edge of the laser sheet, rather than with the more uniform central portion of the sheet.

In an attempt to better quantify these results, a parameter proportional to the mass of liquid or vapor was calculated for each image and plotted against location in the mixing tube for the Spin Jet injector. For these calculations, it was assumed that the flow was axisymmetric about an axial line defined by the radial coordinate of the "center of mass" of the entire image. The results of these calculations are shown in Figures 12 and 13, where the disappearance of liquid along the length of the mixing tube is clearly shown. However, the trend of the vapor data is not so easily interpretable, for example, the vapor signal has a temperature dependence which we are presently investigating. The graphs along with the images do show that 98% vaporization cannot be achieved in the present mixing tube length, especially at the lower inlet temperature. In the high temperature case, there clearly appears to be greater vaporization but not enough to insure that only 2% or less of the liquid remains. Thus, it was concluded that there is no reason to shorten the mixing tube.

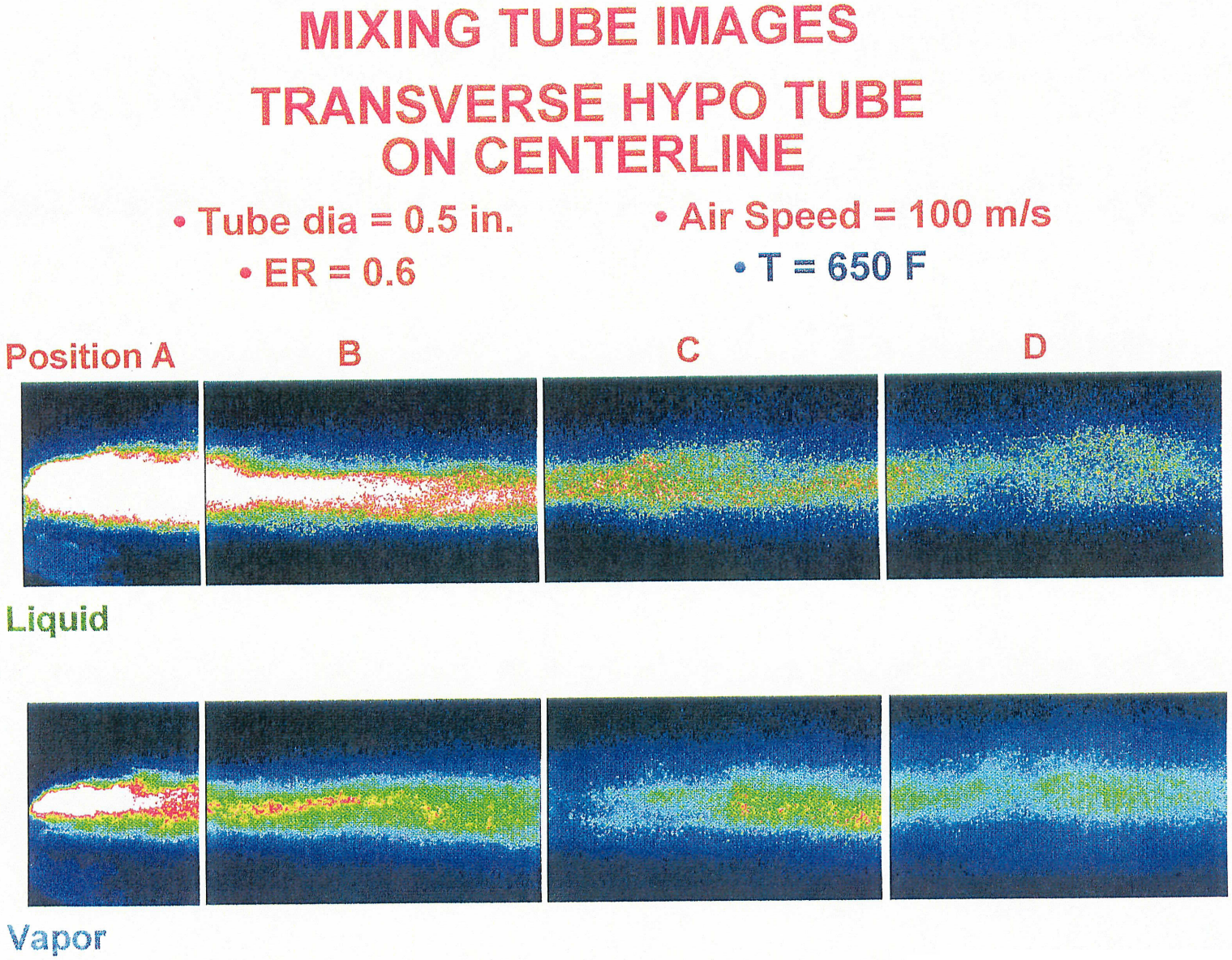


Figure 11 Mixing Tube Images with the Transverse Hypo Tube Injector on the Centerline for 650 Inlet and an Equivalence Ratio of 0.6

