1987

An assessment of the applicability of a Venturi dynamic dilution probe to the collection of odourous samples from stationary sources.

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An Assessment of the Applicability of a Venturi Dynamic Dilution Probe to the Collection of Odourous Samples from Stationary Sources

A Thesis
Submitted to the Faculty of Graduate Studies and Research
Through the Department of Chemical Engineering in Partial
Fulfillment of the Requirements for the Degree of Master of
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by

Andrew E. Wollin

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ABSTRACT

A Venturi, dynamic dilution, sampling probe was evaluated in a laboratory setting, with primary consideration being given to simulating field sampling conditions. On this basis, the sampling probe was operated in a wind tunnel serving as an industrial stack and sulphur hexafluoride (SF_6) simulating an odourous material.

This sampling probe operates by drawing a sample of stack gas into the throat of the Venturi through one or more orifices located at 90 degrees to each other. This sample is mixed with de-odourized ambient air that is pumped through the Venturi. This air also serves as the driving force for the collection process.

The goal of this study was to determine the range of dilution ratios that were achievable with specific :

- orifice sizes
- orifice orientations
- pressure drops across the Venturi throat.

Dilution ratios ranging from 6 to 40 were achieved. These dilution ratios are reproducible and are accurate to 10 per cent. The sampling probe functions without the complications that are necessary to operate other dilution sampling devices, such as the constant monitoring of multiple flow rates.

It is recommended that further studies be conducted to determine the effects of high particulate matter loading in

the gas stream on the efficiency and accuracy of the probe. It is also important to assess the effects that stack gas temperature has on the performance of the probe.

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I. Introduction

The majority of the North American populace has experienced odour pollution. This form of air pollution has become one of the more noticable, generating at least 50 per cent of the total number of complaints to regulatory agencies [1].

To date, the provincial governments have not legislated against odour pollution. This situation is due primarily to lack of adequate research and development of methods for measuring and controlling odours.

In order to prepare a proper legislative deterrent to odour pollution, it is necessary to demonstrate that every step in the evaluation process is properly documented and assessed for accuracy. These steps include:

i) Source Identification
ii) Sampling and Transport of Samples
iii) Analysis of Samples
iv) Determination of the Degree of Odour Pollution
v) Control Implementation

The analysis of odour samples has received most of the attention to date [2]. Now emphasis is being focussed on the development of objective methods of odour analysis [3,4]. The techniques of sampling odourous sources are not as advanced [2].

At present, the Ontario Ministry of the Environment recommends the use of a simple dynamic dilution system for sampling. This sampling train mixes the odourous source stream with a flow of de-odourized air to dilute the odourous sample below the dew point of the component vapours [5]. This mixing is accomplished after the sample has been withdrawn from the stack through a heated glass probe. The dilution of the sample is designed to minimize loss of sample integrity due to adsorption and condensation during and after sampling.

To further simplify the sampling process, and to dilute the sample within the stack, a Venturi, dynamic dilution, sampling probe has been developed by the Air Quality Group at the University of Windsor.

The purpose of this study was to evaluate the Venturi, dynamic dilution, sampling probe in terms of the range of dilution ratios that are achievable with specific:

- orifice sizes
- orifice orientations
- pressure drops across the Venturi throat.

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II. Literature Survey

Early research concerning pollution of the atmosphere by odours has been concerned, primarily, with the analysis of samples collected in the field. This emphasis has helped to develop a wide spectrum of analytical techniques (often based on statistical methods) which make every attempt to ensure an unbiased result [1-16]. Much less attention has been devoted to sampling procedures.

To illustrate the advantages that can be achieved with Venturi dilution probes, a brief history is provided of the sampling devices that have been used in earlier investigations.

One of the earliest techniques involved withdrawing a sample from the suspected source into an evacuated glass bulb [12]. An aliquot of this sample was then removed with a glass syringe containing a predetermined amount of odourless air. This and subsequently diluted mixtures were injected into the nostrils of the members of the odour panel for evaluation. This method provides no accomodation for adsorption or condensation of the stack gases onto the glass surfaces, and as a result, it has been abandoned by most regulatory agencies.

More sophisticated sampling devices were developed to avoid the problems associated with glass surfaces [8,11,12]. Most of these methods involved pumping the sample from the source through a Teflon or Tedlar hose into a Tedlar bag. Two methods of pumping the sample were used.

The original method involved a sampling lung [8,11,12]. In this case, the sample bag was sealed inside a plastic box. The stack sample was drawn into the bag by creating a slight vacuum inside the box containing the bag.

Odourous samples have also been transferred into sampling bags by means of peristaltic pumps [12]. This method avoids the use of the cumbersome sampling lung. A number of simple odour sampling devices is illustrated in Figure 2.1.

These methods do not allow for condensation and adsorption of the sample that may occur due to temperature and pressure differences between the source and the ambient conditions. As these effects may result in loss of some of the sample to the walls of the sampling bag, the subsequent analysis may be in error.

Several attempts have been made to improve sampling procedures [9,11,13]. In general, the stack sample was mixed with de-odourized ambient air after withdrawal through a heated glass probe. The mixing was accomplished externally to the source stack. The goal of these procedures was to dilute the source gases and vapours below the dew points of the mixtures to minimize losses due to condensation.

Schuetzle et al. simply mixed the odourous sample with de-odourized air [11]. The diluting air was metered into the total flow through a valve. The driving force for the sampling device was a sampling lung.

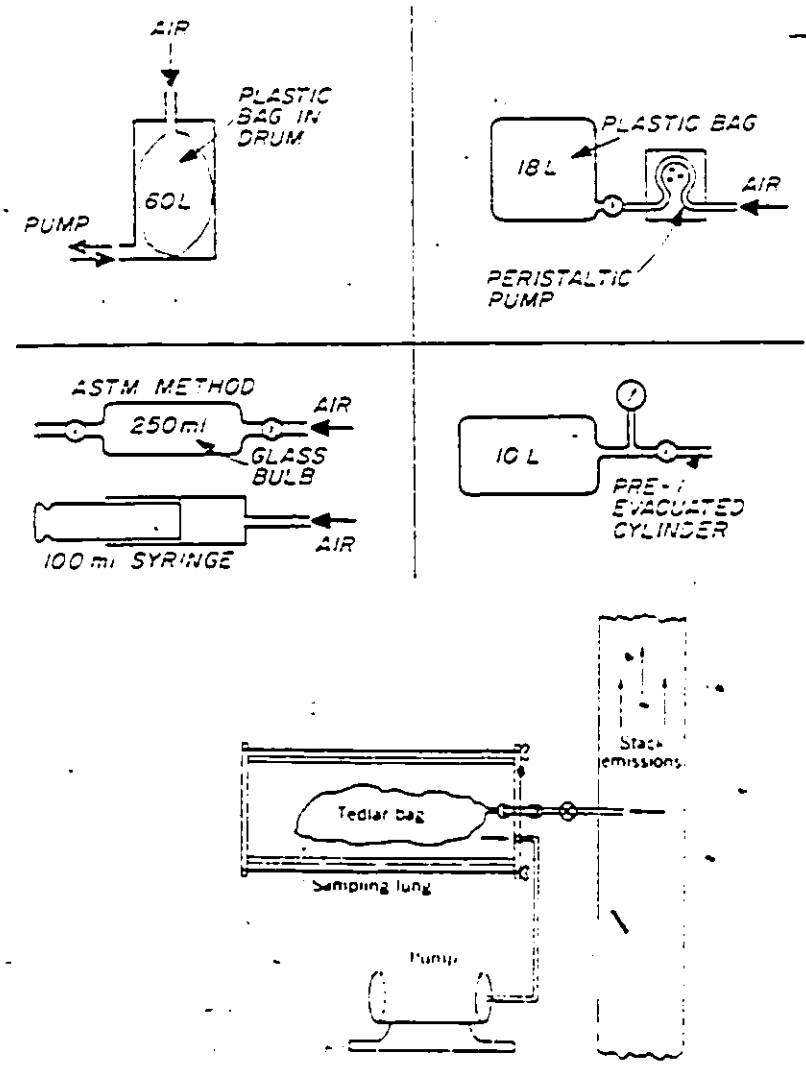

Figure 2.1: Simple Odour Sampling Devices [11,12]

The Ontario Ministry of the Environment procedure involves basically the same process, except that the sampling lung is replaced with a peristaltic pump [13].

The third sampling device is the most sophisticated [9].

The motive force used for withdrawing the sample in this case is a Venturi. As de-odourized air is pumped through the Venturi, the sample is drawn into the throat by the resulting decrease in static pressure. Mixing with the de-odourized air occurs in the throat. The mixture is conveyed to the sampling bag through odourless tubing. Examples of these devices are provided in Figures 2.2, 2.3, and 2.4.

The disadvantages of these methods are not quite as obvious as the problems associated with the simpler methods outlined earlier. Nevertheless, the samples may still provide misleading results for several reasons.

It has been shown that any probe, heated or not, that uses a glass wool plug to prevent the ingress of particulate matter may become saturated with condensate from the stack [9]. This accumulation could also alter the character of the odour.

Use of dilution devices generally requires the monitoring of at least two gas flow rates for the determination of dilution ratios. This approach can be complicated, and since it involves the use of flow disturbing devices it may alter the integrity of the sample. The sample may be changed by the contamination of the rotameter, which is commonly used to monitor the flow rates. In other cases, an orifice meter is used. Passing the odourous stream through an orifice may cause condensation during compression of the

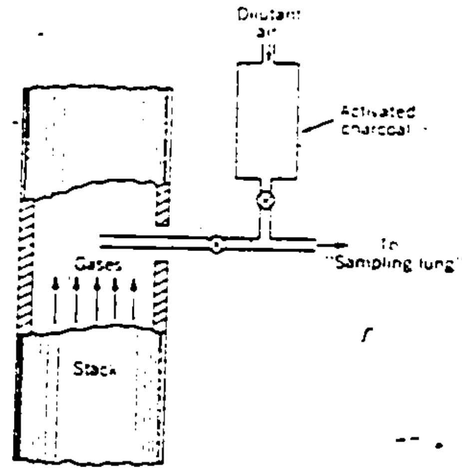

Figure 2.2: An Early Dilution Sampling Device [11]

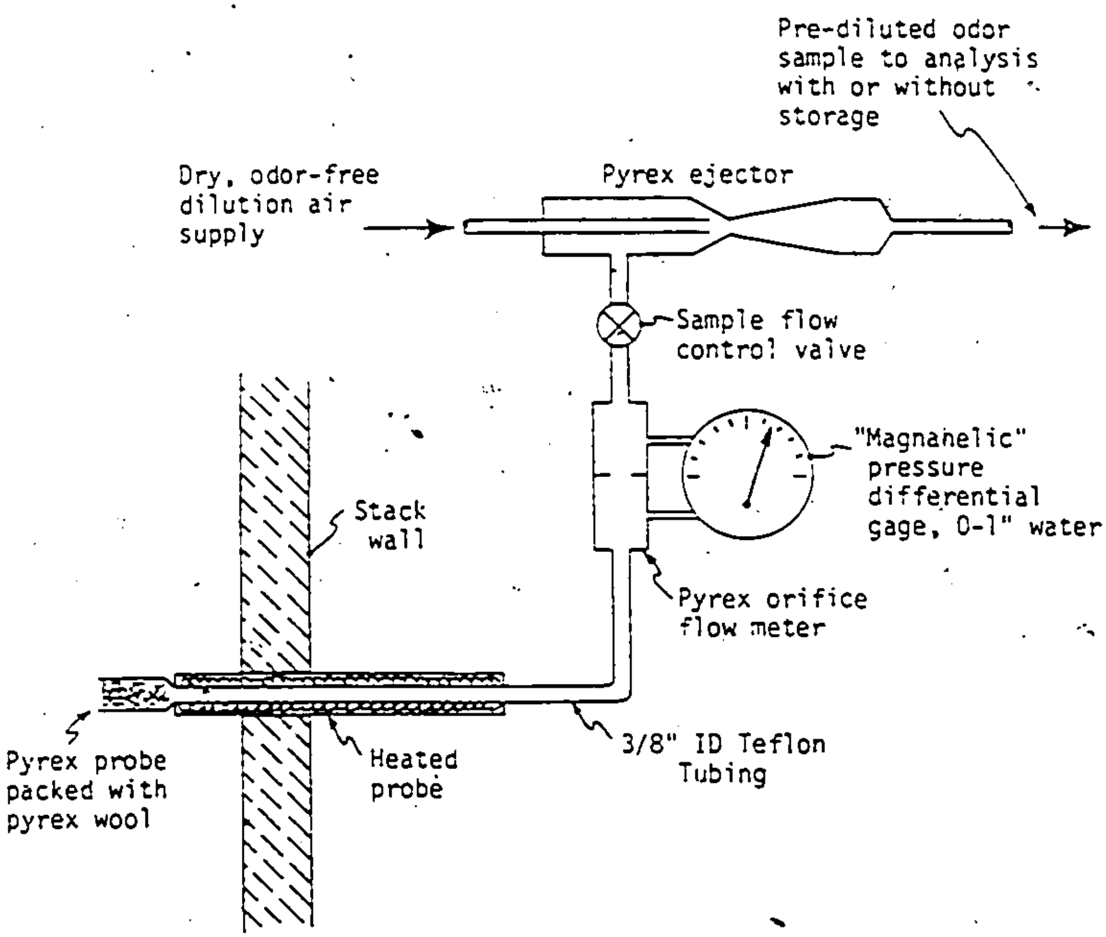

Figure 2.3: An External Venturi Sampling Device [9]

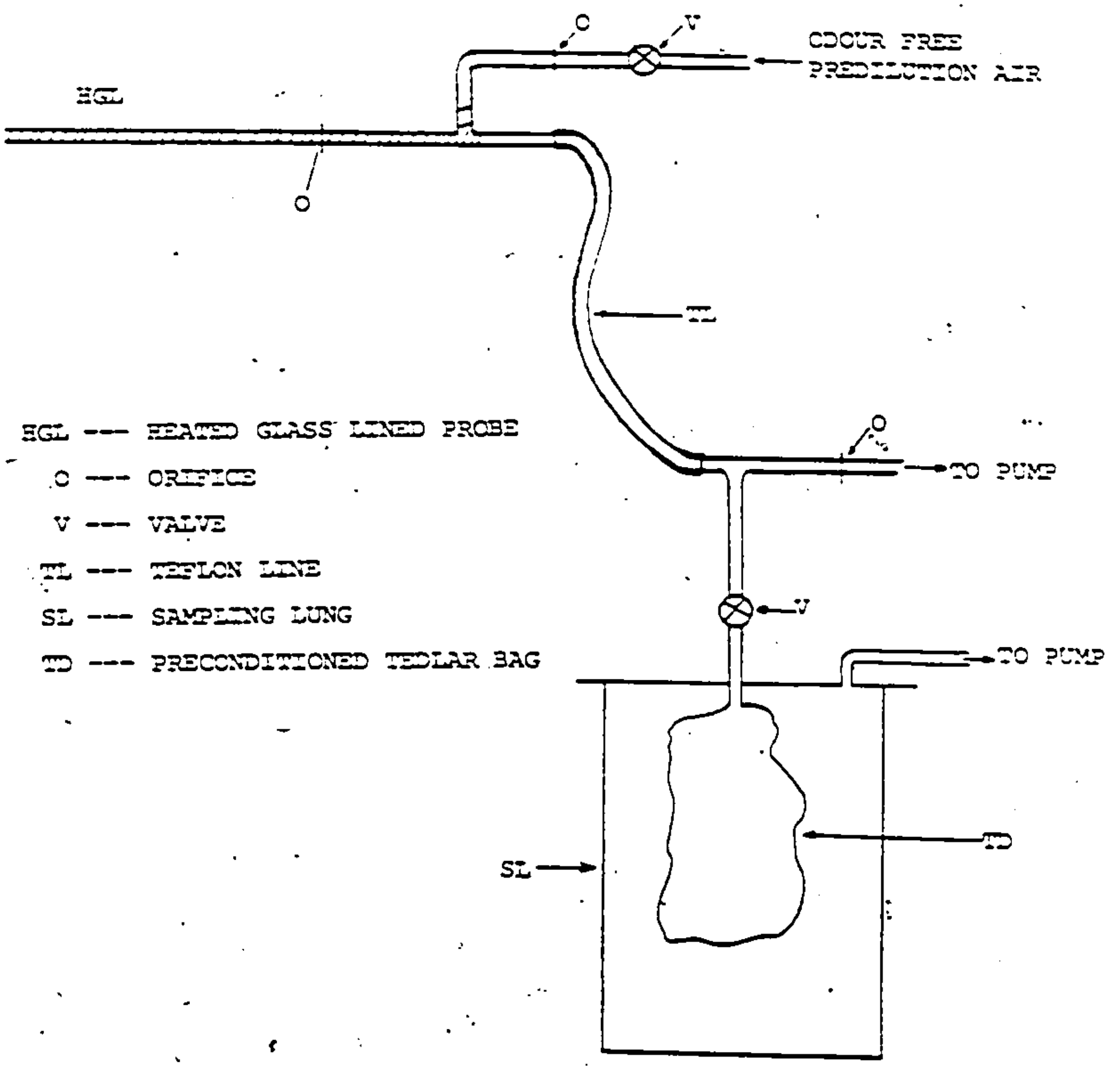

Figure 2.4: Odour Sampling Train Suggested by the Ontario Ministry of the Environment [13]

flow.

In order to simplify the sampling process, and to accomplish a sample dilution before the mixture is removed from the source stack, a Venturi, dynamic dilution, sampling probe was developed by members of the Air Quality Group [17,18].

Early attempts to calibrate the Venturi sampling device with respect to dilution ratio met with limited success due to the size of the simulated source stack. In the early experiments, n-butanol vapour was introduced into a six inch diameter glass chimney. The odourous sample was withdrawn from the chimney using the Venturi sampling probe. Due to the relative sizes, the sampling probe partially blocked the chimney flow area. In addition, the probe collected most of the gas flowing in the chimney. These two factors caused erratic results due to the flow problems that were encountered. Consequently the generated dilution ratio data were inconclusive.

For this research, the chimney was replaced by a wind tunnel. As a result, it was possible to approximate flows in an industrial stack, and to eliminate the flow problems that were associated with the smaller stack.

Previous investigators used a hydrocarbon analyzer to determine the achieved dilution ratios. They withdrew a sample of the stack gas with a sampling lung for later

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evaluation. The concentration of n-butanol in the stack gas was compared with that present in the sample bag that was filled with the Venturi sampling probe.

For this study the n-butanol vapour was replaced with sulphur hexafluoride to reduce interference from other gases. An infrared spectrophotometer was used to determine the concentrations of sulphur hexafluoride gas in the sample and the stack gases. This approach allowed constant monitoring of the gas concentration in the wind tunnel during sampling.

A full description of the system components is provided in Chapter III (Experimental Equipment).

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III. Experimental Equipment

The Venturi, dynamic dilution, sampling probe was studied in a controlled laboratory environment. Primary consideration was given to simulating industrial conditions to ensure that the probe would be assessed in a realistic setting.

The basic equipment used in this study involved:

A. Wind Tunnel
B. Venturi Sampling Probe
C. Infrared Spectrophotometer

A. The Wind Tunnel and Ancillary Equipment

The wind tunnel used for this series of experiments was donated to the Chemical Engineering Department at the University of Windsor by Clayton Environmental Consultants, Ltd., of Windsor, Ontario, in 1981. The fan was manufactured by the Aerovent Company of Piqua, Ohio, USA.

The wind tunnel has a volume of approximately 155 cubic feet. The air is propelled by a hydraulically driven fan. Air velocity is controlled by a throttling valve on the hydraulic supply. A schematic representation of the wind tunnel is provided in Figure 3.1.

The air passes through a Venturi section whose throat has a cross sectional area of 1 foot X 1 foot. All measurements were taken in the throat of the Venturi. The positions of the various sampling ports are illustrated in

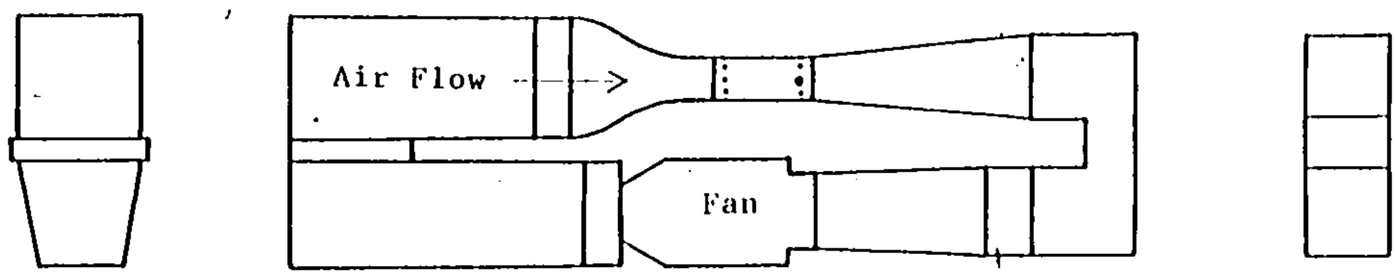

Figure 3.1: Schematic Representation of the Wind Tunnel

Figure 3.2. All dimensions in this figure are in inches.

Air velocity determinations were made by traversing the cross sectional area using a three point by three point grid.

Velocity pressure readings were made using a standard pitot tube, which was connected to a precision manometer purchased from the Airflow Corporation of Whitby, Ontario. The readability of the manometer is illustrated in Table 3.1. The velocity distribution is discussed in Appendix I.

