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Effects of Sleeve Blockages on Air Velocity Distributions in an Unheated 7 x 7 Rod Bundle

January 1976

MASTER

Prepared for the U.S. Nuclear
Regulatory Commission

Battelle
Pacific Northwest Laboratories

BNWL-1975

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EFFECTS OF SLEEVE BLOCKAGES
ON AIR VELOCITY DISTRIBUTIONS
IN AN UNHEATED 7x7 ROD BUNDLE

by
J.M. Creer
J.M. Bates

January 1976

Battelle
Pacific Northwest Laboratories
Richland, Washington 99352

EXECUTIVE SUMMARY

An experimental study was performed to investigate the turbulent air velocity distributions near postulated sleeve blockages in a model nuclear fuel rod bundle. The sleeve blockages were characteristic of fuel clad "swelling" or "ballooning" which might occur during loss-of-coolant accidents (LOCA) in pressurized water reactors. The study was conducted to provide air velocity distributions near postulated blockages, to compare the air results with data obtained in a prior water experiment, and to further evaluate the use of the COBRA computer program for predicting flow distributions in rod bundles containing partial flow blockages.

The experimental flow model, identical to that used in a prior water study, was an unheated 7x7 rod bundle consisting of 0.392-inch diameter rods with a pitch of 0.539 inches. Sleeve blockages were positioned on the center nine rods of the bundle to create area reductions of 90 percent in the center four subchannels of the bundle. These area reductions were not intended to define those that might occur during an actual LOCA, but were chosen to provide a severe test for evaluation of subchannel (core) computer programs. Local mean axial velocities were measured using a one-component laser Doppler anemometer (LDA). The experiment was performed in air at 80°F at a Reynolds number of 1.0×10^4 which modeled flowing steam at a point in time during a postulated LOCA at which all of the flooding water (0.5 in./sec) would be converted to high quality steam.

The experimental results indicated that a 90 percent blockage located midway between two grid spacers created a severe flow disturbance. Axial velocities measured immediately upstream of the blockage cluster were extremely low and flow reversals were detected downstream of the blockage. The recirculation zone existed for approximately five subchannel hydraulic diameters downstream of the blockage axial centerline. Flow recovery was completed approximately fifty subchannel hydraulic diameters downstream of the blockage.

Air velocity profiles were in excellent agreement with prior water velocity data obtained at approximately the same Reynolds numbers.

Agreement between the air and water data indicates that Reynolds number similitude yielded velocity profiles near a sleeve blockage cluster which were independent of the state of the flowing fluid as predicted by basic fluid mechanic similitude theory.

Subchannel average velocity predictions of the COBRA computer program were in good agreement with subchannel average velocities estimated using the measured local velocity data. Because the code successfully predicted both the air and the prior water velocity data with a blockage cluster located midway between two spacers, it is recommended that COBRA be used to aid in the definition of future flow blockage experiments.

Additional information is needed to define "real" flow blockages, heat transfer effects of blockages, and influences of blockages on two-phase flows that might occur during a LOCA. It is further recommended that multi-rod burst experiments be utilized to define "real" flow blockage locations, shapes, and severities expected to occur in nuclear fuel rod bundles during a LOCA. The effects of these "real" blockage configurations on turbulent flow phenomena in rod bundles can then be experimentally evaluated using LDA techniques. In addition, it is recommended that LDA methods similar to those presented herein be used to determine velocity distributions near blockages similar to those proposed for rod bundle heat transfer studies, such as FLECHT. Flow distributions could aid in the selection and placement of thermal instrumentation and assist with the interpretation of the heat transfer results. Future flow blockage experiments in two-phase flowing media typical of those expected during a LOCA should be conducted as state-of-the-art two-phase flow instrumentation is developed. Experiments of this type are needed to verify and improve core safety analysis codes (COBRA) under two-phase flow conditions. It is recommended that laser-optical methods be investigated and developed to permit measurements of velocity and void fraction in two-phase flows.

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1.0 INTRODUCTION

In the event of a loss-of-coolant accident (LOCA) in a pressurized water reactor (PWR), fuel rod overheating may occur. As clad temperatures increase during a LOCA, internal fuel rod pressures may cause clad "swelling" or "ballooning" which could lead to coolant blockages. It is important that flow and heat transfer phenomena near such blockages are well understood to permit detailed safety analyses to be performed for postulated LOCAs. Consequently, as a first step in gaining such an understanding, a program was initiated to study the effects of blockages on flow distributions in rod bundles. The program had the following objectives: 1) to evaluate, develop, and apply laser Doppler anemometry (LDA) methods for measurement of flow and turbulence in the vicinity of blockages and 2) to improve the data base for verification of subchannel (core) codes such as COBRA-IIIC.⁽¹⁾ The intent of the program was to perform a logical sequence of flow blockage experiments using water, air, air-water, and steam-water in model nuclear fuel rod bundles. Such information was not available for relatively large rod bundles in any of the above mentioned flowing media. In addition to providing basic subchannel velocity and turbulence data which could be related to blockages under flowing steam conditions in reactor accident environments, it was anticipated that the LDA experiments using single phase water and air could aid in developing state-of-the-art two-phase flow instrumentation. Such instrumentation could subsequently be used in studies using air-water and, finally, using steam-water flow typical of that expected during a LOCA.

The present study, using air as the flowing medium, was a follow-on to the study reported in Reference 2 where water was used as the working fluid and two blockage severities plus two blockage locations were investigated. The abbreviated study reported herein used the same experimental method used in the water test, but only one blockage severity (90 percent) at one axial location within the bundle was investigated. The air conditions, $Re = 1 \times 10^4$, approximated those of steam at a point in time during a postulated loss-of-coolant accident (LOCA) at which all of the flooding water (0.5 in/sec) would be converted to high quality steam.

The purpose of this report is to present air velocity profiles obtained near a partial flow blockage. Comparisons of the air velocity profiles with water velocity profiles obtained in a prior experiment, and comparisons of the experimental velocity data with predictions of the COBRA code are provided.

2.0 CONCLUSIONS AND RECOMMENDATIONS

2.1 CONCLUSIONS

The present experimental study has provided information regarding the turbulent air velocity distributions resulting from disturbances created by postulated sleeve blockages in a model nuclear fuel rod bundle. The information was obtained with a laser Doppler anemometer by measuring the local mean axial velocity at selected axial locations in the bundle. The results of the experimental investigation permitted the following conclusions:

- The peak-to-average velocity ratios in well developed flow were approximately 1.2, which agree well with turbulent pipe flow theory and other available rod bundle experimental velocity data. (2,3,4,5)
- A 90 percent blockage located midway between two spacers created severe flow disturbances. Immediately upstream of the blockage cluster, extremely low velocities, $U/U_B \approx 0.2$, were measured. Flow reversals, $U/U_B \approx -0.03$, were detected downstream of the blockage. The recirculation zone extended approximately five subchannel hydraulic diameters (2.5 in.) downstream of the blockage axial centerline.
- The flow was essentially recovered from the influence of the blockage fifty subchannel hydraulic diameters downstream of the cluster.
- Air velocity profiles obtained in this study were in excellent agreement with water velocity profiles obtained in a previous blockage study. (2) It was shown that Reynolds number similitude yielded velocity profiles near a sleeve blockage cluster which were independent of the state of the flowing fluid, i.e., gas or liquid. Reynolds number modeling agrees with basic fluid mechanic similitude theory for flow contractions and expansions. (6)
- Air velocity data could not be measured with a frequency tracker signal processor in regions of highly turbulent flow. Velocity

profiles measured with a spectrum analyzer and profiles obtained with a frequency tracker were in good agreement in regions of lesser turbulence.

- A modified version of the COBRA-IIIC computer program⁽¹⁾ satisfactorily predicted the velocity data near a 90 percent blockage cluster. The locations of minimum velocities were predicted exceptionally well both upstream and downstream of the cluster. The computed velocity recovery profiles were in good agreement with measured profiles.

2.2 RECOMMENDATIONS

After considering the results of this experimental study, it is recommended that the following investigations be undertaken:

- Multi-rod burst experiments should be performed to define "real" flow blockage locations, shapes, and severities. The effects of "real" blockages on turbulent flow phenomena in rod bundles can then be thoroughly evaluated using LDA techniques.
- Although the present experiment provides valuable information on velocity distributions near a postulated flow blockage, the implications concerning heat transfer are inconclusive at this time. Heat transfer experiments in rod bundles containing blockages, such as FLECHT,⁽⁷⁾ should be performed and integrated with flow experiments of the type performed in the present study. Flow experiments would aid in the selection and placement of thermal instrumentation and assist the interpretation of the heat transfer experimental results.
- The original intent of this experimental program was to perform a sequence of blockage experiments in water, air, air-water, and finally in steam-water. The water experiment reported in Reference 2 and the air experiment reported herein have been successfully completed; it is therefore recommended that two-phase flow blockage experiments at expected LOCA conditions be performed, once the state-of-the-art advances in two-phase flow measurement techniques.

- Since LDA techniques were successfully used to obtain velocity measurements in water and in air, it is recommended that laser-optical methods be investigated to advance the state-of-the-art in obtaining local void fraction and phase velocity measurements in two-phase flows.
- Predictions performed with the COBRA code should continue to be compared with future flow blockage data and its capability should be improved as a result of the comparisons. Since COBRA has successfully predicted the water and air velocity data with a blockage located midway between two spacers, it should be used to aid in the definition of future flow blockage experiments.

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3.0 EXPERIMENTAL METHOD

Experimental measurements of local axial air velocities were made in an unheated model fuel rod bundle with an existing LDA system. The 7x7 rod bundle contained sleeve blockages characteristic of fuel clad "swelling" and/or "ballooning" of the center nine rods and created area reductions of 90 percent in the center four subchannels. The experiments were performed in air at 80°F and at a Reynolds number of 1.0×10^4 ($U_B = 38$ ft/sec). This flow condition modeled that of steam at a point in time during a postulated LOCA at which all of the flooding water (0.5 in/sec) would be converted to high quality steam.

The model rod bundle was positioned in an existing vertical flow housing. The housing contained windows on the front and back plates to permit a laser beam to pass completely through the rod bundle. Flow from an air loop entered the bottom of the test assembly and exited at the top. The LDA system was positioned at desired axial locations with a lift table. Traverses through the bundle along specific subchannel rows were made to obtain velocity profiles.

The following sections describe the equipment required to perform the air flow blockage experiment, the experimental procedure, and the experimental data obtained during the testing phase of the study.

3.1 EQUIPMENT

The basic equipment required to perform the air flow blockage experiment consisted of an air loop, a test assembly made up of a flow housing and a 7x7 rod bundle, a laser Doppler anemometer, and signal processing instrumentation. The following sections present detailed discussions of each piece of equipment used in the study.

3.1.1 Air Loop

The flow blockage experiment was performed in the air loop shown schematically in Figure 1. A blower rated at 775 cfm at 18 psig was used to produce the desirable air flowrate through the test assembly. An after-cooler was provided to attain an air operating temperature of 80°F. Three

FIGURE 1 Air Test Loop

flow control devices--a damper, a control valve, and a bypass valve--were used to obtain the test flowrate as measured with an orifice meter/pressure transducer combination. Temperatures and absolute pressures were measured just upstream of the orifice meter and at the test assembly inlet. After the air passed through the test assembly, it was exhausted to the atmosphere through a large 12-inch duct.

Ammonia chloride light-scattering particles were injected into the piping system just upstream of the test section. Air was used to agitate hydrochloric acid and ammonia hydroxide to permit mixing their vapors in a tube to form stable ammonia chloride particles. Control valves on the supply lines to the mixing tube were provided to permit proper mixture ratios and seeding flowrates.

3.1.2 Test Assembly

The test assembly used in the present study was identical to that used in the blockage experimental investigation reported in Reference 2. Figure 2 shows an assembly view of the test section. Air entered the bottom of the flow housing, flowed vertically upward through the test section, emerged at the top of the flow housing, and entered the exhaust duct. Rubber expansion couplers were used at the inlet to aid in isolating the test assembly from the normal vibrations of the flow loop.

An 8-inch long flow conditioning section was placed at the inlet to the test assembly. The flow conditioner consisted of four eccentric perforated plates with 1/4-inch holes (60% open) in a triangular array followed by a bank of 1/4-inch tubes 3-1/4 inches long. The plates distributed the flow uniformly across the test assembly cross section; the tubes served as flow straighteners which established a fixed scale of turbulence.

Figure 3 presents a cross sectional view of the test assembly at the blockage axial centerline. Front and back plates containing windows and solid stainless steel side plates containing pressure taps made up the flow housing body. The back plate contained the inlet and outlet nozzles and was permanently installed in the test facility. The front and back plates

FIGURE 2 Test Assembly Arrangement

FIGURE 3 Test Assembly Cross Section at the Blockage Axial Centerline

were bolted together with the side plates placed between them. A continuous O-ring sealed the interface between plates. Internal dimensions of the flow housing (4.065 inches square) were maintained by the restraining shoulder next to the O-ring groove on the front and back plates.

The front and back plates each contained nine windows, 2 inches high by 4 inches wide, located on 6-inch axial intervals. The optically flat and parallel windows were fabricated from borosilicate crown glass. The windows were sealed with O-rings and held in place by thick cover plates. Shims were placed between the windows and cover plates to position the windows flush with the inner surface of the flow housing (± 0.002 inch).

The model fuel bundle was a square unheated 7x7 rod array as shown in Figure 4. The bundle was that used in the water blockage study presented in Reference 2. Various sizes (rod numbers) of square arrays were considered during preliminary design to assure that the flow housing walls would not influence blocked subchannel flowrates. A pretest analysis performed with the COBRA-IIIC program prior to the water experiment⁽²⁾ indicated that the flow housing walls would not force a significant amount of flow through 80 percent blocked subchannels (center four subchannels) of a 7x7 rod bundle. This can be seen graphically in Figure 5 where the ratio of blocked subchannel minimum flow to inlet flow is presented as a function of bundle size. Only the center rod contained a sleeve blockage in the case of the 1x1 and 3x3 rod bundles, whereas the center nine rods contained sleeve blockages for the 5x5, 7x7 and 9x9 rod bundles. The flow ratio became smaller as the rod array was increased, i.e., less flow was forced through the blocked subchannels, until there was essentially no change between a 7x7 and a 9x9 rod bundle. A 7x7 rod array was chosen since an existing flow housing would accept it with rod diameters and rod pitches typical of those found in pressurized water reactors.

Model rods were fabricated from 1/8 inch Sch 10S stainless steel pipe (OD = 0.392 inches) 57 inches in length. Brass lower and upper tie plates, shown in Figure 6, positioned the 49 rods to form the bundle. Flow channels in the tie plates were sized to assure uniform velocity distributions over the cross section of the bundle. A rod pitch of 0.539 inch was maintained.

FIGURE 4 Model Rod Bundle

FIGURE 5 Blocked Subchannel Flow as a Function of Bundle Size

FIGURE 6. Bundle Tie Plate

with three simple "egg crate" spacers fabricated from brass as pictured in the end view of Figure 7. Four "dimples" contacted each rod to firmly hold it in place.

Brass sleeve flow blockages shown in Figure 8 were placed on the center nine rods to characterize clad swelling/ballooning. The blockages were 3 inches in length with one-inch tapers at each end. Flow area reductions of 90 percent could be attained in the center four subchannels. This severity corresponded to area reductions of 45 percent in the subchannels adjacent to the sides of the cluster and 22 percent in the subchannels next to the corners of the blockage. The shape and severity of the blockage cluster used in the present air experiment were identical to those used in a prior water experiment⁽²⁾ and were not intended to define those which will actually exist during a LOCA. The shape of the blockage sleeves was formulated after considering experimental results of high temperature expansion and rupture behavior of Zircaloy tubing.⁽⁸⁾ The severity of 90 percent was chosen since it was used in the prior water experiment and because it created gross flow disturbances in the rod bundle. Gross flow disturbances were required to adequately "test" the capability of the COBRA computer program in predicting maldistributed flow profiles. Determination of prototypic LOCA blockage locations, shapes, and severities must await results of experiments designed to obtain such information.

A jack support spider was provided at the top of the bundle to permit a screw jack to vertically position the rod bundle in the flow housing. A vertical travel of seven inches was possible and, since the windows were on six-inch centerlines, data at any axial location within the bundle could be obtained.

3.1.3 Laser Doppler Anemometer

Turbulent flow measurements were made with a laser Doppler anemometer (LDA). The LDA is a highly advanced system for obtaining measurements of local mean velocity and possesses a definite improvement over other measurement methods in that the noncontact probing does not disturb the flow. An important feature of all LDA systems is that the output signal is a

FIGURE 7. Simple "Egg Crate" Spacer

BLOCKAGE CLUSTER

CORNER SLEEVE

SIDE SLEEVE

CENTER SLEEVE

(3) TAPPED HOLES
WITH SET SCREWS

FIGURE 8 Flow Blockage Sleeves

calibration-free frequency linearly related to flow velocity. Single known components of flow velocity can be measured independently of other velocity components, and velocity measurements in reversing flows are possible.

The LDA system used in the present experiment is shown schematically in Figure 9 and was identical to that used previously⁽²⁾ and discussed in detail by Brayton and Goethert.⁽⁹⁾ The differential Doppler mode, or "fringe mode," of operation was used since it could easily be aligned and operates effectively where the intensity of scattered light is low. As previously mentioned in Section 3.1.1, ammonia chloride particles were used as light-scattering media.

The beam from a 15 MW He-Ne laser was divided with a beam splitter. Each beam was passed through a Bragg Cell where the frequency of one beam was shifted by f_{s1} MHz while the frequency of the other beam was shifted by f_{s2} MHz. Frequency shifting was desired to permit measurements of zero and negative flows, i.e., the Doppler frequency of scattered light from a particle having zero velocity was f_s MHz ($f_{s1} - f_{s2} = f_s$ MHz). Therefore, negative axial velocities produced Doppler signals having frequencies less than f_s MHz and positive axial velocities produced Doppler frequencies greater than f_s MHz.*

The two beams were passed through a lens and focused at a point in the flow channel. The intersection volume (measuring volume) of the two beams was calculated to be ~ 0.008 inches in diameter and ~ 0.089 inches in length which indicates the "localized" characteristics of the measurements. A lens system and $200\ \mu$ aperture were used to collect scattered light from particles passing through the measuring volume and focus the light on the photomultiplier (PM) tube. The aperture also prevented extraneous light from entering

*In the initial stages of the experiment, Bragg Cells were not used because difficulties were encountered in obtaining good Doppler signals under air flow conditions. After the experimental runs were completed without Bragg Cells, it was noted that near zero velocities were obtained downstream of the blockage cluster. The Bragg Cell system was "debugged" and used to remeasure velocity profiles along selected traverses as indicated in Appendix C.

FIGURE 9 Differential Doppler LDA System

the PM tube. The PM tube collected radiant energy resulting from the scattered light and produced an alternating signal current with a beat or "Doppler" frequency, f_D .

At the intersection volume, the two laser beams created interference fringes as shown in Figure 10. Because the two light beams were mutually coherent and identically polarized, they interfered constructively and destructively to form closely spaced fringes of maximum and minimum illuminating intensity. Simple trigonometry was used to determine the distance between fringes:

$$d_f = \frac{\lambda}{2 \sin \theta/2}$$

Since the product of frequency and distance yields velocity, then

$$U = d_f f_D = \frac{\lambda f_D}{2 \sin \theta/2}$$

Note that the velocity was that perpendicular (z direction) to the interference fringes, i.e., normal to the bisector of the beam intersecting angle θ and in the plane of the incident laser beams.

For the LDA system presented in Figure 9, $\lambda = 6328\text{\AA}$ and θ was measured to be 10.66° . Therefore, the final relationship for the axial velocity was

$$U = 11.030 f_D \text{ ft/sec}^*$$

The measuring volume was located in the flow channel by means of a hydraulic lift/traversing table capable of positioning the laser and optics as an integral unit. The table was supported on precision linear ball bearings and was driven by variable speed servo-motors. The motor speed control and position control made it possible to locate the beam intersection volume to within 0.001 inch in both the x and y coordinates in a

*In actuality, three different angles were used during the course of the experiment, $\theta = 10.66^\circ$, 10.80° , and 9.70° , resulting in proportionality constants of 11.030, 11.175, and 12.456, respectively.

FIGURE 10 Detail of the Measuring Volume

horizontal plane. The hydraulic lifting capability of the table permitted the laser and optics to be positioned at desired axial locations.