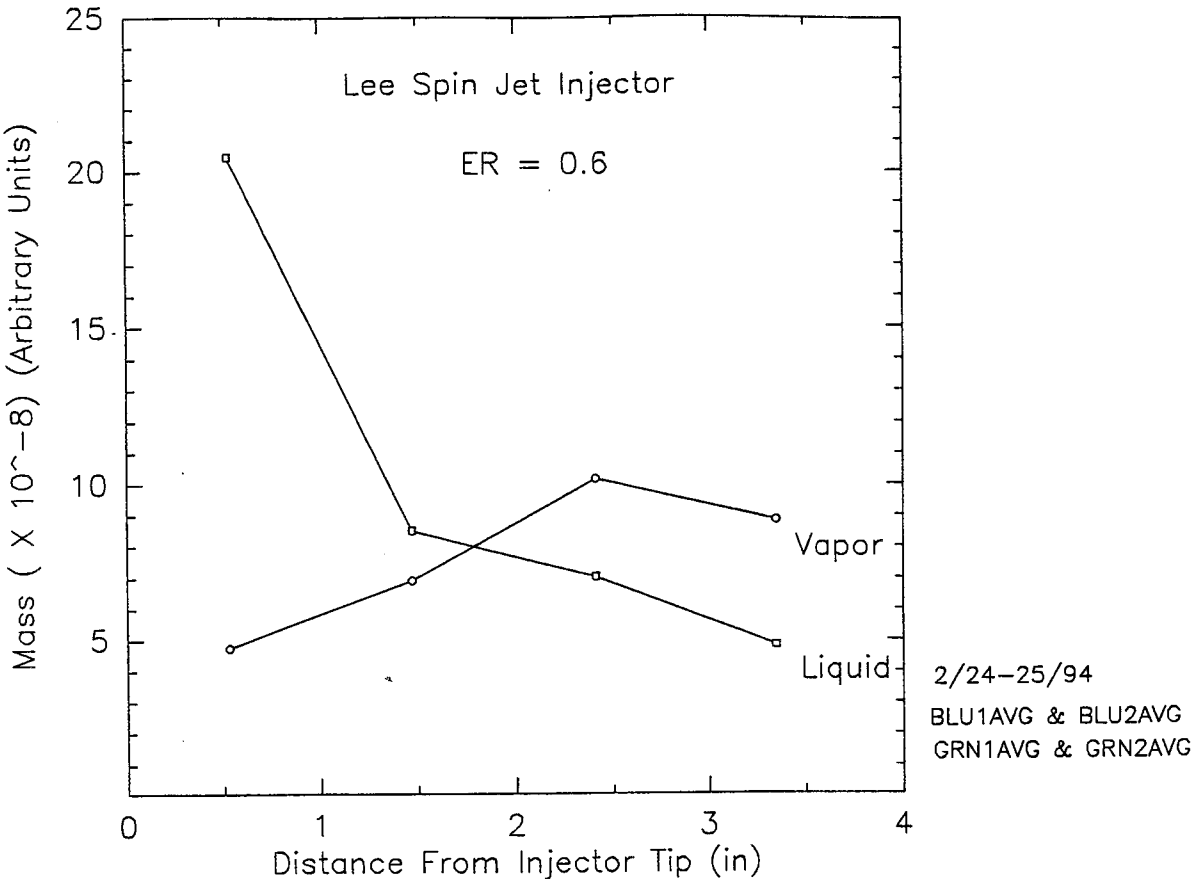


Figure 12 Calculated Mass Parameter Along the Mixing Tube with 650 F Inlet

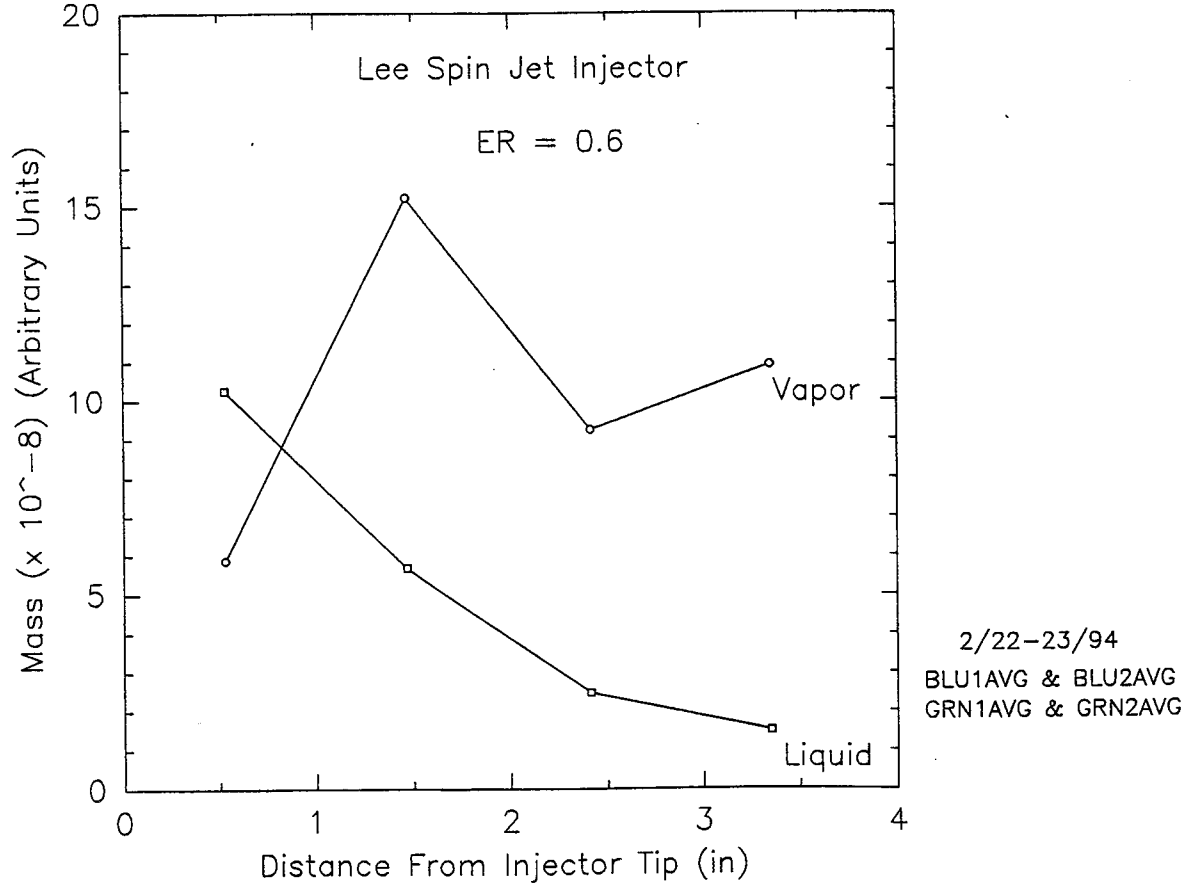


Figure 13 Calculated Mass Parameter Along the Mixing Tube with 950 F Inlet

V. TASK 3 - MIXER TUBE DIAMETER MODIFICATIONS AND TASK 4 - AIR INJECTION AT THE MIXER TUBE EXIT

The objective of Task 3 is to evaluate the effect of increased mixer tube diameter (while maintaining the area ratio for the flame tube diameter) on the degree of vaporization using the previously chosen injector and mixer tube length. In Task 4, this larger diameter system is to be used to evaluate the effect of air injection at the mixer tube exit on fuel mixing and vaporization.

To meet these objectives, a new system was designed and built which employs a 0.67" (17 mm) i.d. quartz mixing tube and a 1.46" (37 mm) i.d. quartz flame tube. The two tubes are held together by a stainless steel joiner, shown in Figure 14. This joiner incorporates internal passages which allow air injection to the mixer tube just upstream of its exit at the flame tube. The interchangeable ring shown in Figure 14 permits use of the system without air injection simply by using a ring with no holes through its wall. The new system is set up so that a portion of the main air flow can be bled off and separately controlled, metered, and pre-heated before it is injected.

In consultation with Paul Heberling and John Matulaitis at GE, however, it was decided to postpone running experiments using this larger diameter system in favor of further testing of three new injector tip geometries in the original, 0.5" diameter mixing tube.

VI. CONTINUED FUEL INJECTOR MODIFICATIONS

Discussions with Paul Heberling and John Matulaitis conveyed that there was keen interest in trying to develop a style of hypo tube injector tip which would perform as well as the Spin Jet tip. Various tip designs were discussed and GE fabricated and sent to us three for testing. These tips and their positioning are shown in Figure 15.

Exciplex imaging experiments were run with these three tips at an inlet temperature of 650°F and an equivalence ratio of 0.6. In the same manner as previously reported in Section IV,