Table 3.1: Readability of the Precision Manometer

Scale Multiplier	Scale Range	Scale Readability	Pressure Range (in H_2O)	Pressure Readability (in H_2O)
1.0	0 - 5	0.01	0 - 5	0.01
1.0	5 - 10	0.05	5 - 10	0.05
0.2	0 - 5	0.01	0 - 1	0.002
0.2	5 - 10	0.05	1 - 2	0.010
0.05	0 - 5	0.01	0 - 0.25	0.0005
0.05	5 - 10	0.05	0.25 - 0.50	0.0025

A standard pitot tube was also mounted permanently at the inlet to the wind tunnel Venturi throat. This pitot tube was used for all subsequent velocity measurements during the course of this investigation, and for the calibration of the S-type pitot tube which was fastened onto the sampling probe. This fixed pitot tube also facilitated the determination of static pressure in the wind tunnel. The S-type pitot tube provided a means of monitoring the stack gas velocities

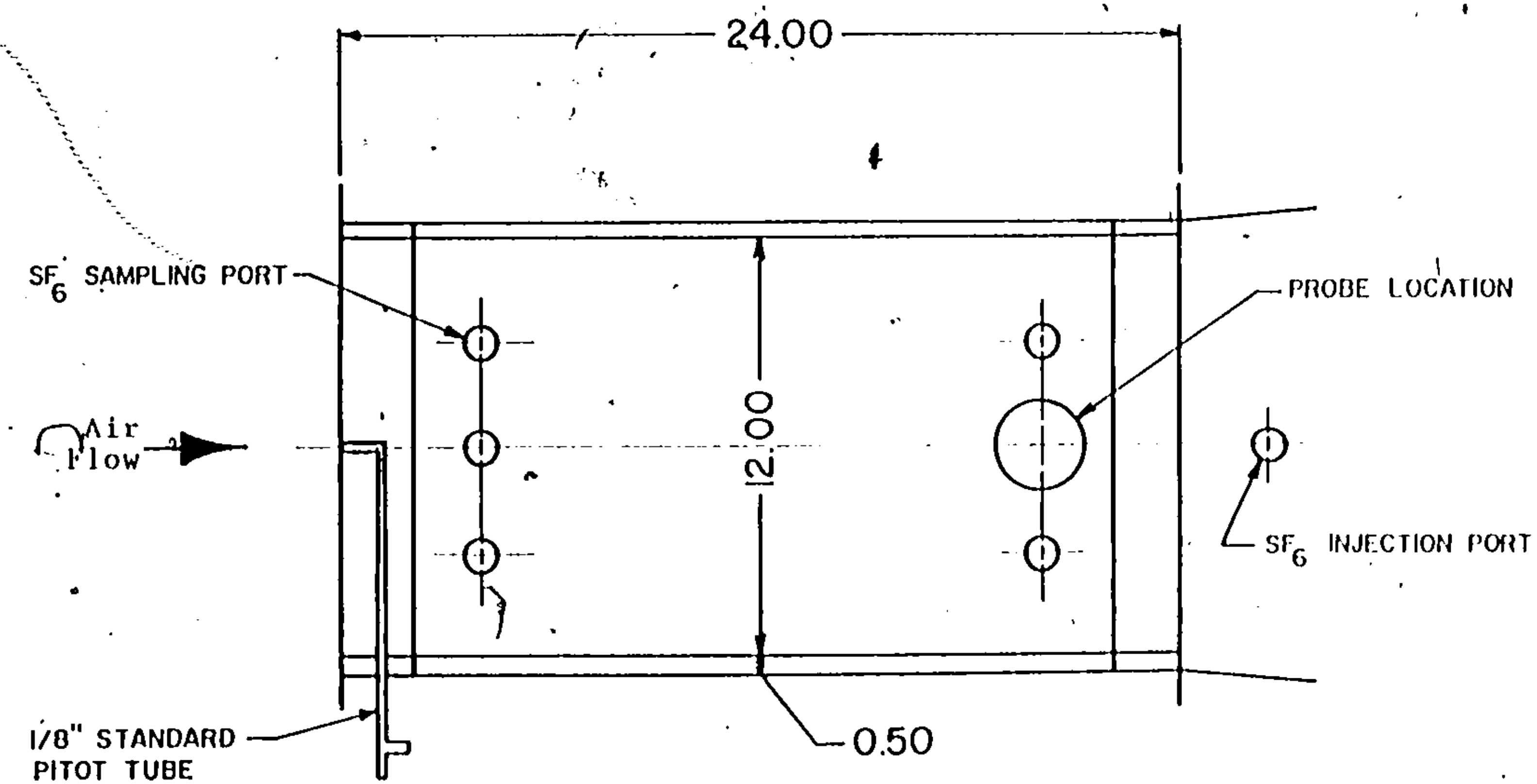

Figure 3.2: Details of the Working Station
All Dimensions are in Inches

during sample collection.

A psychrometer was introduced into the wind tunnel through the window below the traversing pitot tube for the determination of the water vapour content of the gas circulating in the wind tunnel. The dry thermometer in the psychrometer was also used to calibrate a bi-metallic thermocouple which was mounted on the sampling probe. This thermocouple facilitated the monitoring of the gas dry bulb temperature. The thermocouple was purchased from the Cole-Parmer Company, of Chicago, Illinois.

B. The Venturi, Dynamic Dilution, Sampling Probe

The heart of the system being evaluated in this research was the Venturi, dynamic dilution, sampling probe illustrated in longitudinal and cross sectional detail in Figures 3.3 and 3.4. All dimensions in these figures are in inches. The basic function of this device is to dilute an odourous sample within a stack and fill a Tedlar sample bag with this diluted sample.

This device was constructed for evaluation in the early eighties. The actual design criteria have not been located despite inquiries [1].

Deodourized air is supplied to the Venturi probe by an (R3105-1) 60-cfm rotary blower purchased from the Gast Company of Benton Harbour, Michigan, USA.

The inlet air is pre-cleaned with a 10 micron filter

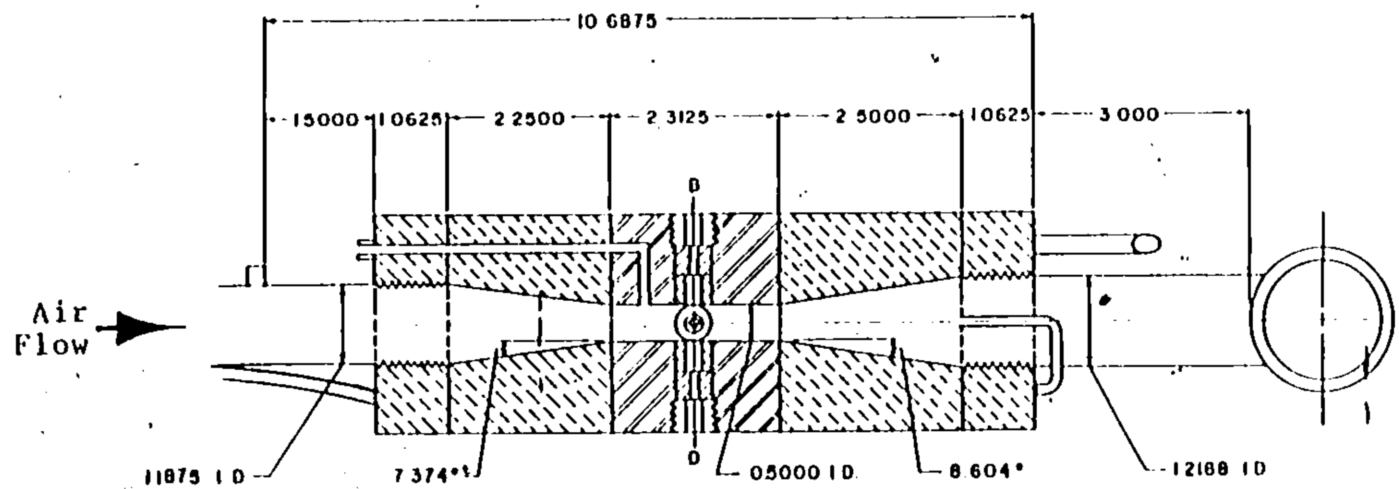

Figure 3.3: Longitudinal View of the Sampling Probe
All Dimensions are in Inches

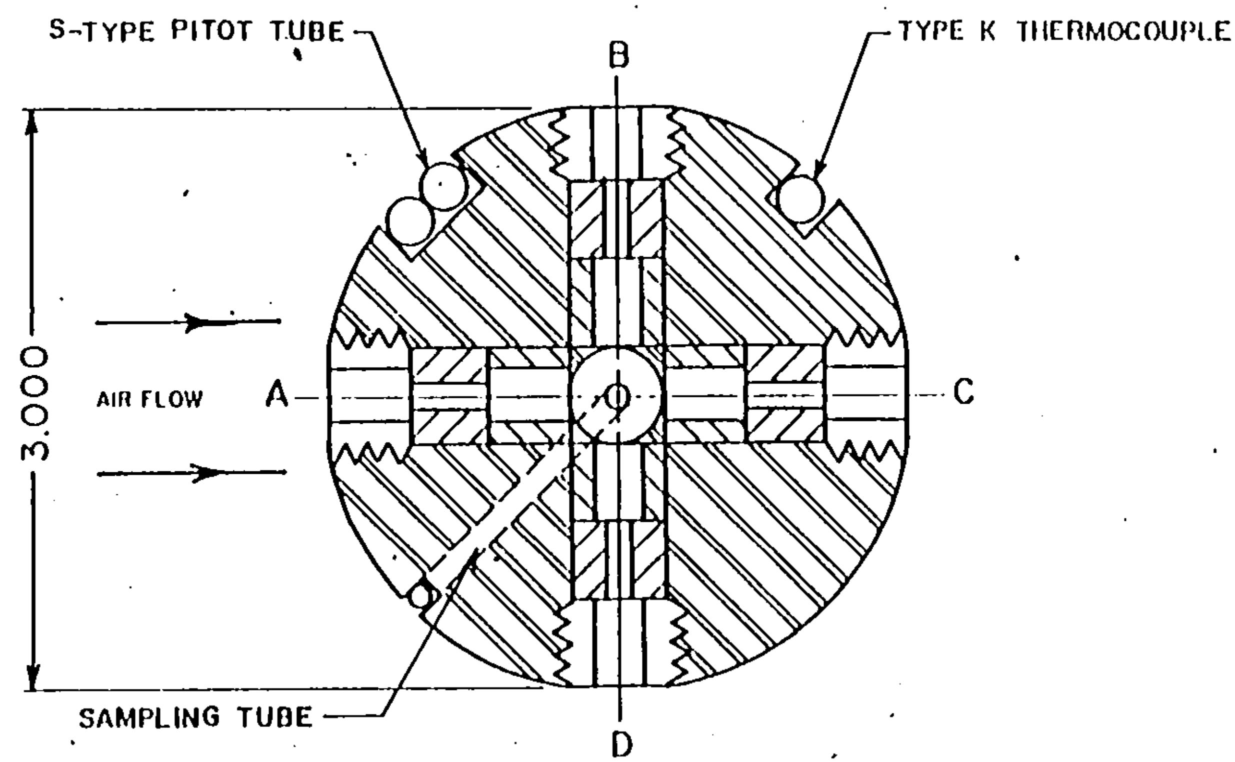

Figure 3.4: Cross Sectional View of the Sampling Probe
All Dimensions are in Inches

before passing through an activated charcoal bed for deodourization. This cleaned air is conveyed to the Venturi probe via a 10 foot long Teflon hose and a 5 foot long 1.1875 inch ID steel pipe.

The Venturi itself is 9.19 inches in length, and has a throat diameter of 0.50 inches. The convergent section of the Venturi is 2.25 inches in length, with an angle of 7.37 degrees. The divergent section of the throat is 2.50 inches long with an angle of 8.60 degrees. The throat is 2.31 inches in length.

There are four 0.25 inch sampling ports located at 90 degrees to each other in the throat. These ports are tapped to allow a 0.125 inch or a 0.0625 inch orifice to be installed and secured in each port as required. These ports are located 5.63 inches from the upstream end plate of the Venturi probe. Their respective positions are identified in Figure 3.4.

An odourous sample is drawn through these ports and mixed with the incoming deodourized air. Part of the diluted sample is channeled into a 0.125 ID stainless steel tube placed centrally at the exit to the Venturi. This tube serves to conduct the sample to a Tedlar sampling bag.

Pressure taps are located in the throat and at the inlet to the Venturi to provide low and high pressure readings respectively.

The gases leaving the Venturi probe pass into a 1.22 inch ID iron pipe and exit through a right angle elbow in the direction of the stack gas flow.

C. Infrared Spectrophotometer and Data Acquisition System

To determine dilution ratios, it was convenient to compare the concentrations of a tracer gas which had been injected into the wind tunnel to those associated with gas samples in the Tedlar bags that were filled during the sampling process.

Sulphur hexafluoride, (SF_6) was chosen to simulate an odour in the wind tunnel. This choice was to minimize background interference from other gases during sample analysis. The gas was injected into the port indicated in Figure 3.2. The supply was from a 100 pound tank of commercial grade gas. This gas was compared to the instrument purity gas that was used to calibrate the infrared spectrophotometer. No detectable difference was found between the two purities. The gas was purchased from Matheson Specialty Gas Products in Whitby, Ontario.

A Miran-1A infrared spectrophotometer was used to determine the concentrations of the SF_6 gas. This instrument was purchased from the Foxboro Company, LaSalle, Quebec.

The Miran-1A was adjusted to:

- a pathlength of 20.25 metres
- a slit width of 1 millimetre
- a wavelength of 10.7 microns,

and set to measure in absorbance units.

The analog output of the instrument detector was displayed on an electrical meter. This output was also available as a 0-1 volt DC signal.

For recording purposes the output was sent to a chart recorder (Hewlett-Packard 1703), and to a CCAD analog-to-digital interface which provided a printed record of the measured absorbance through a Radio Shack TRS-80 Colour Computer. The computer also performed initial calculations that converted the recorded absorbance readings into concentration values by using a non-linear equation which was derived from the original calibration of the spectrophotometer. The Miran-1A calibration procedures are described in Appendix III.

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IV. Experimental Procedures

As mentioned earlier, the goal of this research was to evaluate the Venturi, dynamic dilution, probe in an environment that would approximate a realistic field situation. As a result, the experimental procedure reflects actual sampling methodologies with respect to stack gas and atmospheric conditions. The Ontario Ministry of the Environment manual on source testing [1] and the draft version of the proposed procedure for source sampling of odours [2] were used to determine the parameters required for field testing.

The order of the experimental procedure was as follows:

1) The wind tunnel was turned on. As the wind tunnel warmed up, all electronic equipment was started. During this time the room temperature and barometric pressure were recorded. The wind tunnel usually stabilized within 10 minutes.

2) The wind tunnel was adjusted to provide the appropriate gas velocity. As the manometer reading from the standard pitot tube stabilized, the probe configuration was set, and the probe was inserted through the sampling window. The probe blower was turned on at this time, and set to the appropriate value. The manometer reading usually stabilized within 5 minutes, and was recorded at this time. One lead was now disconnected from the manometer for measurement of the

static pressure.

3) The psychrometer was inserted into the port below the probe sampling port once the velocity reading had stabilized. The psychrometer was left in place for approximately one minute. While the wet and dry bulb temperatures were coming to equilibrium the static pressure was recorded. The manometer leads were then changed to measure the velocity pressure readings from the S-type pitot tube. The psychrometer was removed from the wind tunnel and the wet and dry bulb temperatures were recorded.

4) The velocity pressure reading from the S-type pitot tube was recorded, as was the pressure reading across the Venturi sampling probe.

5) At this point, sulphur hexafluoride (SF_6) was introduced into the wind tunnel at the injection point shown in Figure 3.2. The injection pressure was usually 4 psig. The infrared spectrophotometer was adjusted to read the concentration of the gas in the wind tunnel. The absorbance value was monitored on the Miran-1A gauge, the chart recorder and the computer output to ensure that agreement between the three devices still existed. The absorbance value was allowed to rise to approximately 0.880. At this time the flow of SF_6 was decreased to maintain the desired concentration of the gas in the wind tunnel for the duration of the testing period.

6) Once the absorbance reading had stabilized, the computer was set to begin averaging the absorbance values every thirty seconds. These values were also printed out. Once the recording devices had been initiated, the sample bag was placed on the sampling tube outlet of the Venturi sampling probe and the time was recorded.

7) A sample was collected until the bag was approximately 3/4 full. In most cases, this required approximately 20 minutes. At the end of each sampling period, the bag was removed from the outlet tube, the computer was re-initiated and the time was recorded. Four samples were collected for each probe configuration.

8) After the last sample time was recorded, the final readings were taken for all the parameters of interest. Usually this process was repeated three times each day. The wind tunnel was reset to the highest velocity at the end of each day's work to allow the machine to stabilize quickly when it was turned on the next day. A fresh air line was connected to the Miran-1A to purge the cell prior to analysis of the sample bags.

9) The sample bags were analyzed in reverse order to the order of collection. The analyses involved the use of the Miran-1A, the chart recorder, and the computerized data acquisition system. Once the samples were analyzed, the fresh air line was reconnected to the Miran-1A for purging.

The order of data collection is best demonstrated by the data sheet provided in Figure 4.1.

The information recorded on these sheets facilitated the calculation of stack gas humidity and velocity, as well as the recording of the parameters that pertained to the specific probe configuration, namely the pressure drop across the Venturi and the location and size of the sampling orifice(s). Each probe configuration was tested four times to determine the reproducibility of the results. Analysis of the recorded data will be discussed in the next chapter.

DATE TIME SAMPLE NUMBERS

STARTUP BAROMETRIC PRESSURE mmHg ROOM TEMP °F

	TIME START	Twet	Tdry	Tprobe	TIME FINISH	HUMIDITY
INITIAL						
FINAL						

	TIME	Ppitot msrd (x)	Ppitot act	Pstatic
INITIAL				
FINAL				

	TIME	Pstype	PROBE CONFIGURATION
INITIAL			1/16 1/8 1/4 A B C D
FINAL			

	TIME	PROBE MANOMETER	SAMPLE NUMBERS METER
INITIAL		inH_2O	inH_2O
FINAL		inH_2O	inH_2O

START SF6

SAMPLE

TIME ON

TIME OFF

STOP SF6

FINAL BAROMETRIC PRESSURE mmHg ROOM TEMP °F

COMMENTS:

Figure 4.1: Experimental Data Sheet

REFERENCES

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V. Results and Discussion

In total, 391 experiments were performed during the course of this investigation. However, not all of the collected data are useful for determining whether the Venturi, dynamic dilution, probe is applicable to the sampling of odourous stack gases. Since the factors that might affect dilution ratios were originally unknown, more data were collected than required. A complete record of the useful data is provided in Appendix IV.

A. Results

Dilution ratios for all the probe configurations tested are presented in Tables 5.1 to 5.15. Graphical representations of the dilution ratios are provided in Figures 5.1 to 5.15. The specification of the probe configuration in the figures and tables refers to the size of the orifice used in the sampling port(s), and the location of the sampling port(s), respectively. The locations have been defined in Figure 3.4.

Tables 5.1 to 5.15 summarize the dilution ratios that were achieved with various orifice sizes and locations, stack gas velocities, and Venturi pressure drops. The values of the dilution ratios are presented in order of increasing wind tunnel gas velocities. For most velocities, there are two Venturi pressure readings. They refer to the pressure drop measured across the Venturi in inches of water. The higher of

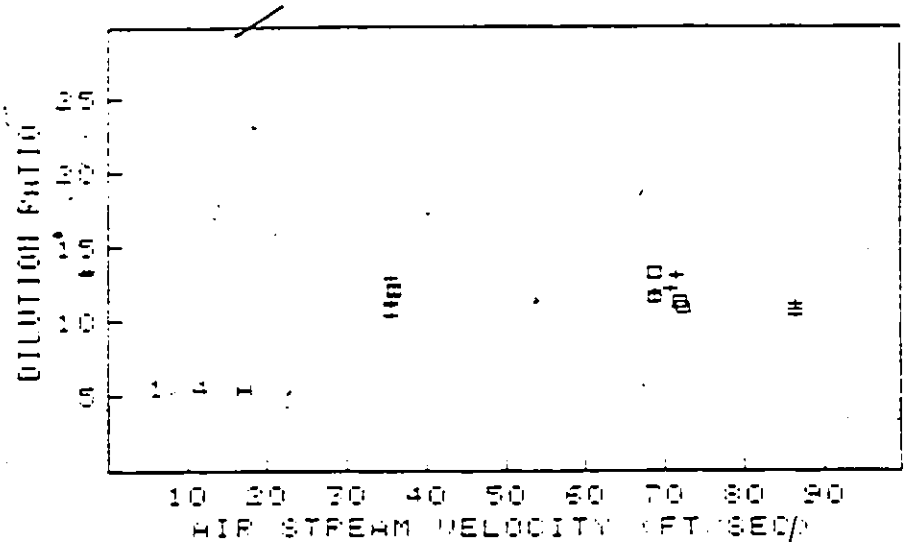

Figure 5.1: Results of Probe Configuration 1/4 A
+ Maximum Venturi Pressure Drop
□ Minumum Venturi Pressure Drop

Table 5.1: Results of Probe Configuration 1/4 A

Average Gas Velocity (ft/sec)	Average Venturi Pressure (in H_2O)	Dilution Ratio			
35.65	19.6	13.0	11.3	11.2	10.5
35.96	5.8	12.2	12.0	12.1	12.1
68.80	19.5	11.9	11.9		
68.80	16.8	13.3	11.7		
70.71	21.6	12.2			
71.70	21.4	12.2			
72.15	14.9	11.4			
72.56	15.2	10.9			
86.42	19.7	11.2	11.2	10.4	10.8

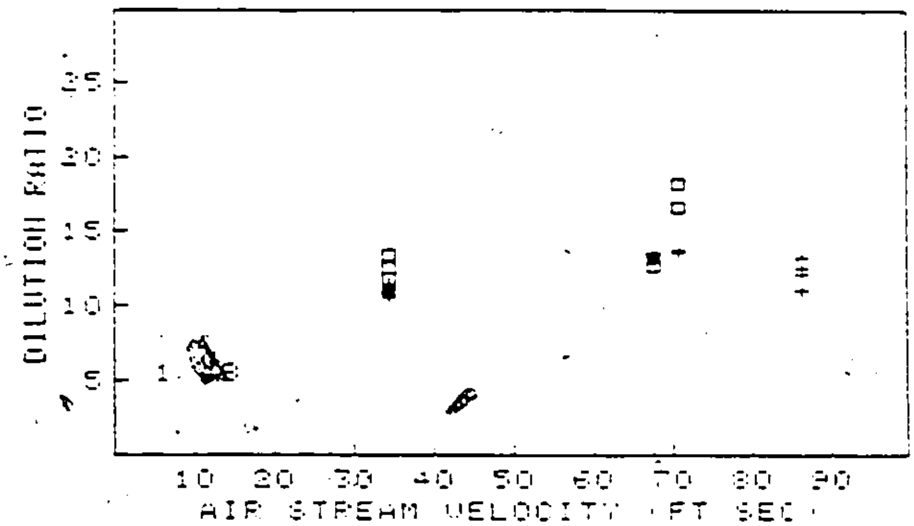

Figure 5.2: Results of Probe Configuration 1/4 B
+ Maximum Venturi Pressure Drop
□ Minumum Venturi Pressure Drop