3.1.4 Signal Processing Instrumentation

The signal processing instrumentation used to condition, interpret, and obtain the axial velocity data from the Doppler signal is presented in Figure 11. The system basically consisted of a Hewlett-Packard spectrum analyzer with a tracking generator, a DISA frequency tracker, and an oscilloscope.

The spectrum analyzer/tracking generator combination was used as the primary data acquisition device since the frequency tracker did not operate satisfactorily in regions of highly turbulent air flow. The spectrum analyzer received a signal from the PM tube and a frequency spectrum (signal amplitude versus frequency) was displayed on the CRT. The tracking generator, a special signal source whose RF output frequency tracks (follows) other signals in the frequency domain, was then used to accurately read the Doppler frequency corresponding to the peak amplitude as measured by the spectrum analyzer.

The frequency tracker was used as a back-up unit to the spectrum analyzer since it would not "hold track" in regions of highly turbulent air flow. When in use, the frequency tracker improved the signal-to-noise ratio of the Doppler signal and converted the Doppler frequency into an analog voltage which was linearly related to local mean axial flow velocity. The tracker had frequency tracking capabilities in that once it was "locked-on" to the Doppler frequency, it followed frequency fluctuations about the mean within each available frequency range. A meter output was supplied on the tracker; however, a digital voltmeter was used to measure tracker voltage output to obtain more accurate determinations of Doppler frequencies.

3.2 EXPERIMENTAL PROCEDURE

Loop flow and temperature were set at desired values. The loop had very stable flow, pressure, and temperature controls and did not require adjustments during data acquisition.

FIGURE 11 LDA Signal Processing Instrumentation

Once the loop was operating at selected conditions, the LDA optical system was adjusted to produce an optimum Doppler signal as observed on the oscilloscope and spectrum analyzer. The inside surfaces of the windows were located to within ± 0.010 inch by observing the loss of signal on the spectrum analyzer as the measuring volume was traversed into the windows. Data acquisition was started approximately 0.100 inches from a window and continued to be taken incrementally (usually every 0.100 inch) along a selected traverse across the rod bundle. The measuring volume was positioned to within 0.001 inches relative to its adjacent data locations with the lift/traversing table.

At each data location, the spectrum analyzer/tracking generator combination was adjusted so that the peak amplitude of the signal was aligned with the center graticule of the analyzer CRT as shown in Figure 12. The tracking generator marker was also adjusted to correspond to the center graticule, i.e., peak amplitude point of the spectrum. Both the tracking generator marker and the frequency spectrum were aligned with the center graticule since the generator would track the center frequency if it "lost track" of the frequency spectrum peak, i.e., Doppler frequency. Therefore, this method of alignment provided an automatic "back-up" if the generator stopped tracking the spectrum since the center frequency corresponded to the Doppler frequency. The frequency tracker, if in use, was checked to assure proper adjustment. The tracking generator output (Doppler frequency), the frequency tracker output (Doppler frequency), the x, y locations and the other pertinent loop information were then recorded. The lift/traversing table was used to reposition the measuring volume. Pressure loss data between taps 1-5 were obtained intermittently throughout the course of the experiment.

After the desired data at one axial location were obtained, the lift/traversing table was used to raise or lower the LDA optics to a new axial location. The above testing procedure was then repeated.

FIGURE 12 Frequency Spectrum Alignment

3.3 EXPERIMENTAL DATA

Data obtained during the course of this experimental investigation are presented in Appendix C. The data have been reduced to engineering units and tabulated based on run number. The sections which follow discuss the data point locations, the data reduction methods, and the accuracy of the data.

3.3.1 Data Point Locations

The 90 percent blockage cluster was positioned midway between spacers #1 and #2 as shown in Figure 13. Data were obtained at the indicated axial locations along the length of the bundle. The distances accompanying the data plane designations were referenced to the blockage axial centerline. A negative distance indicates the respective data plane was upstream of the blockage cluster while a positive distance indicates a downstream data plane.

The locations of the traverses performed at any one axial location (data plane) are presented in Figure 14. Symmetry of the bundle cross section permitted limitation of data acquisition to the indicated quadrant as concluded in Reference 2. For wall subchannels ($y = 0.110$ inches), only one measurement was obtained at a location one-half the distance from the wall to the outside edge of the first rod row.

3.3.2 Data Reduction Methods

A digital computer program was written to reduce the experimental data to desired engineering units. Plotting routines were used to display a significant amount of the data. For each data point, it was necessary to shift the measurement location to a consistent set of reference coordinates and convert the Doppler frequency to local mean axial velocity.

3.3.2.1 Location Corrections

The measurement location corrections were made by referencing all x locations to the location $x = 1.763$ inches (x centerline of the subchannel row containing subchannel #1), and referencing all y locations to the nominal centerlines $y = 0.110, 0.685, 1.224,$ and 1.763 inches of the

FIGURE 13 Blockage Cluster, Spacer, and Data Plane Axial Locations

NOTE: ALL DIMENSIONS IN INCHES
 (N) SUBCHANNEL NUMBERS
 (B) RODS WITH SLEEVE BLOCKAGES
 --- DATA TRAVERSE LOCATIONS
 • DATA POINT LOCATION

FIGURE 14 Data Traverse Locations

Figure 14. The x locations were referenced to $x = 1.763$ inches by examining a particular velocity profile in a data plane and shifting the profile until the peak velocity point in the subchannel containing $x = 1.763$ inches corresponded to $x = 1.763$ inches. The necessary x shift was then applied to each point obtained in that particular data plane. At most data planes, the velocity profile at $y = 0.685$ inches was used to determine the x correction factor since the velocity profile along the x traverse was very distinct even near the blockage cluster. The y locations were referenced to the nominal y subchannel row centerlines by simply assuming that the centerline traverses corresponded to the row centerlines.

3.3.2.2 Mean Axial Velocity

The calculation of mean axial velocity from the Doppler frequency obtained with the spectrum analyzer/tracking generator combination was performed using the following relationship.

$$U = 11.03(f_{sa} - f_s) = 11.03f_D$$

where

- U - local mean axial velocity, ft/sec
- f_{sa} - Doppler frequency measured with the spectrum analyzer, MHz
- f_s - frequency shift, MHz
- f_D - Doppler frequency resulting from the air flow velocity, MHz.

The calculation of local mean axial velocity from the Doppler frequency measured with the DISA frequency tracker was performed by first converting the voltage output from the DC voltmeter to a frequency. The relationship

$$f_D = (E_{DC} \cdot \frac{\text{Range}}{10.0} - f_s) \text{ MHz}$$

was used where

Range - full scale value of the range used on the frequency tracker, MHz

E_{DC} - DC voltmeter output, volts

10.0 - full scale value of the DC voltmeter, volt.

Then, the relationship

$$U = 11.03 f_D \text{ ft/sec}$$

was used to determine local mean axial velocity values.

3.3.3 Accuracy of Data

An error analysis using the error and uncertainty methods of Schenck⁽¹⁰⁾ was performed to estimate data accuracy. These methods are similar to those of describing uncertainties in single sample experiments presented by Kline and McClintock⁽¹¹⁾ and those of compounding errors presented by Wilson.⁽¹²⁾ The methods and analysis are presented and described in detail in Appendix B. Table 1 summarizes the results of the uncertainty analysis based on Run #AB-457 of the test matrix presented in Appendix C.

TABLE 1. Uncertainty Values (Run #AB-457).

Parameter	Nominal Value	Uncertainty	
		Value	Percent
Mean Velocity (Spectrum Analyzer), U_{SA}	20.6 ft/sec	± 1.23 ft/sec	± 6
Mean Velocity (Frequency Tracker), U_{TRK}	20.6 ft/sec	± 0.378 ft/sec	± 2
x Data Point Location, x		± 0.001 in.	
y Data Traverse Location, y		± 0.005 in.	
Axial Data Plane Location, z		± 0.050 in.	

3.3.3.1 Axial Velocity From Spectrum Analyzer

Velocity measurements obtained with the spectrum analyzer were found to have an uncertainty of $\sim \pm 6$ percent. The error was primarily due to 1) the accuracy of the measurement of the Doppler frequency, and 2) the small angle required between incident laser beams to permit measurements near the blockage.

A relatively large uncertainty in the Doppler frequency was inherent since the spectrum analyzer is not capable of highly accurate measurements. The tracking generator greatly improved the frequency measurement; however, the uncertainty involved in the alignment of the frequency spectrum on the CRT center graticule and the nonsymmetric shape of the spectrum itself resulted in an estimated Doppler frequency uncertainty of $\sim \pm 0.1$ MHz.

3.3.3.2 Axial Velocity From DISA Frequency Tracker

Velocity measurement accuracies obtained with the frequency tracker were estimated to be ± 2 percent. The uncertainty was primarily due to the small angle required between the laser beams to permit measurements near the blockage cluster. It is important to remember that, even though the estimated accuracy of the measurements obtained with the tracker are better than those obtained with the spectrum analyzer, measurements could not be performed with the tracker during much of the test in regions of highly turbulent flow.

3.3.3.3. Measurement Locations

Each measurement location was positioned within ± 0.001 inches of its neighbors in the x direction, and each data traverse was located within ± 0.005 inches in the y direction relative to the adjacent rod rows. The axial locations of the data planes were known within ± 0.050 inches relative to the blockage axial centerline.

4.0 EXPERIMENTAL RESULTS AND DISCUSSION

Results obtained during the experiment are presented and discussed in the following section. Unless otherwise noted, velocity measurements presented in this section were obtained with the spectrum analyzer since the frequency tracker did not perform satisfactorily throughout much of the testing phase of the experiment. The first section presents the velocity distributions near a 90 percent blockage located midway between two grid spacers. The next section compares the air velocity data obtained in this investigation with water velocity profiles presented and discussed in a prior experiment.⁽²⁾ The final section compares velocity data obtained using the spectrum analyzer with data obtained using a frequency tracker to determine the consistency between the two signal processing instruments.

4.1 VELOCITY DISTRIBUTIONS NEAR A 90 PERCENT BLOCKAGE

Velocity distributions obtained at specific axial locations along the length of the bundle and along all data traverses at one axial location are presented in this section. The velocity profiles obtained along the length of the bundle indicated that a 90 percent blockage located midway between two grid spacers created a severe flow disturbance. Axial velocities measured immediately upstream of the blockage cluster were extremely low and flow reversals were detected downstream of the blockage. The recirculation zone existed for approximately five subchannel hydraulic diameters downstream of the blockage axial centerline.* Flow recovery was completed fifty subchannel hydraulic diameters downstream of the blockage cluster. Velocity profiles obtained along all data traverses at an axial location 2.5 inches downstream of the blockage centerline indicated that the recirculation zone was laterally restricted to the 90 percent blocked subchannels.

*Note that no attempt was made to relate the length of the recirculation zone to a blockage characteristic length. Until sufficient data have been obtained with different blockage severities and dimensions, it is premature to "guess" the best characteristic length to use to express the length of the recirculation zone.

4.1.1. Velocity Reduction and Recovery

Velocity profiles obtained at specific axial distances (data planes) upstream of the 90 percent blockage cluster are presented in Figure 15. Each of the plots making up Figure 15 presents local mean axial velocities normalized relative to bundle average velocity as functions of distance from the wall ($x = 0$ corresponds to the wall). Each data traverse was obtained at $y = 1.763$ inches as indicated in the cross sectional view of the bundle. Distances accompanying the data plane designations indicate upstream (negative sign) locations relative to the blockage axial centerline.

At a location 8.5 inches upstream of the blockage centerline, ≈ 0.75 inches downstream of spacer #1, the velocity profile shows the effects of the spacer by its "ragged" appearance and a peak-to-average velocity ratio of ~ 1.1 . At an axial location 4.8 inches upstream of the blockage cluster, the velocity profile shows consistent peaks at subchannel centers and valleys at rod gaps. Axial velocity peak-to-average ratios of ~ 1.2 were measured which are in good agreement with those known to exist for well developed turbulent pipe flow and existing rod bundle data.^(2,3,4,5) The velocity profile indicates that the flow conditioning section at the test assembly entrance distributed the flow uniformly across the bundle cross section.

In the tapered region of the blockage, 1.7 and 1.3 inches upstream of the centerline, the influence of the blockage cluster was present as indicated by the relatively low velocities in the inner subchannels and the higher velocities in the outer subchannels. Velocity ratios in the innermost subchannel, subchannel #1 (SC #1), decreased from ~ 1.2 to ~ 0.15 . Low velocities are realizable since SC #1 had an area reduction of 90 percent and flow was forced around the blockage cluster. Peak-to-average velocity ratios in the outer subchannels increased from ~ 1.2 to ~ 1.3 which also indicates that flow was being diverted around the blockage.

Velocity profiles obtained immediately downstream of the blockage cluster are presented in Figure 16. Note that downstream locations are designated by the plus sign preceding the data plane distance values. Velocity distributions obtained 1.3, 1.5, and 2.5 inches downstream of the blockage centerline indicate that zero and negative flows were measured.

FIGURE 15 Velocity Profiles Upstream of a 90 Percent Blockage Located Midway Between Two Spacers, $U_B = 38$ ft/sec

FIGURE 16 Velocity Profiles Immediately Downstream of the 90 Percent Blockage Located Midway Between Two Spacers, $U_B = 38$ ft/sec

The flow reversals define a recirculation zone confined to SC #1 in the lateral direction. The low inner subchannel velocities were accompanied by relatively high outer subchannel velocities as indicated by the high peak-to-average velocity ratios of ~ 1.4 . Axially, the recirculation zone persisted for at least 2.5 inches (~ 5 subchannel hydraulic diameters) downstream of the blockage centerline. Flow reversals were not detected 3.4 inches (~ 7 diameters) downstream of the blockage cluster, and flow recovery was significant 7.5 inches downstream of the blockage centerline.

The data points not included in the velocity profiles at data planes #9 and #13 are missing since the flow was very turbulent, making it impossible to obtain Doppler signals. The frequency spectrum actually disappeared from the spectrum analyzer CRT screen and the frequency tracker could not follow the Doppler frequency. Note that the signal was lost at the entrance to SC #1, but was regained near the rod gap corresponding to the bundle centerline.

Velocity profiles obtained further downstream from the blockage are shown in Figure 17. At an axial location 13 inches downstream from the blockage, the flow at the centerline of the bundle ($x = 2.032$ inches) had recovered to within ~ 90 percent of that which existed 4.8 inches upstream of the blockage cluster (Figure 15, data plane #12). Approximately 50 subchannel hydraulic diameters downstream of the blockage, the flow had essentially recovered from the disturbance created by the blockage cluster.

4.1.2 Velocity Profiles at One Axial Location

Velocity profiles measured along all data traverses obtained at a single cross section, data plane #10, are presented in Figure 18 to indicate the local characteristic of the recirculation zone in the lateral direction. The lower plot contains velocity profiles obtained at $y = 1.763$ and 1.224 inches. Velocity magnitudes are relatively high in the outer subchannels along each traverse. Velocity profiles in the inner subchannels at $y = 1.763$ inches indicate that zero and negative velocities existed, i.e., a recirculation zone was detected. Velocities obtained in inner subchannels at $y = 1.224$ inches were not negative indicating that the recirculation zone was restricted to the 90 percent blocked SC #1 in the lateral direction.

FIGURE 17 Velocity Profiles Far Downstream of a 90 Percent Blockage Located Midway Between Two Spacers, $U_B = 38 \text{ ft/sec}$

FIGURE 18 Velocity Profiles at Data Plan #10 (+2.5 in) with a 90 Percent Blockage, $U_B = 38$ ft/sec

Velocities presented in the upper plot of Figure 18 were obtained in the outer subchannels of the bundle at $y = 0.685$ and 0.110 inches. The outer subchannel velocities are relatively high since flow was diverted around the blockage cluster.

4.2 COMPARISONS OF AIR VELOCITY DATA WITH EXISTING EXPERIMENTAL DATA

Comparisons of air velocity data obtained in this experiment with water velocity data obtained in a prior experiment⁽²⁾ are presented in this section. The comparisons were made to show that Reynolds number similitude resulted in velocity profiles near a sleeve blockage cluster which were independent of the state of the fluid, i.e., gas or liquid, as indicated in basic fluid mechanic similitude theory.⁽⁶⁾ The results of the comparisons indicate that air velocity profiles and water velocity profiles were in excellent agreement.

4.2.1 Velocity Reduction and Recovery

In Figure 19, air velocity data obtained in the present experimental study are compared to water velocity data reported in Reference 2. The Reynolds and Euler numbers of the flowing air ($Re_a \approx 1.0 \times 10^4$, $Eu_a \approx 0.42$) were approximately equal to those of the water ($Re_w \approx 1.4 \times 10^4$, $Eu_w \approx 0.44$). In the upstream tapered region of the blockage cluster, -1.3 inches, the air and water velocity profiles obtained along an x traverse at $y = 1.763$ inches essentially coincide. In the downstream tapered region, $+1.3$ inches, the two velocity profiles are in good agreement; however, the water profile contains some scattered velocity data points. Farther downstream of the blockage axial centerline, the air and water profiles compare well.

It can be seen that in outer subchannels, $X < 0.8$ inches, normalized air velocities were consistently higher than normalized water velocities. No final conclusion has been formulated as to the cause of the higher air velocities. A possible explanation for this difference could be that ammonia chloride particles collected on the windows during the air experiment and, due to extraneous scattered light, may have affected measurements in the wall subchannels. The difference is of minor significance and does not affect the major results of the study.

FIGURE 19 Comparisons of Air Velocity Data with Water Velocity Data Near a 90 Percent Blockage Located Midway Between Two Spacers

Perhaps a better mental picture of what the velocity reduction and recovery profiles along the length of the bundle actually were can be conveyed by examining Figure 20. Normalized subchannel #1 center velocities are presented along the length of the bundle for both air data and existing water data.⁽²⁾ For the most part, the axial velocity profiles are in excellent agreement.

The upstream and downstream minimum velocity magnitudes and locations coincide with one another. Note that the normalized air velocity immediately downstream of spacer #1 is significantly lower than velocity values at other data planes possessing well developed flow. The lower value was caused by spacer #1 which promoted turbulence, and therefore forced the downstream velocity profile to become "flattened". The flow recovery profiles for both sets of velocity data are essentially the same, agreeing within 10 percent at any one data location.

The excellent agreement between the air velocity profiles and the water velocity profiles indicates that dynamic similarity was ensured with Reynolds number and consequently, Euler number modeling. The velocity profiles near the sleeve blockage cluster were independent of the state of the flowing fluid, i.e., gas or liquid, which agrees with basic fluid mechanic theory for low Mach number flow through contractions and expansions.⁽⁶⁾

4.2.2 Velocity Profiles at a Selected Axial Location

Figure 21 presents velocity profiles obtained in air and those obtained in water⁽²⁾ at an axial distance 2.5 inches downstream from the blockage axial centerline. As shown, the velocity profiles are in good agreement with the exception of those obtained at $y = 1.224$ inches where some data scatter was encountered. The traverses at $y = 1.224$ inches were midway between a rod row in which inner rods contained blockage sleeves and a row without blockages. The nonsymmetrical disturbances created in the inner subchannels are thought to be the cause of the data scatter.

FIGURE 20 Axial Profiles of Subchannel #1 Center Velocities in Air and Water

FIGURE 21 Comparisons of Air and Water Velocity Profiles at a Selected Axial Location

4.3 COMPARISONS OF SPECTRUM ANALYZER DATA WITH FREQUENCY TRACKER DATA

Figure 22 presents comparisons of velocity data obtained using the spectrum analyzer/tracking generator combination with the data measured with the frequency tracker. The spectrum analyzer is not known for highly accurate measurements. However, its accuracy was greatly improved by the tracking generator, and it was of interest to compare analyzer results with the more accurate frequency tracker results. Only data obtained at axial locations where the flow exhibited relatively low turbulence are presented since the frequency tracker did not perform satisfactorily in highly turbulent flow regions.

From the profiles presented in Figure 22, it is quite evident that the velocity data obtained with the two signal processors are in excellent agreement. The velocity data obtained 13 inches downstream of the blockage cluster indicate that tracker measurements were consistently higher (~5 percent) than the spectrum analyzer measurements. No exact cause of the discrepancy has been formulated; however, since the data were obtained a relatively short distance downstream of a spacer, the increased turbulence created by the spacer may have caused the tracker readings to be high. This speculation was made after considering the fact that the frequency tracker consistently "lost track" in highly turbulent flow, and the Doppler frequency was biased on the high end of the frequency meter scale just prior to losing track.