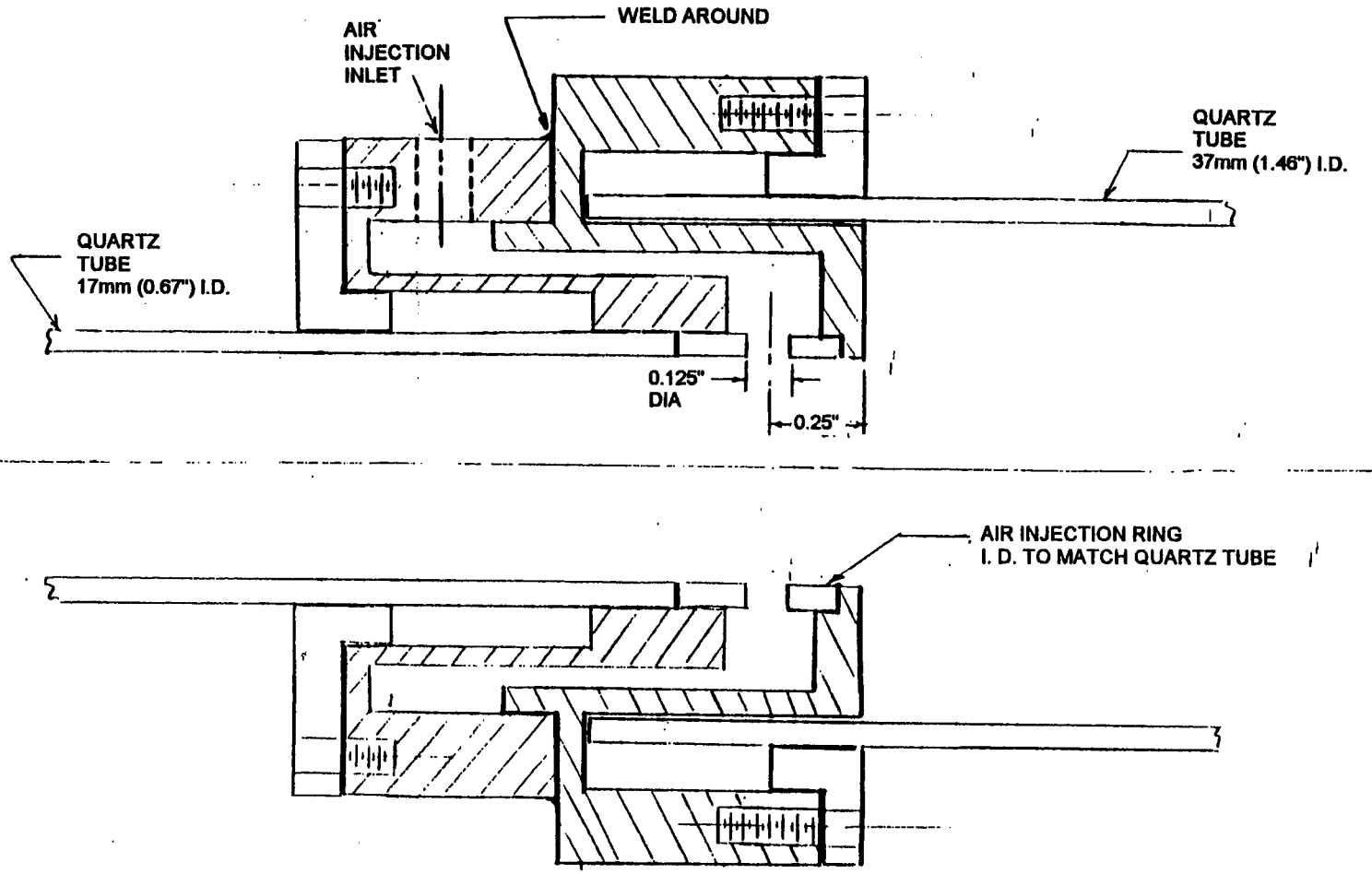
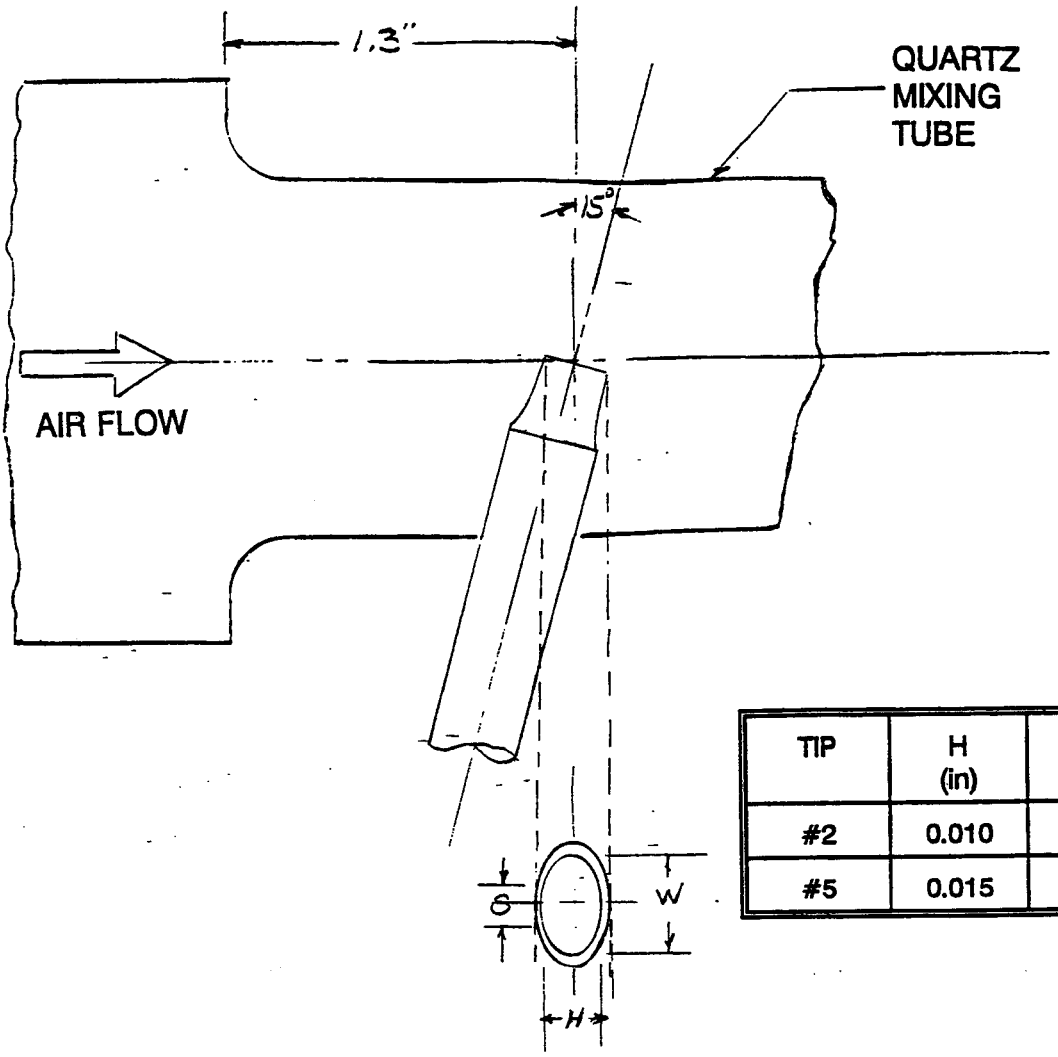
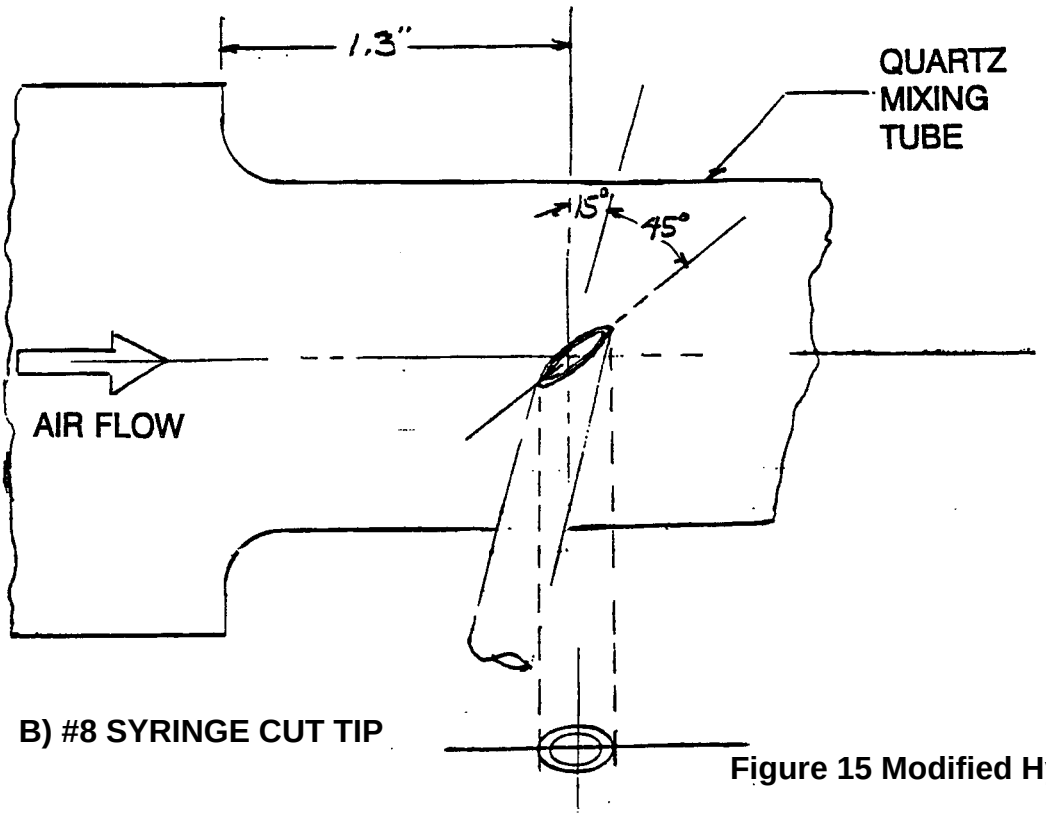


Figure 14 Transition Piece with Air Injection
for Larger Diameter Mixing Tube



TIP	H (in)	W (in)	S (in)
#2	0.010	0.026	0.016
#5	0.015	0.023	0.008

A) #2 & #5 OVALIZED FAN SPRAY TIPS



B) #8 SYRINGE CUT TIP

Figure 15 Modified Hypo Tube Injector Tips

liquid and vapor images were recorded along the mixing tube at positions A, B, C and D (Figures 16-18), as well as at the mixing tube exit in the flame tube (Figures 19-21) for each nozzle tip.

In these tests, the images are not the result of averaging a group of five laser shots, as in all previously shown images, but are individual records of a single laser shot. This was done because we came to realize that the result of averaging five images does not represent a true average in this highly turbulent flow.

In the mixing tube images, Figures 16-18, the field of view in the streamwise direction is about 24.5 mm (0.96") for positions B, C and D, and about 19.0 mm (0.75") for Position A. All the images were recorded under the same laser, camera and lens conditions. The intensity false-color scaling is the same in all the liquid images, and in all the vapor images (but not the same from liquid to vapor).

In the flame tube images (Figures 19-21), the streamwise field of view is about 42.7 mm (1.68"). The intensity false color scaling is the same in all flame tube images, and the same for liquid and vapor pictures, but is not the same as that in the mixing tube images. Note that the oddly shaped, glowing region around the base of the injector in the mixing tube images (Position A) is an image of the cement used to hold the injector in place. It either fluoresces itself when struck by the UV laser light, or is reflecting fluorescence from the brightly fluorescing fuel.