Table 5.2: Results of Probe Configuration 1/4 B

Average Gas Velocity (ft/sec)	Average Venturi Pressure (in H_2O)	Dilution Ratio			
34.38	20.0	11.4	11.1	11.0	10.7
34.57	7.8	12.4	11.1	13.5	11.7
67.69	20.1	13.3	13.4		
67.69	13.1	13.3	12.7		
70.73	22.3	13.7	13.8		
70.73	14.2	16.7	18.3		
86.71	19.9	13.3	12.5	12.2	11.1

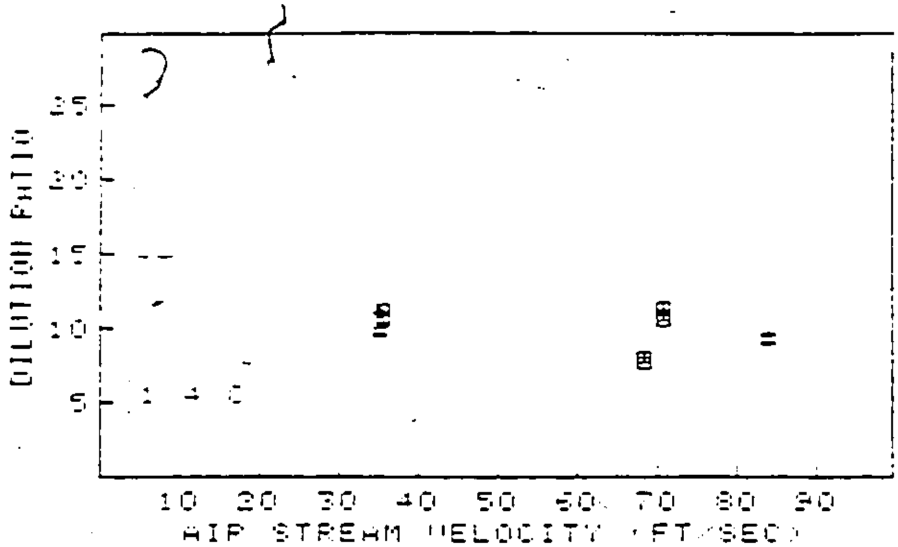

Figure 5.3: Results of Probe Configuration 1/4 C
+ Maximum Venturi Pressure Drop
☐ Minumum Venturi Pressure Drop

Table 5.3: Results of Probe Configuration 1/4 C

Average Gas Velocity (ft/sec)	Average Venturi Pressure (in H_2O)	Dilution Ratio			
35.03	20.3	10.1	9.8	11.2	9.5
35.47	8.8	11.3	10.6	10.7	10.8
68.32	20.0	8.2	8.2		
68.32	15.9	8.1	7.8		
71.02	22.0	11.4	11.2		
71.02	14.4	11.5	10.9		
71.06	14.2	10.6			
83.98	18.0	9.7	9.6	9.2	9.0

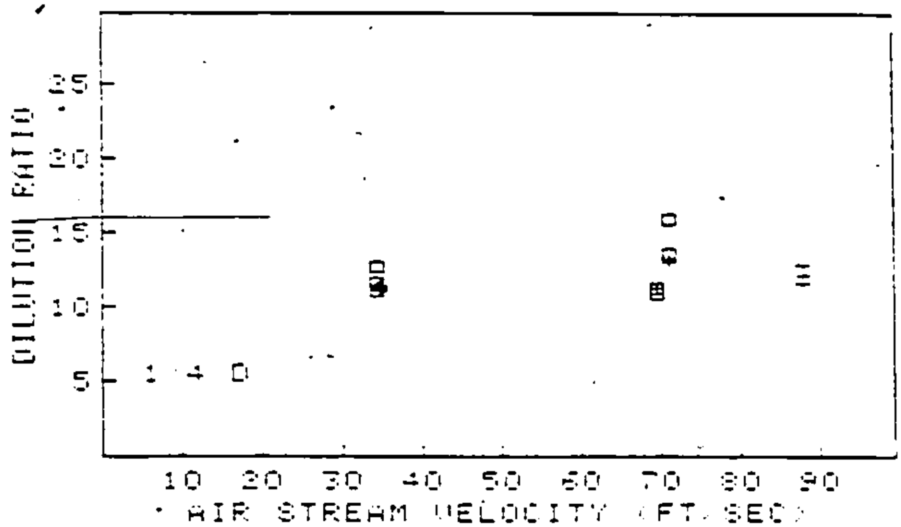

Figure 5.4: Results of Probe Configuration 1/4 D
+ Maximum Venturi Pressure Drop
□ Minumum Venturi Pressure Drop

Table 5.4: Results of Probe Configuration 1/4 D

Average Gas Velocity (ft/sec)	Average Venturi Pressure (in H_2O)	Dilution Ratio			
34.46	10.5	11.7	11.7	12.7	11.2
34.83	20.0	11.4	11.5	11.1	11.1
69.82	19.8	11.3	11.4		
69.82	16.6	11.4	10.9		
71.20	21.4	13.3	13.2		
71.20	14.4	16.0	13.7		
88.23	18.7	13.0	12.3	12.3	11.7

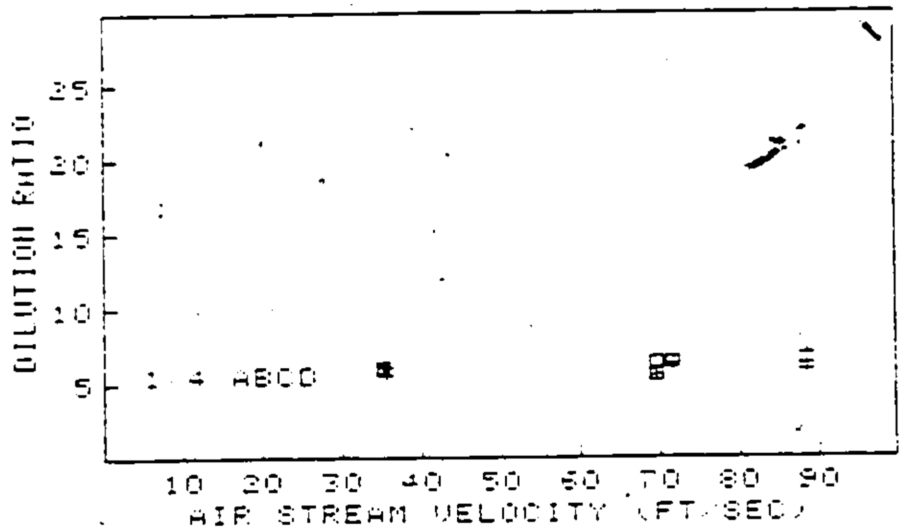

Figure 5.5: Results of Probe Configuration 1/4 ABCD
+ Maximum Venturi Pressure Drop
□ Minumum Venturi Pressure Drop

Table 5.5: Results of Probe Configuration 1/4 ABCD

Average Gas Velocity (ft/sec)	Average Venturi Pressure (in H_2O)	Dilution Ratio			
35.19	3.7	6.1	6.2	6.1	6.0
35.54	18.9	6.2	5.6	5.7	5.6
69.53	18.9	5.6	5.6		
69.53	10.5	6.5	5.6		
71.82	20.7	6.4	6.3		
71.82	11.4	6.4	6.5		
88.39	19.2	7.0	6.4	6.4	6.0

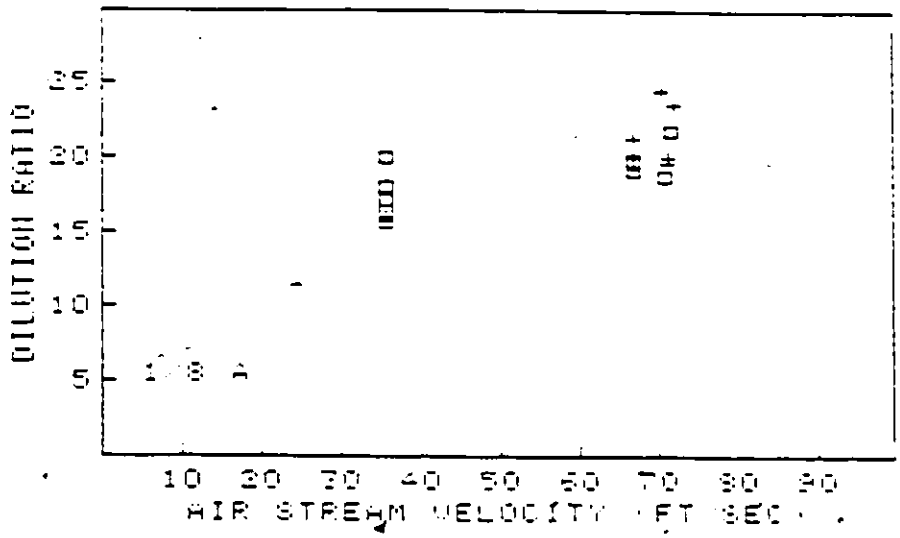

Figure 5.6: Results of Probe Configuration 1/8 A
+ Maximum Venturi Pressure Drop
□ Minumum Venturi Pressure Drop

Table 5.6: Results of Probe Configuration 1/8 A

Average Gas Velocity (ft/sec)	Average Venturi Pressure (in H_2O)	Dilution Ratio			
35.48	20.2	16.0	15.8	15.5	16.0
35.48	7.6	20.0	18.1	17.2	16.4
66.72	20.1	21.3	20.2		
66.72	16.3	19.7	19.2		
70.63	21.2	24.7			
71.05	14.8	18.9			
71.34	21.2	21.1	18.8		
71.68	15.2	21.8			
72.01	21.2	23.7			

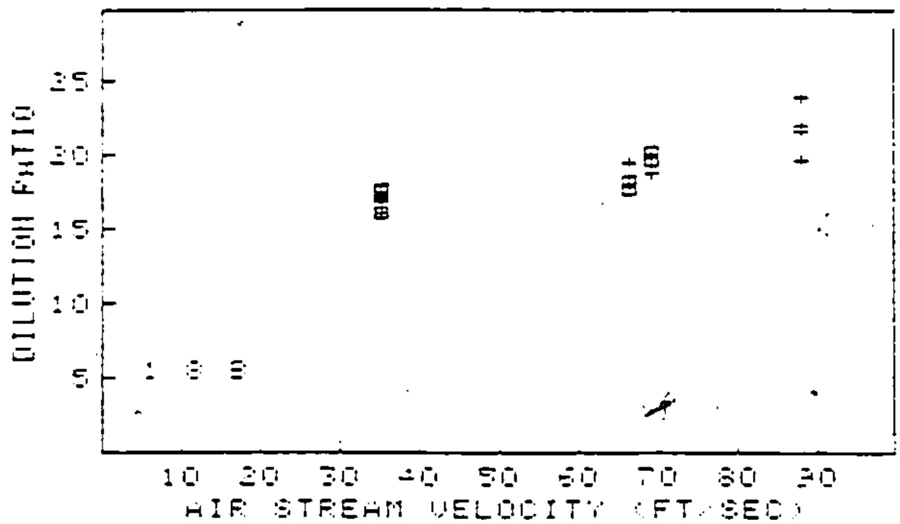

Figure 5.7: Results of Probe Configuration 1/8 B
+ Maximum Venturi Pressure Drop
□ Minumum Venturi Pressure Drop

Table 5.7: Results of Probe Configuration 1/8 B

Average Gas Velocity (ft/sec)	Average Venturi Pressure (in H_2O)	Dilution Ratio			
35.27	8.7	17.6	17.3	17.7	16.2
35.37	20.6	17.1	16.1	16.1	16.1
66.55	20.7	19.5	18.2		
66.55	15.2	18.3	17.8		
69.49	22.4	18.9	19.3		
69.49	14.5	20.3	19.8		
88.22	19.6	24.0	21.7	22.0	19.8

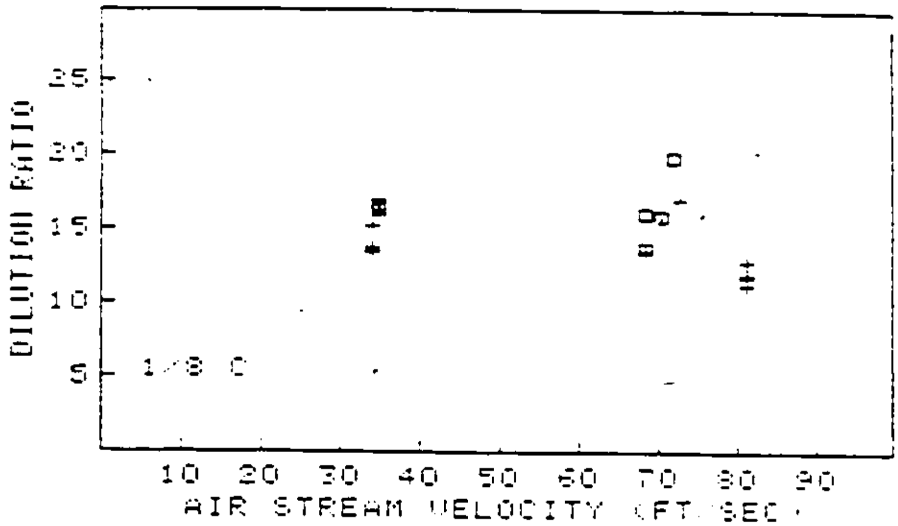

Figure 5.8: Results of Probe Configuration 1/8 C
+ Maximum Venturi Pressure Drop
□ Minumum Venturi Pressure Drop

Table 5.8: Results of Probe Configuration 1/8 C

Average Gas Velocity (ft/sec)	Average Venturi Pressure (in H_2O)	Dilution Ratio			
34.04	20.3	15.3	13.6	13.9	13.5
34.75	5.9	16.5	16.7	16.3	16.3
68.56	20.0	13.7	13.6		
68.56	17.6	16.1	13.9		
70.61	22.5	15.7			
70.61	14.6	16.0			
72.11	14.9	19.9			
72.76	22.6	17.0			
81.51	18.8	12.9	11.3	11.9	12.0

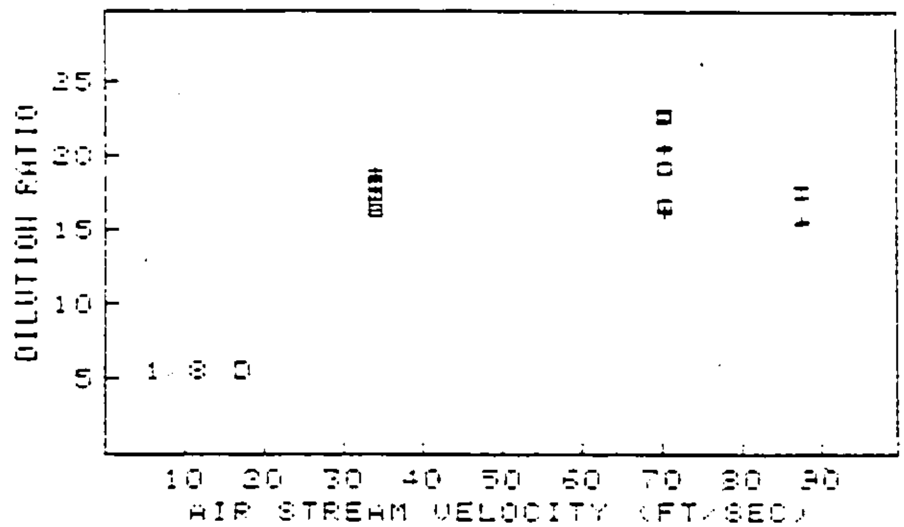

Figure 5.9: Results of Probe Configuration 1/8 D.
+ Maximum Venturi Pressure Drop
□ Minumum Venturi Pressure Drop

Table 5.9: Results of Probe Configuration 1/8 D

Average Gas Velocity (ft/sec)	Average Venturi Pressure (in H_2O)	Dilution Ratio			
34.18	20.5	19.0	18.5	18.6	17.6
34.18	8.1	17.8	17.4	16.7	16.3
70.54	20.1	16.3	16.2		
70.54	16.3	19.2	16.7		
70.65	22.4	20.7	20.5		
70.65	14.5	22.8	22.6		
87.57	18.7	17.9	15.6	17.3	15.4

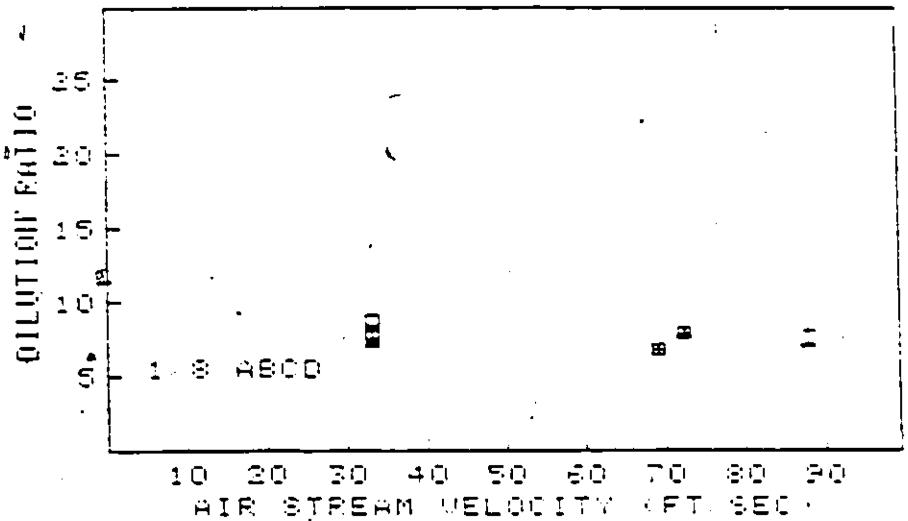

Figure 5.10: Results of Probe Configuration 1/8 ABCD
+ Maximum Venturi Pressure Drop
□ Minumum Venturi Pressure Drop

Table 5.10: Results of Probe Configuration 1/8 ABCD

Average Gas Velocity (ft/sec)	Average Venturi Pressure (in H_2O)	Dilution Ratio			
33.26	19.2	7.2	7.1	7.0	7.0
33.26	4.9	8.9	7.8	7.7	7.8
69.38	19.7	6.8	6.9		
69.38	10.8	6.8	6.8		
72.48	20.6	7.8	7.9		
72.48	13.2	7.9	7.9		
88.08	19.3	8.1	7.2	7.0	7.0

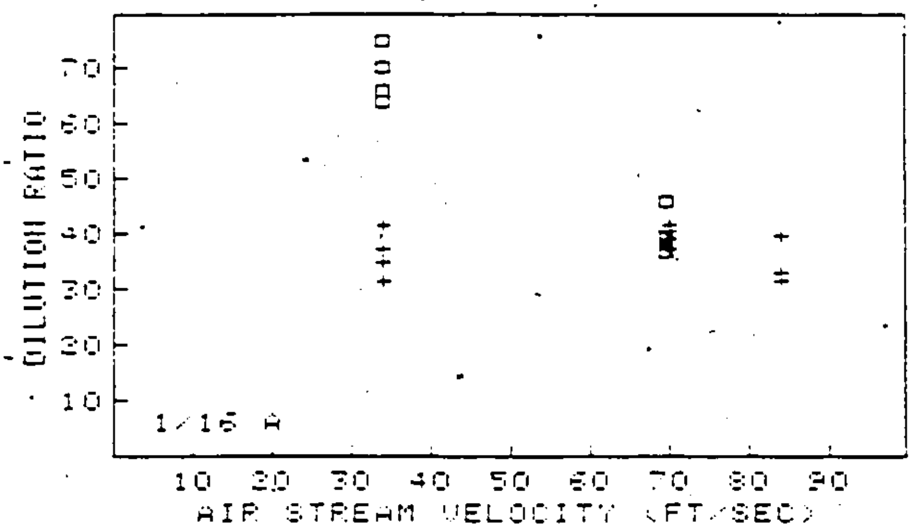

Figure 5.11: Results of Probe Configuration 1/16 A
+ Maximum Venturi Pressure Drop
□ Minumum Venturi Pressure Drop

Table 5.11: Results of Probe Configuration 1/16 A

Average Gas Velocity (ft/sec)	Average Venturi Pressure (in H_2O)	Dilution Ratio			
33.90	20.3	37.6	35.0	41.5	31.5
34.12	5.4	75.1	70.2	66.1	64.2
69.69	17.1	36.9	39.6	45.9	39.3
70.15	21.0	41.7	40.9	39.5	37.3
84.17	21.4	39.6	31.9	31.8	32.9

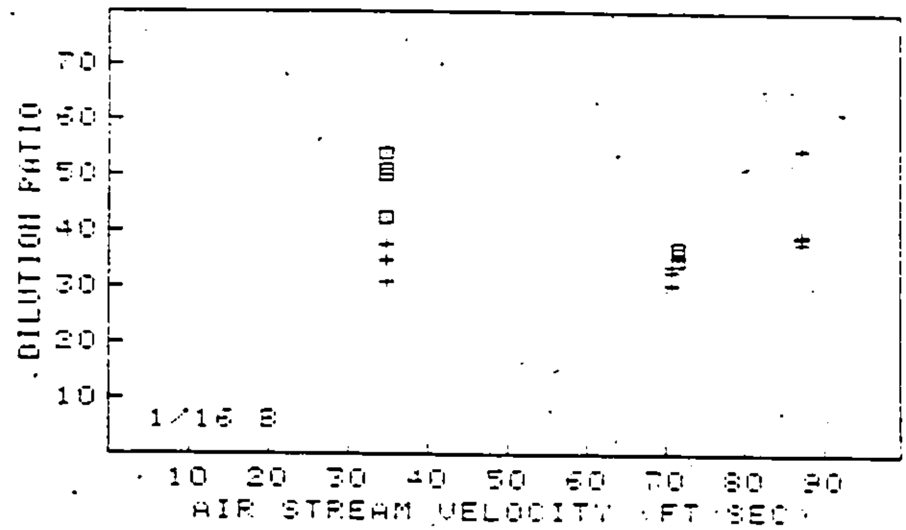

Figure 5.12: Results of Probe Configuration 1/16 B
+ Maximum Venturi Pressure Drop
□ Minumum Venturi Pressure Drop