FIGURE 22 Comparisons of Spectrum Analyzer Velocity Data with Frequency Tracker Data

5.0 COMPARISONS WITH COBRA PREDICTIONS

Comparisons of the measured velocity data with predictions obtained using the COBRA code are presented in this section. The comparisons are of major importance in the continuing development of the COBRA code for subchannel (core) analyses at postulated nuclear reactor accident conditions. Similar measured and predicted velocity comparisons were performed using water in a prior investigation⁽²⁾ and it was confirmed that COBRA could predict water velocities satisfactorily with a blockage located midway between two spacers. Such a confirmation is required for low density air flow to add to the data base required for future analyses of two-phase steam-water flows expected to exist during actual LOCAs.

Subchannel average velocity predictions of the COBRA computer program were in good agreement with subchannel average velocities calculated using the measured local velocity data. The version of COBRA used to perform the predictions and the input model are discussed first. Then, the methods used to estimate subchannel average velocities from measured local axial velocity values will be presented. Finally, COBRA average subchannel velocity predictions will be compared to measured values with a 90 percent sleeve blockage cluster positioned midway between two grid spacers.

5.1 COBRA VERSION AND INPUT MODEL

The local air velocity data could not be predicted with COBRA-III⁽¹⁾ using standard steady-state techniques since instabilities in the numerical solution were encountered. Therefore, predictions of the velocity data were performed with a modified version of COBRA-IIIC using a "two step" approach as follows:

- (1) Steady-state predictions with a 70 percent blockage were performed.
- (2) A transient solution, which extended the 70 percent blockage solution to a 90 percent blockage solution, was then performed. During each transient time increment, a slightly greater blockage severity was introduced into the input geometry. After

a 90 percent severity had been obtained, sufficient time steps were completed to assure convergence to the correct solution. It is important to note that the solution was transient with respect to blockage severity only, and that all other input parameters remained constant with time.

The input parameters used to predict the axial velocity data are summarized in Table 2. As indicated, the values of the parameters are typical of those commonly used in nonheated bundle predictions. The blockage loss coefficients were those determined in Reference 2. They were varied from subchannel to subchannel and ranged from 0 to 0.5 depending on subchannel location relative to the blockage cluster. The spacer loss coefficients as well as the friction factor relationship were also obtained from Reference 2.

TABLE 2. COBRA Input Parameters

Parameter	COBRA Symbol	Value
Cross Flow Resistance	K_{ij}	0.02
Transverse Momentum	s/l	0.25
Turbulent Momentum Factor	f_t	1.0
Bare Rod Friction Factor	f	$0.34 \text{ Re}^{-0.25}$
Subchannel Spacer Loss Coefficient	K_{s1}	1.14
Subchannel Blockage Loss Coefficient	K_{s2}	
For Subchannel #1		0.5
For Subchannel #2		0.05
Other Subchannels		0.0
Model Length (in.)		40.0
Calculation Increment (in.)	Δz	0.5
Total Transient Time (sec)	t	2.0
Turbulent Mixing	β	0.02
Temperature (°F)	T	80.0

The geometry model presented in Figure 23 identifies the location of the subchannels. The model was a one-eighth sector of the total bundle cross section and was justifiable based on geometric symmetry as previously verified.⁽²⁾ Dimensions of the model were as-built dimensions measured during and after bundle assembly. The rod diameters were measured to be 0.392 inches. The rod pitch was 0.539 inches and the rod-to-wall spacing was 0.220 inches. The sleeve blockages were modeled as flow area reductions. The area reductions in the tapered region of the blockage sleeves were assumed to vary linearly along the length of the tapers.

5.2 SUBCHANNEL AVERAGE VELOCITY ESTIMATES

Prior to comparing the measured axial velocity profiles with COBRA predictions, the local measured velocity data were used to estimate subchannel average velocities. Subchannel average velocities were required to compare with average values computed by COBRA.

For subchannels #1, #2, and #3, an area-weighting approach in conjunction with the assumption of highly turbulent flow was used to estimate subchannel average velocities from experimental local velocity data. The subchannel cross sections were simplified by replacing the round rods with square rods of equal area as shown in Figure 24. This greatly simplified the area-weighting calculations without altering the actual cross sectional subchannel flow areas. Sub-area boundaries were defined as being one-half the distance between a data location and its adjacent neighbors. Weighting factors for each sub-area were obtained by dividing the appropriate sub-area by the total subchannel flow area. Subchannel average velocities were calculated by summing the products of the weighting factors and corresponding measured velocities.

Average velocities for subchannels #4 through #10 were determined by inspecting the velocity profiles at nondisturbed data planes, e.g., #12, and estimating the ratio of the average subchannel velocity to the centerpoint subchannel velocity. Average subchannel velocities at undisturbed data planes were known to be approximately equal to the average bundle velocity. This approach was also used for subchannels #1, #2, and #3 at locations not influenced by the blockage cluster.

FIGURE 23 COBRA Geometry Model at the Blockage Axial Centerline

FIGURE 24 Simplified Subchannel Geometry Used for Calculating Subchannel Average Velocities

In Table 3, a selected number of calculated bundle flowrates using the measured LDA velocity data are compared to bundle flowrates measured with the loop orifice meter. Calculated flows were determined by summing the flowrates in each subchannel,

$$F \propto \sum_{sc=1}^{10} U_{sc} A_{sc},$$

and multiplying the sum by eight to account for all eight sectors making up the bundle cross section. As indicated, the calculated flowrates agreed exceptionally well with the measured flowrates.

TABLE 3. Comparisons of Calculated and Measured Bundle Flowrates

Data Plane No.	Calculated Flow, cfm	Measured Flow, cfm	Percent Diff. $\left(\frac{F_m - F_c}{F_m} \right) 100$
1 (+25.5 in.)	171	168	-1.8
4 (+7.5 in.)	171	168	-1.8
6 (+3.7 in.)	171	166	-3.0
8 (-1.7 in.)	172	168	-2.4
10 (+2.5 in.)	169	166	-1.8

5.3 COBRA PREDICTIONS

COBRA predictions of the measured air velocity data are presented in Figures 25, 26, and 27. In each figure, the ratio of average subchannel velocity to bundle average velocity is presented as a function of axial distance along the length of the bundle. The measured data points are actually subchannel average velocities estimated using measured local axial velocities as discussed in the previous section.

Predictions of subchannel #1, #2, and #3 average velocities are shown in Figure 25. COBRA predicted subchannel #1 average velocities extremely well. The predicted normalized minimum velocity magnitude upstream of the

blockage cluster was higher, 0.45 versus 0.32, than the measured value; however, the predicted minimum velocity location coincided with the measured location. Jetting predicted at the entrance to the blockage cluster was not detected experimentally. Jetting may not have been measured because the LDA measuring volume could not be positioned close enough to the blockage axial centerline. This geometrical restriction was encountered since the exterior sleeve blockages "blocked out" the incident laser beams due to the angle θ between beams.

The predicted recovery profile in subchannel #1 downstream of the blockage was in excellent agreement with the measured profile. Again, jetting predicted at the exit of the blockage was not experimentally measured for the possible reason discussed above. COBRA predictions of subchannel #2 and #3 velocities agree satisfactorily with measured values (± 10 percent).

Figures 26 and 27 present COBRA predictions of subchannel #4, #5, #6, #7, #8, #9, and #10 average velocities. The predicted velocity profiles agree well with the measured profiles. Note that estimates of measured subchannel average velocity values are slightly higher than predicted values. This trend would indicate that the predictions are low or the estimates of subchannel average velocities are high. In any event, COBRA appears to have satisfactorily predicted average subchannel velocity values near the blockage cluster.

FIGURE 25 COBRA Velocity Predictions in Blocked Subchannels #1, #2, and #3 with a 90 Percent Blockage, $U_B = 38$ ft/sec

FIGURE 26 COBRA Velocity Predictions in Unblocked Subchannels #4, #5, and #6 with a 90 Percent Blockage, $U_B = 38$ ft/sec

FIGURE 27 COBRA Velocity Predictions in Unblocked Subchannels #7, #8, #9, and #10 with a 90 Percent Blockage, $U_B = 38$ ft/sec

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APPENDICES

APPENDIX A
NOMENCLATURE

APPENDIX A

NOMENCLATURE

A_{sc}	- subchannel area,
b_o	- laser beam radius at focal point,
BLC	- blockage axial centerline,
d_f	- distance between fringes,
DP	- designates data plane,
E, E_{DC}	- DC voltage,
Eu	- Euler number, $U_B (\rho/2g \Delta P_{1-5})^{1/2}$,
f_i	- frequency of incident laser beam,
f_D	- Doppler frequency,
f_s, f_{s1}, f_{s2}	- frequency shift,
$F, Flow$	- bundle flowrate,
F_c	- calculated bundle flowrate,
F_m	- measured bundle flowrate,
ft	- turbulent momentum factor,
g	- gravitational constant,
K_{ij}	- crossflow resistance,
K_{s1}	- subchannel spacer loss coefficient,
K_{s2}	- subchannel blockage loss coefficient,
n	- number of readings,
P	- pressure,
PT	- pressure tap location,
ΔP_{1-5}	- pressure loss between taps 1 and 5,
R	- resultant,

Re	- Reynolds number,
Range	- full scale value of a frequency tracker range,
s	- standard deviation,
s/l	- transverse momentum,
t	- time,
T,Temp	- temperature,
U, U _{local} , U _{SA}	- local mean axial velocity obtained with spectrum analyzer,
U _B , U _B	- bundle average velocity,
U _{TRK}	- local mean axial velocity obtained with frequency tracker,
U/U _B , VRATIO	- ratio of local mean velocity to bundle average velocity,
U _{sc} , $\bar{U}$	- subchannel average velocity,
W	- uncertainty,
x	- x coordinate,
x ₁ , y ₁ , r ₁	- deviations from a correct reading,
X _c , Y _c	- measured variables,
y	- y coordinate,
y _T	- y traverse location,
Δy	- distance between rod rows,
z	- z coordinate,
Δz	- calculational increment,
β	- turbulent mixing,
λ	- wavelength,
ρ	- density,
θ	- angle between incident laser beams.

APPENDIX B
UNCERTAINTY ANALYSIS

APPENDIX B

UNCERTAINTY ANALYSIS

THEORETICAL APPROACH

Accuracies of the results of the blockage study were estimated using the uncertainty method presented by Schenck.⁽¹⁰⁾ Consider the general case of a result R , which is a function of the two measured variables X_c and Y_c :

$$R + r_1 = f(X_c + x_1, Y_c + y_1).$$

If this function is continuous and has derivatives, it can be expanded in a "Taylor series," using the first two terms only:

$$R + r_1 = f(X_c, Y_c) + \left[\left(\frac{\partial R}{\partial X_c} \right) \frac{X_c + x_1 - X_c}{1!} + \left(\frac{\partial R}{\partial Y_c} \right) \frac{Y_c + y_1 - Y_c}{1!} \right].$$

Or, since $R = f(X_c, Y_c)$:

$$r_1 = \left(\frac{\partial R}{\partial X_c} \right) x_1 + \left(\frac{\partial R}{\partial Y_c} \right) y_1$$

where the lower case letters (r_1 , x_1 , and y_1) apply to deviations from the correct readings, and

$$\sum r_1^2 = \left(\frac{\partial R}{\partial X_c} \right)^2 \sum x_1^2 + 2 \left(\frac{\partial R}{\partial X_c} \right) \left(\frac{\partial R}{\partial Y_c} \right) \sum x_1 y_1 + \left(\frac{\partial R}{\partial Y_c} \right)^2 \sum y_1^2$$

$\sum x_1 y_1$ tends to zero and $s_r^2 = \sum r_1^2 / n$ (standard deviation) so that

$$s_r^2 = \left(\frac{\partial R}{\partial X_c} \right)^2 s_x^2 + \left(\frac{\partial R}{\partial Y_c} \right)^2 s_y^2$$

and, for the uncertainty interval W

$$W_r^2 = \left(\frac{\partial R}{\partial X_c} \right)^2 W_x^2 + \left(\frac{\partial R}{\partial Y_c} \right)^2 W_y^2$$

where W for this analysis is that precision index enclosing 95 percent of all readings or values.

ANALYSIS DETAILS

Velocity Uncertainty

The uncertainty of the local axial velocity measurements can be estimated by referring to the relationship,

$$U = \lambda f_D / \sin \theta / 2$$
$$\therefore W_u^2 = \left(\frac{\partial U}{\partial \lambda} \right)^2 W_\lambda^2 + \left(\frac{\partial U}{\partial f_D} \right)^2 W_{f_D}^2 + \left(\frac{\partial U}{\partial \theta / 2} \right)^2 W_{\theta / 2}^2$$

It can be assumed that the uncertainty of the wavelength of the laser light is negligible. It was estimated, by considering spectrum analyzer/tracking generator accuracies, that the Doppler frequency uncertainty was $W_{f_D} \approx \pm 0.1$ MHz. The half angle uncertainty was calculated to be 0.06° using the above uncertainty methods. Since $\lambda = 6328 \text{ \AA}$, $\theta \approx 10^\circ$, and let $f_D = 1.84$ MHz (Run #AB-457) then,

$$W_u^2 = (f_D / 2 \sin \theta / 2)^2 W_\lambda^2 + (\lambda / 2 \sin \theta / 2)^2 W_{f_D}^2 + \left(\frac{-\lambda f_D}{2} \csc \theta / 2 \cdot \cot \theta / 2 \right)^2 W_{\theta / 2}^2$$

The uncertainty term associated with λ goes to zero since $W_\lambda \approx 0$. Therefore,

$$W_u^2 = (2.1 \times 10^{-6} / 2 \cdot 0.0872)^2 (0.1 \times 10^6)^2$$
$$+ (-2.1 \times 10^{-6} \cdot 1.84 \times 10^6 / 2 \cdot 11.47 \cdot 11.43)^2 0.001^2$$
$$W_u^2 = 1.45 + 0.0641$$
$$W_u = \pm 1.23 \text{ ft/sec.}$$

Therefore, the percent accuracy of the spectrum analyzer velocity measurement was

$$W_u / U = 1.23 / 20.6 \approx \pm 6\% \text{ (Spectrum Analyzer).}$$

The uncertainty of the frequency tracker velocity measurement can be estimated in exactly the same manner with the exception that $W_{fD} \approx \pm 0.05$ MHz. Therefore,

$$W_U^2 = (2.1 \times 10^{-6} / 2 \cdot 0.0872)^2 (0.05 \times 10^6)^2 + (-2.1 \times 10^{-6} \cdot 1.84 \times 10^6 \cdot 11.47 \cdot 11.43)^2 0.001^2$$

$$W_U^2 = 0.362 + 0.0641 = 0.4261$$

$$W_U/U = 0.426/20.6 \approx \pm 2\% \text{ (Frequency Tracker).}$$

Data Point Location Uncertainty

The uncertainty in the location of a particular data point relative to its neighbors in the x direction (parallel to the laser beam) was ± 0.001 inches. This uncertainty is essentially that of the positioning capability of the lift/traversing table.

Uncertainties of the locations of the data traverses in the y direction (perpendicular to the laser beam) relative to adjacent rod rows can be estimated as follows:

$$Y_T = \Delta y / 2$$

where

y_T = y location of the data traverse midway between rod rows

Δy = distance between rod rows as measured with the LDA.

The uncertainty of measuring the distance between rods was estimated to be ± 0.010 inches. Therefore,

$$W_{yT}^2 = \left(\frac{\partial y_T}{\partial \Delta y}\right)^2 W_{\Delta y}^2$$

$$W_{yT}^2 = (1/2)^2 W_{\Delta y}^2$$

$$W_{yT}^2 = 1/4 \cdot 0.01^2 = 2.5 \times 10^{-5}$$

$$W_{yT} = \pm 0.005 \text{ inches.}$$

The axial location of a particular data plane relative to the blockage axial centerline could be determined within ± 0.050 inches. This uncertainty estimate was determined by considering measurement accuracy and trueness of the horizontal travel of the lift/traversing table during any one data traverse.

APPENDIX C

TABULATION OF REDUCED DATA

TABLE C-1. TABULATION OF EXPERIMENTAL LDA DATA

DATA PLANE NO. 1. AXIAL DISTANCE FROM BLOCKAGE CENTERLINE = 25.46 IN. P = 14.93 PSI
 RE = 10400; THEIA = 10.66 DEGREES FREQ. SHIFT = 0.0 MHZ.

RUN ID/NO.	TEMP F	NOM. FLOW CFM	X IN.	Y IN.	UB FPS	F-DOP S.A. MHZ	U (LOCAL) S.A. FPS	VRATIO S.A. FREQ. RG. MHZ/10V.	TRACKER E (DOP) VOLTS	U (LOCAL) TRACKER FPS	VRATIO TRACKER	
AB 1.	80.0	168.0	.133	1.763	38.00	4.44	49.62	1.306	15.0	2.94	49.28	1.297
AB 2.	80.0	168.0	.233	1.763	38.00	4.29	47.94	1.262	15.0	2.94	49.28	1.297
AB 3.	80.0	168.0	.333	1.763	38.00	3.95	44.14	1.162	15.0	2.72	45.59	1.200
AB 4.	80.0	168.0	.433	1.763	38.00	3.76	42.02	1.106	15.0	2.58	43.25	1.138
AB 5.	80.0	168.0	.533	1.763	38.00	3.90	43.58	1.147	15.0	2.68	44.92	1.182
AB 6.	80.0	168.0	.633	1.763	38.00	4.11	45.93	1.209	15.0	2.84	47.61	1.253
AB 7.	80.0	168.0	.733	1.763	38.00	4.09	45.71	1.203	15.0	2.83	47.44	1.248
AB 8.	80.0	168.0	.833	1.763	38.00	3.78	42.24	1.112	15.0	2.66	44.59	1.173
AB 9.	80.0	168.0	.933	1.763	38.00	3.73	41.68	1.097	15.0	2.56	42.91	1.129
AB 10.	80.0	168.0	1.033	1.763	38.00	3.78	42.24	1.112	15.0	2.64	44.25	1.164
AB 11.	80.0	168.0	1.133	1.763	38.00	4.00	44.70	1.176	15.0	2.78	46.60	1.226
AB 12.	80.0	168.0	1.233	1.763	38.00	4.11	45.93	1.209	15.0	2.83	47.44	1.248
AB 13.	80.0	168.0	1.333	1.763	38.00	3.85	43.02	1.132	15.0	2.66	44.59	1.173
AB 14.	80.0	168.0	1.433	1.763	38.00	3.54	39.56	1.041	15.0	2.48	41.57	1.094
AB 15.	80.0	168.0	1.533	1.763	38.00	3.60	40.23	1.059	15.0	2.50	41.91	1.103
AB 16.	80.0	168.0	1.633	1.763	38.00	3.80	42.47	1.117	15.0	2.63	44.09	1.160
AB 17.	80.0	168.0	1.733	1.763	38.00	3.97	44.36	1.167	15.0	2.76	46.26	1.217
AB 18.	80.0	168.0	1.833	1.763	38.00	3.96	44.25	1.164	15.0	2.71	45.43	1.195
AB 19.	80.0	168.0	1.933	1.763	38.00	3.70	41.35	1.088	15.0	2.59	42.74	1.125
AB 20.	80.0	168.0	2.033	1.763	38.00	3.50	39.11	1.029	15.0	2.43	40.73	1.072
AB 21.	80.0	168.0	2.133	1.763	38.00	3.58	40.01	1.053	15.0	2.53	42.41	1.116
AB 22.	80.0	168.0	2.233	1.763	38.00	3.86	43.14	1.135	15.0	2.67	44.76	1.178
AB 23.	80.0	168.0	2.333	1.763	38.00	4.00	44.70	1.176	15.0	2.71	45.43	1.195
AB 27.	81.0	168.0	.233	1.224	38.00	4.46	49.84	1.312	15.0	2.75	46.10	1.213
AB 26.	81.0	168.0	.685	1.224	38.00	4.18	46.71	1.229	15.0	2.91	48.78	1.284
AB 25.	81.0	168.0	1.223	1.224	38.00	4.09	45.71	1.203	15.0	2.84	47.61	1.253
AB 24.	81.0	168.0	1.763	1.224	38.00	4.18	46.71	1.229	15.0	2.85	47.77	1.257
AB 31.	81.0	168.0	.233	1.224	38.00	0.00	0.00	0.000	15.0	.06	1.01	.026
AB 30.	81.0	168.0	.685	1.224	38.00	4.25	47.49	1.250	15.0	2.91	48.78	1.284
AB 29.	81.0	168.0	1.223	1.224	38.00	4.11	45.93	1.209	15.0	2.85	47.77	1.257
AB 28.	81.0	168.0	1.763	1.224	38.00	4.20	46.94	1.235	15.0	2.87	48.11	1.266
AB 35.	81.0	168.0	.233	.685	38.00	4.16	46.49	1.223	15.0	2.81	47.10	1.239
AB 34.	81.0	168.0	.685	.685	38.00	4.26	47.61	1.253	15.0	2.85	47.77	1.257
AB 33.	81.0	168.0	1.223	.685	38.00	4.35	48.61	1.279	15.0	3.00	50.29	1.323
AB 32.	81.0	168.0	1.763	.685	38.00	4.39	49.06	1.291	15.0	2.97	49.78	1.310
AB 39.	81.0	165.3	.233	.110	37.39	4.27	47.72	1.276	15.0	2.88	48.28	1.291
AB 38.	81.0	165.3	.685	.110	38.00	4.19	46.82	1.232	15.0	2.87	48.11	1.266
AB 37.	81.0	165.3	1.223	.110	38.00	4.36	48.72	1.282	15.0	2.93	49.11	1.292
AB 36.	81.0	165.3	1.763	.110	38.00	4.24	47.38	1.247	15.0	2.92	48.95	1.288

TABULATION OF EXPERIMENTAL LDA DATA

DATA PLANE NO. 2. AXIAL DISTANCE FROM BLOCKAGE CENTERLINE = 13.05 IN. P = 14.94 PSI
 RE = 10200. MEI = 10.66 DEGREES FREQ. SHIFT = 0.0 MHZ.