From reviewing the images, perhaps one of the most noticeable things about them is how similarly the three injectors seem to behave. In the mixing tube images, with the injector tip on the centerline, the images for all three injectors show that neither vapor nor liquid is significantly present in the bottom say quarter of the mixing tube. The hypo tube creates a wake region, and the fuel just never gets into that region, at least in the mixing tube. In general , the liquid and vapor are still confined to the middle region of the tube, though perhaps the #2 fan tip and the #8 syringe cut tip seem to spread the fuel out vertically a little better than does the #5 fan tip. It should be noted that we cannot tell from these images what the fuel distribution is like in the third dimension; however, perhaps we can conclude that the

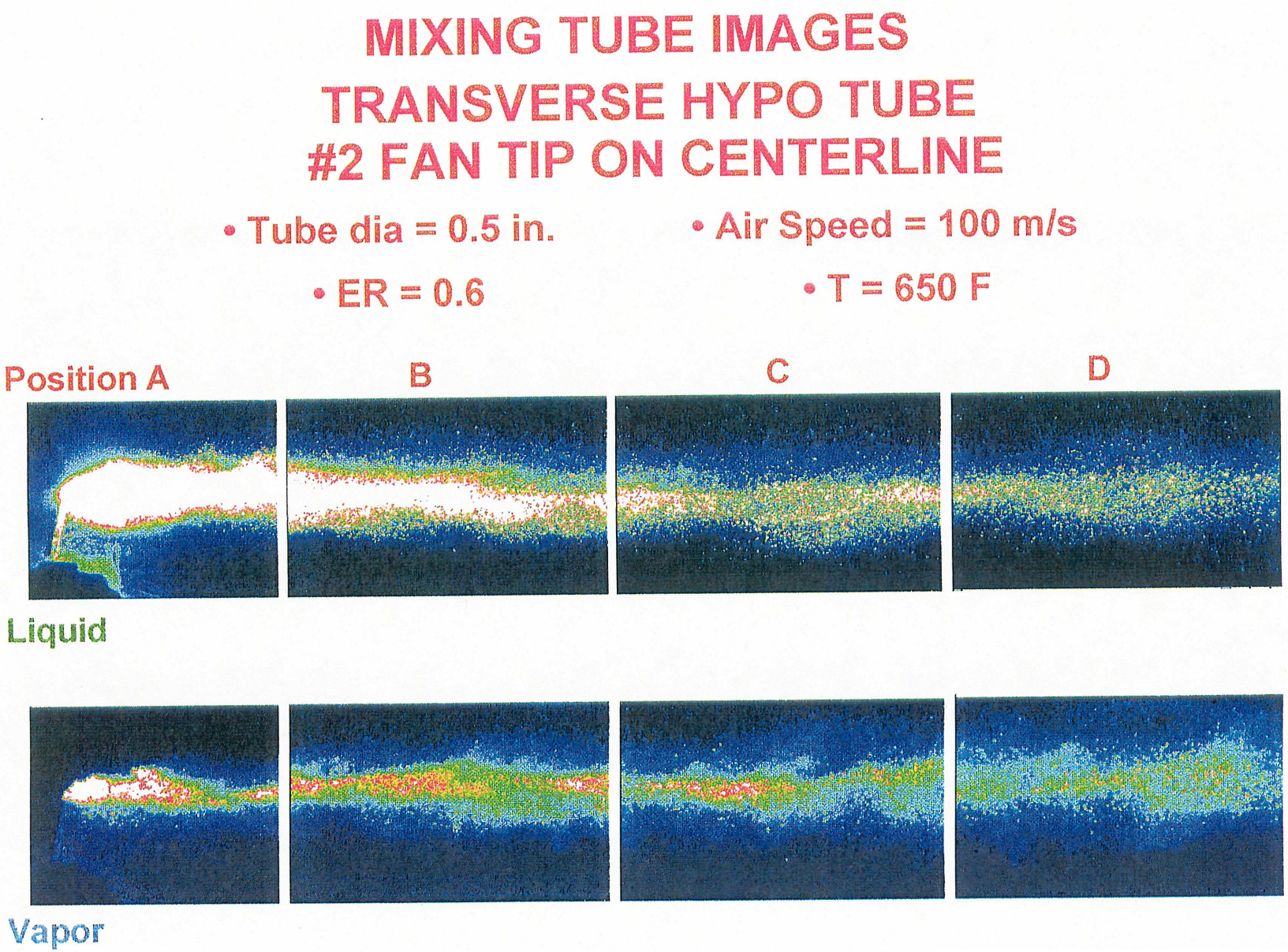


Figure 16 Mixing Tube Images with the #2 Fan Tip Hypo Tube Injector on the Centerline for 650 F Inlet and an Equivalence Ratio of 0.6

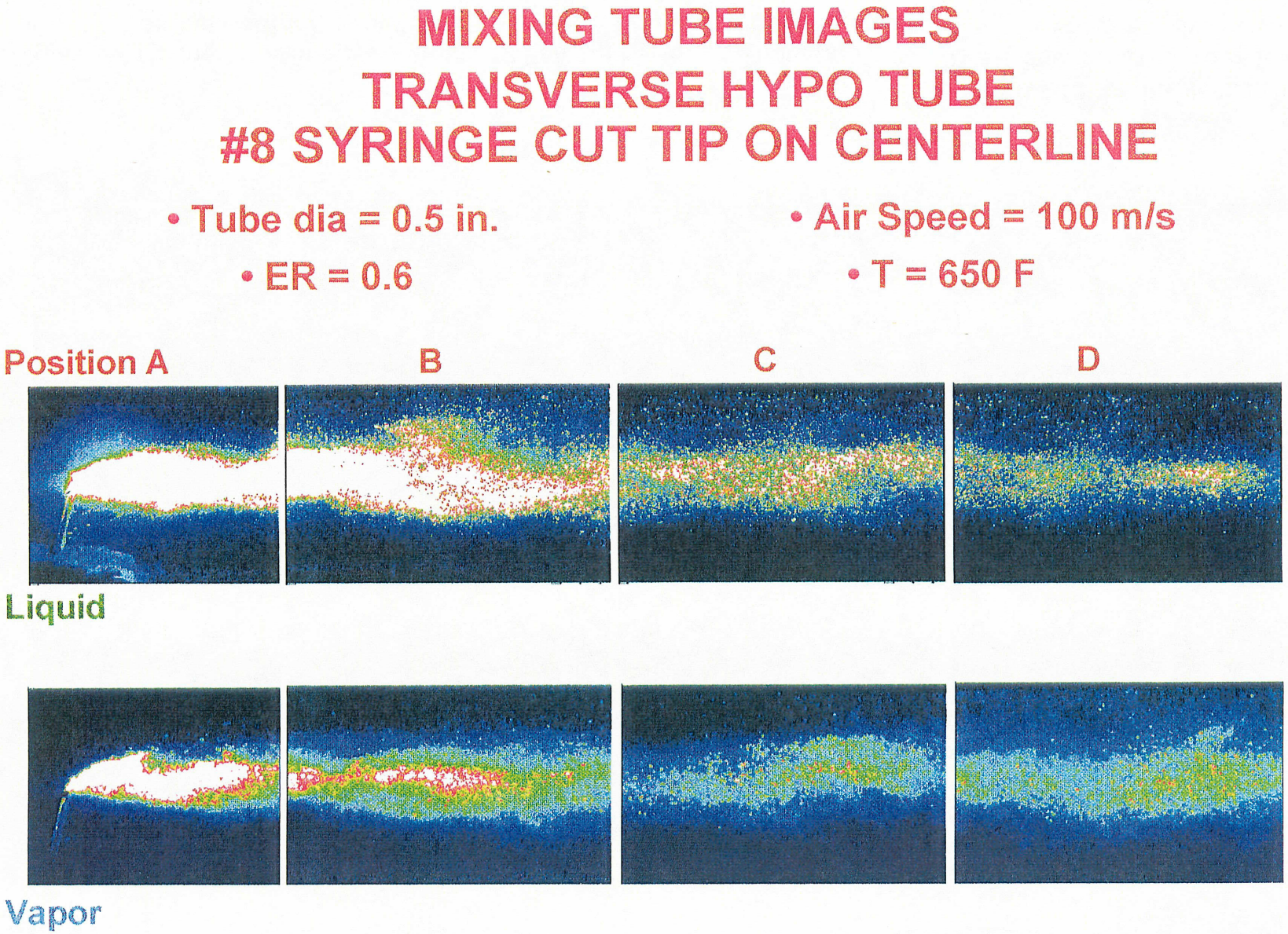


Figure 17 Mixing Tube Images with the #8 Syringe Cut Tip Hypo Tube Injector on the Centerline for 650 F Inlet and an Equivalence Ratio of 0.6