Table 5.12: Results of Probe Configuration 1/16 B

Average Gas Velocity (ft/sec)	Average Venturi Pressure (in H_2O)	Dilution Ratio			
34.81	8.2	42.6	50.4	53.9	51.0
34.93	20.6	35.1	37.9	34.8	31.2
71.02	21.6	34.0	30.9	33.0	34.2
71.68	13.9	37.3	37.3	36.5	34.8
87.21	21.4	55.2	38.4	39.4	39.8

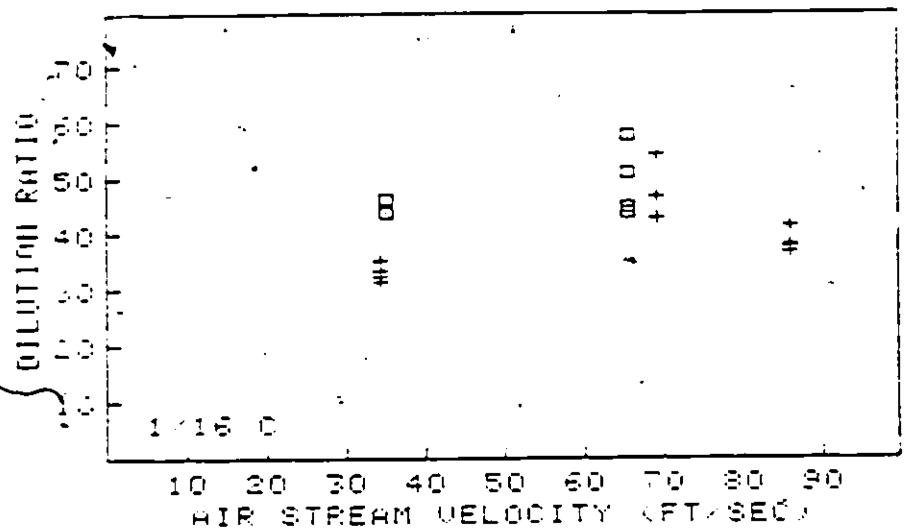

Figure 5.13: Results of Probe Configuration 1/16 C
+ Maximum Venturi Pressure Drop
□ Minumum Venturi Pressure Drop

Table 5.13: Results of Probe Configuration 1/16 C

Average Gas Velocity (ft/sec)	Average Venturi Pressure (in H_2O)	Dilution Ratio			
34.50	20.7	33.7	32.6	35.5	31.9
35.07	4.8	46.6	46.3	43.9	44.2
65.50	12.5	57.8	45.0	51.2	44.2
69.19	21.1	47.0	47.1	54.4	43.3
86.32	21.3	41.9	38.0	36.8	38.5

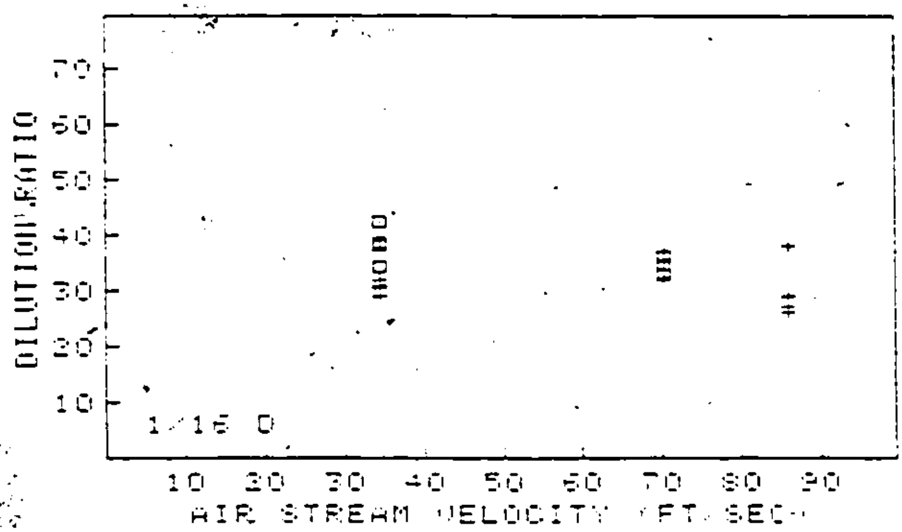

Figure 5.14: Results of Probe Configuration 1/16 D
+ Maximum Venturi Pressure Drop
□ Minumum Venturi Pressure Drop

Table 5.14: Results of Probe Configuration 1/16 D

Average Gas Velocity (ft/sec)	Average Venturi Pressure (in H_2O)	Dilution Ratio			
34.36	20.4	32.2	31.2	30.9	29.1
34.56	10.7	38.5	38.6	42.7	34.5
70.38	20.5	36.5	34.8	35.1	33.3
70.68	20.5	35.6	35.3	37.6	32.8
86.06	22.1	38.3	29.2	26.4	27.4

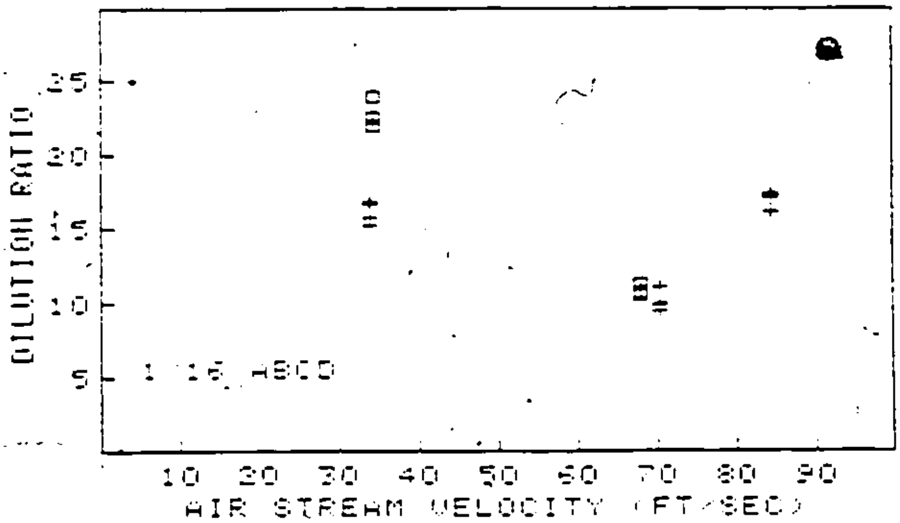

Figure 5.15: Results of Probe Configuration 1/16 ABCD
+ Maximum Venturi Pressure Drop
□ Minumum Venturi Pressure Drop

Table 5.15: Results of Probe Configuration 1/16 ABCD

Average Gas Velocity (ft/sec)	Average Venturi Pressure (in H_2O)	Dilution Ratio			
34.04	20.1	16.8	15.8	16.7	15.2
34.45	5.3	24.1	22.6	22.1	22.6
68.03	13.4	11.3	10.7	10.7	10.8
70.63	20.7	10.1	9.9	11.2	9.5
84.74	20.7	17.4	16.1	17.0	17.2

the two Venturi pressures listed represents the maximum pressure drop that could be achieved for that set of operating conditions. The lower of the two values represents the lowest pressure drop that would still provide a sample acquisition from the wind tunnel. The lowest Venturi pressure drop value was established by decreasing the flow through the probe and measuring the pressure at the outlet of the sample tube. The limiting Venturi pressure drop was defined when the pressure measured at the end of the sampling tube was at one inch of water gauge. This was a value that would provide a full sample bag in approximately 45 minutes. On the basis of practical field considerations such a sampling interval was considered to be limiting. According to the data in Table 5.6 there are no dilution ratio evaluations for the probe configuration of 1/8 A at the highest wind tunnel velocity. Under this experimental condition it was impossible to fill a sample bag.

B. Discussion

As illustrated in Appendix IV, some of the data presented in this study were not collected in a sequential order. This is an important point to consider, since it demonstrates that despite the fact that some experimental values for the same probe configuration were collected some months after the original determinations, the values show a high degree of agreement. Therefore, it can be argued that the dilution ratios are dependent only on the experimental conditions. Such agreement suggests that deviations in the data were not due to long term changes in the experimental sampling equipment.

To identify any trends that might be demonstrated by the data, the results were averaged in terms of wind tunnel gas velocities and Venturi pressure drops. Tables 5.16 to 5.30 relate average dilution ratios to two realistic pressure drops across the sampling device for a range of wind tunnel velocities. A graphical representation of this information is presented in Figures 5.16 to 5.30. The limits for each point represent the standard deviation of the data involved in calculating the average values.

A review of the data presented in Tables 5.16 to 5.30 indicates that the dilution ratios increased as the orifice size decreased. The lowest dilution was achieved for each orifice size when all four sampling ports were used.

These observations can be discussed in terms of a simplified hydrodynamic model.

1. Hydrodynamic Considerations

The operation of the Venturi, dynamic dilution, sampling probe can be modelled in terms of a combination of two flows, one through the Venturi, and one through the sampling port orifice. A simplified diagram of the Venturi, dynamic dilution, probe is presented in Figure 5.31.

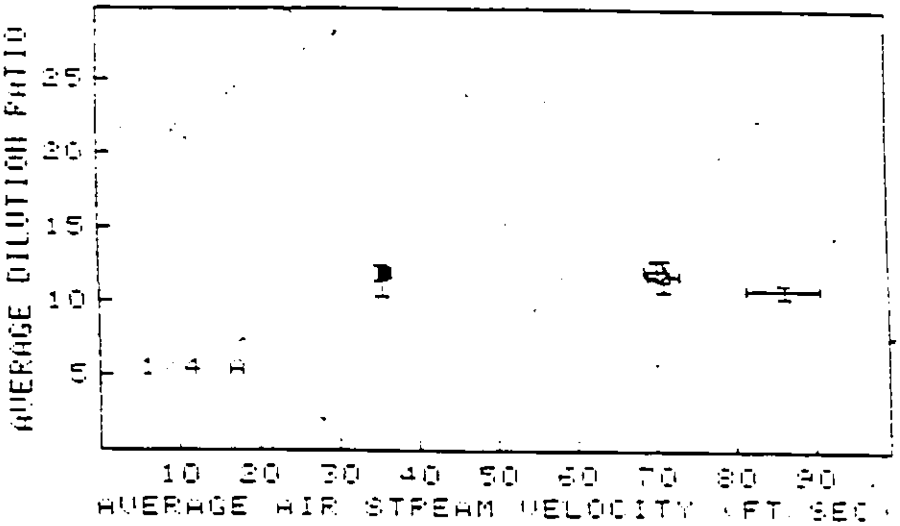

Figure 5.16: Averaged Results of Probe Configuration 1/4 A
+ Maximum Venturi Pressure Drop
□ Minimum Venturi Pressure Drop

Table 5.16: Averaged Results of Probe Configuration 1/4 A

Average Gas Velocity (ft/sec)	Average Venturi Pressure (in H_2O)	Averaged Dilution Ratio	Standard Deviation
35.65	19.6	11.5	1.06
35.96	5.8	12.1	0.08
70.40	20.8	12.3	0.62
71.18	15.6	11.3	1.04
86.42	19.7	10.9	0.38
	Mean Dilution Ratio	11.6	0.58

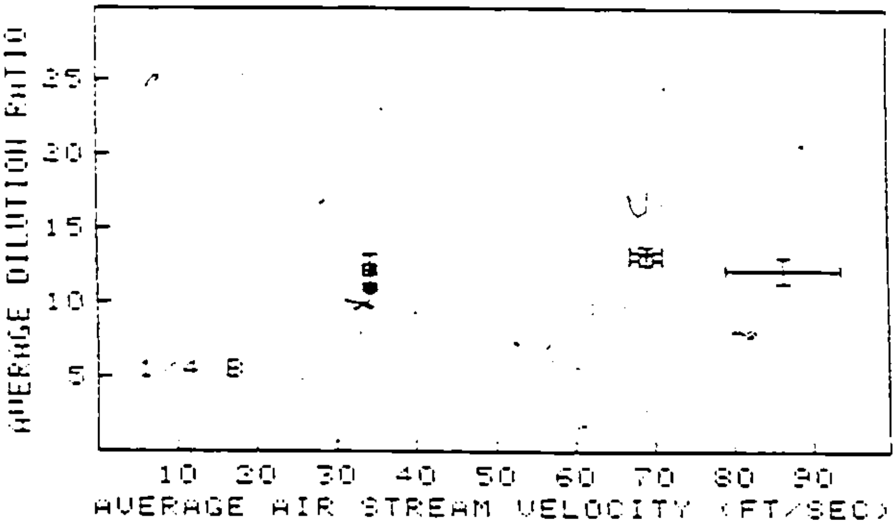

Figure 5.17: Averaged Results of Probe Configuration 1/4 B
+ Maximum Venturi Pressure Drop
□ Minimum Venturi Pressure Drop

Table 5.17: Averaged Results of Probe Configuration 1/4 B

Average Gas Velocity (ft/sec)	Average Venturi Pressure (in H_2O)	Averaged Dilution Ratio	Standard Deviation
34.38	20.0	11.1	0.29
34.57	7.8	12.2	1.02
67.21	21.2	13.6	0.24
67.21	13.7	13.0	0.42
86.71	22.3	12.3	0.91
	Mean Dilution Ratio	12.4	0.94

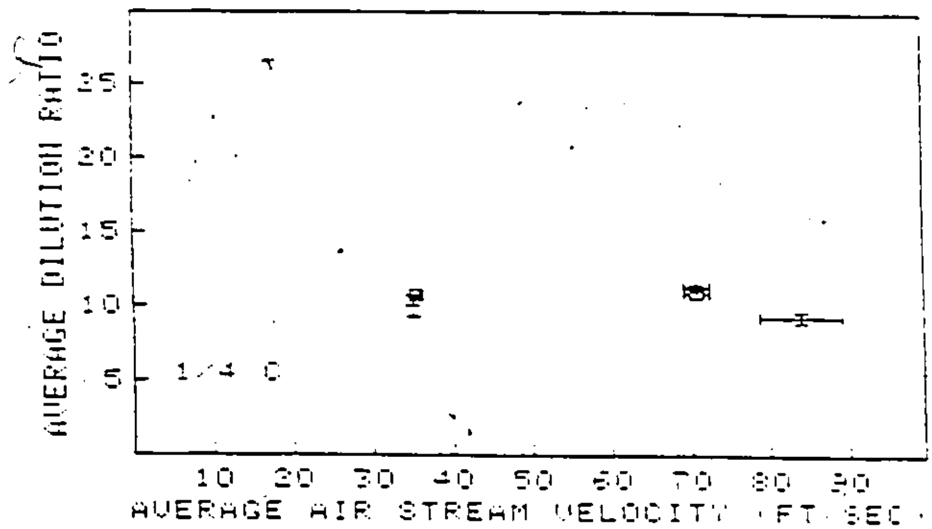

Figure 5.18: Averaged Results of Probe Configuration 1/4 C
+ Maximum Venturi Pressure Drop
□ Minimum Venturi Pressure Drop

Table 5.18: Averaged Results of Probe Configuration 1/4 C

Average Gas Velocity (ft/sec)	Average Venturi Pressure (in H_2O)	Averaged Dilution Ratio	Standard Deviation
35.03	20.3	10.1	0.75
35.47	8.8	10.9	0.31
71.02	22.0	11.3	0.14
71.04	14.3	11.0	0.46
83.98	18.0	9.4	0.33
	Mean Dilution Ratio	10.5	0.78

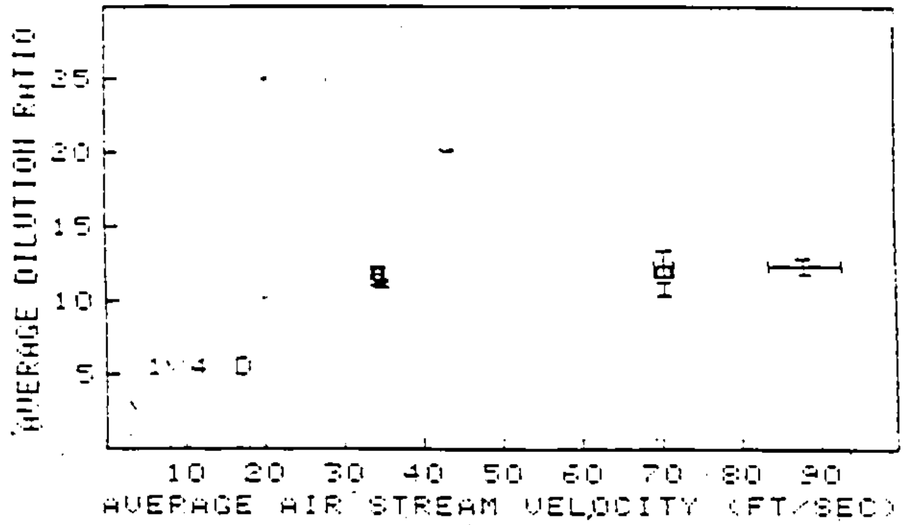

Figure 5.19: Averaged Results of Probe Configuration 1/4 D
+ Maximum Venturi Pressure Drop
□ Minimum Venturi Pressure Drop

Table 5.19: Averaged Results of Probe Configuration 1/4 D

Average Gas Velocity (ft/sec)	Average Venturi Pressure (in H_2O)	Averaged Dilution Ratio	Standard Deviation
34.46	10.5	11.8	0.63
34.83	20.0	11.3	0.24
70.51	20.6	12.3	1.07
70.51	15.5	12.0	1.49
88.23	18.7	12.3	0.53
	Mean Dilution Ratio	11.9	0.42

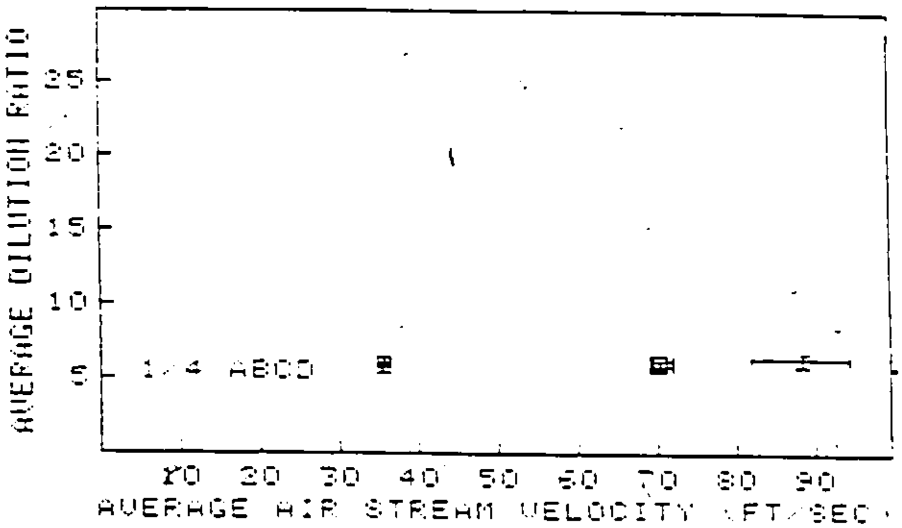

Figure 5.20: Averaged Results of Probe Configuration 1/4 ABCD
+ Maximum Venturi Pressure Drop
□ Minimum Venturi Pressure Drop

Table 5.20: Averaged Results of Probe Configuration 1/4 ABCD

Average Gas Velocity (ft/sec)	Average Venturi Pressure (in H_2O)	Averaged Dilution Ratio	Standard Deviation
35.54	18.9	5.8	0.29
35.54	3.7	6.1	0.08
70.67	19.8	6.0	0.43
70.67	11.0	6.3	0.45
88.39	19.2	6.4	0.41
	Mean Dilution Ratio	6.1	0.24

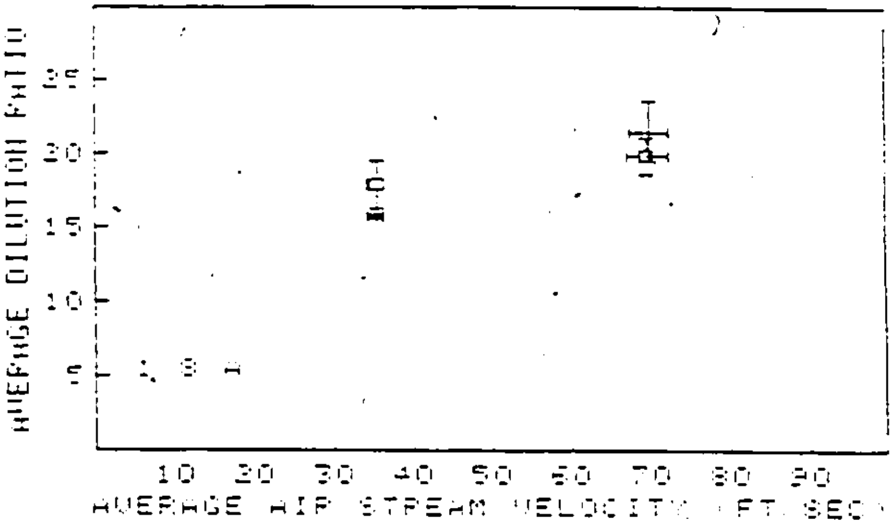

Figure 5.21: Averaged Results of Probe Configuration 1/8 A
+ Maximum Venturi Pressure Drop
□ Minimum Venturi Pressure Drop

Table 5.21: Averaged Results of Probe Configuration 1/8 A

Average Gas Velocity (ft/sec)	Average Venturi Pressure (in H_2O)	Averaged Dilution Ratio	Standard Deviation
35.48	20.2	21.6	0.24
35.48	7.6	15.8	1.56
69.81	15.4	19.9	1.31
70.17	20.9	21.6	2.02
	Mean Dilution Ratio	19.7	2.74

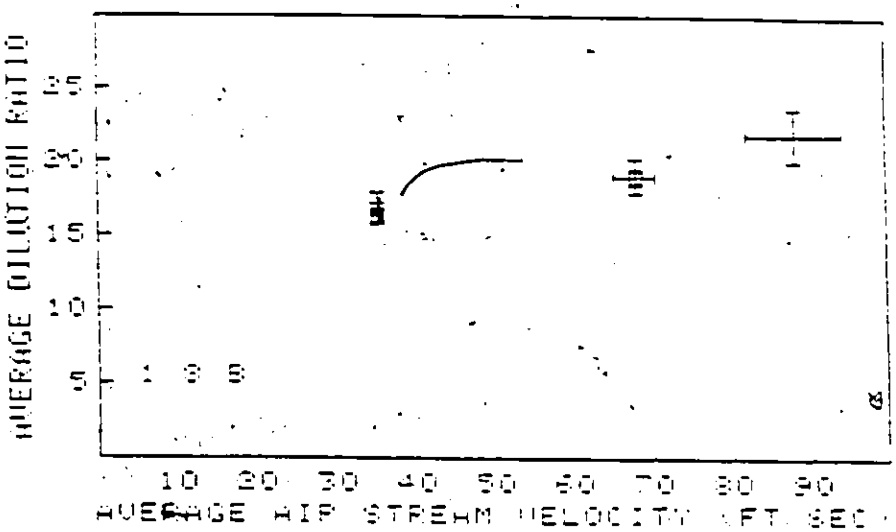

Figure 5.22: Averaged Results of Probe Configuration 1/8 B
+ Maximum Venturi Pressure Drop
□ Minimum Venturi Pressure Drop

Table 5.22: Averaged Results of Probe Configuration 1/8 B

Average Gas Velocity (ft/sec)	Average Venturi Pressure (in H_2O)	Averaged Dilution Ratio	Standard Deviation
35.27	8.7	17.2	0.69
35.37	20.6	16.4	0.50
68.02	21.5	19.0	0.57
68.02	14.8	19.1	1.19
88.22	19.6	21.9	1.72
	Mean Dilution Ratio	18.7	2.12

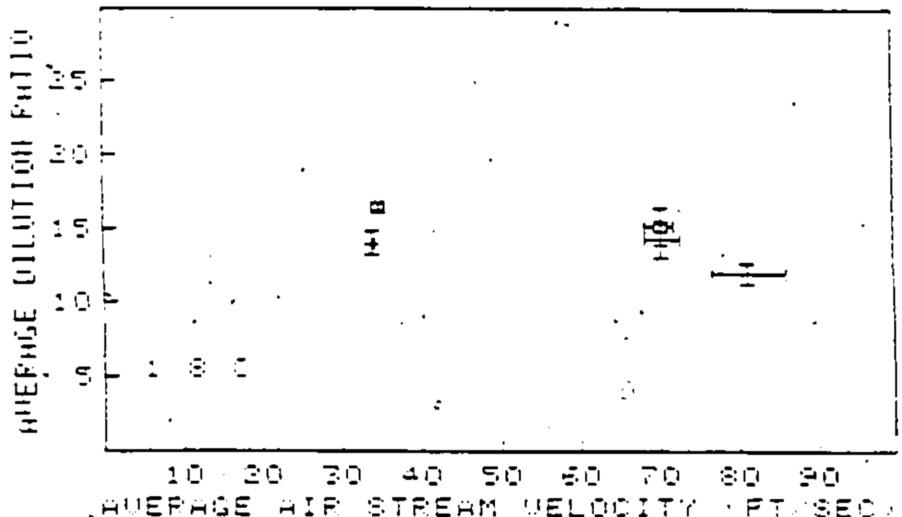

Figure 5.23: Averaged Results of Probe Configuration 1/8 C.
+ Maximum Venturi Pressure Drop
□ Minimum Venturi Pressure Drop

Table 5.23: Averaged Results of Probe Configuration 1/8 C.