RUN ID: NO.	TEMP F	NOM. FLOW CFM	X IN.	Y IN.	UB FPS	F-DOP S.A. MHZ	U(LOCAL) S.A. FPS	VRATIO TRACKER S.A. FREQ. RG. MHZ/10V.	E(DOP) TRACKER VOLTS	U(LOCAL) TRACKER FPS	VRATIO TRACKER	
AB 40.	81.0	165.3	.133	1.763	37.39	4.15	46.38	1.240	15.0	2.86	47.94	1.282
AB 41.	81.0	165.3	.233	1.763	37.39	4.04	45.15	1.207	15.0	2.78	46.60	1.246
AB 42.	81.0	165.3	.333	1.763	37.39	3.93	43.92	1.175	15.0	2.72	45.59	1.219
AB 43.	81.0	165.3	.433	1.763	37.39	3.70	41.35	1.106	15.0	2.64	44.25	1.184
AB 44.	81.0	165.3	.533	1.763	37.39	3.63	40.57	1.085	15.0	2.62	43.92	1.175
AB 45.	81.0	165.3	.633	1.763	37.39	3.52	39.34	1.052	15.0	2.56	42.91	1.148
AB 46.	81.0	165.3	.733	1.763	37.39	3.47	38.78	1.037	15.0	2.53	42.41	1.134
AB 47.	81.0	165.3	.833	1.763	37.39	3.41	38.11	1.019	15.0	2.57	43.08	1.152
AB 48.	81.0	165.3	.933	1.763	37.39	3.49	39.00	1.043	15.0	2.50	41.91	1.121
AB 49.	81.0	165.3	1.033	1.763	37.39	3.47	38.78	1.037	15.0	2.51	42.07	1.125
AB 50.	81.0	165.3	1.133	1.763	37.39	3.48	38.89	1.040	15.0	2.49	41.74	1.116
AB 51.	81.0	165.3	1.233	1.763	37.39	3.45	38.55	1.031	15.0	2.49	41.74	1.116
AB 52.	81.0	165.3	1.333	1.763	37.39	3.41	38.11	1.019	15.0	2.47	41.40	1.107
AB 53.	81.0	165.3	1.433	1.763	37.39	3.39	37.88	1.013	15.0	2.46	41.24	1.103
AB 54.	81.0	165.3	1.533	1.763	37.39	3.29	36.77	.983	15.0	2.44	40.90	1.094
AB 55.	81.0	165.3	1.633	1.763	37.39	3.42	38.22	1.022	15.0	2.48	41.57	1.112
AB 56.	81.0	165.3	1.733	1.763	37.39	3.45	38.55	1.031	15.0	2.48	41.57	1.112
AB 57.	81.0	165.3	1.833	1.763	37.39	3.42	38.22	1.022	15.0	2.49	41.07	1.098
AB 58.	81.0	165.3	1.933	1.763	37.39	3.25	36.32	.971	15.0	2.39	40.06	1.071
AB 59.	81.0	165.3	2.033	1.763	37.39	3.18	35.54	.950	15.0	2.31	38.72	1.036
AB 60.	81.0	165.3	2.133	1.763	37.39	3.10	34.64	.926	15.0	2.30	38.55	1.031
AB 61.	81.0	165.3	2.233	1.763	37.39	3.19	35.65	.953	15.0	2.32	38.89	1.040
AB 62.	81.0	165.3	2.333	1.763	37.39	3.21	35.87	.959	15.0	2.33	39.06	1.045
AB 66.	81.0	165.3	.196	1.224	37.39	3.92	43.81	1.172	15.0	2.81	47.10	1.260
AB 65.	81.0	165.3	.685	1.224	37.39	3.50	39.11	1.046	15.0	2.57	43.08	1.152
AB 64.	81.0	165.3	1.224	1.224	37.39	3.73	41.68	1.115	15.0	2.67	44.76	1.197
AB 63.	81.0	165.3	1.763	1.224	37.39	3.56	39.78	1.064	15.0	2.54	42.58	1.139
AB 70.	82.0	165.3	.196	.685	37.39	3.85	43.02	1.151	15.0	2.66	44.59	1.192
AB 69.	82.0	165.3	.685	.685	37.39	3.85	43.02	1.151	15.0	2.75	46.10	1.233
AB 68.	82.0	165.3	1.224	.685	37.39	4.26	47.61	1.273	15.0	2.87	48.11	1.287
AB 67.	82.0	165.3	1.763	.685	37.39	3.80	42.47	1.136	15.0	2.70	45.26	1.210
AB 74.	82.0	163.9	.196	.110	37.07	4.49	50.18	1.353	15.0	2.99	50.12	1.352
AB 73.	82.0	163.9	.685	.110	37.39	4.20	46.94	1.255	15.0	2.91	48.78	1.305
AB 72.	82.0	163.9	1.224	.110	37.39	4.25	47.49	1.270	15.0	2.91	48.78	1.305
AB 71.	82.0	163.9	1.763	.110	37.39	3.97	44.36	1.187	15.0	2.81	47.10	1.260

TABULATION OF EXPERIMENTAL LDA DATA

DATA PLANE NO. 3. AXIAL DISTANCE FROM BLOCKAGE CENTERLINE = -4.80 IN. P = 14.85 PSI
 RE = 10400. THEIA = 10.66 DEGREES FREQ. SHIFT = 0.0 MHZ.

RUN ID: NO.	TEMP F	NOM. FLOW CFM	X IN.	Y IN.	UB FPS	F-DOP S.A. MHZ	U (LOCAL) S.A. FPS	VRATIO TRACKER S.A. FREQ. RG. MHZ/10V.	F (DOP) TRACKER VOLTS	U (LOCAL) TRACKER FPS	VRATIO TRACKER	
AB 75.	80.0	167.6	.163	1.763	38.21	4.06	45.37	1.188	15.0	2.66	44.59	1.167
AB 76.	80.0	167.6	.263	1.763	38.21	4.06	45.37	1.188	15.0	2.78	46.26	1.211
AB 77.	80.0	167.6	.363	1.763	38.21	3.76	42.02	1.100	15.0	2.62	43.92	1.150
AB 78.	80.0	167.6	.463	1.763	38.21	3.63	40.57	1.062	15.0	2.56	42.91	1.123
AB 79.	80.0	167.6	.563	1.763	38.21	3.81	42.58	1.114	15.0	2.66	44.59	1.167
AB 80.	80.0	167.6	.663	1.763	38.21	4.10	45.82	1.199	15.0	2.80	46.94	1.228
AB 81.	80.0	167.6	.763	1.763	38.21	4.08	45.59	1.193	15.0	2.85	47.77	1.250
AB 82.	80.0	167.6	.863	1.763	38.21	4.05	45.26	1.185	15.0	2.78	46.60	1.220
AB 83.	80.0	167.6	.963	1.763	38.21	3.98	44.48	1.164	15.0	2.76	46.26	1.211
AB 84.	80.0	167.6	1.063	1.763	38.21	4.00	44.70	1.170	15.0	2.78	46.60	1.220
AB 85.	80.0	167.6	1.163	1.763	38.21	4.05	45.26	1.185	15.0	2.84	47.61	1.246
AB 86.	80.0	167.6	1.263	1.763	38.21	4.11	45.93	1.202	15.0	2.82	47.27	1.237
AB 87.	80.0	167.6	1.363	1.763	38.21	3.93	43.92	1.150	15.0	2.70	45.26	1.185
AB 88.	80.0	167.6	1.463	1.763	38.21	3.74	41.79	1.094	15.0	2.60	43.58	1.141
AB 89.	80.0	167.6	1.563	1.763	38.21	3.73	41.68	1.091	15.0	2.62	43.92	1.150
AB 90.	80.0	167.6	1.663	1.763	38.21	3.93	43.92	1.150	15.0	2.73	45.76	1.198
AB 91.	80.0	167.6	1.763	1.763	38.21	3.99	44.59	1.167	15.0	2.80	46.94	1.228
AB 92.	80.0	167.6	1.863	1.763	38.21	4.06	45.37	1.188	15.0	2.78	46.26	1.211
AB 93.	80.0	167.6	1.963	1.763	38.21	3.91	43.69	1.144	15.0	2.67	44.76	1.171
AB 94.	80.0	167.6	2.063	1.763	38.21	3.77	42.13	1.103	15.0	2.57	43.08	1.128
AB 95.	80.0	167.6	2.163	1.763	38.21	3.68	41.12	1.076	15.0	2.63	44.09	1.154
AB 96.	80.0	167.6	2.263	1.763	38.21	3.97	44.36	1.161	15.0	2.73	45.76	1.198
AB 97.	80.0	167.6	2.363	1.763	38.21	3.98	44.48	1.164	15.0	2.78	46.60	1.220
AB 98.	80.0	167.6	2.463	1.763	38.21	3.97	44.36	1.161	15.0	2.77	46.43	1.215
AB 99.	80.0	167.6	2.563	1.763	38.21	3.93	43.92	1.150	15.0	2.70	45.26	1.185
AB 100.	80.0	167.6	2.663	1.763	38.21	3.96	44.25	1.158	15.0	2.72	45.59	1.193
AB 101.	80.0	167.6	2.763	1.763	38.21	4.06	45.37	1.188	15.0	2.82	47.27	1.237
AB 102.	80.0	167.6	2.863	1.763	38.21	4.19	46.82	1.226	15.0	2.87	48.11	1.259
AB 103.	80.0	167.6	2.963	1.763	38.21	4.11	45.93	1.202	15.0	2.83	47.44	1.242
AB 104.	80.0	167.6	3.063	1.763	38.21	3.81	42.58	1.114	15.0	2.68	44.92	1.176
AB 105.	80.0	167.6	3.163	1.763	38.21	3.83	42.80	1.120	15.0	2.69	44.09	1.154
AB 106.	80.0	167.6	3.263	1.763	38.21	3.86	43.14	1.129	15.0	2.70	45.26	1.185
AB 107.	80.0	167.6	3.363	1.763	38.21	3.98	44.48	1.164	15.0	2.78	46.60	1.220
AB 108.	80.0	167.6	3.463	1.763	38.21	3.96	44.25	1.158	15.0	2.72	45.59	1.193
AB 109.	80.0	167.6	3.563	1.763	38.21	3.72	41.57	1.088	15.0	2.58	43.25	1.132
AB 110.	80.0	167.6	3.663	1.763	38.21	3.57	39.89	1.044	15.0	2.46	41.24	1.079
AB 111.	80.0	167.6	3.763	1.763	38.21	3.60	40.23	1.053	15.0	2.56	42.91	1.123
AB 112.	80.0	167.6	3.863	1.763	38.21	3.98	44.48	1.164	15.0	2.75	46.10	1.207
AB 113.	80.5	167.6	3.963	1.763	37.91	4.17	46.60	1.229	15.0	2.86	47.94	1.265
AB 117.	81.0	167.6	.146	1.224	37.91	4.07	45.48	1.200	15.0	2.69	45.09	1.189
AB 116.	81.0	167.6	.685	1.224	37.91	3.95	44.14	1.164	15.0	2.79	46.77	1.234
AB 115.	81.0	167.6	1.224	1.224	37.91	3.94	44.03	1.161	15.0	2.76	46.26	1.220
AB 114.	81.0	167.6	1.763	1.224	37.91	4.03	45.04	1.188	15.0	2.76	46.26	1.220

RUN ID NO.	TEMP F	NOM. FLOW CFM	X IN.	Y IN.	UB FPS	F-DOP S.A. MHZ	U(LOCAL) S.A. FPS	VRATIO TRACKER S.A. FREQ. RG. MHZ/10V.	F(DOP) TRACKER VOLTS	U(LOCAL) TRACKER FPS	VRATIO TRACKER	
AB 121.	81.0	167.6	.146	.685	37.91	0.00	0.00	0.000	15.0	.06	1.01	.027
AB 120.	81.0	167.6	.685	.685	37.91	3.90	43.58	1.150	15.0	2.79	46.77	1.234
AB 119.	81.0	167.6	1.224	.685	37.91	3.86	43.14	1.138	15.0	2.68	44.92	1.185
AB 118.	81.0	167.6	1.763	.685	37.91	3.85	43.02	1.135	15.0	2.74	45.93	1.211
AB 125.	81.0	167.6	.146	.110	37.91	0.00	0.00	0.000	15.0	.06	1.01	.027
AB 124.	81.0	167.6	.685	.110	37.91	4.19	46.82	1.235	15.0	2.89	48.44	1.278
AB 123.	81.0	167.6	1.224	.110	37.91	4.18	46.71	1.232	15.0	2.88	48.28	1.273
AB 122.	81.0	167.6	1.763	.110	37.91	4.40	49.17	1.297	15.0	3.03	50.79	1.340

TABULATION OF EXPERIMENTAL LOA DATA

DATA PLANE NO. 4. AXIAL DISTANCE FROM BLOCKAGE CENTERLINE = 7.50 IN. P = 14.98 PSI
 RE = 10200. THEIA = 10.66 DEGREES FREQ. SHIFT = 0.0 MHZ.

RUN ID. NO.	TEMP F	NOM. FLOW CFM	X IN.	Y IN.	UB FPS	F-DOP S.A. MHZ	U(LOCAL) S.A. FPS	VRATIO S.A. FREQ. RG. MHZ/10V.	TRACKER E(DOP) VOLTS	U(LOCAL) TRACKER FPS	VRATIO TRACKER	
AB 126.	80.0	166.8	.149	1.763	37.50	4.62	51.63	1.377	15.0	2.96	49.62	1.323
AB 127.	80.0	166.8	.249	1.763	37.50	4.31	48.16	1.284	15.0	2.86	47.94	1.278
AB 128.	80.0	166.8	.349	1.763	37.50	4.00	44.70	1.192	15.0	2.74	45.93	1.225
AB 129.	80.0	166.8	.449	1.763	37.50	3.94	44.03	1.174	15.0	2.67	44.76	1.193
AB 130.	80.0	166.8	.549	1.763	37.50	4.07	45.48	1.213	15.0	2.77	46.43	1.238
AB 131.	80.0	166.8	.649	1.763	37.50	4.25	47.49	1.266	15.0	2.89	48.44	1.292
AB 132.	80.0	166.8	.749	1.763	37.50	4.39	49.06	1.308	15.0	2.94	49.28	1.314
AB 133.	80.0	166.8	.849	1.763	37.50	4.34	48.50	1.293	15.0	2.89	48.44	1.292
AB 134.	80.0	166.8	.949	1.763	37.50	3.94	44.03	1.174	15.0	2.74	45.93	1.225
AB 135.	80.0	166.8	1.049	1.763	37.50	3.69	41.24	1.099	15.0	2.61	43.75	1.167
AB 136.	80.0	166.8	1.149	1.763	37.50	3.53	39.45	1.052	15.0	2.54	42.58	1.135
AB 137.	80.0	166.8	1.249	1.763	37.50	3.50	39.11	1.043	15.0	2.50	41.91	1.117
AB 138.	80.0	166.8	1.349	1.763	37.50	3.37	37.66	1.004	15.0	2.39	40.06	1.068
AB 139.	80.0	166.8	1.449	1.763	37.50	3.18	35.54	.948	15.0	2.33	39.06	1.041
AB 140.	80.0	166.8	1.549	1.763	37.50	2.76	30.84	.822	5.0	5.42	30.28	.807
AB 141.	80.0	166.8	1.649	1.763	37.50	2.73	30.51	.813	5.0	5.36	29.95	.799
AB 142.	80.0	166.8	1.749	1.763	37.50	2.65	29.61	.790	5.0	5.16	28.83	.769
AB 143.	80.0	166.8	1.849	1.763	37.50	2.58	28.83	.769	5.0	5.05	28.22	.752
AB 144.	80.0	166.8	1.949	1.763	37.50	2.54	28.38	.757	5.0	4.86	27.16	.724
AB 145.	80.0	166.8	2.049	1.763	37.50	2.45	27.38	.730	5.0	4.81	26.88	.717
AB 146.	80.0	166.8	2.149	1.763	37.50	2.54	28.38	.757	5.0	4.96	27.71	.739
AB 147.	80.0	166.8	2.249	1.763	37.50	2.59	28.94	.772	5.0	4.94	27.60	.736
AB 148.	81.0	166.8	2.349	1.763	37.73	2.70	30.17	.800	5.0	5.06	28.27	.749
AB 149.	80.5	168.0	.149	1.224	38.00	4.34	48.50	1.276	15.0	2.94	49.28	1.297
AB 150.	80.5	168.0	.249	1.224	38.00	4.46	49.84	1.312	15.0	2.93	49.11	1.292
AB 151.	80.5	168.0	.349	1.224	38.00	4.05	45.26	1.191	15.0	2.76	46.26	1.217
AB 152.	80.5	168.0	.449	1.224	38.00	3.90	43.58	1.147	15.0	2.72	45.59	1.200
AB 153.	80.5	168.0	.549	1.224	38.00	4.10	45.82	1.206	15.0	2.77	46.43	1.222
AB 154.	80.5	168.0	.649	1.224	38.00	4.22	47.16	1.241	15.0	2.86	47.94	1.262
AB 155.	80.5	168.0	.749	1.224	38.00	4.35	48.61	1.279	15.0	2.91	48.78	1.284
AB 156.	80.5	168.0	.849	1.224	38.00	4.28	47.83	1.259	15.0	2.88	47.44	1.248
AB 157.	80.5	168.0	.949	1.224	38.00	3.87	43.25	1.138	15.0	2.68	44.92	1.182
AB 158.	80.5	168.0	1.049	1.224	38.00	3.87	43.25	1.138	15.0	2.61	43.75	1.151
AB 159.	80.5	168.0	1.149	1.224	38.00	3.93	43.92	1.156	15.0	2.68	44.92	1.182
AB 160.	80.5	168.0	1.249	1.224	38.00	3.94	44.03	1.159	15.0	2.71	45.43	1.195
AB 161.	80.5	168.0	1.349	1.224	38.00	3.92	43.81	1.153	15.0	2.66	44.59	1.173
AB 162.	80.5	168.5	1.449	1.763	38.00	3.77	42.13	1.109	15.0	2.53	42.41	1.116
AB 163.	80.5	168.5	1.549	1.763	38.00	3.45	38.55	1.015	15.0	2.42	40.57	1.067
AB 164.	80.5	168.5	1.649	1.763	38.00	3.45	38.55	1.015	15.0	2.42	40.57	1.067
AB 165.	80.5	168.5	1.749	1.763	38.00	3.48	38.89	1.023	15.0	2.50	41.91	1.103
AB 166.	80.5	168.5	1.849	1.763	38.00	3.38	37.77	.994	5.0	6.90	38.55	1.015
AB 167.	80.5	168.5	1.949	1.763	38.00	3.20	35.76	.941	5.0	6.54	36.54	.962
AB 168.	80.5	168.5	2.049	1.763	38.00	3.18	35.54	.935	5.0	6.53	36.49	.960
AB 169.	80.5	168.5	2.149	1.763	38.00	3.25	36.43	.959	5.0	6.52	36.43	.959