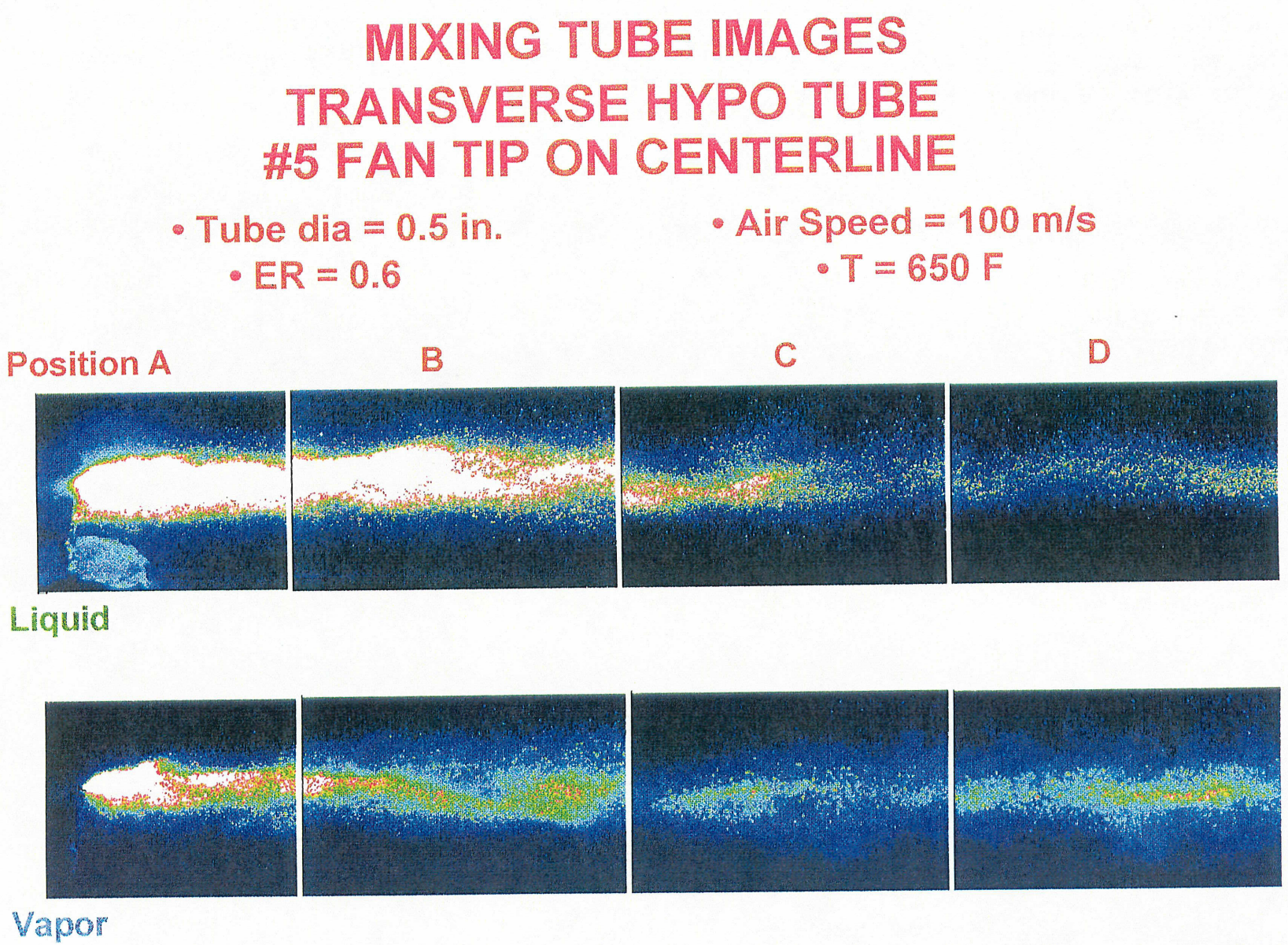


Figure 18 Mixing Tube Images with the #5 Fan Tip Hypo Tube Injector on the Centerline for 650 F Inlet and an Equivalence Ratio of 0.6

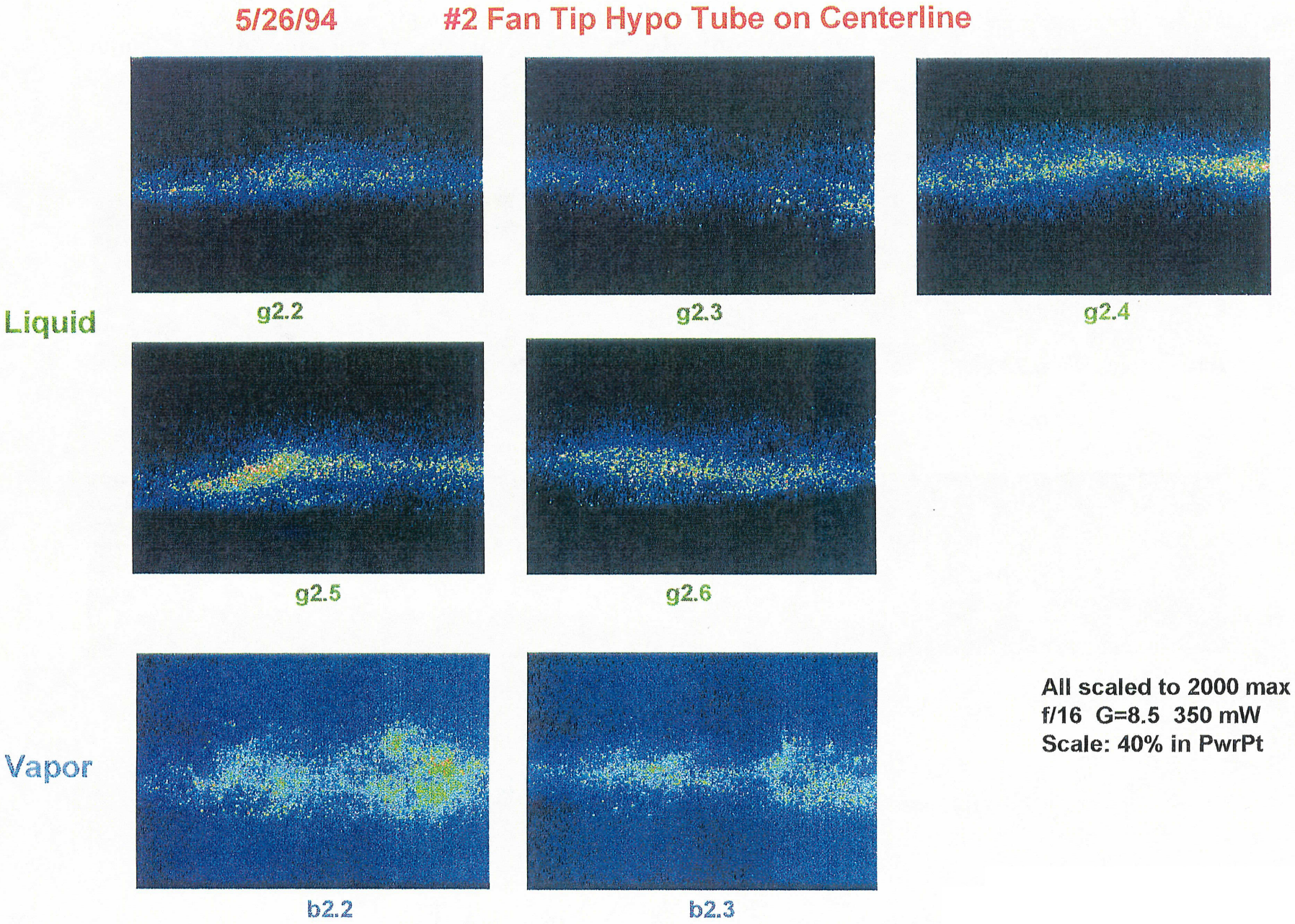


Figure 19 Flame Tube Images at the Mixing Tube Exit with the #2 Fan Tip Injector on the Centerline for 650 F Inlet and an Equivalence Ratio of 0.6