Average Gas Velocity (ft/sec)	Average Venturi Pressure (in H_2O)	Averaged Dilution Ratio	Standard Deviation
34.04	20.3	14.1	0.83
34.75	5.9	16.5	0.19
70.43	15.7	15.3	1.24
70.65	21.7	14.3	1.18
81.51	18.8	12.0	0.66
	Mean Dilution Ratio	14.5	1.67

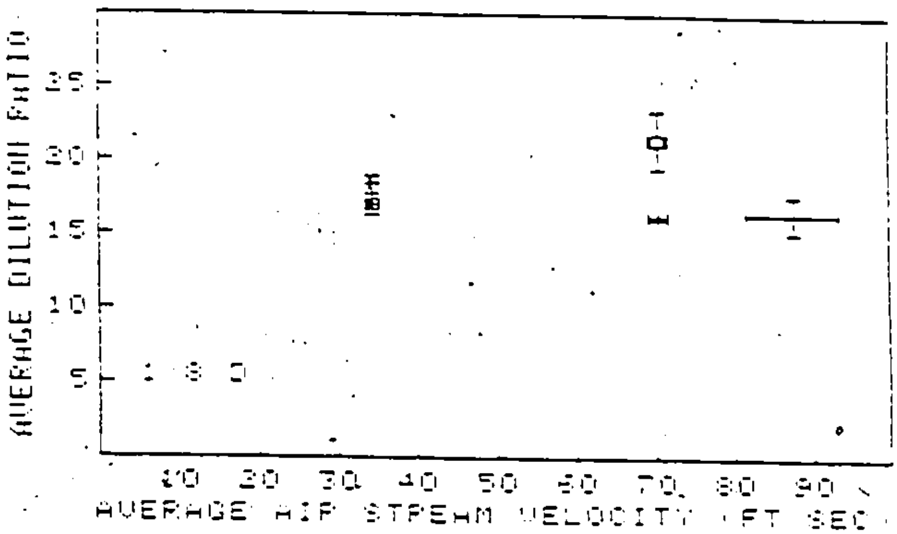

Figure 5.24: Averaged Results of Probe Configuration 1/8 D
+ Maximum Venturi Pressure Drop
□ Minimum Venturi Pressure Drop

Table 5.24: Averaged Results of Probe Configuration 1/8 D

Average Gas Velocity (ft/sec)	Average Venturi Pressure (in H_2O)	Averaged Dilution Ratio	Standard Deviation
34.18	20.5	18.5	0.60
34.18	8.1	17.1	0.71
70.59	21.3	16.3	0.07
70.59	15.4	21.5	2.02
87.57	18.7	16.6	1.24
	Mean Dilution Ratio	18.0	2.13

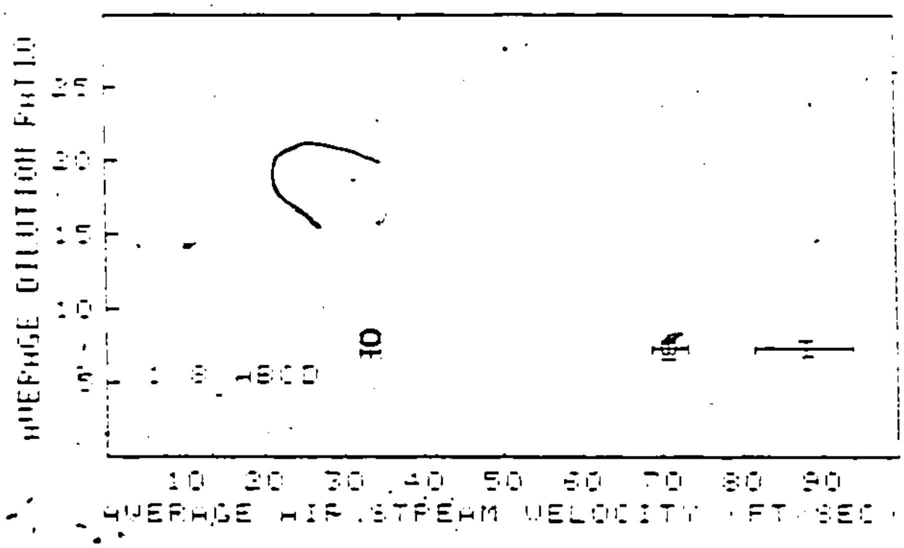

Figure 5.25: Averaged Results of Probe Configuration 1/8 ABCD
+ Maximum Venturi Pressure Drop
□ Minimum Venturi Pressure Drop

Table 5.25: Averaged Results of Probe Configuration 1/8 ABCD

Average Gas Velocity (ft/sec)	Average Venturi Pressure (in H_2O)	Averaged Dilution Ratio	Standard Deviation
33.26	19.2	7.1	0.10
33.26	4.9	8.1	0.56
70.93	20.2	7.4	0.58
70.93	12.0	7.4	0.67
88.08	19.3	7.4	0.52
	Mean Dilution Ratio	7.5	0.37

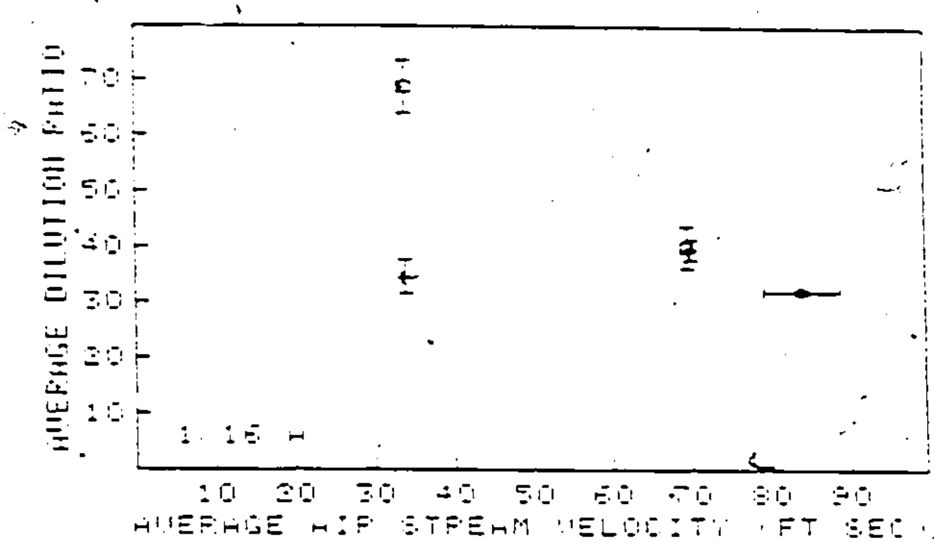

Figure 5.26: Averaged Results of Probe Configuration 1/16 A
+ Maximum Venturi Pressure Drop
□ Minimum Venturi Pressure Drop

Table 5.26: Averaged Results of Probe Configuration 1/16 A

Average Gas Velocity (ft/sec)	Average Venturi Pressure (in H_2O)	Averaged Dilution Ratio	Standard Deviation
33.90	20.3	34.7	3.06
34.12	5.4	68.9	4.83
69.69	17.1	40.5	3.81
70.15	21.0	39.9	1.93
84.17	21.4	32.2	0.61
	Mean Dilution Ratio	43.2	14.8

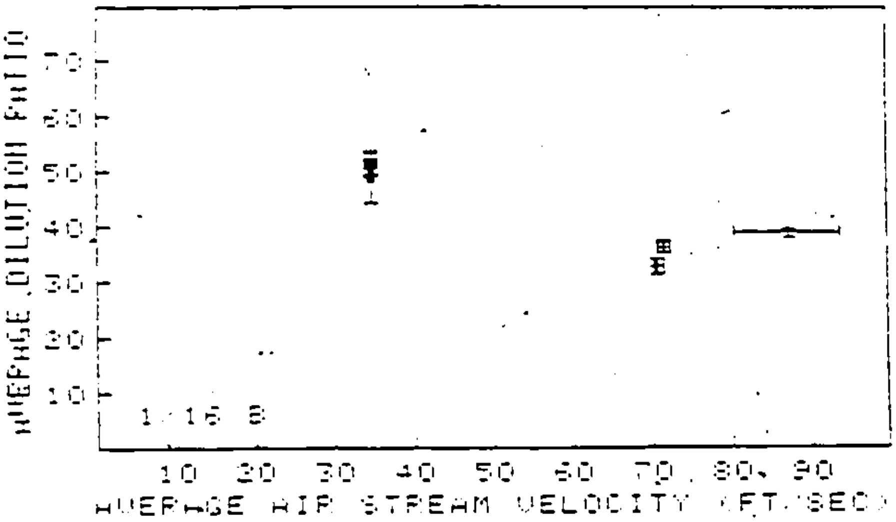

Figure 5.27: Averaged Results of Probe Configuration 1/16 B
+ Maximum Venturi Pressure Drop
□ Minimum Venturi Pressure Drop

Table 5.27: Averaged Results of Probe Configuration 1/16 B

Average Gas Velocity (ft/sec)	Average Venturi Pressure (in H_2O)	Averaged Dilution Ratio	Standard Deviation
34.81	8.2	51.8	1.87
34.93	20.6	49.5	4.78
71.02	21.6	33.0	1.51
71.68	13.9	36.5	1.18
87.21	21.4	39.2	0.72
	Mean Dilution Ratio	42.0	8.24

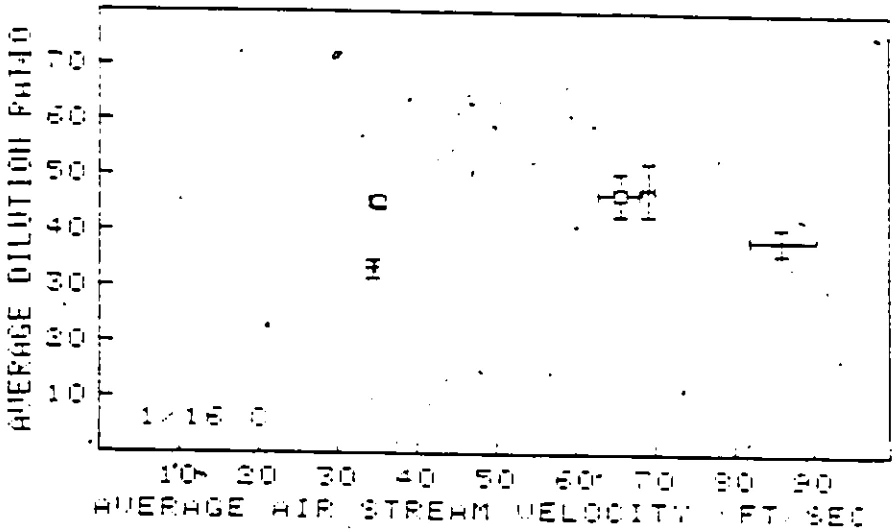

Figure 5.28: Averaged Results of Probe Configuration 1/16 C
+ Maximum Venturi Pressure Drop
□ Minimum Venturi Pressure Drop

Table 5.28: Averaged Results of Probe Configuration 1/16 C

Average Gas Velocity (ft/sec)	Average Venturi Pressure (in H_2O)	Averaged Dilution Ratio	Standard Deviation
34.50	20.7	33.4	1.57
35.10	4.8	45.3	1.40
65.50	12.5	46.8	3.83
69.19	21.1	48.0	4.65
86.32	21.3	38.8	2.19
	Mean Dilution Ratio	42.5	6.19

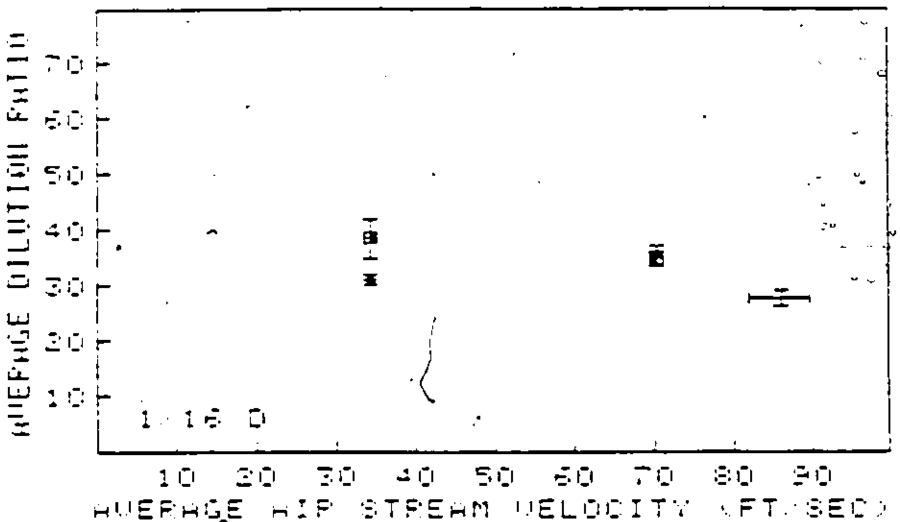

Figure 5.29: Averaged Results of Probe Configuration 1/16 D
+ Maximum Venturi Pressure Drop
☐ Minimum Venturi Pressure Drop

Table 5.29: Averaged Results of Probe Configuration 1/16 D

Average Gas Velocity (ft/sec)	Average Venturi Pressure (in H_2O)	Averaged Dilution Ratio	Standard Deviation
34.36	20.4	31.1	0.95
34.36	10.7	38.6	3.35
70.38	14.8	34.9	1.31
70.68	20.5	35.3	1.97
86.06	22.1	27.7	1.42
	Mean Dilution Ratio	33.5	4.20

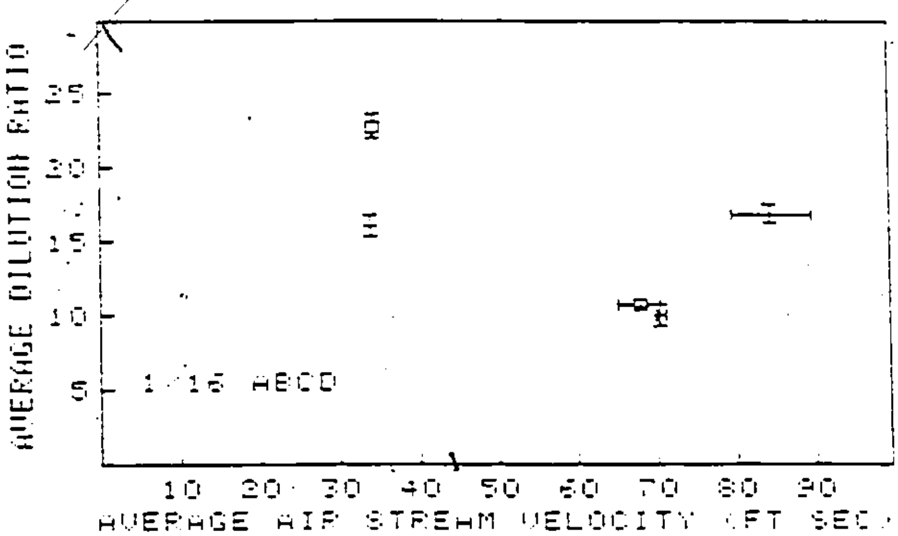

Figure 5.30: Averaged Results of Probe Configuration 1/16 ABCD
+ Maximum Venturi Pressure Drop
☐ Minimum Venturi Pressure Drop

Table 5.30: Averaged Results of Probe Configuration 1/16 ABCD

Average Gas Velocity (ft/sec)	Average Venturi Pressure (in H_2O)	Averaged Dilution Ratio	Standard Deviation
34.04	20.1	16.1	0.76
34.50	5.3	22.9	0.87
68.03	13.4	10.9	0.29
70.63	20.7	10.1	0.73
84.74	20.7	16.9	0.57
	Mean Dilution Ratio	15.4	5.18

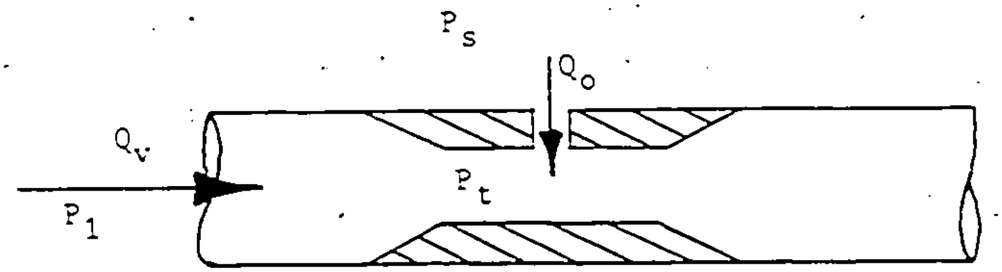

Figure 5.31: Modelling the Sample Process

The measured dilution ratio, DR, is related to the volumetric flow rate through the Venturi throat and the volumetric flow rate through the sampling port orifice. This magnitude is determined from the expression:

$$DR = \frac{Q_v + Q_o}{Q_o} \quad \text{.....................(1)}$$

where: Q_v = volumetric flow rate through the Venturi
Q_o = volumetric flow rate through the Orifice

The volumetric flow rates can be calculated from:

$$Q_v = \langle v_t \rangle A_t \quad \text{.....................(2)}$$

$$Q_o = \langle v_o \rangle A_o \quad \text{.....................(3)}$$

where: $\langle v_t \rangle$ = average gas velocity through the throat
$\langle v_o \rangle$ = average gas velocity through the orifice
A_t = cross sectional area of the Venturi throat
A_o = cross sectional area of the orifice

Substituting Equations 2 and 3 into Equation 1 yields:

$$DR = \frac{\langle v_t \rangle A_t + \langle v_o \rangle A_o}{\langle v_o \rangle A_o} \quad \ldots\ldots\ldots\ldots(4)$$

Simplification of Equation 4 yields:

$$DR = \frac{\langle v_t \rangle A_t}{\langle v_o \rangle A_o} + 1 \quad \ldots\ldots\ldots\ldots(5)$$

The standard expressions for flows through Venturi and orifice devices provide values of $\langle v_t \rangle$ and $\langle v_o \rangle$ according to:

$$\langle v_t \rangle = C_v \sqrt{\frac{2g_c\ (P_1 - P_t)}{\rho_A}} \quad \ldots\ldots(6)$$

$$\langle v_o \rangle = C_o \sqrt{\frac{2g_c\ (P_s - P_t)}{\rho_s}} \quad \ldots\ldots(7)$$

where: C_v = Venturi discharge coefficient
C_o = orifice discharge coefficient
g_c = gravitational constant conversion factor
P_1 = pressure at the inlet to the Venturi

P_t = pressure in the throat of the Venturi

P_s = pressure outside the probe in the wind tunnel

ρ_A = density of the gas flowing through the Venturi throat

ρ_s = density of the gas flowing through the wind tunnel

The respective cross sectional areas are calculated using the expressions:

$$A_t = \frac{\pi D_t^2}{4}$$

$$A_o = \frac{\pi D_o^2}{4}$$

where: D_t = diameter of the Venturi throat

D_o = diameter of the orifice

Substituting the relationships for $\langle v_t \rangle$, $\langle v_o \rangle$, A_t, and A_o into Equation 1 and simplifying yields:

$$DR = 1 + \frac{C_v}{C_o} \sqrt{\frac{\rho_s (P_1 - P_t)}{\rho_A (P_s - P_t)}} \left[\frac{D_t}{D_o}\right]^2 \quad ..(8)$$

To check if Equation 8 correlates the measured data, three tests were analyzed and reported in Table 5.31.