RUN ID: NO.	TEMP F	NOM. #LOW CFM	X IN.	Y IN.	UB FPS	F-DOP S.A. MHZ	U(LOCAL) S.A. FRS	VRATIO S.A. FREQ. RG. MHZ/10V.	TRACKER FREQ. RG. MHZ/10V.	F(DOP) TRACKER VOLTS	U(LOCAL) TRACKER FPS	VRATIO TRACKER
AB 170.	80.5	168.5	2.249	1.763	38.00	3.37	37.66	.991	5.0	6.81	38.05	1.001
AB 171.	80.0	168.5	2.349	1.763	38.11	3.41	38.11	1.000	5.0	6.80	38.00	.997
AB 172.	80.0	167.1	.149	.685	37.80	4.47	49.95	1.322	15.0	2.90	48.61	1.286
AB 173.	80.0	167.1	.249	.685	37.80	4.16	48.72	1.289	15.0	2.88	47.94	1.268
AB 174.	80.0	167.1	.349	.685	37.80	3.95	44.14	1.168	15.0	2.66	44.59	1.180
AB 175.	80.0	167.1	.449	.685	37.80	3.75	41.91	1.109	15.0	2.57	43.08	1.140
AB 176.	80.0	167.1	.549	.685	37.80	3.89	43.47	1.150	15.0	2.67	44.76	1.184
AB 177.	80.0	167.1	.649	.685	37.80	4.25	47.49	1.257	15.0	2.84	47.61	1.259
AB 178.	80.0	167.1	.749	.685	37.80	4.32	48.28	1.277	15.0	2.88	48.28	1.277
AB 179.	80.0	167.1	.849	.685	37.80	4.04	45.15	1.194	15.0	2.73	45.76	1.211
AB 180.	80.0	167.1	.949	.685	37.80	3.83	42.80	1.132	15.0	2.64	44.25	1.171
AB 181.	80.0	167.1	1.049	.685	37.80	3.89	43.47	1.150	15.0	2.70	45.26	1.197
AB 182.	80.0	167.1	1.149	.685	37.80	4.14	46.26	1.224	15.0	2.82	47.27	1.251
AB 183.	80.0	167.1	1.249	.685	37.80	4.35	48.61	1.286	15.0	2.91	48.78	1.291
AB 184.	80.0	167.1	1.349	.685	37.80	4.61	44.81	1.186	15.0	2.76	46.26	1.224
AB 185.	80.0	167.1	1.449	.685	37.80	3.66	40.90	1.082	15.0	2.57	43.08	1.140
AB 186.	80.0	167.1	1.549	.685	37.80	3.75	41.91	1.109	15.0	2.61	43.75	1.157
AB 187.	80.0	167.1	1.649	.685	37.80	4.61	44.81	1.186	15.0	2.78	46.60	1.233
AB 188.	80.0	167.1	1.749	.685	37.80	4.24	47.38	1.254	15.0	2.90	48.61	1.286
AB 189.	80.0	167.1	1.849	.685	37.80	4.33	46.15	1.221	15.0	2.77	46.43	1.228
AB 190.	80.0	167.1	1.949	.685	37.80	3.80	42.47	1.123	15.0	2.60	43.58	1.153
AB 191.	80.0	167.1	2.049	.685	37.80	3.71	41.46	1.097	15.0	2.58	43.25	1.144
AB 192.	80.0	167.1	2.149	.685	37.80	3.97	44.36	1.174	15.0	2.72	45.59	1.205
AB 193.	80.0	167.1	2.249	.685	37.80	4.24	47.38	1.254	15.0	2.93	49.11	1.299
AB 194.	80.0	167.1	2.349	.685	37.80	4.29	47.94	1.268	15.0	2.94	49.28	1.304
AB 198.	80.0	168.0	.149	.110	38.00	4.16	46.49	1.223	15.0	2.78	46.60	1.226
AB 197.	80.0	168.0	.685	.110	37.80	4.32	48.28	1.277	15.0	2.91	48.78	1.291
AB 196.	80.0	168.0	1.224	.110	37.80	4.50	50.29	1.330	15.0	2.86	47.94	1.268
AB 195.	80.0	168.0	1.763	.110	37.80	4.56	50.96	1.348	15.0	2.92	48.95	1.295

TABULATION OF EXPERIMENTAL LDA DATA

DATA PLANE NO. 6. AXIAL DISTANCE FROM BLOCKAGE CENTERLINE = 3.70 IN. P = 14.81 PSI
 RE = 10300. IMEIA = 9.53 DEGREES

RUN ID.NO.	TEMP F	NOM. FLOW CFM	X IN.	Y IN.	FREQ. SHIFT MHZ	S.A. FREQ. MHZ	DOP.FREQ. S.A. MHZ	U(LOCAL) S.A. FPS	UB FPS	VRATIO S.A.
AR 923.	79.5	164.9	.233	1.763	1.0	5.18	4.18	52.10	37.59	1.386
AR 924.	79.5	164.9	.333	1.763	1.0	5.08	4.08	50.86	37.59	1.353
AR 925.	79.5	164.9	.433	1.763	1.0	4.83	3.83	47.74	37.59	1.270
AR 926.	79.5	164.9	.533	1.763	1.0	4.85	3.85	47.99	37.59	1.277
AR 927.	79.5	164.9	.633	1.763	1.0	4.78	3.78	47.12	37.59	1.253
AR 928.	79.5	164.9	.733	1.763	1.0	4.87	3.87	48.24	37.59	1.283
AR 929.	79.5	164.9	.833	1.763	1.0	4.88	3.88	48.36	37.59	1.286
AR 930.	79.5	164.9	.933	1.763	1.0	4.86	3.86	48.11	37.59	1.280
AR 931.	79.5	164.9	1.033	1.763	1.0	4.51	3.51	43.75	37.59	1.164
AR 932.	79.5	164.9	1.133	1.763	1.0	4.08	3.08	38.39	37.59	1.021
AR 933.	79.5	164.9	1.233	1.763	1.0	3.81	2.81	35.03	37.59	.932
AR 934.	79.5	164.9	1.333	1.763	1.0	3.77	2.77	34.53	37.59	.918
AR 935.	79.5	164.9	1.433	1.763	1.0	3.74	2.74	34.15	37.59	.908
AR 936.	79.5	164.9	1.533	1.763	1.0	3.55	2.55	31.79	37.59	.845
AR 937.	79.5	164.9	1.633	1.763	1.0	3.29	2.29	28.54	37.59	.759
AR 938.	79.5	164.9	1.733	1.763	1.0	2.75	1.75	21.81	37.59	.580
AR 939.	79.5	164.9	1.833	1.763	1.0	2.63	1.63	20.32	37.59	.540
AR 940.	79.5	164.9	1.933	1.763	1.0	2.28	1.28	15.96	37.59	.424
AR 941.	79.5	164.9	2.033	1.763	1.0	2.16	1.16	14.46	37.59	.385
AR 942.	79.5	164.9	2.133	1.763	1.0	2.15	1.15	14.33	37.59	.381
AR 943.	79.5	164.9	2.233	1.763	1.0	2.27	1.27	15.83	37.59	.421
AR 944.	80.8	164.9	2.333	1.763	1.0	2.55	1.55	19.32	37.30	.518

TABULATION OF EXPERIMENTAL LDA DATA

DATA PLANE NO: 6. AXIAL DISTANCE FROM BLOCKAGE CENTERLINE = 3.80 IN. P = 14.82 PSI
 RE = 10300. IMETA = 10.66 DEGREES FREQ. SHIFT = 0.0 MHZ.

RUN ID.NO.	TEMP F	NOM. FLOW CFM	X IN.	Y IN.	UB FPS	F-DOP S.A. MHZ	U(LOCAL) S.A. FPS	VRATIO TRACKER S.A. FREQ.RG. MHZ/10V.	E(DOP) TRACKER VOLTS	U(LOCAL) TRACKER FPS	VRATIO- TRACKER
AB 312.	80.0	166.7	.251	1.224	37.53	4.62	51.63	1.376 15.0	3.04	50.96	1.358
AB 313.	80.0	166.7	.351	1.224	37.53	4.34	48.50	1.292 15.0	2.88	48.28	1.286
AR 314.	80.0	166.7	.451	1.224	37.53	4.08	45.59	1.215 15.0	2.81	47.10	1.255
AB 315.	80.0	166.7	.551	1.224	37.53	4.13	46.15	1.230 15.0	2.84	47.61	1.269
AR 316.	80.0	166.7	.651	1.224	37.53	4.41	49.28	1.313 15.0	2.88	48.28	1.286
AB 317.	80.0	166.7	.751	1.224	37.53	4.42	49.39	1.316 15.0	2.97	49.78	1.327
AR 318.	80.0	166.7	.851	1.224	37.53	4.38	48.95	1.304 15.0	2.91	48.78	1.300
AB 319.	80.0	166.7	.951	1.224	37.53	4.20	46.94	1.251 15.0	2.81	47.10	1.255
AB 320.	80.0	166.7	1.051	1.224	37.53	3.93	43.92	1.170 15.0	2.71	45.43	1.211
AB 321.	80.0	166.7	1.151	1.224	37.53	3.69	41.24	1.099 15.0	2.61	43.75	1.166
AR 322.	80.0	166.7	1.251	1.224	37.53	3.72	41.57	1.108 15.0	2.56	42.91	1.144
AB 323.	80.0	166.7	1.351	1.224	37.53	3.63	40.57	1.081 15.0	2.53	42.41	1.130
AR 324.	80.0	166.7	1.451	1.224	37.53	3.51	39.22	1.045 15.0	2.49	41.07	1.094
AB 325.	80.0	166.7	1.551	1.224	37.53	3.29	36.77	.980 15.0	2.50	41.91	1.117
AB 326.	80.0	166.7	1.651	1.224	37.53	3.33	37.21	.992 15.0	2.16	36.21	.965
AR 327.	80.0	166.7	1.751	1.224	37.53	3.31	36.99	.986 15.0	2.17	36.37	.969
AB 328.	80.0	166.7	1.851	1.224	37.53	3.24	36.21	.965 15.0	2.13	35.70	.951
AB 329.	80.0	166.7	1.951	1.224	37.53	2.69	30.06	.801 5.0	5.45	30.45	.811
AR 330.	80.0	166.7	2.051	1.224	37.53	2.70	30.17	.804 5.0	5.28	29.50	.786
AB 331.	80.0	166.7	2.151	1.224	37.53	2.84	31.74	.846 5.0	5.30	29.61	.789
AB 332.	80.0	166.7	2.251	1.224	37.53	2.93	32.74	.873 5.0	5.60	31.29	.834
AB 333.	80.0	166.7	2.351	1.224	37.53	2.94	32.85	.875 5.0	5.73	32.02	.853
AR 334.	80.0	166.7	2.451	1.224	37.71	3.04	33.97	.901 5.0	5.90	32.97	.874
AR 335.	80.0	165.3	.251	.645	37.71	4.62	51.63	1.369 15.0	3.00	50.29	1.334
AB 336.	80.0	165.3	.351	.685	37.71	4.12	46.04	1.221 15.0	2.82	47.27	1.254
AB 337.	80.0	165.3	.451	.685	37.71	4.03	45.04	1.194 15.0	2.72	45.59	1.209
AR 338.	80.0	165.3	.551	.685	37.71	4.16	46.49	1.233 15.0	2.81	47.10	1.249
AB 339.	80.0	165.3	.651	.685	37.71	4.39	49.06	1.301 15.0	2.97	49.78	1.320
AB 340.	80.0	165.3	.751	.685	37.71	4.53	50.62	1.342 15.0	3.01	50.46	1.338
AR 341.	80.0	165.3	.851	.685	37.71	4.29	47.94	1.271 15.0	2.91	48.78	1.294
AB 342.	80.0	165.3	.951	.685	37.71	4.14	46.26	1.227 15.0	2.80	46.94	1.245
AR 343.	80.0	165.3	1.051	.685	37.71	4.04	45.15	1.197 15.0	2.74	45.93	1.218
AB 344.	80.0	165.3	1.151	.685	37.71	4.15	46.38	1.230 15.0	2.80	46.94	1.245
AR 345.	80.0	165.3	1.251	.685	37.71	4.36	48.72	1.292 15.0	2.96	49.62	1.316
AB 346.	80.0	165.3	1.351	.685	37.71	4.20	46.94	1.245 15.0	2.85	47.77	1.267
AR 347.	80.0	165.3	1.451	.685	37.71	3.95	44.14	1.171 15.0	2.74	45.93	1.218
AR 348.	80.0	165.3	1.551	.685	37.71	3.86	43.14	1.144 15.0	2.72	45.59	1.209
AR 349.	80.0	165.3	1.651	.685	37.71	3.94	44.03	1.168 15.0	2.78	46.26	1.227
AR 350.	80.0	165.3	1.751	.685	37.71	4.28	47.83	1.268 15.0	3.01	50.46	1.338
AR 351.	80.0	165.3	1.851	.685	37.71	4.13	46.15	1.224 15.0	2.84	47.61	1.262
AR 352.	80.0	165.3	1.951	.685	37.71	3.85	43.02	1.141 15.0	2.73	45.76	1.214
AB 353.	80.0	165.3	2.051	.685	37.71	3.91	43.69	1.159 15.0	2.69	45.09	1.196
AB 354.	80.0	165.3	2.151	.685	37.71	3.83	42.80	1.135 15.0	2.72	45.59	1.209
AR 355.	80.0	165.3	2.251	.685	37.71	4.18	46.71	1.239 15.0	2.91	48.78	1.294
AB 356.	80.0	165.3	2.351	.685	37.71	4.48	50.06	1.328 15.0	3.01	50.46	1.338
AB 357.	80.3	165.3	2.451	.685	37.39	4.09	45.71	1.222 15.0	2.79	46.77	1.251

RUN ID: NO.	TEMP F	NOM. FLOW CFM	X IN.	Y IN.	UB FPS	F-DOP S.A. MHZ	U(LOCAL) S.A. FRS	VRATIO TRACKER S.A. FREQ. RG. MHZ/10V.	E(DOP) TRACKER VOLTS	U(LOCAL) TRACKER FPS	VRATIO TRACKER
AB 361.	80.4	165.3	.151	.110	37.39	4.36	48.72	1.303 15.0	2.77	46.43	1.242
AB 360.	80.3	165.3	.085	.110	37.39	4.64	51.85	1.387 15.0	3.06	51.29	1.372
AB 359.	80.3	165.3	1.224	.110	37.39	4.51	50.40	1.348 15.0	3.04	50.96	1.363
AB 358.	80.3	165.3	1.763	.110	37.39	4.58	51.18	1.369 15.0	3.19	52.47	1.403

TABULATION OF EXPERIMENTAL LDA DATA

DATA PLANE NO. 7. AXIAL DISTANCE FROM BLOCKAGE CENTERLINE = -1.30 IN. P = 14.87 PSI
 RE = 10300. THETA = 9.53 DEGREES

RUN ID. NO.	TEMP F	NO. M. FLOW CFM	X IN.	Y IN.	FREQ. SHIFT MHZ	S.A. FREQ. MHZ	DOR. FREQ. S.A. MHZ	U (LOCAL) S.A. FPS	UB FPS	VRATIO S.A.
AB 901.	81.0	167.1	.233	1.703	.5	4.39	3.89	48.49	37.80	1.283
AB 902.	81.0	167.1	.333	1.703	.5	4.23	3.73	46.49	37.80	1.230
AB 903.	81.0	167.1	.433	1.703	.5	4.20	3.70	46.12	37.80	1.220
AB 904.	81.0	167.1	.533	1.703	.5	4.33	3.83	47.74	37.80	1.263
AB 905.	81.0	167.1	.633	1.703	.5	4.25	3.75	46.74	37.80	1.237
AB 906.	81.0	167.1	.733	1.703	.5	4.09	3.59	44.75	37.80	1.194
AB 907.	81.0	167.1	.833	1.703	.5	4.14	3.64	45.37	37.80	1.200
AB 908.	81.0	167.1	.933	1.703	.5	4.19	3.69	46.00	37.80	1.217
AB 909.	81.0	167.1	1.033	1.703	.5	4.17	3.67	45.75	37.80	1.210
AB 910.	81.0	167.1	1.133	1.703	.5	3.99	3.49	43.50	37.80	1.151
AB 911.	81.0	167.1	1.233	1.703	.5	3.86	3.36	41.88	37.80	1.108
AB 912.	81.0	167.1	1.333	1.703	.5	3.81	3.31	41.26	37.80	1.092
AB 913.	81.0	167.1	1.433	1.703	.5	3.18	2.68	33.41	37.80	.884
AB 914.	81.0	167.1	1.533	1.703	.5	2.58	2.08	25.93	37.80	.686
AB 915.	81.0	167.1	1.633	1.703	1.0	2.27	1.27	15.83	37.80	.419
AB 919.	81.0	167.1	1.733	1.703	1.0	1.66	.66	8.23	37.80	.218
AB 918.	81.0	167.1	1.833	1.703	1.0	1.68	.68	8.48	37.80	.224
AB 917.	81.0	167.1	1.933	1.703	1.0	1.96	.96	11.97	37.80	.317
AB 916.	81.0	167.1	2.033	1.703	1.0	2.01	1.01	12.59	37.80	.333
AB 922.	81.3	167.1	2.133	1.703	1.0	1.92	.92	11.47	37.80	.303
AB 920.	81.0	167.1	2.233	1.703	1.0	1.37	.37	4.61	37.80	.122
AB 921.	81.0	167.1	2.333	1.703	1.0	1.44	.44	5.48	37.80	.145

TABULATION OF EXPERIMENTAL LDA DATA

DATA PLANE NO. 7. AXIAL DISTANCE FROM BLOCKAGE CENTERLINE = -1.30 IN. P = 14.90 PSI
 RE = 10300. THEIA = 10.66 DEGREES FREQ. SHIFT = 0.0 MHZ.