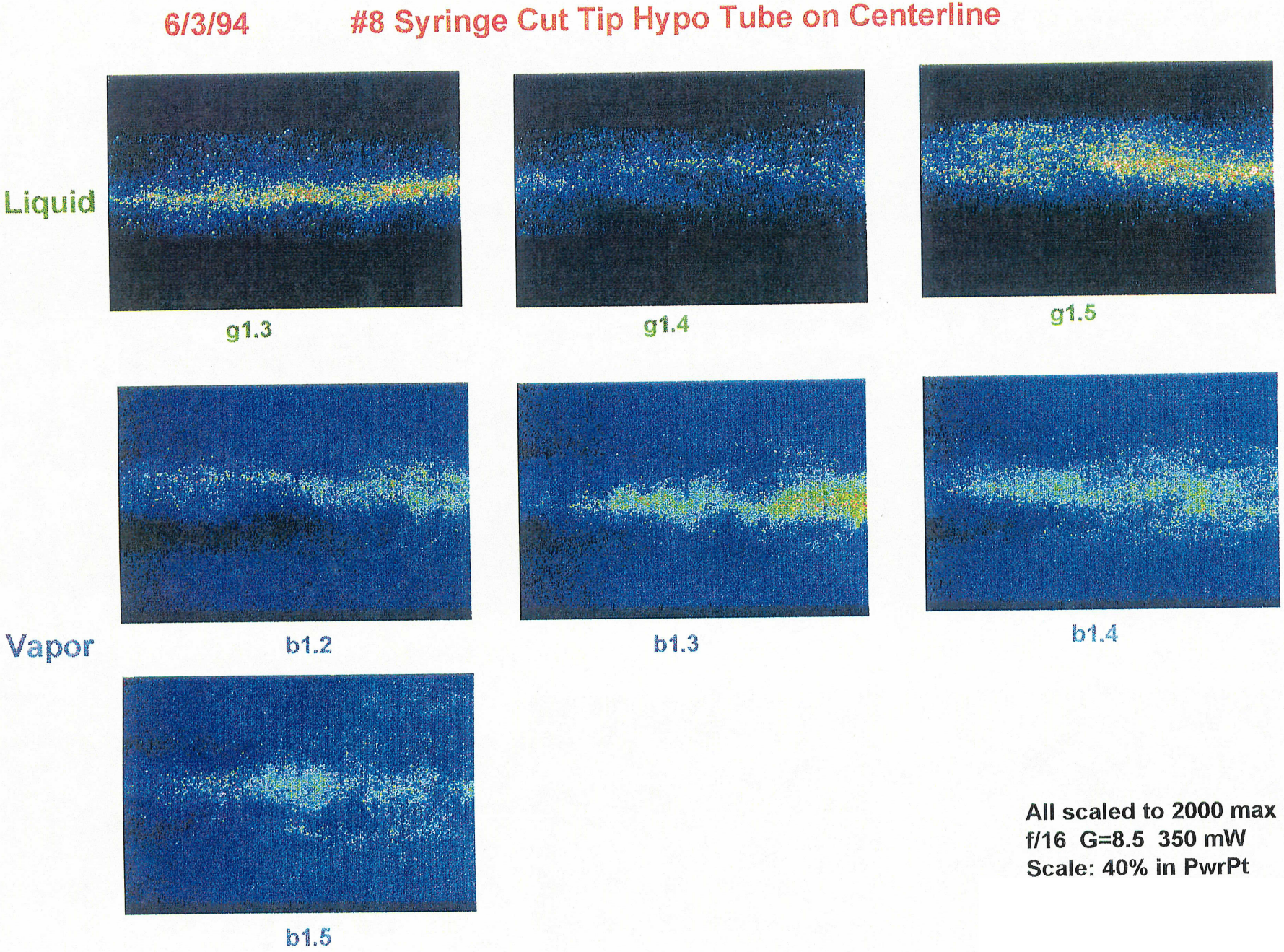


Figure 20 Flame Tube Images at the Mixing Tube Exit with the #8 Syringe Cut Tip Injector on the Centerline for 650 F Inlet and an Equivalence Ratio of 0.6

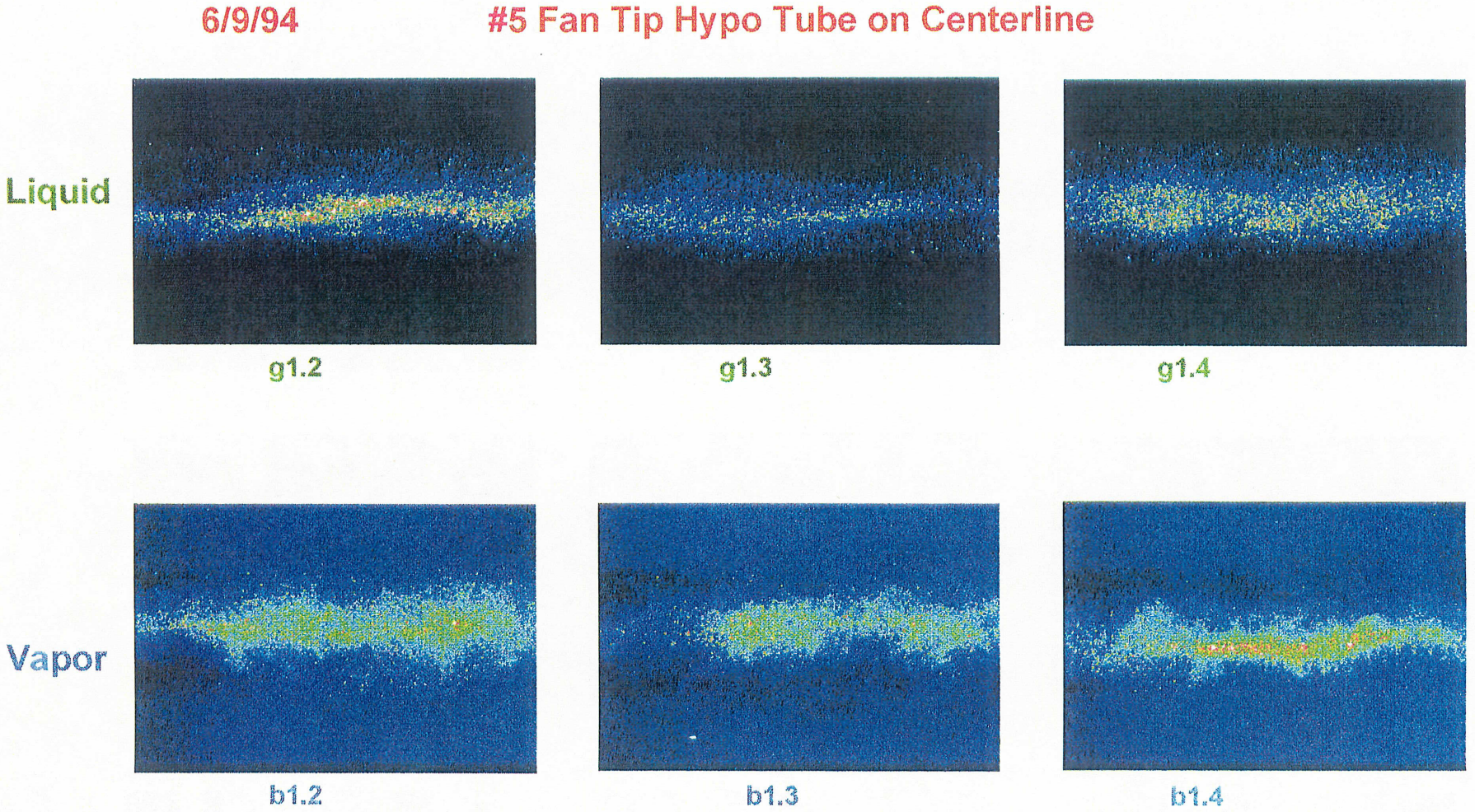


Figure 21 Flame Tube Images at the Mixing Tube Exit with the #5 Fan Tip Injector on the Centerline for 650 F Inlet and an Equivalence Ratio of 0.6

that direction than does the syringe-cut tip, simply by virtue of their shape. The combustor images (at the mixing tube exit) also appear strikingly similar. In all cases, the remaining liquid is clearly confined to a central core region. The vapor does spread to most regions of the field of view, but is still noticeably more concentrated near the centerline.

From visual observation of the injection process in the mixing tube with the laser firing, it was seen that the fuel stream generally dances around wildly but does seem to favor the top half of the tube, as shown in the images. Also, it seemed that some fuel always hit the upper wall of the mixing tube before reaching its exit. Confirmation of this can be seen in the last vapor images of Figures 16 and 17.

The main conclusions from this portion of the study are that no one hypo tube injector tip configuration performs much better than any other. Perhaps averaging over many images would reveal some clear distinction; development of an averaging method will be discussed in the next section. Also, at least with the tips positioned as they were, on the centerline, the fuel is not distributed well in the combustor. Instead, the liquid, and to a lesser extent, the vapor and fuel tend to remain confined to a core, jet-like region near the centerline.