For these tests, it was assumed that the difference between the values of ρ_s and ρ_A is negligible. The value of C_v was assumed to be 1.00 for this initial examination of Equation 8. Similarily, the value of C_o was set at 0.60. By design the magnitude of D_t is 0.5 inches. The value (P_1-P_t) had been recorded as the average Venturi pressure drop. Tests have shown that the value of (P_s-P_t) is typically 1 inch of water for the probe configuration used.

Table 5.31: Comparison Between Theoretical and Experimental Dilution Ratios

Probe Configuration	Average Gas Velocity (ft/sec)	Average Venturi Pressure (in H_2O)	Measured Dilution Ratio	Calculated Dilution Ratio
1/4 A	70	20	12.3	30.8
1/8 A	70	21	21.6	123.2
1/16 A	70	21	39.9	489.8

It is evident that Equation 8 predicts an increase in dilution ratio with a decrease in orifice size. However, the magnitude of the change in dilution ratio predicted by the equation is much larger than was actually measured. In addition, the equation does not predict the correct magnitudes of the dilution ratios. Consequently, it can be concluded that this simplistic model does not explain the actual operation of the Venturi probe.

2. Positional Differences

According to the discussion in Appendix III, the relative random error involved in the evaluation of each dilution ratio is 1.4 %.

In order to examine the flow effects more extensively and to provide a more realistic dilution value for each probe configuration, the experimental data were averaged with respect to gas velocity and dilution ratio. On this basis each velocity classification and Venturi pressure drop classification could be represented in terms of one average dilution ratio.

A review of the data presented in Tables 5.16 to 5.30 demonstrates that most of the data can be grouped within a 10 % range of the average dilution ratio. This spread in the data would imply that there are factors affecting the results that cannot be attributed solely to the random instrumental error value of 1.4 %. However, a total random error of 10 % was assumed for the assessment of the dilution ratios, to allow a more realistic evaluation of the data.

Some of the experimental values, that were used to calculate each average were not included in the final average that is presented. Any measured dilution ratio that caused the standard deviation of the averaged dilution ratios to exceed this error value were excluded. It was concluded that such determinations resulted from operational errors.

The dilution ratios that were determined for any single 1/4 inch sampling port agreed within the limits of this experimental error. The dilution ratios that were obtained by opening all four 1/4 inch sampling ports are lower than those achieved with a single 1/4 inch sampling port, as expected. These data show a high degree of agreement for all velocity classes and Venturi pressure drops. Such agreement was not evident when the smaller (1/8 inch, 1/16 inch) sampling ports were used.

For the 1/8 inch sampling ports, the use of a single orifice in any of the four positions provided a dilution ratio that depended on the position of the port through which the sample was collected. The highest dilution ratios were achieved with the A sampling position. The use of ports B or D produced dilution ratios that were higher than those achieved with port C. however, the dilution ratios that were obtained using port B were higher than those related to port D. Under some conditions a change in the average Venturi pressure drop caused a change in the achieved dilution ratio, when a single sampling port was used. This variation did not occur when all four sampling ports were used.

Sampling with the 1/16 inch ports also demonstrated positional differences among dilution ratios. For the smallest orifices, port C provided higher dilution ratios than those obtained when ports B or D were used. As in the case of the 1/8 inch orifices, the dilution ratios achieved using the B position were higher than those obtained by sample acquisition at D. Differences in measured dilution ratios resulted when the probe operated at the minimum and maximum Venturi pressure drops for all single orifices at lower air stream velocities. This variation also occured when all four sampling ports were used.

The positional factor is related to the gas flow around the sampling probe in the wind tunnel. There are differences among dilutions obtained using different single ports and there are also differences among the dilutions derived using the same probe configuration at different wind tunnel gas velocities and Venturi pressure drops. Differences in probe performance due to external gas velocity and Venturi pressure drop variations were not evident when all four sampling ports were used simultaneously, except for the 1/16 inch orifice combination.

While quantitative studies of the flow characteristics were considered beyond the scope of this investigation, a qualitative interpretation indicates that fluid motion around the probe body causes the positional differences in the measured dilution ratios. It may also account for the differences illustrated in Table 5.31.

One explanation for the positional differences may be provided in terms of the pressure distributions around a cylinder. Typical pressure distributions around a cylinder are illustrated in Figure 5.32 [1].

Recalling that position A is on the leading surface of the probe body, with respect to the gas flow, and position C is on the trailing surface, and that positions B and D are oriented at 90 degrees to the flow, it is reasonable to expect that dilution ratios derived from the use of different sampling ports will have different values for any specific wind tunnel velocities and Venturi pressure drops.

Figure 5.32 illustrates that gas flow around a cylinder produces a positive pressure in front of position A, which is at the 0 degree location.

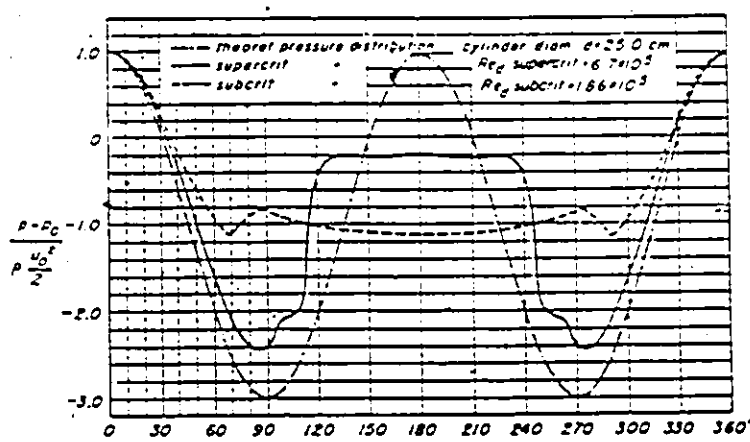

Figure 5.32: Pressure Distribution Around a Cylinder due to External Gas Flow [1]

The pressures in the vicinities of ports B and D are equal, and slightly negative. The pressure behind position C is more negative than at any other sampling point.

Since the driving force for the sampling process is the magnitude of the negative pressure in the throat of the Venturi, it may be expected that in all cases, more sample would be drawn in at position A than at any other port location. It could also be expected that the amount of sample drawn into ports B and D would be greater than at port C, and that the dilution ratios measured at B and D would be equal. According to this argument, the measured dilution ratios would be lowest at position A, and highest at position C. However, this trend was not evident.

When sampling port B was used the dilution ratio obtained with the 1/8 inch insert was higher than the value obtained using port D. This variation was also evident when the 1/16 inch insert was installed. These variations may be due to flow disturbances created by the S-type pitot tube mounted between port positions A and B. Even minor irregularities created on the probe surface could disrupt the flow near port B, enough to effect the dilution ratio achieved when using this port.

Deviations from the results expected on the basis of the simplistic modelling may result from the changes in the characteristics of the sampling port when the 1/8 inch and 1/16 inch inserts are installed.

The use of a 1/4 inch sampling port requires that all inserts be removed from the openings. As a result there is a 1/2 inch entrance to the sampling port, with a 1/4 inch orifice at the bottom of the port. Utilization of either of the smaller two sizes requires that the appropriate insert be installed into the port. Each insert is secured in place by a threaded plug that has a 1/4 inch hole drilled through it. These modifications generate more complex flow conditions than exist when the 1/4 inch size is used. Consequently, it can be expected that the flow of sample through the smaller size sampling ports is more complicated than originally anticipated.

To demonstrate the capabilities of the Venturi sampling probe in more detail, the data have been reorganized to illustrate conditions under which dilution ratios of 6, 7.5, 10, 12.5, 15, 17.5, 20, 25, 30, 35 and 40 can be achieved. These ratios are considered to be the most useful for field purposes [2]. This information is presented in Tables 5.32 to 5.42.

3. Sampling Considerations

Since this device was being evaluated to assess its applicability to the sampling of odourous stack emissions, it is important to define difficulties that might be experienced under field conditions.

Of primary concern is the deposition of particulate matter around and inside the orifice openings and throat of the Venturi. This contamination could have two effects.

The first problem deals with the blocking of the

Table 5.32: Probe Configurations Which Provide Approximately 6 Dilutions

Average Gas Velocity (ft/sec)	Venturi Probe Configuration	Average Venturi Pressure (in H_2O)	Dilution Ratio
35.54	1/4 ABCD	3.7	6.1
35.54	1/4 ABCD	18.9	5.8
70.67	1/4 ABCD	19.8	6.0
70.67	1/4 ABCD	11.0	6.3
88.39	1/4 ABCD	19.2	6.4

Table 5.33: Probe Configurations Which Provide Approximately 7.5 Dilutions

Average Gas Velocity (ft/sec)	Venturi Probe Configuration	Average Venturi Pressure (in H_2O)	Dilution Ratio
33.26	1/8 ABCD	19.2	7.1
33.26	1/8 ABCD	4.9	8.1
70.93	1/8 ABCD	20.2	7.4
70.93	1/8 ABCD	12.0	7.4
88.08	1/8 ABCD	19.3	7.4

Table 5.34: Probe Configurations Which Provide Approximately 10 Dilutions

Average Gas Velocity (ft/sec)	Venturi Probe Configuration	Average Venturi Pressure (in. H_2O)	Dilution Ratio
35.02	1/4 C	20.3	10.9
35.46	1/4 C	8.8	10.9
68.03	1/16 ABCD	13.4	10.9
83.98	1/4 C	18.0	9.4
86.42	1/4 A	19.7	10.9

Table 5.35: Probe Configurations Which Provide Approximately 12.5 Dilutions

Average Gas Velocity (ft/sec)	Venturi Probe Configuration	Average Venturi Pressure (in H_2O)	Dilution Ratio
34.46	1/4 D	10.5	11.8
34.57	1/4 B	7.8	12.2
35.65	1/4 A	19.6	11.5
35.96	1/4 A	5.8	12.1
69.21	1/4 B	21.2	13.6
70.40	1/4 A	20.8	12.3
70.51	1/4 D	20.6	12.3
70.51	1/4 D	15.5	12.0
81.51	1/8 C	18.8	12.0
86.71	1/4 B	22.3	12.3
88.23	1/4 D	18.7	12.3

Table 5.36: Probe Configurations Which Provide Approximately 15 Dilutions

Average Gas Velocity (ft/sec)	Venturi Probe Configuration	Average Venturi Pressure (in H_2O)	Dilution Ratio
34.04	1/16 ABCD	20.1	16.1
34.04	1/8 C	20.3	14.1
35.37	1/8 B	20.6	16.4
35.48	1/8 A	7.6	15.8
69.21	1/4 B	13.7	15.2
70.43	1/8 C	15.7	15.3
70.65	1/8 C	21.7	14.3

Table 5.37: Probe Configurations Which Provide Approximately 17.5 Dilutions

Average Gas Velocity (ft/sec)	Venturi Probe Configuration	Average Venturi Pressure (in H_2O)	Dilution Ratio
34.18	1/8 D	20.5	18:5
34.18	1/8 D	8.1	17.1
34.75	1/8 C	5.9	16.5
35.27	1/8 B	8.7	17.2
35.48	1/8 A	7.6	17.8
87.57	1/8 D	18.7	16.6

Table 5.38: Probe Configurations Which Provide Approximately 20 Dilutions

Average Gas Velocity (ft/sec)	Venturi Probe Configuration	Average Venturi Pressure (in H_2O)	Dilution Ratio
69.81	1/8 A	15.4	19.9
70.18	1/8 A	20.9	21.6
88.22	1/8 B	19.6	21.9

Table 5.39: Probe Configurations Which Provide Approximately 25 Dilutions

Average Gas Velocity (ft/sec)	Venturi Probe Configuration	Average Venturi Pressure (in H_2O)	Dilution Ratio
34.50	1/16 ABCD	5.3	22.9

Table 5.40: Probe Configurations Which Provide Approximately 30 Dilutions

Average Gas Velocity (ft/sec)	Venturi Probe Configuration	Average Venturi Pressure (in H_2O)	Dilution Ratio
34.36	1/16 D	20.4	31.1
86.06	1/16 D	22.1	27.7

Table 5.41: Probe Configurations Which Provide Approximately 35 Dilutions

Average Gas Velocity (ft/sec)	Venturi Probe Configuration	Average Venturi Pressure (in H_2O)	Dilution Ratio
33.90	1/16 A	20.3	34.7
34.50	1/16 C	20.7	33.4
70.38	1/16 D	14.8	34.9
70.68	1/16 D	20.5	35.3
71.02	1/16 B	21.6	33.0
71.68	1/16 B	13.9	36.5

Table 5.42: Probe Configurations Which Provide Approximately 40 Dilutions

Average Gas Velocity (ft/sec)	Venturi Probe Configuration	Average Venturi Pressure (in H_2O)	Dilution Ratio
34.36	1/16 D	10.7	38.6
69.69	1/16 A	17.1	40.5
70.15	1/16 A	21.0	39.9
86.32	1/16 C	21.3	38.8
87.21	1/16 B	21.4	39.2

orifice openings by deposited particulate matter. This deposition is likely to be of greatest concern when the stack has a high moisture content. The decrease of flow through an orifice, due to increased pressure drop, would alter the dilution ratio in an unpredictable manner. Resolution of this problem is of primary importance to the sampling of humid stack gases containing relatively high concentrations of particulate matter.

The second problem is related to the transport of particulate matter into the sample bag. Since undesirable particles are conducted through the sampling tube they can be controlled by locating a glass wool plug at the exit of the tube. Tests show that this method of particle control will not alter the dilution ratios, but will increase the sampling time.

All experiments were conducted at temperatures and pressures that were in the range of normal ambient conditions. To examine the effect on the dilution ratios when sampling sources that do not operate within this range of conditions, it is suggested that the ideal gas law can be used to adjust the volume of the odourous stack sample to the sample bag conditions. This correction is demonstrated in the following example:

Given a dilution ratio of 20, obtained for a wind tunnel temperature of 70 degrees Fahrenheit and one atmosphere pressure, with similar ambient conditions, determine the effect of sampling a stack at a temperature of 700 degrees Fahrenheit and a stack pressure of one atmosphere.

The laboratory sampling and diluting conditions are illustrated in Figure 5.33.

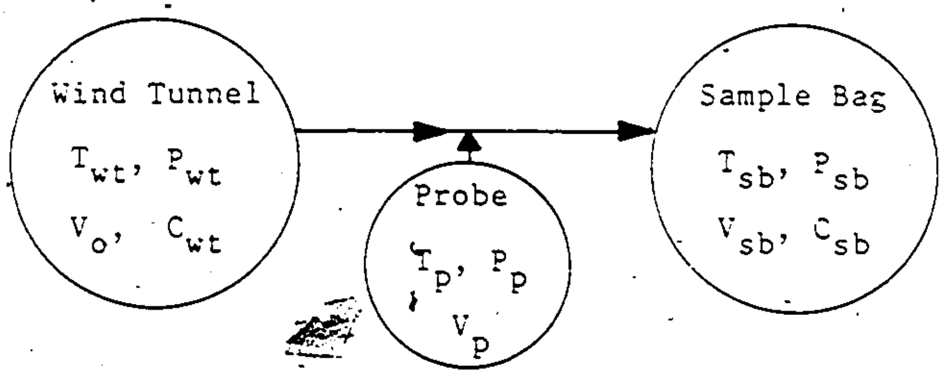

Figure 5.33: Laboratory Conditions

The dilution ratio is determined by the following expression:

$$DR = \frac{C_{wt}}{C_{sb}} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots (9)$$

where: DR = dilution ratio

C_{wt} = concentration of SF_6 in wind tunnel (ppm)

C_{sb} = concentration of SF_6 in sample bag (ppm)

$$= \frac{(C_{wt})(V_o)}{V_{sb}}$$

$V_{sb} = V_p + V_o$

V_o = volume of sample from wind tunnel (litres)

V_p = volume of diluting air from probe (litres)

V_{sb} = volume of sample bag (litres)

Substituting the expression for C_{sb} into Equation 9 yields:

$$DR = \frac{(C_{wt})(V_p + V_o)}{(C_{wt})(V_o)}$$

$$= \frac{(V_p + V_o)}{V_o} \quad \ldots\ldots\ldots\ldots\ldots\ldots (10)$$

The ideal gas law can be used to relate the temperature and pressure of the stack sample to the conditions of the probe diluting gas and the sample bag.

Applying the ideal gas law yields:

$$(P_s)(V_s) = (n_s)(R)(T_s) \ldots\ldots\ldots\ldots\ldots\ldots (11)$$

where: P_s = stack pressure

V_s = volume of sample at stack conditions

n_s = number of moles of gas collected from the stack

R = universal gas constant

T_s = stack temperature

$$(P_{sb})(V_o') = (n_{sb})(\underline{R})(T_{sb}) \ldots\ldots\ldots\ldots\ldots (12)$$

where: P_{sb} = sample bag pressure.

V_o' = volume of stack sample at sample bag conditions

n_{sb} = number of moles of gas collected from the stack

T_{sb} = sample bag temperature

The number of moles of gas collected from the stack, n_s, and transferred to the sample bag, n_{sb}, will be identical. Therefore rearranging Equations 11 and 12 to solve for the corrected sample volume yields:

$$\frac{(P_s)(V_s)}{T_s} = \frac{(P_{sb})(V_o')}{T_{sb}} \ldots\ldots\ldots\ldots\ldots (13)$$

It can be assumed that the pressures in the stack and in the sample bag are essentially the same, and therefore:

$$\frac{V_s}{T_s} = \frac{V_o'}{T_{sb}} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (14)$$

$$V_o' = \frac{(T_{sb})(V_s)}{T_s} \ldots\ldots\ldots\ldots\ldots\ldots (15)$$

Substituting Equation (15) into Equation (10) yields:

$$DR = \frac{(V_p + V_o')}{V_o'} \ldots\ldots\ldots\ldots\ldots (16)$$

and

$$DR = \frac{V_D + [(T_{sb})(V_s)]/T_s)}{[(T_{sb})(V_s)]/T_s)} \quad ......(17)$$

Recalling that a dilution ratio of 20 is based on 19 parts of diluting air and 1 part sample gas, and that the given stack temperature is 700 °F, and the sample bag temperature is 70 °F, the corrected dilution ratio becomes:

$$DR = \frac{19 + (((70 + 460)(1))/(700 + 460))}{(((70 + 460)(1))/(700 + 460))}$$

$$= (19 + (530/1160))/(530/1160)$$

$$= 42.6$$

if the sampling probe extracts 1 volume of odourous gas at stack conditions for every 19 volumes of clean air.

Considering that the uncorrected dilution ratio is 20, while the corrected value is 42.6, it is obvious that it is necessary to apply this correction to any measurement where the stack conditions differ from the ambient values.

It is now necessary to evaluate the effect that laboratory conditions had on the reported results. The highest temperature recorded in the wind tunnel was 96 °F. The room temperature at this time was 69 °F. The measured dilution ratio for a typical experiment was approximately 34. Using these values in the developed Equation yields:

$$DR = \frac{V_D + [(T_{sb})(V_s)]/T_s}{[(T_{sb})(V_s)]/T_s} \quad \ldots\ldots(17)$$

$$= \frac{33 + ((69+460)(1)/(96+460))}{((69+460)(1)/(96+460))}$$

$$= \frac{33 + 0.95}{0.95}$$

$$= 35.7$$

This magnitude is well within the 10 per cent operational error value that was assigned to the dilution ratio calculations. Consequently, the minor temperature differences that existed during the laboratory investigations created insignificant variations in reported dilution factors.

REFERENCES

1. Eckert, E.R.G., Heat and Mass Transfer, McGraw-Hill Publishing Company, New York, USA., p. 160. (1959)

2. Gnyp, A.W., Professor, Department of Chemical Engineering, University of Windsor, Windsor, Ontario, personal communications.

VI. Conclusions and Recommendations

A. Conclusions

The data collected during this investigation indicate that the Venturi, dynamic dilution, sampling probe operates well in clean air streams. The wide range of dilution ratios achieved in the laboratory provides adequate capabilities for practical field studies.

Operation of the probe is simple. It eliminates the need for constant monitoring of pressure measuring devices that determine flow rates.

It has also been demonstrated that the probe can be operated over a wide range of stack velocities, provided that the particulate matter loading is not excessive.

Under field conditions it is important to monitor the stack temperature in order to establish the temperature difference between the stack and the sample bag. As demonstrated earlier, this temperature difference can have a significant effect on the value of the measured dilution ratio.

B. Recommendations

The first priority is to construct a probe from inert materials in order to establish the practicality of the device under actual field sampling situations. The material of construction should be a high chrome stainless steel to provide thermal and mechanical strength as well as freedom from odour contamination.

In addition to testing the probe under actual sampling conditions, it is important to define the problems associated with the sampling of gas streams with high particulate matter loadings. This investigation would establish the importance of contamination of the sampling ports by particulate matter.

Further theoretical studies should be undertaken to resolve the nature of the gas flow around the probe body. They would be complementary to computer modelling of the dilution process. These investigations would help to optimize the design of future modifications through computer simulation. The efforts and expense of building and testing different versions of the basic device would be reduced considerably.

Although it has been shown that, in principle, differences between stack and ambient temperatures can be accounted for by applying ideal gas law corrections, it is important to validate the predicted dilution ratios by conducting laboratory investigations with the wind tunnel operating at relatively high temperatures. It is recommended that the heat exchanger in the wind tunnel be connected to a steam line to provide circulating gas temperatures of at least 300 °F.

Appendix I: Velocity Distribution Determination

This appendix outlines the process whereby the velocity distribution in the wind tunnel was determined. Included in this study was an observation of the stability of the gas velocity in the wind tunnel.

A. Equipment

The following is the list of equipment used in this determination:

1) Wind Tunnel
2) Precision Manometer
3) Standard Pitot Tube supplied with Precision Manometer, 1/4 inch O.D. (Calibrating)
4) Standard Pitot Tube mounted permanently in Wind Tunnel, 1/8 inch O.D. (Reference)
5) Psychrometer
6) Mercury Barometer

B. Experimental

The experimental procedure for this determination followed the Ontario Ministry of the Environment Source Testing Code [1].