RUN ID: NO.	TEMP F	NOM. FLOW CFM	X IN.	Y IN.	UB FPS	F-DOP S.A. MHZ	U(LOCAL) S.A. FPS	VRATIO TRACKER S.A. FREQ. RG. MHZ/10V.	E(DOP) TRACKER VOLTS	U(LOCAL) TRACKER FPS	VRATIO TRACKER	
AB 385.	80.0	167.1	.151	1.224	37.80	4.75	53.08	1.404	15.0	2.81	47.10	1.246
AB 386.	80.0	167.1	.251	1.224	37.80	4.57	51.07	1.351	15.0	2.90	48.61	1.286
AB 387.	80.0	167.1	.351	1.224	37.80	4.31	48.16	1.274	15.0	2.89	48.44	1.282
AB 388.	80.0	167.1	.451	1.224	37.80	4.51	50.40	1.333	15.0	2.92	48.95	1.295
AB 389.	80.0	167.1	.551	1.224	37.80	4.54	50.73	1.342	15.0	2.98	49.95	1.322
AB 390.	80.0	167.1	.651	1.224	37.80	4.59	51.29	1.357	15.0	2.98	49.95	1.322
AB 391.	80.0	167.1	.751	1.224	37.80	4.27	47.72	1.262	15.0	2.84	47.61	1.259
AB 392.	80.0	167.1	.851	1.224	37.80	3.96	44.25	1.171	15.0	2.70	45.26	1.197
AB 393.	80.0	167.1	.951	1.224	37.80	3.92	43.81	1.159	15.0	2.74	45.93	1.215
AB 394.	80.0	167.1	1.051	1.224	37.80	3.97	44.36	1.174	15.0	2.77	46.43	1.228
AB 395.	80.0	167.1	1.151	1.224	37.80	4.03	45.04	1.191	15.0	2.76	46.26	1.224
AB 396.	80.0	167.1	1.251	1.224	37.80	3.72	41.57	1.100	15.0	2.63	44.09	1.166
AB 397.	80.0	167.1	1.351	1.224	37.80	2.59	28.94	.766	5.0	5.26	29.39	.778
AB 398.	80.0	167.1	1.451	1.224	37.80	2.53	28.27	.748	5.0	5.26	29.39	.778
AB 399.	80.0	167.1	1.551	1.224	37.80	2.42	27.04	.715	5.0	4.98	27.83	.736
AB 400.	80.0	167.1	1.651	1.224	37.80	2.52	28.16	.745	5.0	5.01	27.99	.741
AB 401.	80.0	167.1	1.751	1.224	37.80	2.44	27.27	.721	5.0	5.03	28.11	.744
AB 402.	80.0	167.1	1.851	1.224	37.80	2.43	27.16	.718	5.0	5.06	28.27	.748
AB 403.	80.0	167.1	1.951	1.224	37.80	2.49	27.83	.736	5.0	4.98	27.71	.733
AB 404.	80.0	167.1	2.051	1.224	37.80	2.62	29.28	.775	5.0	5.10	28.50	.754
AB 405.	80.0	167.1	2.151	1.224	37.80	2.60	29.06	.769	5.0	5.19	29.00	.767
AB 406.	80.0	167.1	2.251	1.224	37.80	2.49	27.83	.736	5.0	4.91	27.43	.726
AB 407.	80.0	167.1	2.351	1.224	37.80	2.49	27.83	.736	5.0	4.96	27.71	.733
AB 408.	79.3	166.2	.151	.685	37.91	4.67	52.19	1.377	15.0	2.99	50.12	1.322
AB 409.	79.3	166.2	.251	.685	37.91	4.49	50.18	1.324	15.0	2.93	49.11	1.295
AB 410.	79.3	166.2	.351	.685	37.91	4.13	46.15	1.217	15.0	2.87	48.11	1.269
AB 411.	79.3	166.2	.451	.685	37.91	4.16	46.49	1.226	15.0	2.87	48.11	1.269
AB 412.	79.3	166.2	.551	.685	37.91	4.29	47.94	1.265	15.0	2.92	48.95	1.291
AB 413.	79.3	166.2	.651	.685	37.91	4.45	49.73	1.312	15.0	2.95	49.45	1.304
AB 414.	79.3	166.2	.751	.685	37.91	4.23	47.27	1.247	15.0	2.88	48.28	1.273
AB 415.	79.3	166.2	.851	.685	37.91	3.91	43.69	1.153	15.0	2.76	46.26	1.220
AB 416.	79.3	166.2	.951	.685	37.91	3.82	42.69	1.126	15.0	2.70	45.26	1.194
AB 417.	79.3	166.2	1.051	.685	37.91	3.93	43.92	1.158	15.0	2.74	45.93	1.211
AB 418.	79.3	166.2	1.151	.685	37.91	4.01	44.81	1.182	15.0	2.77	46.43	1.225
AB 419.	79.3	166.2	1.251	.685	37.91	4.02	44.92	1.185	15.0	2.76	46.26	1.220
AB 420.	79.3	166.2	1.351	.685	37.91	3.83	42.80	1.129	15.0	2.69	45.09	1.189
AB 421.	79.3	166.2	1.451	.685	37.91	3.80	42.47	1.120	15.0	2.63	44.09	1.163
AB 422.	79.3	166.2	1.551	.685	37.91	3.86	43.14	1.138	15.0	2.68	44.42	1.172
AB 423.	79.3	166.2	1.651	.685	37.91	3.98	44.48	1.173	15.0	2.75	46.10	1.216
AB 424.	79.3	166.2	1.751	.685	37.91	4.14	46.26	1.220	15.0	2.81	47.10	1.242
AB 425.	79.3	166.2	1.851	.685	37.91	3.95	44.14	1.164	15.0	2.73	45.76	1.207
AB 426.	79.3	166.2	1.951	.685	37.91	3.74	41.79	1.102	15.0	2.59	43.41	1.145
AB 427.	79.3	166.2	2.051	.685	37.91	3.76	42.02	1.108	15.0	2.62	43.92	1.158
AB 428.	79.3	166.2	2.151	.685	37.91	3.74	41.79	1.102	15.0	2.61	43.75	1.154
AB 429.	79.3	166.2	2.151	.685	37.91	3.71	41.46	1.094	15.0	2.61	43.75	1.154
AB 430.	79.3	166.2	2.251	.685	37.91	3.97	44.36	1.170	15.0	2.74	45.93	1.211

RUN ID.NO.	TEMP F	NOM. FLOW CFM	X IN.	Y IN.	UE FPS	F-DOP S.A. MHZ	U(LOCAL) S.A. FRS	VRATIO TRACKER S.A. FREQ. RD. MHZ/10V.	E(DOP) TRACKER VOLTS	U(LOCAL) TRACKER FPS	VRATIO TRACKER
AB 431.	79.8	166.2	2.351	.685	37.59	4.10	45.82	1.219 15.0	2.78	46.60	1.240
AB 435.	79.8	166.2	.146	.110	37.59	0.00	0.00	0.000 15.0	.06	1.01	.027
AB 434.	79.8	166.2	.685	.110	37.59	4.92	54.98	1.462 15.0	3.39	56.15	1.494
AB 433.	79.8	166.2	1.224	.110	37.59	4.99	55.76	1.483 15.0	3.38	56.66	1.507
AB 432.	79.8	166.2	1.763	.110	37.59	5.25	58.67	1.561 15.0	3.50	58.67	1.561

TABULATION OF EXPERIMENTAL LDA DATA

DATA PLANE NO. 8. AXIAL DISTANCE FROM BLOCKAGE CENTERLINE = -1.70 IN. P = 14.84 PSI
 RE = 10300. MEIA = 10.66 DEGREES FREQ. SHIFT = 0.0 MHZ.

RUN ID NO.	TEMP F	NOM. FLOW CFM	X IN.	Y IN.	UB FPS	F-DOP S.A. MHZ	U(LOCAL) S.A. FPS	VRATIO TRACKER S.A. FREQ. RB. MHZ/10V.	F(DOP) TRACKER VOLTS	U(LOCAL) TRACKER FPS	VRATIO TRACKER	
AB 436.	80.4	168.5	.151	1.763	37.59	4.53	50.62	1.347	15.0	2.74	45.93	1.222
AB 437.	80.4	168.5	.251	1.763	37.59	4.34	48.50	1.290	15.0	2.89	47.77	1.271
AB 438.	80.4	168.5	.351	1.763	37.59	4.00	44.70	1.189	15.0	2.77	46.43	1.235
AB 439.	80.4	168.5	.451	1.763	37.59	3.95	44.14	1.174	15.0	2.70	45.26	1.204
AB 440.	80.4	168.5	.551	1.763	37.59	4.22	47.16	1.254	15.0	2.89	47.44	1.262
AB 441.	80.4	168.5	.651	1.763	37.59	4.31	48.16	1.281	15.0	2.93	49.11	1.306
AB 442.	80.4	168.5	.751	1.763	37.59	4.25	47.49	1.263	15.0	2.84	47.61	1.266
AB 443.	80.4	168.5	.851	1.763	37.59	3.95	44.14	1.174	15.0	2.68	44.92	1.195
AB 444.	80.4	168.5	.951	1.763	37.59	3.88	43.36	1.153	15.0	2.67	44.76	1.190
AB 445.	80.4	168.5	1.051	1.763	37.59	4.02	44.92	1.195	15.0	2.71	45.43	1.208
AB 446.	80.4	168.5	1.151	1.763	37.59	3.88	43.36	1.153	15.0	2.67	44.76	1.190
AB 447.	80.4	168.5	1.251	1.763	37.59	3.63	40.57	1.079	15.0	2.54	42.58	1.133
AB 448.	80.4	168.5	1.351	1.763	37.59	3.15	35.20	.936	5.0	6.26	34.98	.930
AB 449.	80.4	168.5	1.451	1.763	37.59	3.10	34.64	.921	5.0	6.08	33.97	.904
AB 450.	80.4	168.5	1.551	1.763	37.59	2.99	33.41	.889	5.0	5.82	32.52	.865
AB 451.	80.4	168.5	1.651	1.763	37.59	2.79	31.18	.829	5.0	5.56	31.07	.826
AB 452.	80.4	168.5	1.751	1.763	37.59	2.80	31.29	.832	5.0	5.50	30.73	.817
AB 453.	80.4	168.5	1.851	1.763	37.59	2.46	27.49	.731	5.0	5.08	28.38	.755
AB 454.	80.4	168.5	1.951	1.763	37.59	1.88	21.01	.559	5.0	3.98	22.24	.592
AB 455.	80.4	168.5	2.051	1.763	37.59	1.95	21.79	.580	5.0	3.90	21.79	.580
AB 456.	80.4	168.5	2.151	1.763	37.59	1.89	21.12	.562	5.0	3.60	20.12	.535
AB 457.	80.4	168.5	2.251	1.763	37.59	1.84	20.56	.547	5.0	3.61	20.17	.537
AB 458.	81.0	168.5	2.351	1.763	38.11	2.33	26.04	.683	5.0	4.71	26.32	.690
AB 459.	81.0	168.5	.251	1.224	38.11	4.40	49.17	1.290	15.0	2.77	46.43	1.218
AB 460.	81.0	168.5	.351	1.224	38.11	4.09	45.71	1.199	15.0	2.79	46.77	1.227
AB 461.	81.0	168.5	.451	1.224	38.11	3.98	44.48	1.167	15.0	2.75	46.10	1.209
AB 462.	81.0	168.5	.551	1.224	38.11	4.11	45.93	1.205	15.0	2.82	47.27	1.240
AB 463.	81.0	168.5	.651	1.224	38.11	4.21	47.05	1.234	15.0	2.87	48.11	1.262
AB 464.	81.0	168.5	.751	1.224	38.11	4.12	46.04	1.208	15.0	2.82	47.27	1.240
AB 465.	81.0	168.5	.851	1.224	38.11	3.87	43.25	1.135	15.0	2.68	44.92	1.179
AB 466.	81.0	168.5	.951	1.224	38.11	3.73	41.68	1.094	15.0	2.59	43.41	1.139
AB 467.	81.0	168.5	1.051	1.224	38.11	3.79	42.35	1.111	15.0	2.63	44.09	1.157
AB 468.	81.0	168.5	1.151	1.224	38.11	3.89	43.47	1.141	15.0	2.66	44.59	1.170
AB 469.	81.0	168.5	1.251	1.224	38.11	3.98	44.48	1.167	15.0	2.68	44.92	1.179
AB 470.	81.0	168.5	1.351	1.224	38.11	3.65	40.79	1.070	15.0	2.54	42.58	1.117
AB 471.	81.0	168.5	1.451	1.224	38.11	3.50	39.11	1.026	15.0	2.28	38.22	1.003
AB 472.	81.0	168.5	1.551	1.224	38.11	3.49	39.00	1.023	15.0	2.31	38.72	1.016
AB 473.	81.0	168.5	1.651	1.224	38.11	3.58	40.01	1.050	15.0	2.38	39.89	1.047
AB 474.	81.0	168.5	1.751	1.224	38.11	3.69	41.24	1.082	15.0	2.56	42.91	1.126
AB 475.	81.0	168.5	1.851	1.224	38.11	3.43	38.33	1.006	15.0	2.29	38.39	1.007
AB 476.	81.0	168.5	1.951	1.224	38.11	3.05	34.08	.894	15.0	2.04	34.20	.897
AB 477.	81.0	168.5	2.051	1.224	38.11	3.08	34.42	.903	15.0	2.03	34.03	.893
AB 478.	81.0	168.5	2.151	1.224	38.11	3.01	33.64	.883	15.0	2.00	33.53	.880
AB 479.	81.0	168.5	2.251	1.224	38.11	3.02	33.75	.885	15.0	2.06	34.53	.906

RUN ID-NO.	TEMP F	NOM. FLOW CFM	X IN.	Y IN.	UR FPS	F-DOP S.A. MHZ	U(LOCAL) S.A. FPS	VRATIO TRACKER S.A. FREQ. RG. MHZ/10V.	F(DOP) TRACKER VOLTS	U(LOCAL) TRACKER FPS	VRATIO TRACKER	
AB 481.	81.3	167.1	.251	.645	37.91	4.47	49.95	1.318	15.0	2.60	43.58	1.150
AB 482.	81.3	167.1	.351	.645	37.91	4.35	48.61	1.282	15.0	2.62	43.92	1.158
AB 483.	81.3	167.1	.451	.645	37.91	4.01	44.81	1.182	15.0	2.65	44.42	1.172
AB 484.	81.3	167.1	.551	.645	37.91	3.99	44.59	1.176	15.0	2.73	45.76	1.207
AB 485.	81.3	167.1	.651	.645	37.91	4.15	46.38	1.223	15.0	2.70	45.26	1.194
AB 486.	81.3	167.1	.751	.645	37.91	4.22	47.16	1.244	15.0	2.75	46.10	1.216
AB 487.	81.3	167.1	.851	.645	37.91	4.00	44.70	1.179	15.0	2.79	46.10	1.216
AB 488.	81.3	167.1	.951	.645	37.91	3.86	43.14	1.138	15.0	2.66	44.59	1.176
AB 489.	81.3	167.1	1.051	.645	37.91	3.87	43.25	1.141	15.0	2.69	44.42	1.172
AB 490.	81.3	167.1	1.151	.645	37.91	3.93	44.48	1.173	15.0	2.75	46.10	1.216
AB 491.	81.3	167.1	1.251	.645	37.91	4.00	45.26	1.194	15.0	2.77	46.43	1.225
AB 492.	81.3	167.1	1.351	.645	37.91	3.93	44.48	1.173	15.0	2.70	45.26	1.194
AB 493.	81.3	167.1	1.451	.645	37.91	3.79	41.68	1.099	15.0	2.61	43.75	1.154
AB 494.	81.3	167.1	1.551	.645	37.91	3.70	42.24	1.114	15.0	2.62	43.92	1.158
AB 495.	81.3	167.1	1.651	.645	37.91	3.79	42.35	1.117	15.0	2.69	44.42	1.172
AB 496.	81.3	167.1	1.751	.645	37.91	3.93	43.92	1.158	15.0	2.74	45.93	1.211
AB 497.	81.3	167.1	1.851	.645	37.91	3.90	44.36	1.170	15.0	2.74	45.93	1.211
AB 498.	81.3	167.1	1.951	.645	37.91	3.80	43.14	1.138	15.0	2.74	45.93	1.211
AB 499.	81.3	167.1	2.051	.645	37.91	3.84	42.91	1.132	15.0	2.68	44.92	1.185
AB 500.	81.3	167.1	2.151	.645	37.91	3.86	43.14	1.138	15.0	2.68	44.92	1.185
AB 501.	81.3	167.1	2.251	.645	37.91	4.01	44.81	1.182	15.0	2.76	46.26	1.220
AB 480.	81.2	167.1	2.351	.645	37.91	3.55	39.67	1.046	15.0	2.36	39.61	1.045
AB 502.	81.3	167.1	2.351	.645	37.80	4.26	47.61	1.259	15.0	2.88	48.28	1.277
AB 506.	81.3	167.1	.351	.110	37.80	4.16	46.49	1.230	15.0	2.81	47.10	1.246
AB 505.	81.3	167.1	.685	.110	37.80	4.55	50.85	1.345	15.0	2.99	50.12	1.326
AB 504.	81.3	167.1	1.224	.110	37.80	4.53	50.62	1.339	15.0	3.00	50.29	1.330
AB 503.	81.3	167.1	1.763	.110	37.80	4.67	52.19	1.381	15.0	3.08	51.63	1.366

TABULATION OF EXPERIMENTAL LDA DATA

DATA PLANE No. 9. AXIAL DISTANCE FROM BLOCKAGE CENTERLINE = 1.50 IN. P = 14.73 PSI
 RE = 10300. INCIA = 9.53 DEGREES

RUN ID-NO.	TEMP F	NOM. FLOW CFM	X IN.	Y IN.	FREQ. SHIFT MHZ	S.A. FREQ. MHZ	DOP.FREQ. S.A. MHZ	U(LOCAL) S.A. FPS	UB FPS	VRATIO S.A.
AB 884.	79.0	169.8	.237	1.763	.5	4.74	4.24	52.85	37.59	1.406
AB 885.	79.0	169.8	.337	1.763	.5	4.65	4.15	51.73	37.59	1.376
AB 886.	79.0	169.8	.437	1.763	.5	4.60	4.19	52.23	37.59	1.389
AB 887.	79.0	169.8	.537	1.763	.5	4.72	4.22	52.60	37.59	1.399
AB 888.	79.0	169.8	.637	1.763	.5	4.63	4.13	51.48	37.59	1.369
AB 889.	79.0	169.8	.737	1.763	.5	4.55	4.05	50.48	37.59	1.343
AB 890.	79.0	169.8	.837	1.763	.5	4.16	3.66	45.62	37.59	1.214
AB 891.	79.0	169.8	.937	1.763	.5	4.15	3.65	45.50	37.59	1.210
AB 892.	79.0	169.8	1.037	1.763	.5	4.10	3.60	44.87	37.59	1.194
AB 893.	79.0	169.8	1.137	1.763	.5	3.95	3.45	43.00	37.59	1.144
AB 894.	79.0	169.8	1.237	1.763	.5	3.61	3.11	38.77	37.59	1.091
AB 895.	79.0	169.8	1.337	1.763	.5	3.20	2.70	33.66	37.59	.895
AB 900.	79.0	169.8	1.937	1.763	1.0	1.04	.04	.50	38.41	.013
AB 899.	79.0	169.8	2.037	1.763	1.0	.92	-.08	-1.00	37.59	-.027
AB 898.	79.0	169.8	2.137	1.763	1.0	.90	-.10	-1.25	37.59	-.033
AB 897.	79.0	169.8	2.237	1.763	1.0	.91	-.09	-1.12	37.59	-.030
AB 896.	79.0	169.8	2.337	1.763	1.0	.77	-.23	-2.87	37.59	-.076

TABLE OF EXPERIMENTAL LDA DATA

DATA PLANE NO. 9. AXIAL DISTANCE FROM BLOCKAGE CENTERLINE = 1.55 IN. P = 14.81 PSI
 RE = 10300. MEI A = 10.80 DEGREES FREQ. SHIFT = 0.0 MHZ.