VII. AVERAGING OF IMAGES

Because of the highly turbulent nature of this flow, individual images recorded with a single laser shot can vary considerably. Thus, average images are more useful and meaningful for comparisons with predictions and actual combustor performance. However, having observed many images which were the result of averaging five individual images, it was concluded that the result of averaging only five images was quite inadequate to yield a true average. Indeed, by investigating the standard deviation and average intensity from regions of these images, it was concluded that the number of images required to give a reasonable average representation would make the image acquisition and processing procedure impractical. For example, consider the images of Figure 9D. A small (10 pixels x 10 pixels) square region near the center of each of the

five images which were averaged to produce the liquid and vapor images shown here was extracted and analyzed. Assuming variations in intensity of these large "pixels" are normally distributed about the true average from laser shot to laser shot, these samples were then used to determine the number of sample images required to say with a 95% confidence interval that the calculated average intensity lies within 10% of the true average. In the case of the vapor image, at least 10 images are required. And in the case of the liquid image, at least 50 images are required. Other such investigations showed that it is not unusual to find that 50 to 100 images are required.

Even with a computer running at 33 MHz, given the present capabilities of the camera and the CSMA software, the time required to acquire and store 50 images at a single test condition is prohibitive (approximately 15-20 minutes) since the present nitrogen supply capabilities, with 12 bottles, allow for run times on this order. Additionally, the time required to average and otherwise process such a large number of images would be very large.

While it is understood that only acquisition and saving of individual images enables the calculation of standard deviations, these time limitations presently seem insurmountable.

Recently, some work has been done utilizing features of the Princeton Instruments camera and associated hardware which enable "on-chip" (meaning on the CCD chip) accumulation of images. The camera allows separate control of gating (which turns the intensifier on and off) and shuttering (which opens the camera to light). In recent tests, the camera has been gated for a few microseconds around each laser pulse, and shuttered for between 5 and 30 seconds. With the laser operating at 10 Hz, this allows the accumulation of 50 to 300 laser shot records on the chip. Once the shuttering time expires, the hardware stores the resulting image on disk. The problem which arises in using this method is that of properly choosing the number of accumulations, the camera gain, and lens aperture setting to insure a meaningful average and to be sure that an image is recorded with a good signal-to-noise ratio, while also being sure that the pixels are not saturated. This is particularly difficult to achieve with a single group of settings in

a flow with greatly varying liquid and vapor concentrations, as occurs in the mixing tube.

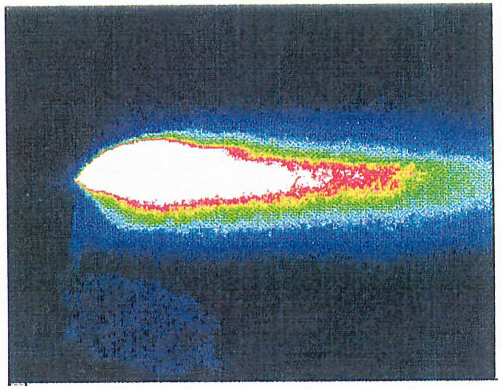
The on-chip accumulation technique for creating an average image has been used to record images at two locations in the mixing tube, at the low inlet temperature condition, at an equivalence ratio of 0.6. Figure 22 shows both liquid and vapor images recorded at the mixing tube Position A under the same conditions of laser power, and camera and lens settings. Figures 22A and C are images resulting from exposure to 50 laser shots, while Figure 22B and D are the result of exposure to 100 laser shots. The intensity values in A & C have been multiplied by 2 so that when the intensities are scaled for the color scheme, A & C can be compared with B & D. One of the more noticeable features of these images is that the edges of the liquid or vapor envelope are now smooth, unlike those in the images of Figure 18 where the unsteadiness and turbulence of the flow are recorded as fluctuations and eddy-like structures on the boundaries. Comparing images A & B, it can be seen that the distributions of liquid depicted in the images are remarkably similar visually. The similarities are even more striking in the vapor images C & D. At this point, no analysis has been done to more quantitatively determine the strength of the similarities. But it does appear that, at least for these flow conditions at Position A, accumulating 100 laser shots is adequate to record an accurate average image.

Figure 23 shows liquid images and Figure 24 vapor images, recorded at the mixing tube Position D under the same conditions of laser power, and camera and lens settings. In both figures, images A, B, & C correspond to accumulating 100, 200 and 300 laser shots, respectively. Again, in order to be able to compare the three images after false-color scaling, the intensities in image A were multiplied by 3, and those in image B by 1.5. Visual inspection of the liquid images shows that the liquid boundary in image 23B is noticeably smoother than that in image 23A; the change is not as noticeable from B to C. The core of the liquid region looks similar in images A and B, but there appear to be many more pixels with intensities greater than 100 in image C than in either A or B. Similar comments can be made about the vapor images of

6/29/94 Mixing Tube Images @ Position A #5 Fan Tip Hypo Tube Injector on Centerline

On Chip Accumulation of Images

Liquid Images



A

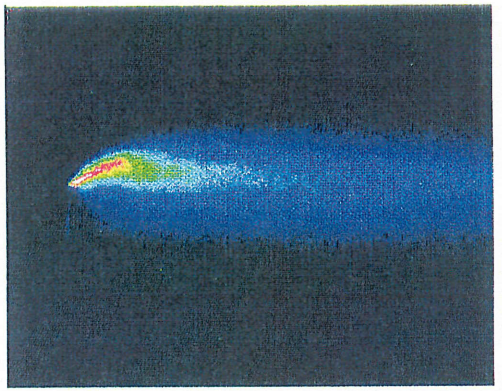
g3

50 shots f/32 G=2.00 100mW Imax=14560

(multiplied by 2)

Background subtracted
Clipped at zero intensity
Images cut to O. D. of tube
Flow from left to right
Liquid scaled to 2500 max I
Vapor scaled to 1000 max I
Laser Power = 100 mW
+10/-0 mW
WinView Zoom Factor: 1.065
PwrPnt Scale: 50%

Vapor Images

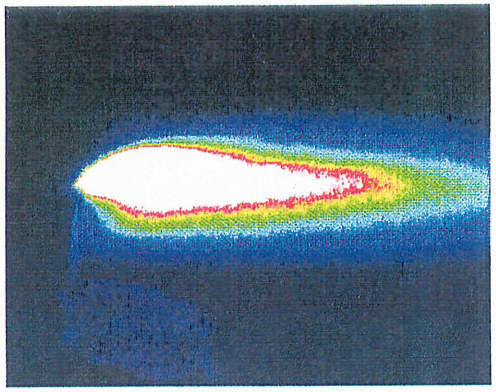


C

b3

50 shots f/32 G=2.00 100mW Imax=645

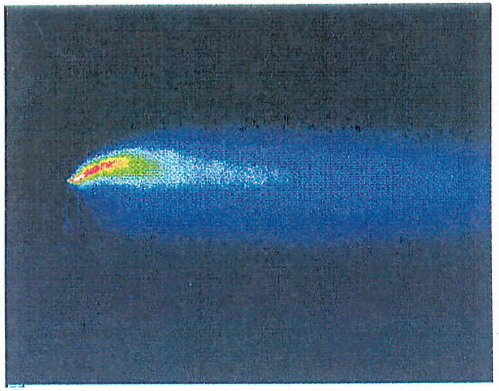
(multiplied by 2)



B

g4

100 shots f/32 G=2.00 100mW Imax=16320



D

b4

100 shots f/32 G=2.00 100mW Imax=1195

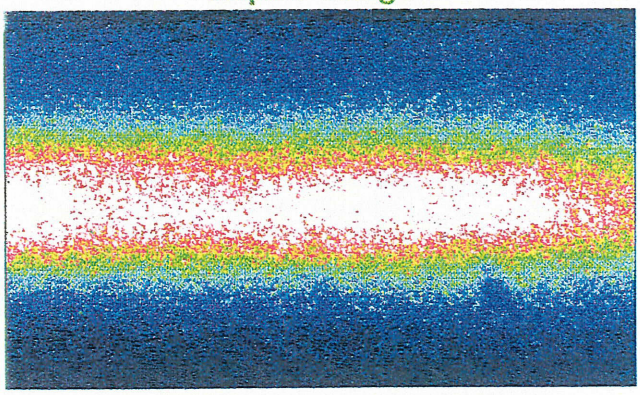
Figure 22 Mixing Tube Images @ Position A with the #5 Fan Tip Injector Using On-Chip Accumulation for Averaging

6/30/94

Mixing Tube Images @ Position D #5 Fan Tip Injector on Centerline On Chip Accumulation of Images