1) The standard pitot tube that was supplied with the precision manometer, (hereafter referred to as the calibrating pitot tube), was installed with its nose positioned on the intersection points of an equilateral three by three grid, perpendicular to the air flow. The position of the pitot tube and the various sampling points are illustrated in Figure AI.1.

2) The wind tunnel was set to a predetermined velocity and allowed to stabilize for 5 minutes. During this time, room atmospheric pressure and temperature readings were

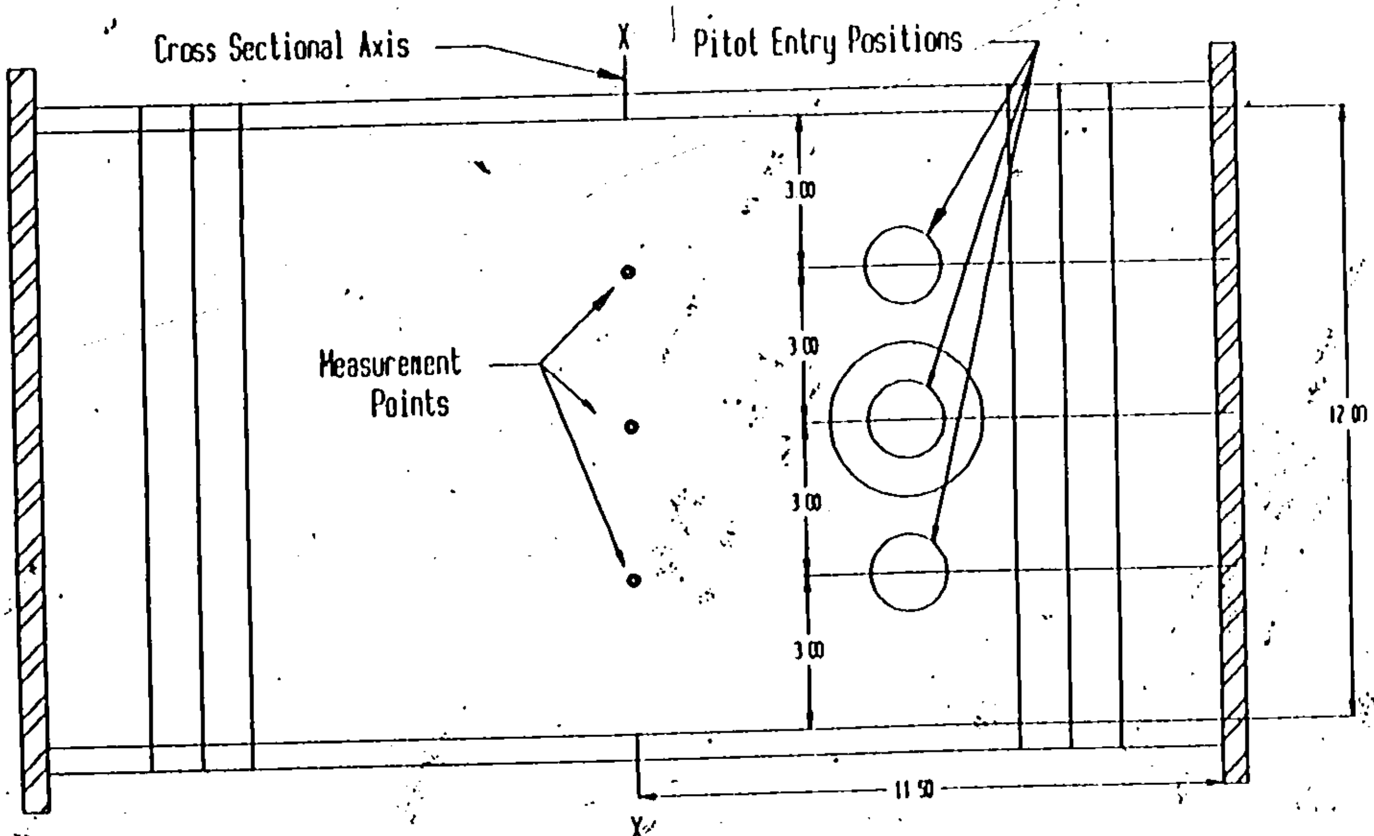

Figure AI.1: Calibrating Standard Pitot Tube Measurement
Points, Longitudinal View
All Dimensions are in Inches

taken.

3) After the wind tunnel gas velocity had achieved a steady reading on the manometer that was attached to the installed reference pitot tube, a static pressure reading was taken.

4) ~~Finally~~, readings were taken with the calibrating pitot tube at the nine positions across the throat of the Venturi which are depicted in Figure AI.2. These readings were taken over approximately one minute, and were repeated three times for each position.

Velocity pressure readings were also taken with the reference pitot tube at the beginning and completion of each set of nine pressure readings, as well as once during each set of nine, after the fourth velocity pressure reading was recorded.

5) The described procedure was performed initially for a velocity of approximately 90 feet per second. Determinations were repeated for velocities of 80, 70, 50, and 20 feet per second. These values include the operating velocities that would be used to evaluate the Venturi ~~probe~~.

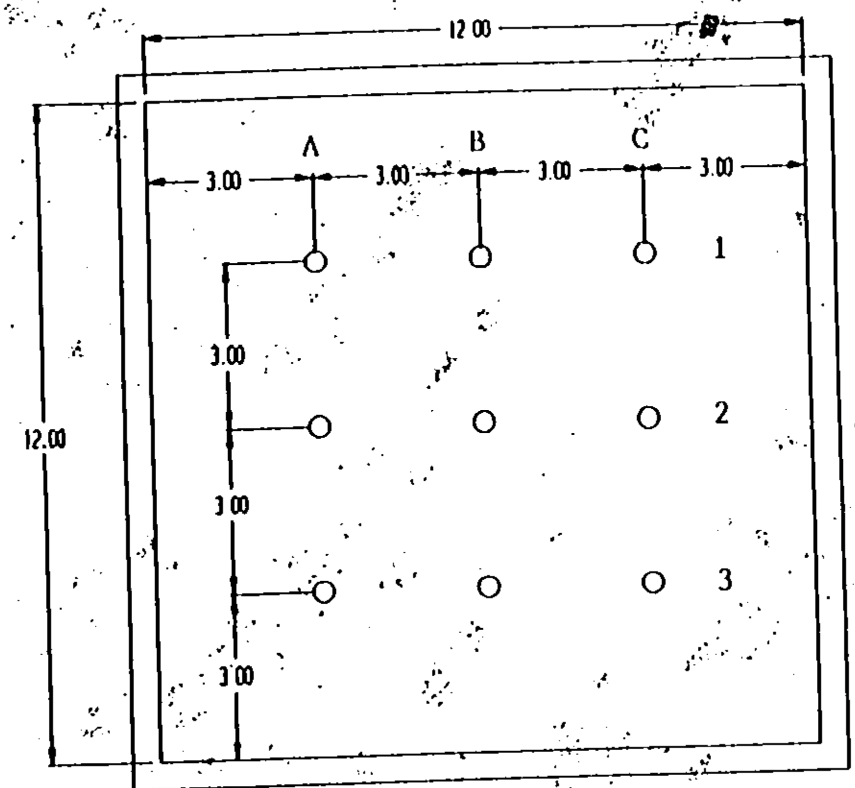

Figure AI.2: Calibrating Standard Pitot Tube Measurement Points, Cross Sectional View
All Dimensions are in Inches

C. Calculations

To convert the velocity pressure readings into velocities, the following formula [2] was used:

$$Us = (85.33)(Cp)\left[\frac{(\Delta P)(Ts)}{(Ms)(Ps)}\right]^{1/2}$$

where
- Us = Point Velocity (ft/sec)
- Ts = Absolute Stack Temperature (°R)
- Ps = Absolute Stack Pressure (in Hg)
- Ms = Stack gas molecular weight, wet basis (lbm/lb mol)
- Cp = Pitot tube coefficient.
- ΔP = Stack gas velocity pressure (in H_2O)

In this study, the standard pitot tubes were of ellipsoidal design. This configuration allows determination of the pitot tube coefficient from measured dimensions. Following the procedures outlined in the Windsor Stack Sampling Notes [3], the dimensions of the pitot tubes were evaluated. These values were used to determine the pitot tube coefficients using the calibration curve illustrated in Figure AI.3. The pitot tube coefficients were found to be 0.9975.

The stack gas velocity pressure, ΔP, is determined by multiplying the scale reading obtained from the inclined manometer by the appropriate scale factor.

The volume fraction of water vapour in the stack gas, Bwo, was calculated from psychrometric data involving wet and dry bulb temperatures. The calculation of relative humidity, absolute humidity, and Bwo are described in Appendix II.

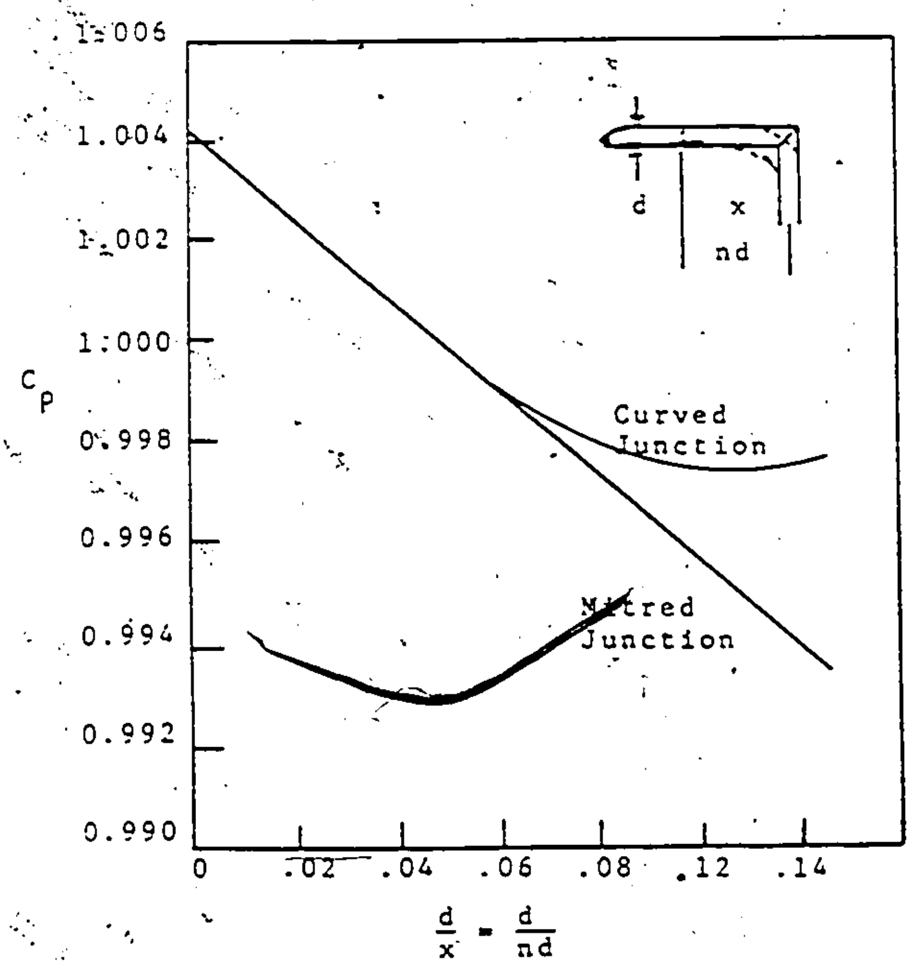

Figure AI.3: Measurement Calibration for Standard Pitot Tubes [2]

The molecular weight of the stack gas (Ms) was calculated using the formula [2]:

$$Ms = Md(1-Bwo) + 18(Bwo)$$

The dry molecular weight of the air, Md, was determined by multiplying the traditional mole fractions of nitrogen and oxygen by the appropriate molecular weights. It was assumed that this would be ~~an~~ adequate approximation.

The actual volumetric flow rate, Q, is given by [2]:

$$Q = (Us)(A)(60)\ [ft^3/min]$$

where A = cross sectional area of stack at the point of velocity measurement

To convert the actual volumetric flow rate to a volumetric flow rate ~~on a~~ dry basis at standard conditions, the following formula was used [2]:

$$Q_{dry,ref} = Q(1-Bwo)\ \frac{(Tref)(Pstack)}{(Tstack)(Pref)}$$

where Tref = 537 °R
Tstack = stack temperature, °R
Pref = 760 mmHg
Pstack = (Pbarometric - Pstatic), mmHg

The Reynolds Number, N_{Re}, for the flow was determined from the standard expression:

$$N_{Re} = \frac{(\rho)(V)(Deq)}{\mu}$$

where Deq = equivalent diameter, ft
V = average velocity, ft/sec
ρ = density of air, lbm/ft³
μ = viscosity of air, lbm/ftXsec

The equivalent diameter of the square cross section where the velocities were measured was determined by dividing the cross sectional area by the wetted perimeter [2]. In this case the equivalent diameter was one foot.

Since the value of the Reynolds Number was used only to determine whether the flow was turbulent or laminar, standard values of density and viscosity were used to simplify calculations. The values used were [3]:

ρ = 0.07528 lbm/ft^3, @ 68°F, 1 atmosphere
μ = 1.21 E-5 lbm/ftXsec, @ 60°F, 1 atmosphere

The velocity used for these calculations was derived from the dry volumetric flow rate at standard conditions.

D. Discussion

The results of the velocity distribution determination are presented in Tables AI.5-1a to AI.5-5d. The results are summarized in Figures AI.4 to AI.8. There are three major conclusions that can be reached after reviewing the data.

On the basis of the Reynolds Number values (NRe > 2200) the flow of gas in the wind tunnel was turbulent throughout the range of velocities that were used to evaluate the probe. Turbulence is important since it ensures that the tracer gas will be fully mixed with the stack air prior to sampling.

The second conclusion is that the reference pitot tube readings agreed sufficiently with the calibrating pitot tube data to be considered accurate and precise throughout the velocity ranges used.

Table AI.5-1a: Velocity Traverse Results (90 ft/sec)

DATA SHEET #1, DECEMBER 2, 1985
VELOCITY TRAVERSE FOR WIND TUNNEL

DATE: DECEMBER 2, 1985

Static pressure from reference pitot tube

	Measured	Actual (IN H2O)
Initial	7.80	-1.56
Final	6.85	-1.37

Average Static Pressure -1.47

****

Humidity Calculation

	Tdry °F	Twet °F	Tdry °R	Twet °R	TIME (MIN)
INITIAL	75.00	57.00	534.70	516.70	2.30
FINAL	82.00	61.00	541.70	520.70	63:00
CHANGE	7.00	4.00			60.70
AVERAGE	78.50	59.00	538.20	518.70	

	Kdry	Kwet
INITIAL	3.28	3.30
FINAL	3.28	3.30

	Pdry	Pwet
INITIAL	22.28	11.93
FINAL	28:05	13.76

			Pmi	Pmf
BAROMETRIC PRESSURE	740.90	742.80	4.97	5.83
(mm Hg)	Average	741.85		

RHi	RHf
31.22	28.28
DELTA RH	2.94

	INITIAL	FINAL
	.0091525316	.0104381978
	.1648859133	.1880476204
Absolute Humidity	.0059181149	.0067409627
Bwo	.0093884758	.0106798973
Average Bwo	.0100341866	

Table AI.5-1b: Velocity Traverse Results (90 ft/sec)

PROBE POSITION	TIME START	STOP	ELAPSED TIME	MANOMETER READING	ACTUAL DELTA P	VELOCITY (ft/sec)
1a	3.00	4.00	1.00	9.34	1.87	91.07
3a	5.00	5.80	.80	9.20	1.84	90.39
3b	6.30	7.00	.70	9.05	1.81	89.65
1b	7.70	8.50	.80	9.10	1.82	89.90
1c	11.00	12.00	1.00	9.00	1.80	89.40
3c	12.40	13.50	1.10	8.90	1.78	88.90
2c	14.00	15.50	1.50	8.85	1.77	88.65
2b	16.10	17.00	.90	8.81	1.76	88.45
2a	17.50	18.70	1.20	8.90	1.78	88.90
1a	22.40	23.80	1.40	8.91	1.78	88.95
3a	24.30	25.30	1.00	8.79	1.76	88.35
3b	25.90	27.00	1.10	8.73	1.75	88.05
1b	27.70	28.70	1.00	8.70	1.74	87.90
1c	31.30	32.60	1.30	8.62	1.72	87.49
3c	33.30	34.30	1.00	8.55	1.71	87.14
2c	35.00	36.00	1.00	8.50	1.70	86.88
2b	36.50	37.50	1.00	7.91	1.58	83.81
2a	38.00	39.00	1.00	8.56	1.71	87.19
1a	42.40	43.40	1.00	8.55	1.71	87.14
3a	43.90	45.00	1.10	8.55	1.71	87.14
3b	45.50	46.50	1.00	8.41	1.68	86.42
1b	47.10	48.10	1.00	8.40	1.68	86.37
1c	50.50	51.50	1.00	8.31	1.66	85.91
3c	52.00	53.00	1.00	8.30	1.66	85.85
2c	53.70	54.90	1.20	8.20	1.64	85.34
2b	55.60	56.60	1.00	8.05	1.61	84.55
2a	57.10	58.10	1.00	8.25	1.65	85.60

ELAPSED TIME (MINUTES) 55.10

AVERAGE SAMPLE TIME 1.04

AVERAGE VELOCITY (ft/sec) 87.81

RANGE 7.26

****

PROBE POSITION	TIME START	STOP	ELAPSED TIME	MANOMETER READING	ACTUAL DELTA P	VELOCITY (FT/SEC)
Pref	1.00	2.50	1.50	9.00	1.80	89.40
Pref	9.00	10.00	1.00	8.83	1.77	88.55
Pref	19.10	20.10	1.00	8.60	1.72	87.39
Pref	20.30	21.30	1.00	8.58	1.72	87.29
Pref	29.30	30.40	1.10	8.34	1.67	86.06
Pref	39.30	40.30	1.00	8.19	1.64	85.28
Pref	40.50	41.50	1.00	8.15	1.63	85.08
Pref	48.40	49.50	1.10	8.11	1.62	84.87
Pref	58.30	59.30	1.00	7.91	1.58	83.81

ELAPSED TIME 58.30

AVERAGE SAMPLE TIME 1.08

AVERAGE VELOCITY (FT/SEC) 86.42

RANGE 5.59

Table AI.5-Ic: Velocity Traverse Results (90 ft/sec)

PROBE POSITION	ELAPSED TIME	DELTA P READING	DELTA P READINGS	AVERAGE VELOCITY	VELOCITY RANGE
1A	40.40	1.79	.16	89.07	3.94
1B	43.80	1.75	.14	88.07	3.53
1C	40.50	1.73	.14	87.61	3.50
2A	40.60	1.71	.13	87.24	3.31
2B	40.50	1.65	.15	85.63	3.90
2C	40.90	1.70	.13	86.97	3.32
3A	40.00	1.77	.13	88.64	3.25
3B	40.20	1.75	.13	88.05	3.23
3C	40.60	1.72	.12	87.31	3.05

Average Stack Temperature (°R) 538.20
Average Stack Pressure (inHg) 28.42
Average Molar Water Content (Bwo) .0100341866

PROBE POSITION	ACTUAL DELTA P	Q (cfm)	Q (dscfm)	Reynolds Number
1a	1.87	5464	5032	521935
3a	1.84	5423	4994	518009
3b	1.81	5379	4953	513768
1b	1.82	5394	4967	515186
1c	1.80	5364	4939	512347
3c	1.78	5334	4912	509493
2b	1.77	5319	4898	508060
2b	1.76	5307	4887	506910
2a	1.78	5334	4912	509493
1a	1.78	5337	4915	509779
3a	1.76	5301	4881	506334
3b	1.75	5283	4865	504603
1b	1.74	5274	4856	503736
1c	1.72	5250	4834	501414
3c	1.71	5228	4814	499374
2c	1.70	5213	4800	497912
2b	1.58	5029	4631	480321
2a	1.71	5231	4817	499666
1a	1.71	5228	4814	499374
3a	1.71	5228	4814	499374
3b	1.68	5185	4775	495269
1b	1.68	5182	4772	494974
1c	1.66	5154	4746	492316
3c	1.66	5151	4743	492019
2c	1.64	5120	4715	489046
2b	1.61	5073	4671	484553
2a	1.65	5136	4729	490535

Table AI.5-1d: Velocity Traverse Results (90-ft/sec)

PROBE POSITION	ACTUAL DELTA P	Q (cfm)	Q (dscfm)	Reynolds Number
Pref	1.80	5364	4939	512347
Pref	1.77	5313	4893	507485
Pref	1.72	5244	4828	500832
Pref	1.72	5237	4823	500250
Pref	1.67	5164	4755	493203
Pref	1.64	5117	4712	488748
Pref	1.63	5105	4700	487553
Pref	1.62	5092	4689	486355
Pref	1.58	5029	4631	480321

Table AI.5-2a: Velocity Traverse Results (80 ft/sec)

DATA SHEET #2, DECEMBER 3, 1985
VELOCITY TRAVERSE FOR WIND TUNNEL

DATE: DECEMBER 3, 1985

Static pressure from reference pitot tube

	Measured	Actual (IN H2O)
Initial	6.10	-1.22
Final	5.65	-1.13
Average Static Pressure		-1.18

****

Humidity Calculation

	Tdry °F	Twet °F	Tdry °R	Twet °R	TIME (MIN)
INITIAL	72.00	49.00	531.70	508.70	2.00
FINAL	81.00	54.00	540.70	513.70	64.80
CHANGE	9.00	5.00			62.80
AVERAGE	76.50	51.50	536.20	511.20	

	Kdry	Kwet
INITIAL	3.29	3.31
FINAL	3.28	3.30

	Pdry	Pwet
INITIAL	20.15	8.89
FINAL	27.16	10.70

BAROMETRIC			Pmi	Pmf
PRESSURE	755.72	756.17	6.45	7.60
(mm Hg)	Average	755.95		

RHi	RHf
12.12	11.41
DELTA RH	.71

	INITIAL	FINAL
	.0032140311	.0040771185
	.0579018430	.0734506519
Absolute Humidity	.0020248847	.0025693443
Bwo	.0032322326	.0040977678
Average Bwo	.0036650002	