RUN ID. NO.	TEMP F	NOM. FLOW CFM	X IN.	Y IN.	UR FPS	F-DOP S.A. MHZ	U(LOCAL) S.A. FPS	VRATIO TRACKER S.A. FREQ. RG. MHZ/10V.	E(DOP) TRACKER VOLTS	U(LOCAL) TRACKER FPS	VRATIO TRACKER	
AB 507.	79.1	167.1	.233	.685	37.80	4.95	54.60	1.444	15.0	3.08	50.96	1.348
AB 508.	79.1	167.1	.333	.685	37.80	4.60	50.74	1.342	15.0	3.02	49.97	1.322
AB 509.	79.1	167.1	.433	.685	37.80	4.27	47.10	1.246	15.0	2.86	47.32	1.252
AB 510.	79.1	167.1	.533	.685	37.80	4.33	47.76	1.264	15.0	2.88	47.65	1.261
AB 511.	79.1	167.1	.633	.685	37.80	4.66	51.40	1.360	15.0	3.05	50.46	1.335
AB 512.	79.1	167.1	.733	.685	37.80	4.53	49.97	1.322	15.0	3.06	50.63	1.339
AB 513.	79.1	167.1	.833	.685	37.80	4.47	49.30	1.304	15.0	2.98	49.30	1.304
AB 514.	79.1	167.1	.933	.685	37.80	4.34	47.87	1.266	15.0	2.98	48.97	1.296
AB 515.	79.1	167.1	1.033	.685	37.80	4.38	48.31	1.278	15.0	2.98	49.30	1.304
AB 516.	79.1	167.1	1.133	.685	37.80	4.67	51.51	1.363	15.0	3.12	51.62	1.366
AB 517.	79.1	167.1	1.233	.685	37.80	4.61	50.85	1.345	15.0	3.09	51.12	1.353
AB 518.	79.1	167.1	1.333	.685	37.80	4.42	48.75	1.290	15.0	2.96	48.97	1.296
AB 519.	79.1	167.1	1.433	.685	37.80	4.33	47.76	1.264	15.0	2.93	48.48	1.283
AB 520.	79.1	167.1	1.533	.685	37.80	4.39	48.42	1.281	15.0	2.98	49.30	1.304
AB 521.	79.1	167.1	1.633	.685	37.80	4.63	51.07	1.351	15.0	3.08	50.96	1.348
AB 522.	79.1	167.1	1.733	.685	37.80	4.67	51.51	1.363	15.0	3.18	52.61	1.392
AB 523.	79.1	167.1	1.833	.685	37.80	4.67	51.51	1.363	15.0	3.18	52.28	1.383
AB 524.	79.1	167.1	1.933	.685	37.80	4.57	50.41	1.334	15.0	3.06	50.63	1.339
AB 525.	79.1	167.1	2.033	.685	37.80	4.41	48.64	1.287	15.0	2.97	49.14	1.300
AB 526.	79.1	167.1	2.133	.685	37.80	4.46	49.19	1.301	15.0	3.00	49.64	1.313
AB 527.	79.1	167.1	2.233	.685	37.80	4.51	49.75	1.316	15.0	3.12	51.62	1.366
AB 528.	79.1	167.1	2.333	.685	37.80	4.75	52.39	1.386	15.0	3.22	53.27	1.409
AB 529.	79.4	167.1	2.433	.685	37.80	4.80	52.94	1.401	15.0	3.27	54.10	1.431
AB 532.	79.7	167.1	.686	.110	37.80	4.77	52.61	1.392	15.0	3.09	51.12	1.353
AB 531.	79.7	167.1	1.225	.110	37.80	4.73	52.17	1.380	15.0	3.19	51.79	1.370
AB 530.	79.7	167.1	1.763	.110	37.80	5.01	55.26	1.462	15.0	3.26	53.94	1.427
AB 573.	79.0	167.0	.233	1.224	37.78	4.90	54.05	1.431	15.0	3.06	50.63	1.340
AB 574.	79.0	167.0	.333	1.224	37.78	4.70	51.84	1.372	15.0	3.04	50.30	1.331
AB 575.	79.0	167.0	.433	1.224	37.78	4.58	50.52	1.337	15.0	3.03	50.13	1.327
AB 576.	79.0	167.0	.533	1.224	37.78	4.81	53.05	1.404	15.0	3.09	51.12	1.353
AB 577.	79.0	167.0	.633	1.224	37.78	4.75	52.39	1.387	15.0	3.12	51.62	1.366
AB 578.	79.0	167.0	.733	1.224	37.78	4.59	50.63	1.340	15.0	3.04	50.30	1.331
AB 579.	79.0	167.0	.833	1.224	37.78	4.53	49.97	1.323	15.0	3.03	50.13	1.327
AB 580.	79.0	167.0	.933	1.224	37.78	4.45	49.08	1.299	15.0	2.92	48.31	1.279
AB 581.	79.0	167.0	1.033	1.224	37.78	4.10	45.22	1.197	15.0	2.80	46.33	1.226
AB 582.	79.0	167.0	1.133	1.224	37.78	4.13	45.55	1.206	15.0	2.78	46.00	1.218
AB 583.	79.0	167.0	1.233	1.224	37.78	4.25	46.88	1.241	15.0	2.80	46.33	1.226
AB 584.	79.0	167.0	1.333	1.224	37.78	4.24	46.77	1.238	15.0	2.83	46.82	1.239
AB 585.	79.0	167.0	1.433	1.224	37.78	2.87	31.66	.838	5.0	6.06	33.42	.885
AB 586.	79.0	167.0	1.533	1.224	37.78	2.00	22.06	.584	5.0	4.04	22.56	.597
AB 587.	79.0	167.0	1.633	1.224	37.78	1.82	20.07	.531	5.0	3.74	20.63	.546
AB 588.	79.0	167.0	1.733	1.224	37.78	2.23	24.60	.651	5.0	4.31	23.77	.629
AB 589.	79.0	167.0	1.833	1.224	37.78	2.14	23.60	.625	5.0	4.27	23.55	.623
AB 590.	79.0	167.0	1.933	1.224	37.78	2.15	23.71	.628	5.0	4.19	23.11	.612

RUN ID.NO.	TEMP F	NOM. FLOW CFM	X IN.	Y IN.	UB FPS	F-DOP S.A. MHZ	U(LOCAL) S.A. FPS	VRATIO TRACKER S.A. FREQ. RG. S.A. MHZ/10V.	F(DOP) TRACKER VOLTS	U(LOCAL) TRACKER FPS	VRATIO TRACKER	
AB 591.	79.0	167.0	2.033	1.224	37.78	2.23	24.60	.651	5.0	4.36	24.05	.637
AB 592.	79.0	167.0	2.133	1.224	37.78	2.04	22.50	.596	5.0	4.13	22.78	.603
AB 593.	79.0	167.0	2.233	1.224	37.78	2.14	23.60	.625	5.0	4.16	22.94	.607
AB 594.	79.0	167.0	2.333	1.224	37.78	2.51	27.69	.733	5.0	5.01	27.63	.731
AB 595.	81.0	167.0	2.433	1.224	37.78	2.58	28.46	.753	5.0	4.99	27.52	.729

TABLELLATION OF EXPERIMENTAL LDA DATA

DATA PLANE NO. 10. AXIAL DISTANCE FROM BLOCKAGE CENTERLINE = 2.45 IN. P = 14.78 PSI
 RE = 10200. INCIA = 9.53 DEGREES

RUN ID NO.	TEMP F	NOH. FLOW CFM	X IN.	Y IN.	FREQ. SHIFT MHZ	S.A. FREQ. MHZ	DOP.FREQ. S.A. MHZ	U(LOCAL) S.A. FPS	UR FPS	VRATIO S.A.
AB 945.	80.0	166.7	.233	1.763	1.0	5.29	4.29	53.47	37.39	1.430
AB 946.	80.0	166.7	.333	1.763	1.0	5.15	4.15	51.73	37.39	1.383
AR 947.	80.0	166.7	.433	1.763	1.0	5.10	4.10	51.11	37.39	1.367
AR 948.	80.0	166.7	.533	1.763	1.0	5.11	4.11	51.23	37.39	1.370
AR 949.	80.0	166.7	.633	1.763	1.0	5.12	4.12	51.36	37.39	1.373
AB 950.	80.0	166.7	.733	1.763	1.0	5.08	4.08	50.86	37.39	1.360
AR 951.	80.0	166.7	.833	1.763	1.0	4.84	3.84	47.87	37.39	1.280
AR 952.	80.0	166.7	.933	1.763	1.0	4.76	3.76	46.87	37.39	1.253
AR 953.	80.0	166.7	1.033	1.763	1.0	4.41	3.41	42.51	37.39	1.137
AR 954.	80.0	166.7	1.133	1.763	1.0	4.25	3.25	40.51	37.39	1.083
AR 955.	80.0	166.7	1.233	1.763	1.0	3.98	2.98	37.15	37.39	.993
AR 956.	80.0	166.7	1.333	1.763	1.0	3.64	2.64	32.91	37.39	.880
AB 957.	80.0	166.7	1.433	1.763	1.0	3.32	2.32	28.92	37.39	.773
AR 958.	80.0	166.7	1.533	1.763	1.0	2.81	1.81	22.56	37.39	.603
AB 959.	80.0	166.7	1.633	1.763	1.0	2.54	1.54	19.20	37.39	.513
AR 960.	80.0	166.7	1.733	1.763	1.0	1.91	.91	11.34	37.39	.303
AR 961.	80.0	166.7	1.833	1.763	1.0	1.59	.59	7.35	37.39	.197
AB 964.	80.0	166.7	1.933	1.763	1.0	1.30	.30	3.74	37.39	.100
AB 963.	80.0	166.7	2.033	1.763	1.0	.92	-.08	-1.00	37.39	-.027
AR 966.	80.0	166.7	2.133	1.763	1.0	1.09	.09	1.12	37.39	.030
AB 967.	80.0	166.7	2.233	1.763	1.0	1.02	.02	.25	37.39	.007
AB 968.	80.0	166.7	2.333	1.763	1.0	1.24	.24	2.99	37.39	.080
AB 969.	31.8	166.7	2.433	1.763	1.0	1.63	.63	7.85	37.71	.208

TABULATION OF EXPERIMENTAL LDA DATA

DATA PLANE NO. 10. AXIAL DISTANCE FROM BLOCKAGE CENTERLINE = 2.43 IN. P = 14.57 PSI
 RE = 10200. IMETA = 10.80 DEGREES FREQ. SHIFT = 0.0 MHZ.

RUN ID&NO.	TEMP F	NOM. FLOW CFM	X IN.	Y IN.	UB FPS	F-DOP S.A. MHZ	U(LOCAL) S.A. FPS	VRATIO TRACKER S.A. FREQ. RG. MHZ/10V.	F(DOP) TRACKER VOLTS	U(LOCAL) TRACKER FPS	VRATIO TRACKER	
AB 641.	79.4	165.8	.151	1.224	37.50	4.81	53.05	1.415	15.0	3.26	53.94	1.438
AB 640.	79.0	165.8	.251	1.224	37.78	4.61	50.85	1.346	15.0	3.30	54.60	1.445
AB 639.	79.0	165.8	.351	1.224	37.78	4.51	49.75	1.317	15.0	3.23	53.44	1.415
AB 638.	79.0	165.8	.451	1.224	37.78	4.53	49.97	1.323	15.0	3.23	53.44	1.415
AB 637.	79.0	165.8	.551	1.224	37.78	4.73	52.17	1.381	15.0	3.29	54.43	1.441
AB 636.	79.0	165.8	.651	1.224	37.78	4.63	51.07	1.352	15.0	3.09	51.12	1.353
AB 635.	79.0	165.8	.751	1.224	37.78	4.60	50.74	1.343	15.0	3.06	50.63	1.340
AB 634.	79.0	165.8	.851	1.224	37.78	4.48	49.41	1.308	15.0	2.98	49.30	1.305
AB 633.	79.0	165.8	.951	1.224	37.78	4.27	47.10	1.247	15.0	2.88	47.65	1.261
AB 632.	79.0	165.8	1.051	1.224	37.78	3.80	41.91	1.110	15.0	2.69	44.51	1.178
AB 631.	79.0	165.8	1.151	1.224	37.78	3.64	40.15	1.063	15.0	2.54	42.02	1.112
AB 630.	79.0	165.8	1.251	1.224	37.78	3.88	42.80	1.133	15.0	2.66	44.01	1.165
AB 629.	79.0	165.8	1.351	1.224	37.78	3.83	42.24	1.118	15.0	2.66	44.01	1.165
AB 628.	79.0	165.8	1.451	1.224	37.78	2.80	30.88	.818	5.0	5.64	31.10	.823
AB 627.	79.0	165.8	1.551	1.224	37.78	2.55	28.13	.745	5.0	5.28	29.12	.771
AB 626.	79.0	165.8	1.651	1.224	37.78	2.50	27.58	.730	5.0	5.16	28.46	.753
AB 625.	79.0	165.8	1.751	1.224	37.78	2.81	30.99	.820	5.0	5.75	31.71	.839
AB 624.	79.0	165.8	1.851	1.224	37.78	2.75	30.33	.803	5.0	5.41	29.84	.790
AB 623.	79.0	165.8	1.951	1.224	37.78	2.59	28.57	.756	5.0	5.22	28.79	.762
AB 622.	79.0	165.8	2.051	1.224	37.78	2.70	29.78	.788	5.0	5.40	29.78	.788
AB 621.	79.0	165.8	2.151	1.224	37.78	2.82	31.10	.823	5.0	5.61	30.94	.819
AB 620.	79.0	165.8	2.251	1.224	37.78	2.94	32.43	.858	5.0	.06	.33	.009
AB 619.	79.0	165.8	2.351	1.224	37.78	2.81	30.99	.820	5.0	.06	.33	.009
AB 664.	79.5	164.4	.151	.685	37.19	4.18	46.11	1.240	15.0	2.68	44.34	1.192
AB 663.	79.4	164.4	.251	.685	37.50	4.22	46.55	1.241	15.0	2.67	44.18	1.178
AB 662.	79.4	164.4	.351	.685	37.50	4.05	44.67	1.191	15.0	2.69	44.51	1.187
AB 661.	79.4	164.4	.451	.685	37.50	4.05	44.67	1.191	15.0	2.62	43.35	1.156
AB 660.	79.4	164.4	.551	.685	37.50	4.42	48.75	1.300	15.0	2.73	45.17	1.204
AB 659.	79.4	164.4	.651	.685	37.50	4.47	49.30	1.315	15.0	2.82	46.66	1.244
AB 658.	79.4	164.4	.751	.685	37.50	4.48	49.41	1.318	15.0	2.85	47.15	1.257
AB 657.	79.4	164.4	.851	.685	37.50	4.31	47.54	1.268	15.0	2.82	46.66	1.244
AB 656.	79.4	164.4	.951	.685	37.50	4.22	46.55	1.241	15.0	2.77	45.83	1.222
AB 655.	79.4	164.4	1.051	.685	37.50	4.17	46.00	1.226	15.0	2.72	45.00	1.200
AB 654.	79.4	164.4	1.151	.685	37.50	4.58	50.52	1.347	15.0	2.93	48.48	1.293
AB 653.	79.4	164.4	1.251	.685	37.50	4.39	48.42	1.291	15.0	2.95	48.81	1.301
AB 652.	79.4	164.4	1.351	.685	37.50	4.15	45.77	1.221	15.0	2.84	46.99	1.253
AB 651.	79.4	164.4	1.451	.685	37.50	4.05	44.67	1.191	15.0	2.76	45.66	1.218
AB 650.	79.4	164.4	1.551	.685	37.50	4.07	44.89	1.197	15.0	2.76	45.66	1.218
AB 649.	79.4	164.4	1.651	.685	37.50	4.52	49.86	1.329	15.0	2.90	47.98	1.279
AB 648.	79.4	164.4	1.751	.685	37.50	4.56	50.30	1.341	15.0	3.02	49.97	1.332
AB 647.	79.4	164.4	1.851	.685	37.50	4.28	47.21	1.259	15.0	2.80	46.33	1.235
AB 646.	79.4	164.4	1.951	.685	37.50	4.27	47.10	1.256	15.0	2.79	46.16	1.231
AB 645.	79.4	164.4	2.051	.685	37.50	4.20	46.33	1.235	15.0	2.79	46.16	1.231
AB 644.	79.4	164.4	2.151	.685	37.50	4.34	47.87	1.276	15.0	2.84	46.99	1.253
AB 643.	79.4	164.4	2.251	.685	37.50	4.64	51.18	1.365	15.0	3.10	51.29	1.368
AB 642.	79.4	164.4	2.351	.685	37.50	4.74	52.28	1.394	15.0	3.27	54.10	1.443

RUN ID: NO.	TEMP F	NOM. FLOW CFM	X IN.	Y IN.	UB FPS	F-DOP S.A. MHZ	U(LOCAL) S.A. FPS	VRATIO TRACKER S.A. FREQ. RG. MHZ/10V.	E(DOP) TRACKER VOLTS	U(LOCAL) TRACKER FPS	VRATIO TRACKER
AB 668.	79.7	164.4	.146	.110	37.19	4.25	46.88	1.261 15.0	3.18	52.61	1.415
AB 667.	79.5	164.4	.685	.110	37.19	4.75	52.39	1.409 15.0	3.26	53.94	1.450
AB 666.	79.5	164.4	1.224	.110	37.19	4.75	52.39	1.409 15.0	3.22	53.27	1.433
AB 665.	79.5	164.4	1.763	.110	37.19	4.82	53.16	1.430 15.0	3.28	54.27	1.459

TABLEULATION OF EXPERIMENTAL LDA DATA

DATA PLANE NO. 11. AXIAL DISTANCE FROM BLOCKAGE CENTERLINE = -8.25 IN. P = 14.82 PSI
 RE = 10200. INCIA = 10.80 DEGREES FREQ. SHIFT = 0.0 MHZ.

RUN ID NO.	TEMP F	NOM. FLOW CFM	X IN.	Y IN.	UB FPS	F-DOP S.A. MHZ	U(LOCAL) S.A. FPS	VRATIO S.A. MHZ/10V.	TRACKER FREQ. RG. MHZ/10V.	E(DOP) TRACKER VOLTS	U(LOCAL) TRACKER FPS	VRATIO TRACKER
AR 691.	79.7	165.2	.163	1.779	37.37	3.73	41.14	1.101	15.0	2.60	43.02	1.151
AB 690.	79.0	165.2	.263	1.779	37.35	4.02	44.34	1.187	15.0	2.67	44.18	1.183
AB 689.	79.0	165.2	.363	1.779	37.35	4.03	44.45	1.190	15.0	2.70	44.67	1.196
AB 688.	79.0	165.2	.463	1.779	37.35	3.77	41.58	1.113	15.0	2.76	45.66	1.223
AR 687.	79.0	165.2	.563	1.779	37.35	3.76	41.47	1.111	15.0	2.71	44.84	1.201
AB 686.	79.0	165.2	.663	1.779	37.50	3.85	42.47	1.132	15.0	2.69	44.51	1.187
AB 685.	79.0	165.2	.763	1.779	37.50	4.13	45.55	1.215	15.0	2.74	45.33	1.209
AB 684.	79.0	165.2	.863	1.779	37.50	4.26	46.99	1.253	15.0	2.86	47.32	1.262
AB 683.	79.0	165.2	.963	1.779	37.50	4.07	44.89	1.197	15.0	2.81	46.49	1.240
AR 682.	79.0	165.2	1.063	1.779	37.50	3.92	43.24	1.153	15.0	2.74	45.33	1.209
AB 681.	79.0	165.2	1.163	1.779	37.50	3.77	41.58	1.109	15.0	2.60	43.02	1.147
AB 680.	79.0	165.2	1.263	1.779	37.50	3.77	41.58	1.109	15.0	2.57	42.52	1.134
AB 679.	79.0	165.2	1.363	1.779	37.50	3.78	41.69	1.112	15.0	2.70	44.67	1.191
AB 678.	79.0	165.2	1.463	1.779	37.50	3.66	40.37	1.076	15.0	2.64	43.68	1.165
AR 677.	79.0	165.2	1.563	1.779	37.50	3.67	40.48	1.079	15.0	2.60	43.02	1.147
AB 676.	79.0	165.2	1.663	1.779	37.50	3.66	40.37	1.076	15.0	2.52	41.69	1.112
AB 675.	79.0	165.2	1.763	1.779	37.50	3.64	40.15	1.071	15.0	2.46	40.70	1.085
AB 674.	79.0	165.2	1.863	1.779	37.50	3.73	41.14	1.097	15.0	2.62	43.35	1.156
AB 673.	79.0	165.2	1.963	1.779	37.50	3.92	43.24	1.153	15.0	2.67	44.18	1.178
AR 672.	79.0	165.2	2.063	1.779	37.50	3.74	41.25	1.100	15.0	2.60	43.02	1.147
AB 671.	79.0	165.2	2.163	1.779	37.50	3.58	39.49	1.053	15.0	2.52	41.69	1.112
AB 670.	79.0	165.2	2.263	1.779	37.50	3.45	38.05	1.015	15.0	2.55	42.19	1.125
AB 669.	79.0	165.2	2.363	1.779	37.50	3.47	38.27	1.021	15.0	2.57	42.52	1.134
AB 692.	79.7	165.2	2.463	1.779	37.37	3.86	42.58	1.139	15.0	2.69	44.51	1.191
AB 693.	79.7	165.2	2.563	1.779	37.37	4.00	44.12	1.181	15.0	2.76	45.66	1.222
AB 694.	79.7	165.2	2.663	1.779	37.37	3.90	43.02	1.151	15.0	2.68	44.34	1.187
AB 695.	80.2	166.2	.150	1.763	38.00	3.48	38.38	1.010	15.0	2.48	41.03	1.080
AB 696.	80.2	166.2	.250	1.763	38.00	4.01	44.23	1.164	15.0	2.78	46.00	1.210
AR 697.	80.2	166.2	.350	1.763	38.00	4.18	46.11	1.213	15.0	2.80	46.33	1.219
AB 698.	80.2	166.2	.450	1.763	38.00	3.73	41.14	1.083	15.0	2.64	43.68	1.149
AR 699.	80.2	166.2	.550	1.763	38.00	3.61	39.82	1.048	15.0	2.55	42.19	1.110
AB 700.	80.2	166.2	.650	1.763	38.00	3.51	38.72	1.019	15.0	2.49	41.20	1.084
AB 701.	80.2	166.2	.750	1.763	38.00	3.66	40.37	1.062	15.0	2.55	42.19	1.110
AB 702.	80.2	166.2	.850	1.763	38.00	4.04	44.56	1.173	15.0	2.80	46.33	1.219
AB 703.	80.2	166.2	.950	1.763	38.00	4.10	45.22	1.190	15.0	2.72	45.00	1.184
AB 704.	80.2	166.2	1.050	1.763	38.00	3.95	43.57	1.146	15.0	2.73	45.17	1.189
AB 705.	80.2	166.2	1.150	1.763	38.00	3.71	40.92	1.077	15.0	2.59	42.85	1.128
AB 706.	80.2	166.2	1.250	1.763	38.00	3.55	39.16	1.030	15.0	2.45	40.54	1.067
AR 707.	80.2	166.2	1.350	1.763	38.00	3.71	40.92	1.077	15.0	2.58	42.69	1.123
AB 708.	80.2	166.2	1.450	1.763	38.00	3.68	40.59	1.068	15.0	2.58	42.69	1.123
AB 709.	80.2	166.2	1.550	1.763	38.00	3.75	41.36	1.088	15.0	2.55	42.19	1.110
AR 710.	80.2	166.2	1.650	1.763	38.00	3.74	41.25	1.086	15.0	2.55	42.19	1.110
AB 712.	80.2	166.2	1.750	1.763	38.00	3.54	39.05	1.027	15.0	2.45	40.54	1.067
AB 713.	80.2	166.2	1.850	1.763	38.00	3.57	39.38	1.036	15.0	2.54	42.02	1.106
AB 714.	80.2	166.2	1.950	1.763	38.00	3.66	40.37	1.062	15.0	2.60	43.02	1.132
AB 715.	80.2	166.2	2.050	1.763	38.00	3.73	41.14	1.083	15.0	2.49	41.20	1.084