Liquid Images

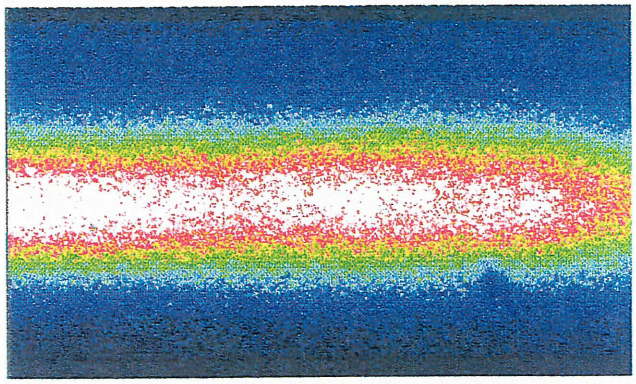
A



g1

100 shots f/32 G=2.00 100mW Imax=73
(multiplied by 3)

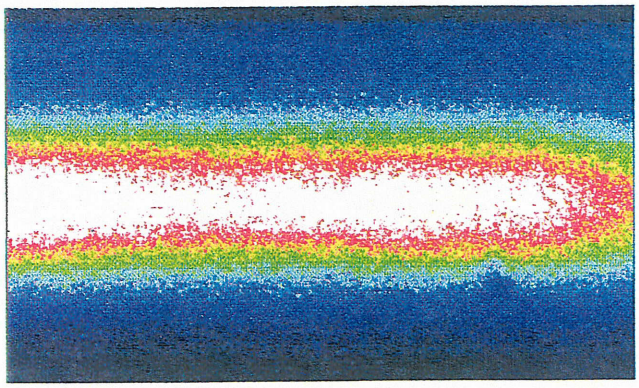
B



g2

200 shots f/32 G=2.00 100mW Imax=121
(multiplied by 1.5)

C



g3

300 shots f/32 G=2.00 100mW Imax=167

Background subtracted
Clipped at zero intensity
Images cut to O. D. of tube
Flow from left to right
Liquid scaled to 100 max I
Laser Power = 100 mW +10/-0 mW
WinView Zoom Factor: unchanged
PwrPnt Scale: 50%

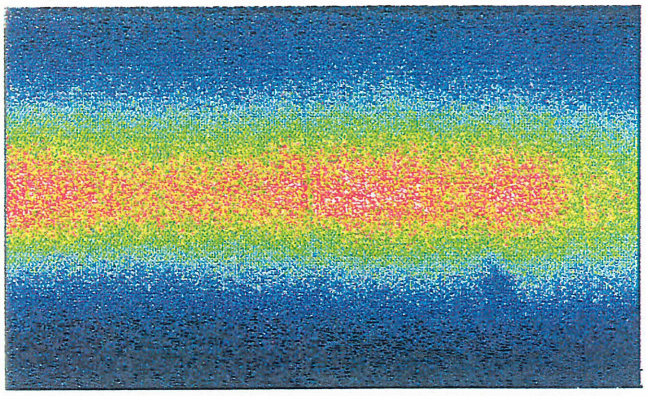
Figure 23 Mixing Tube Liquid Images @ Position D with the #5 Fan Tip Injector Using On-Chip Accumulation for Averaging

6/30/94

Mixing Tube Images @ Position D #5 Fan Tip Injector on Centerline On Chip Accumulation Of Images

Vapor Images

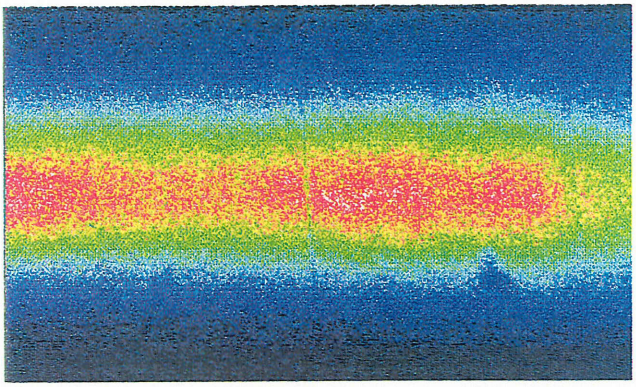
A



b1

100 shots f/32 G=2.00 100mW Imax=31
(multiplied by 3)

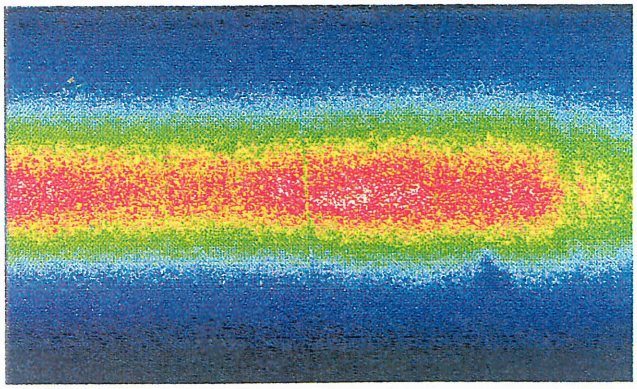
B



b2

200 shots f/32 G=2.00 100mW Imax=70
(multiplied by 1.5)

C



b3

300 shots f/32 G=2.00 100mW Imax=113

Background subtracted
Clipped at zero intensity
Images cut to O. D. of tube
Flow from left to right
Vapor scaled to 75 max I
Laser Power = 100 mW +10/-0 mW
WinView Zoom Factor: unchanged
PwrPnt Scale: 50%

Figure 24 Mixing Tube Vapor Images @ Position D with the #5 Fan Tip Injector Using On-Chip Accumulation for Averaging

Figure 24. It may be that a larger number of accumulations, perhaps 200-300, are necessary to obtain an accurate average image at the downstream end of the mixing tube. Further studies are needed to clarify this question. It will also be necessary to investigate this point for image recording in the combustor at the mixing tube exit.

While we realize that standard deviation information is lost when using this averaging technique, it does appear to yield accurate average information and is a very practical method. It is currently planned that all future images will be acquired using this method.

VIII. CONCLUSIONS

Laser-induced exciplex fluorescence imaging has been used to study the vaporization and mixing characteristics of various IMFH configurations. Initial tests found that an axial hypo tube injector left most of the liquid and vapor confined to a central core region of the flame tube at both high and low inlet temperatures. A Lee spin jet injector was found to produce a better mixed, more vaporized fuel-air region at the exit of the mixing tube.

Using the spin jet injector, it was found that the mixing tube length could not be reduced from its present 4.5" length without reducing the amount of vaporization at the mixing tube exit well below the desired 98%.

During this contract period, a transparent, larger diameter mixing tube/flame holder configuration, which provides for air injection, was designed and built. Its use, however, was delayed in favor of further testing of other injector configurations.

In an effort to design an injector tip which would produce mixing and vaporization characteristics similar to those of the spin jet, but which would be simpler to produce and implement, the sprays generated by three new hypo tube injector tips were studied. Two were ovalized tips designed to produce a fan spray and one was a syringe cut tip. All were mounted transverse to the flow with the tip on the flow centerline. The main conclusion. however, is that no one of these hypo tube-style tips performs very much better than any other. In general they

all do a rather poor job of spreading the fuel to create a uniform field, especially at the low inlet temperature condition. The fuel mixture tends to remain confined to a central core region.

Finally, it was concluded that for meaningful comparisons of imaging data with combustor performance test data, averaging over many images is required. A technique employing on-chip accumulation of images for averaging has been tried and appears to be an excellent, practical method of obtaining average images in these highly turbulent flows.

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13. ABSTRACT ***(Maximum 200 words)***

In LET Task 10, critical development issues of the HSCT lean-burn low emissions combustor were addressed with a range of engineering tools. Laser diagnostics and CFD analysis were applied to develop a clearer understanding of the fuel-air premixing process and premixed combustion. Subcomponent tests evaluated the emissions and operability performance of the fuel-air premixers. Sector combustor tests evaluated the performance of the integrated combustor system. A 3-cup sector was designed and procured for laser diagnostics studies at NASA Glenn. The results of these efforts supported the earlier selection of the Cyclone Swirler as the pilot stage premixer and the IMFH (Integrated Mixer Flame Holder) tube as the main stage premixer of the LPP combustor. In the combustor system preliminary design subtask, initial efforts to transform the sector combustor design into a practical subscale engine combustor met with significant challenges. Concerns about the durability of a stepped combustor dome and the need for a removable fuel injection system resulted in the invention and refinement of the MRA (Multistage Radial Axial) combustor system in 1994. The MRA combustor was selected for the HSR Phase II LPP subscale combustor testing in the CPC Program.

14. SUBJECT TERMS

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