RUN ID: NO.	TEMP F	NOM. FLOW CFM	X IN.	Y IN.	UR FPS	F-DOP S.A. MHZ	U(LOCAL) S.A. FRS	VRATIO TRACKER S.A. FREQ. RG. MHZ/10V.	E(DOP) TRACKER VOLTS	U(LOCAL) TRACKER FPS	VRATIO TRACKER	
AB 716.	80.2	166.2	2.150	1.763	38.00	3.63	40.04	1.054	15.0	2.50	41.36	1.088
AB 717.	80.2	166.2	2.250	1.763	38.00	3.56	39.27	1.033	15.0	2.49	41.20	1.084
AB 718.	80.2	166.2	2.350	1.763	38.00	3.60	40.37	1.062	15.0	2.58	42.69	1.123
AB 719.	80.2	166.2	2.450	1.763	38.00	3.97	43.79	1.152	15.0	2.81	46.49	1.223
AB 720.	80.2	166.2	2.550	1.763	38.00	4.12	45.44	1.196	15.0	2.81	46.49	1.223
AB 721.	80.2	166.2	2.650	1.763	38.00	3.93	43.35	1.141	15.0	2.71	44.84	1.180
AB 722.	80.2	166.2	2.750	1.763	38.00	3.88	42.80	1.126	15.0	2.59	42.85	1.128
AB 723.	80.2	166.2	2.850	1.763	38.00	3.67	40.48	1.065	15.0	2.54	42.02	1.106
AB 724.	80.2	166.2	2.950	1.763	38.00	3.91	43.13	1.135	15.0	2.70	44.67	1.176
AB 725.	80.2	166.2	3.050	1.763	38.00	3.84	42.36	1.115	15.0	2.63	43.51	1.145
AB 726.	80.2	166.2	3.150	1.763	38.00	3.74	41.25	1.086	15.0	2.58	42.69	1.123
AB 727.	80.2	166.2	3.250	1.763	38.00	3.79	41.80	1.100	15.0	2.64	43.68	1.149
AB 728.	80.2	166.2	3.350	1.763	38.00	3.78	41.69	1.097	15.0	2.57	42.52	1.119
AB 729.	80.2	166.2	3.450	1.763	38.00	3.76	41.47	1.091	15.0	2.62	43.35	1.141
AB 730.	80.2	166.2	3.550	1.763	38.00	3.77	41.58	1.094	15.0	2.62	43.35	1.141
AB 731.	80.2	166.2	3.650	1.763	38.00	3.54	39.05	1.027	15.0	2.50	41.36	1.088
AB 732.	80.2	166.2	3.750	1.763	38.00	3.54	39.05	1.027	15.0	2.59	42.85	1.128
AB 733.	81.0	166.2	3.850	1.763	37.59	3.64	40.15	1.068	15.0	2.61	43.18	1.149
AB 736.	81.0	166.2	.684	1.223	37.59	3.58	39.49	1.050	15.0	2.59	42.85	1.140
AB 735.	81.0	166.2	1.223	1.223	37.59	3.57	39.38	1.047	15.0	2.46	40.70	1.083
AB 734.	81.0	166.2	1.763	1.223	37.59	3.64	40.15	1.068	15.0	2.44	40.37	1.074
AB 739.	81.0	166.2	.684	.685	37.59	3.61	39.82	1.059	15.0	2.58	42.69	1.135
AB 738.	81.0	166.2	1.223	.685	37.59	3.48	38.38	1.021	15.0	2.50	41.36	1.100
AB 737.	81.0	166.2	1.763	.685	37.59	3.57	39.38	1.047	15.0	2.46	40.70	1.083
AB 742.	81.1	167.1	.684	.110	37.80	3.84	42.36	1.121	15.0	2.70	44.67	1.182
AB 741.	81.0	167.1	1.223	.110	37.59	3.76	41.47	1.103	15.0	2.60	43.02	1.144
AB 740.	81.0	167.1	1.763	.110	37.59	3.73	41.14	1.094	15.0	2.61	43.18	1.149

TABULATION OF EXPERIMENTAL LDA DATA

DATA PLANE NO. 12. AXIAL DISTANCE FROM BLOCKAGE CENTERLINE = -4.75 IN. P = 14.79 PSI
 RE = 10300. INETA = 10.80 DEGREES FREQ. SHIFT = 0.0 MHZ.

RUN ID: NO.	TEMP F	NOM. FLOW CFM	X IN.	Y IN.	UB FPS	F-DOP S.A. MHZ	U(LOCAL) S.A. FPS	VRATIO TRACKER S.A. FREQ. RG. MHZ/10V.	F(DOP) TRACKER VOLTS	U(LOCAL) TRACKER FPS	VRATIO TRACKER
AB 743.	79.1	166.7	.150	1.763	37.71	4.07	44.89	1.191 15.0	2.85	47.15	1.250
AB 744.	79.1	166.7	.250	1.763	37.71	4.13	45.55	1.208 15.0	2.79	46.16	1.224
AB 745.	79.1	166.7	.350	1.763	37.71	3.88	42.80	1.135 15.0	2.67	44.18	1.172
AB 746.	79.1	166.7	.450	1.763	37.71	3.90	43.02	1.141 15.0	2.69	43.84	1.163
AB 747.	79.1	166.7	.550	1.763	37.71	4.04	44.56	1.182 15.0	2.76	45.66	1.211
AB 748.	79.1	166.7	.650	1.763	37.71	4.18	46.11	1.223 15.0	2.86	47.32	1.255
AB 749.	79.1	166.7	.750	1.763	37.71	4.17	46.00	1.220 15.0	2.86	47.32	1.255
AB 750.	79.1	166.7	.850	1.763	37.71	4.12	45.44	1.205 15.0	2.78	46.00	1.220
AB 751.	79.1	166.7	.950	1.763	37.71	4.04	44.56	1.182 15.0	2.72	45.00	1.193
AB 752.	79.1	166.7	1.050	1.763	37.71	4.06	44.78	1.188 15.0	2.76	45.66	1.211
AB 753.	79.1	166.7	1.150	1.763	37.71	4.20	46.33	1.229 15.0	2.87	47.48	1.259
AB 754.	79.1	166.7	1.250	1.763	37.71	4.13	45.55	1.208 15.0	2.83	46.82	1.242
AB 755.	79.1	166.7	1.350	1.763	37.71	4.01	44.23	1.173 15.0	2.72	45.00	1.193
AB 756.	79.1	166.7	1.450	1.763	37.71	3.82	42.13	1.117 15.0	2.61	43.18	1.145
AB 757.	79.1	166.7	1.550	1.763	37.71	3.86	42.58	1.129 15.0	2.61	43.18	1.145
AB 758.	79.1	166.7	1.650	1.763	37.71	3.97	43.79	1.161 15.0	2.72	45.00	1.193
AB 759.	79.1	166.7	1.750	1.763	37.71	4.07	44.89	1.191 15.0	2.78	46.00	1.220
AB 760.	79.1	166.7	1.850	1.763	37.71	4.02	44.34	1.176 15.0	2.74	45.33	1.202
AB 761.	79.1	166.7	1.950	1.763	37.71	3.91	43.13	1.144 15.0	2.63	43.51	1.154
AB 762.	79.1	166.7	2.050	1.763	37.71	3.74	41.25	1.094 15.0	2.58	42.69	1.132
AB 763.	79.1	166.7	2.150	1.763	37.71	3.80	41.91	1.112 15.0	2.62	43.35	1.150
AB 764.	79.1	166.7	2.250	1.763	37.71	4.00	44.12	1.170 15.0	2.74	45.33	1.202
AB 765.	79.8	166.7	2.350	1.763	37.71	4.05	44.67	1.185 15.0	2.78	46.00	1.220
AB 769.	79.8	166.7	.146	1.224	37.71	4.11	45.33	1.202 15.0	2.69	44.51	1.180
AB 768.	79.8	166.7	.685	1.224	37.71	4.07	44.89	1.191 15.0	2.80	46.33	1.229
AB 767.	79.8	166.7	1.224	1.224	37.71	4.03	44.45	1.179 15.0	2.79	46.16	1.224
AB 766.	79.8	166.7	1.763	1.224	37.71	4.04	44.56	1.182 15.0	2.76	45.66	1.211
AB 770.	79.8	166.7	.146	.685	37.71	4.20	46.33	1.229 15.0	2.78	46.00	1.220
AB 771.	79.8	166.7	.685	.685	37.71	4.07	44.89	1.191 15.0	2.76	45.66	1.211
AB 772.	79.8	166.7	1.224	.685	37.71	3.95	43.57	1.155 15.0	2.69	44.51	1.180
AB 773.	79.8	166.7	1.763	.685	37.71	3.95	43.57	1.155 15.0	2.71	44.84	1.189
AB 777.	80.2	166.8	.146	.110	37.73	4.08	45.00	1.193 15.0	2.72	45.00	1.193
AB 776.	79.8	166.8	.685	.110	37.71	4.39	48.42	1.284 15.0	2.91	48.15	1.277
AB 775.	79.8	166.8	1.224	.110	37.71	4.31	47.54	1.261 15.0	2.92	48.31	1.281
AB 774.	79.8	166.8	1.763	.110	37.71	4.40	48.53	1.287 15.0	3.00	49.64	1.316

TABULATION OF EXPERIMENTAL LDA DATA

DATA PLANE NO. 13. AXIAL DISTANCE FROM BLOCKAGE CENTERLINE = 1.30 IN. P = 14.74 PSI
 RE = 10300. THEIA = 9.53 DEGREES

RUN ID.NO.	TEMP F	NOM. FLOW CFM	X IN.	Y IN.	FREQ. SHIFT MHZ	S.A. FREQ. MHZ	DOP.FREQ. S.A. MHZ	U(LOCAL) S.A. FPS	UB FPS	VRATIO S.A.
AB 865.	78.7	165.3	.233	1.763	.5	4.73	4.23	52.73	37.59	1.403
AB 866.	78.7	165.3	.333	1.763	.5	4.69	4.19	52.23	37.59	1.389
AB 867.	78.7	165.3	.433	1.763	.5	4.67	4.17	51.98	37.59	1.383
AB 868.	78.7	165.3	.533	1.763	.5	4.66	4.16	51.85	37.59	1.379
AB 869.	78.7	165.3	.633	1.763	.5	4.70	4.20	52.35	37.59	1.393
AB 870.	78.7	165.3	.733	1.763	.5	4.43	3.93	48.99	37.59	1.303
AB 871.	78.7	165.3	.833	1.763	.5	4.27	3.72	46.37	37.59	1.233
AB 872.	78.7	165.3	.933	1.763	.5	4.16	3.66	45.62	37.59	1.214
AB 873.	78.7	165.3	1.033	1.763	.5	4.13	3.63	45.25	37.59	1.204
AB 874.	78.7	165.3	1.133	1.763	.5	4.03	3.53	44.00	37.59	1.170
AB 875.	78.7	165.3	1.233	1.763	.5	3.69	3.19	39.76	37.59	1.058
AB 876.	78.7	165.3	1.333	1.763	.5	3.61	3.11	38.77	37.59	1.031
AB 861.	78.7	165.3	1.933	1.763	1.0	.97	-.03	-.37	37.59	-.010
AB 880.	78.7	165.3	2.033	1.763	1.0	1.01	.01	.12	37.59	.003
AB 879.	78.7	165.3	2.133	1.763	1.0	1.02	.02	.25	37.59	.007
AB 878.	78.7	165.3	2.233	1.763	1.0	.94	-.06	-.75	37.59	-.020
AB 877.	78.7	165.3	2.333	1.763	1.0	.76	-.24	-2.99	37.59	-.080
AB 882.	78.7	165.3	2.433	1.763	1.0	.80	-.20	-2.49	37.59	-.066
AB 883.	79.0	165.3	2.533	1.763	1.0	.87	-.13	-1.62	37.39	-.043

TARULATION OF EXPERIMENTAL LDA DATA

DATA PLANE NO. 13. AXIAL DISTANCE FROM BLOCKAGE CENTERLINE = 1.25 IN. P = 14.81 PSI
 RE = 10300. THEIA = 10.80 DEGREES FREQ. SHIFT = 0.0 MHZ.

RUN ID-NO.	TEMP F	NOM. FLOW CFM	X IN.	Y IN.	UB FPS	F-DOP S.A. MHZ	U(LOCAL) S.A. FPS	VRATIO TRACKER S.A. FREQ. RG. MHZ/10V.	F(DOP) TRACKER VOLTS	U(LOCAL) TRACKER FPS	VRATIO TRACKER	
AB 799.	81.5	165.8	.263	1.224	37.80	4.78	52.72	1.395	15.0	3.22	53.27	1.409
AB 800.	81.5	165.8	.363	1.224	37.80	4.67	51.51	1.363	15.0	3.06	50.63	1.339
AB 801.	81.5	165.8	.463	1.224	37.80	4.72	52.06	1.377	15.0	3.13	51.79	1.370
AB 802.	81.5	165.8	.563	1.224	37.80	4.81	53.05	1.404	15.0	3.18	52.61	1.392
AB 803.	81.5	165.8	.663	1.224	37.80	4.81	53.05	1.404	15.0	3.25	53.77	1.423
AB 804.	81.5	165.8	.763	1.224	37.80	4.74	52.28	1.383	15.0	3.16	52.28	1.383
AB 805.	81.5	165.8	.863	1.224	37.80	4.64	51.18	1.354	15.0	3.15	52.12	1.379
AB 806.	81.5	165.8	.963	1.224	37.80	4.53	49.97	1.322	15.0	3.03	50.13	1.326
AB 807.	81.5	165.8	1.063	1.224	37.80	4.32	47.65	1.261	15.0	2.96	48.97	1.296
AB 808.	81.5	165.8	1.163	1.224	37.80	4.21	46.44	1.229	15.0	2.86	47.32	1.252
AB 809.	81.5	165.8	1.263	1.224	37.80	4.51	49.75	1.316	15.0	3.08	50.96	1.348
AB 810.	81.5	165.8	1.363	1.224	37.80	4.44	48.97	1.296	15.0	2.96	48.97	1.296
AB 811.	81.5	165.8	1.463	1.224	37.80	3.52	38.83	1.027	15.0	2.50	41.36	1.094
AB 812.	81.5	165.8	1.563	1.224	37.80	2.32	25.59	.677	-0.0	.06	0.00	0.000
AB 813.	81.5	165.8	1.663	1.224	37.80	2.58	28.46	.753	-0.0	.06	0.00	0.000
AB 814.	81.5	165.8	1.763	1.224	37.80	3.21	35.41	.937	-0.0	.06	0.00	0.000
AB 815.	81.5	165.8	1.863	1.224	37.80	3.80	41.91	1.109	15.0	2.63	43.51	1.151
AB 816.	81.5	165.8	1.963	1.224	37.80	3.90	43.02	1.138	15.0	2.65	43.84	1.160
AB 817.	81.5	165.8	2.063	1.224	37.80	3.11	34.30	.908	-0.0	.06	0.00	0.000
AB 818.	81.5	165.8	2.163	1.224	37.80	2.78	30.66	.811	-0.0	.06	0.00	0.000
AB 819.	81.5	165.8	2.263	1.224	37.80	3.61	39.82	1.053	-0.0	.06	0.00	0.000
AB 820.	81.5	165.8	2.363	1.224	37.80	3.79	41.80	1.106	15.0	2.65	43.84	1.160
AB 821.	81.8	165.8	2.463	1.224	37.50	3.36	37.06	.988	-0.0	.06	0.00	0.000
AB 822.	81.8	165.8	.263	.685	37.50	4.81	53.05	1.415	15.0	3.26	53.94	1.438
AB 823.	81.8	165.8	.363	.685	37.50	4.68	51.62	1.376	15.0	3.17	52.45	1.398
AB 824.	81.8	165.8	.463	.685	37.50	4.38	48.31	1.288	15.0	2.98	49.30	1.315
AB 825.	81.8	165.8	.563	.685	37.50	4.54	50.08	1.335	15.0	2.88	47.65	1.271
AB 826.	81.8	165.8	.663	.685	37.50	4.71	51.95	1.385	15.0	3.13	51.79	1.381
AB 827.	81.8	165.8	.763	.685	37.50	4.61	50.85	1.356	15.0	3.09	51.12	1.363
AB 828.	81.8	165.8	.863	.685	37.50	4.54	50.08	1.335	15.0	3.06	50.63	1.350
AB 829.	81.8	165.8	.963	.685	37.50	4.58	50.52	1.347	15.0	3.06	50.63	1.350
AB 830.	81.8	165.8	1.063	.685	37.50	4.67	51.51	1.373	15.0	3.09	51.12	1.363
AB 831.	81.8	165.8	1.163	.685	37.50	4.72	52.06	1.388	15.0	3.16	52.28	1.394
AB 832.	81.8	165.8	1.263	.685	37.50	4.64	51.18	1.365	15.0	3.09	50.46	1.346
AB 833.	81.8	165.8	1.363	.685	37.50	4.45	49.08	1.309	15.0	2.97	49.14	1.310
AB 834.	81.8	165.8	1.463	.685	37.50	4.44	48.97	1.306	15.0	2.94	48.64	1.297
AB 835.	81.8	165.8	1.563	.685	37.50	4.45	49.08	1.309	15.0	2.97	49.14	1.310
AB 836.	81.8	165.8	1.663	.685	37.50	4.66	51.40	1.371	15.0	3.04	50.30	1.341
AB 837.	81.8	165.8	1.763	.685	37.50	4.76	52.50	1.400	15.0	3.10	51.29	1.368
AB 838.	81.8	165.8	1.863	.685	37.50	4.73	52.17	1.391	15.0	3.08	50.63	1.350
AB 839.	81.8	165.8	1.963	.685	37.50	4.67	51.51	1.373	15.0	3.03	50.13	1.337
AB 840.	81.8	165.8	2.063	.685	37.50	4.65	51.29	1.368	15.0	3.04	50.30	1.341
AB 841.	81.8	165.8	2.163	.685	37.50	4.50	49.64	1.323	15.0	3.05	50.46	1.346
AB 842.	81.8	165.8	2.263	.685	37.50	4.59	50.63	1.350	15.0	3.14	51.95	1.385
AB 843.	81.8	165.8	2.363	.685	37.50	4.86	53.61	1.429	15.0	3.21	53.11	1.416
AB 844.	82.4	165.8	2.463	.685	37.50	4.88	53.83	1.435	15.0	3.24	53.61	1.429

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AB 848.	82.6	166.2	.263	.110	37.59	4.47	49.30	1.311	15.0	3.02	49.97	1.329
AB 847.	82.4	166.2	.685	.110	37.50	4.93	54.38	1.450	15.0	3.33	55.09	1.469
AB 846.	82.4	166.2	1.224	.110	37.50	4.89	53.94	1.438	15.0	3.33	55.09	1.469
AB 845.	82.4	166.2	1.763	.110	37.50	5.03	55.48	1.479	15.0	3.36	55.59	1.482

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