Table AI.5-2b: Velocity Traverse Results (80 ft/sec)

PROBE POSITION	TIME START	STOP	ELAPSED TIME	MANOMETER READING	ACTUAL DELTA P	VELOCITY (ft/sec)
1a	3.10	4.60	1.50	7.41	1.48	81.12
3a	5.00	6.00	1.00	7.35	1.47	80.79
3b	6.60	7.60	1.00	7.13	1.43	79.57
1b	8.00	9.00	1.00	7.25	1.45	80.24
1c	11.20	12.20	1.00	7.20	1.44	79.96
3c	12.70	13.70	1.00	7.17	1.43	79.80
2c	14.20	15.20	1.00	7.10	1.42	79.41
2b	15.80	17.50	1.70	7.12	1.42	79.52
2a	18.20	19.20	1.00	7.20	1.44	79.96
1a	25.20	26.20	1.00	7.15	1.43	79.69
3a	26.60	27.80	1.20	7.10	1.42	79.41
3b	28.20	29.20	1.00	7.05	1.41	79.13
1b	29.50	30.50	1.00	7.04	1.41	79.07
1c	32.70	33.70	1.00	7.01	1.40	78.90
3c	34.00	35.00	1.00	6.95	1.39	78.56
2c	35.50	36.50	1.00	6.95	1.39	78.56
2b	37.00	38.00	1.00	6.88	1.38	78.17
2a	38.50	39.50	1.00	6.98	1.40	78.73
1a	43.80	44.90	1.10	6.96	1.39	78.62
3a	45.40	46.40	1.00	6.85	1.37	78.00
3b	47.00	48.00	1.00	6.80	1.36	77.71
1b	48.50	49.50	1.00	6.85	1.37	78.00
1c	51.80	52.80	1.00	6.80	1.36	77.71
3c	53.50	54.50	1.00	6.82	1.36	77.82
2c	55.20	56.20	1.00	6.80	1.36	77.71
2b	56.40	57.40	1.00	6.70	1.34	77.14
2a	58.10	59.10	1.00	6.80	1.36	77.71

ELAPSED TIME (MINUTES) 56.00

AVERAGE SAMPLE TIME 1.06

AVERAGE VELOCITY (ft/sec) 79.05

RANGE 3.98

****

PROBE POSITION	TIME START	STOP	ELAPSED TIME	MANOMETER READING	ACTUAL DELTA P	VELOCITY (FT/SEC)
Pref	.60	2.50	1.90	7.10	1.42	79.41
Pref	9.50	10.50	1.00	7.02	1.40	78.96
Pref	19.50	21.00	1.50	6.88	1.38	78.17
Pref	22.00	23.50	1.50	6.83	1.37	77.88
Pref	31.00	32.00	1.00	6.79	1.36	77.65
Pref	40.00	41.00	1.00	6.66	1.33	76.91
Pref	41.90	42.90	1.00	6.65	1.33	76.85
Pref	49.90	50.90	1.00	6.85	1.37	78.00
Pref	59.50	60.50	1.00	6.50	1.30	75.98

ELAPSED TIME 59.90

AVERAGE SAMPLE TIME 1.21

AVERAGE VELOCITY (FT/SEC) 77.75

RANGE 3.43

Table AI.5-2c: Velocity Traverse Results (80 ft/sec)

PROBE POSITION	ELAPSED TIME	DELTA P READING	DELTA P READINGS	AVERAGE VELOCITY	VELOCITY RANGE
1A	41.80	1.43	.09	79.82	2.50
1B	44.80	1.41	.08	79.11	2.24
1C	41.60	1.40	.08	78.86	2.25
2A	40.90	1.40	.08	78.81	2.25
2B	41.60	1.38	.08	78.28	2.38
2C	42.00	1.39	.06	78.56	1.70
3A	41.40	1.42	.10	79.41	2.80
3B	41.40	1.40	.07	78.81	1.86
3C	41.80	1.40	.07	78.73	1.97

Average Stack Temperature (°R)	536.20
Average Stack Pressure (inHg)	29.13
Average Molar Water Content (Bwo)	.0036650002

PROBE POSITION	ACTUAL DELTA P	Q (cfm)	Q (dscfm)	Reynolds Number.
1a	1.48	4867	4641	481363
3a	1.47	4848	4622	479410
3b	1.43	4774	4552	472181
1b	1.45	4814	4590	476138
1c	1.44	4798	4574	474493
3c	1.43	4788	4565	473503
2c	1.42	4764	4543	471186
2b	1.42	4771	4549	471850
2a	1.44	4798	4574	474493
1a	1.43	4781	4559	472843
3a	1.42	4764	4543	471186
3b	1.41	4748	4527	469524
1b	1.41	4744	4523	469191
1c	1.40	4734	4514	468191
3c	1.39	4714	4494	466183
2c	1.39	4714	4494	466183
2b	1.38	4690	4472	463829
2a	1.40	4724	4504	467188
1a	1.39	4717	4498	466518
3a	1.37	4680	4462	462817
3b	1.36	4663	4446	461124
1b	1.37	4680	4462	462817
1c	1.36	4663	4446	461124
3c	1.36	4669	4452	461802
2c	1.36	4663	4446	461124
2b	1.34	4628	4413	457721
2a	1.36	4663	4446	461124

Table AI.5-2d: Velocity Traverse Results (80 ft/sec)

PROBE POSITION	ACTUAL DELTA P	Q (cfm)	Q (dscfm)	Reynolds Number
Pref	1.42	4764	4543	471186
Pref	1.40	4737	4517	468524
Pref	1.38	4690	4472	463829
Pref	1.37	4673	4455	462140
Pref	1.36	4659	4442	460785
Pref	1.33	4614	4400	456353
Pref	1.33	4611	4396	456010
Pref	1.37	4680	4462	462817
Pref	1.30	4559	4346	450838

Table AI.5-3a: Velocity Traverse Results (70 ft/sec)

DATA SHEET #3, DECEMBER 3, 1985
VELOCITY TRAVERSE FOR WIND TUNNEL

DATE: DECEMBER 3,1985

Static pressure from reference pitot tube

	Measured	Actual (IN H20)
Initial	4.50	-.90
Final	4.43	-.89

Average Static Pressure* -.89

****

Humidity Calculation

	Tdry °F	Twet °F	Tdry °R	Twet °R	TIME (MIN)
INITIAL	83.00	55.00	542.70	514.70	3.50
FINAL	82.00	54.00	541.70	513.70	68.00
CHANGE	1.00	1.00			60.70
AVERAGE	82.50	54.50	542.20	514.20	

	Kdry	Kwet
INITIAL	3.28	3.30
FINAL	3.28	3.30

	Pdry	Pwet
INITIAL	28.98	11.09
FINAL	28.05	10.70

			Pmi	Pmf
BAROMETRIC PRESSURE (mm Hg)	755.72	756.17	7.88	7.88
	Average	755.95		

RHi	RHf
11.09	10.04
DELTA RH	1.05

	INITIAL	FINAL
	.0042296013	.0037068545
	.0761976794	.0667802220
Absolute Humidity	.0026674413	.0023351365
Bwo	.0042535541	.0037256285
Average Bw		.0039895913

Table AI.5-3b: Velocity Traverse Results (70 ft/sec)

PROBE POSITION	TIME START	STOP	ELAPSED TIME	MANOMETER READING	ACTUAL DELTA P	VELOCITY (ft/sec)
1a	4.30	5.30	1.00	5.40	1.08	69.25
3a	5.70	6.70	1.00	5.30	1.06	68.61
3b	7.10	8.10	1.00	5.27	1.05	68.41
1b	8.50	9.50	1.00	5.32	1.06	68.74
1c	11.70	12.70	1.00	5.30	1.06	68.61
3c	13.30	14.30	1.00	5.31	1.06	68.67
2c	14.70	15.70	1.00	5.25	1.05	68.28
2b	16.00	17.00	1.00	5.12	1.02	67.43
2a	17.50	18.50	1.00	5.31	1.06	68.67
1a	24.00	25.00	1.00	5.35	1.07	68.93
3a	25.50	26.50	1.00	5.35	1.07	68.93
3b	26.80	27.80	1.00	5.25	1.05	68.28
1b	28.10	29.10	1.00	5.30	1.06	68.61
1c	31.25	32.30	1.05	5.30	1.06	68.61
3c	32.90	33.90	1.00	5.30	1.06	68.61
2c	34.40	35.40	1.00	5.25	1.05	68.28
2b	35.80	36.80	1.00	5.20	1.04	67.96
2a	37.30	38.30	1.00	5.31	1.06	68.67
1a	46.90	47.90	1.00	5.31	1.06	68.67
3a	49.90	50.90	1.00	5.25	1.05	68.28
3b	51.30	52.80	1.50	5.15	1.03	67.63
1b	53.40	54.40	1.00	5.28	1.06	68.48
1c	56.20	57.20	1.00	5.25	1.05	68.28
3c	57.50	58.50	1.00	5.21	1.04	68.02
2c	58.90	59.90	1.00	5.20	1.04	67.96
2b	60.30	61.30	1.00	4.50	.90	63.22
2a	62.00	63.00	1.00	5.28	1.06	68.48

ELAPSED TIME (MINUTES) 58.70

AVERAGE SAMPLE TIME 1.02

AVERAGE VELOCITY (ft/sec) 68.43

RANGE 6.03

****

PROBE POSITION	TIME START	STOP	ELAPSED TIME	MANOMETER READING	ACTUAL DELTA P	VELOCITY (FT/SEC)
Pref	1.50	3.00	1.50	5.15	1.03	67.63
Pref	9.80	10.80	1.00	5.18	1.04	67.82
Pref	19.00	20.00	1.00	5.15	1.03	67.63
Pref	22.10	23.10	1.00	5.12	1.02	67.43
Pref	29.50	30.50	1.00	5.14	1.03	67.56
Pref	38.50	39.50	1.00	5.10	1.02	67.30
Pref	44.90	45.90	1.00	5.10	1.02	67.30
Pref	54.60	55.60	1.00	5.11	1.02	67.37
Pref	63.30	64.50	1.20	5.09	1.02	67.23

ELAPSED TIME 63.00

AVERAGE SAMPLE TIME 1.08

AVERAGE VELOCITY (FT/SEC) 67.47

RANGE .59

Table AI.5-3c: Velocity Traverse Results (70 ft/sec)

PROBE POSITION	ELAPSED TIME	DELTA P READING	DELTA P READINGS	AVERAGE VELOCITY	VELOCITY RANGE
1A	43.60	1.07	.02	68.95	.58
1B	48.70	1.06	.01	68.61	.26
1C	45.50	1.06	.01	68.50	.32
2A	45.50	1.06	.01	68.61	.19
2B	45.30	.99	.12	66.24	4.21
2C	45.20	1.05	.01	68.17	.33
3A	45.20	1.06	.01	68.61	.32
3B	45.70	1.04	.02	68.11	.78
3C	45.20	1.05	.02	68.43	.65

Average Stack Temperature (°R)	542.20
Average Stack Pressure (inHg)	29.28
Average Molar Water Content (Bwo)	.0039895913

PROBE POSITION	ACTUAL DELTA P	Q (cfm)	Q (dscfm)	Reynolds Number
1a	1.08	4155	3937	408349
3a	1.06	4116	3900	404550
3b	1.05	4105	3889	403404
1b	1.06	4124	3908	405313
1c	1.06	4116	3900	404550
3c	1.06	4120	3904	404932
2c	1.05	4097	3882	402637
2b	1.02	4046	3833	397621
2a	1.06	4120	3904	404932
1a	1.07	4136	3919	406454
3a	1.07	4136	3919	406454
3b	1.05	4097	3882	402637
1b	1.06	4116	3900	404550
1c	1.06	4116	3900	404550
3c	1.06	4116	3900	404550
2c	1.05	4097	3882	402637
2b	1.04	4077	3863	400716
2a	1.06	4120	3904	404932
1a	1.06	4120	3904	404932
3a	1.05	4097	3882	402637
3b	1.03	4058	3845	398784
1b	1.06	4109	3893	403786
1c	1.05	4097	3882	402637
3c	1.04	4081	3867	401101
2c	1.04	4077	3863	400716
2b	.90	3793	3594	372770
2a	1.06	4109	3893	403786

Table AI.5-3d: Velocity Traverse Results (70 ft/sec)

PROBE POSITION	ACTUAL DELTA P	Q (cfm)	Q (dscfm)	Reynolds Number
Pref	1.03	4058	3845	398784
Pref	1.04	4069	3856	399944
Pref	1.03	4058	3845	398784
Pref	1.02	4046	3833	397621
Pref	1.03	4054	3841	398397
Pref	1.02	4038	3826	396844
Pref	1.02	4038	3826	396844
Pref	1.02	4042	3830	397233
Pref	1.02	4034	3822	396455

Table AI.5-4a: Velocity Traverse Results (50 ft/sec)

DATA SHEET #4, DECEMBER 3, 1985
VELOCITY TRAVERSE FOR WIND TUNNEL

DATE: DECEMBER 3,1985

Static pressure from reference pitot tube

	Measured	Actual (IN H2O)
Initial	2.66	-.53
Final	2.69	-.54

Average Static Pressure -.54

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Humidity Calculation

	Tdry °F	Twet °F	Tdry °R	Twet °R	TIME (MIN)
INITIAL	80.00	54.00	539.70	513.70	2.50
FINAL	78.00	52.00	537.70	511.70	67.30
CHANGE	2.00	2.00			64.80
AVERAGE	79.00	53.00	538.70	512.70	

	Kdry	Kwet
INITIAL	3.28	3.30
FINAL	3.28	3.31

	Pdry	Pwet
INITIAL	26.29	10.70
FINAL	24.62	9.94

			Pmi	Pmf
BAROMETRIC				
PRESSURE	755.72	756.17	7.31	7.31
(mm Hg)	Average	755.95		

RHi	RHf
12.88	10.69
DELTA RH	2.18

	INITIAL	FINAL
	.0044531115	.0034625183
	.0802242914	.0623784238
Absolute Humidity	.0028090344	.0021806791
Bwo	.0044783301	.0034800548
Average Bwo		.0039791925

Table AI.5-4b: Velocity Traverse Results (50 ft/sec)

PROBE POSITION	TIME START	STOP	ELAPSED TIME	MANOMETER READING	ACTUAL DELTA P	VELOCITY (ft/sec)
1a	3.70	4.70	1.00	3.12	.62	52.64
3a	5.20	6.20	1.00	3.10	.62	52.47
3b	6.50	7.50	1.00	2.97	.59	51.36
1b	7.90	8.90	1.00	3.09	.62	52.38
1c	11.00	12.00	1.00	2.99	.60	51.53
3c	13.30	14.30	1.00	2.98	.60	51.44
2c	14.80	15.80	1.00	2.97	.59	51.36
2b	16.00	17.00	1.00	3.04	.61	51.96
2a	17.50	18.50	1.00	3.10	.62	52.47
1a	26.50	27.50	1.00	3.13	.63	52.72
3a	27.80	28.80	1.00	3.13	.63	52.72
3b	29.20	30.20	1.00	2.99	.60	51.53
1b	30.60	32.00	1.40	3.11	.62	52.55
1c	34.40	35.60	1.20	3.11	.62	52.55
3c	35.90	36.90	1.00	3.08	.62	52.30
2c	37.30	38.30	1.00	3.08	.62	52.30
2b	38.80	39.80	1.00	2.76	.55	49.51
2a	40.40	41.40	1.00	3.14	.63	52.81
1a	49.00	50.00	1.00	3.15	.63	52.89
3a	50.30	51.60	1.30	3.15	.63	52.89
3b	52.00	53.00	1.00	3.05	.61	52.04
1b	53.50	54.50	1.00	3.13	.63	52.72
1c	56.90	57.90	1.00	3.12	.62	52.64
3c	58.20	59.20	1.00	3.12	.62	52.64
2c	59.60	60.60	1.00	3.10	.62	52.47
2b	61.00	62.00	1.00	2.93	.59	51.01
2a	62.40	63.40	1.00	3.16	.63	52.97

ELAPSED TIME (MINUTES)	AVERAGE SAMPLE TIME	AVERAGE VELOCITY (ft/sec)	52.20
59.70	1.03	RANGE	3.47

****

PROBE POSITION	TIME START	STOP	ELAPSED TIME	MANOMETER READING	ACTUAL DELTA P	VELOCITY (FT/SEC)
Pref	.80	3.00	2.20	2.99	.60	51.53
Pref	9.50	10.50	1.00	3.01	.60	51.70
Pref	18.90	19.90	1.00	3.00	.60	51.62
Pref	24.20	25.70	1.50	3.00	.60	51.62
Pref	32.60	33.60	1.00	3.02	.60	51.79
Pref	41.60	42.60	1.00	3.02	.60	51.79
Pref	47.30	48.30	1.00	3.02	.60	51.79
Pref	55.10	56.10	1.00	3.04	.61	51.96
Pref	63.80	64.80	1.00	3.04	.61	51.96

ELAPSED TIME	AVERAGE SAMPLE TIME	AVERAGE VELOCITY (FT/SEC)	51.75
64.00	1.19	RANGE	.43

Table AI.5-4c: Velocity Traverse Results (50 ft/sec)

PROBE POSITION	ELAPSED TIME	DELTA P READING	DELTA P READINGS	AVERAGE VELOCITY	VELOCITY RANGE
1A	46.30	.63	.01	52.75	.25
1B	50.00	.62	.01	52.55	.34
1C	46.90	.61	.03	52.24	1.11
2A	45.90	.63	.01	52.75	.51
2B	46.00	.58	.02	50.84	.95
2C	45.80	.61	.03	52.04	1.11
3A	46.40	.63	.01	52.69	.42
3B	46.50	.60	.02	51.64	.69
3C	45.90	.61	.03	52.13	1.19

Average Stack Temperature (°R)	538.70
Average Stack Pressure (inHg)	29.48
Average Molar Water Content (Bwo)	.0039791925

PROBE POSITION	ACTUAL DELTA P	Q (cfm)	Q (dscfm)	Reynolds Number
1a	.62	3158	3032	314458
3a	.62	3148	3022	313448
3b	.59	3081	2958	306806
1b	.62	3143	3017	312942
1c	.60	3092	2968	307837
3c	.60	3087	2963	307322
2c	.59	3081	2958	306806
2b	.61	3118	2993	310400
2a	.62	3148	3022	313448
1a	.63	3163	3036	314961
3a	.63	3163	3036	314961
3b	.60	3092	2968	307837
1b	.62	3153	3027	313954
1c	.62	3153	3027	313954
3c	.62	3138	3012	312436
2c	.62	3138	3012	312436
2b	.55	2971	2851	295760
2a	.63	3168	3041	315464
1a	.63	3173	3046	315966
3a	.63	3173	3046	315966
3b	.61	3123	2997	310910
1b	.63	3163	3036	314961
1c	.62	3158	3032	314458
3c	.62	3158	3032	314458
2c	.62	3148	3022	313448
2b	.59	3061	2938	304733
2a	.63	3178	3051	316467

Table AI.5-4d: Velocity Traverse Results (50 ft/sec)

PROBE POSITION	ACTUAL DELTA P	Q (cfm)	Q (dscfm)	Reynolds Number
Pref	.60	3092	2968	307837
Pref	.60	3102	2978	308865
Pref	.60	3097	2973	308351
Pref	.60	3097	2973	308351
Pref	.60	3107	2983	309377
Pref	.60	3107	2983	309377
Pref	.60	3107	2983	309377
Pref	.61	3118	2993	310400
Pref	.61	3118	2993	310400

Table AI.5-5a: Velocity Traverse Results (20 ft/sec)

DATA SHEET #5, FEBRUARY 20,1986
VELOCITY TRAVERSE FOR WIND TUNNEL

DATE: FEBRUARY 20,1986

Static pressure from reference pitot tube

	Measured	Actual (IN H2O)
Initial	1.80	-.09
Final	1.80	-.09

Average Static Pressure -.09

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Humidity Calculation

	Tdry °F	Twet °F	Tdry °R	Twet °R	TIME (MIN)
INITIAL	78.00	56.00	537.70	515.70	26.00
FINAL	80.00	57.00	539.70	516.70	96.00
CHANGE	2.00	1.00			70.00
AVERAGE	79.00	56.50	538.70	516.20	

	Kdry	Kwet
INITIAL	3.28	3.30
FINAL	3.28	3.30

	Pdry	Pwet
INITIAL	24.62	11.50
FINAL	26.29	11.93

BAROMETRIC PRESSURE (mm Hg)			Pmi	Pmf
	755.72	756.17	6.19	6.48
	Average	755.95		

RHi	RHf
21.57	20.71
DELTA RH	.86

	INITIAL	FINAL
	.0069862396	.0071628844
	.1258594403	.1290417551
Absolute Humidity	.0044182443	.0045280529
Bwo	.0070258037	.0071991620
Average Bwo	.0071124829	

Table AI.5-5b: Velocity Traverse Results (20 ft/sec)

PROBE POSITION	TIME START	STOP	ELAPSED TIME	MANOMETER READING	ACTUAL DELTA P	VELOCITY (ft/sec)
1a	28.00	29.00	1.00	1.94	.10	20.75
3a	29.57	30.58	1.01	1.94	.10	20.75
3b	31.12	32.67	1.55	1.90	.10	20.54
1b	33.17	34.42	1.25	1.94	.10	20.75
1c	37.00	38.27	1.27	1.94	.10	20.75
3c	38.83	40.00	1.17	1.91	.10	20.59
2c	40.68	41.75	1.07	1.90	.10	20.54
2b	42.33	43.50	1.17	1.90	.10	20.54
2a	44.22	45.50	1.28	1.94	.10	20.75
1a	49.75	50.75	1.00	1.94	.10	20.75
3a	51.20	52.25	1.05	1.92	.10	20.65
3b	52.75	53.75	1.00	1.88	.09	20.43
1b	54.17	55.58	1.41	1.94	.10	20.75
1c	57.83	59.07	1.24	1.90	.10	20.54
3c	60.00	61.09	1.09	1.90	.10	20.54
2c	61.92	62.92	1.00	1.90	.10	20.54
2b	63.88	64.92	1.04	1.89	.09	20.48
2a	65.33	66.33	1.00	1.90	.10	20.54
1a	76.28	77.50	1.22	1.94	.10	20.75
3a	78.37	79.37	1.00	1.93	.10	20.70
3b	80.00	81.00	1.00	1.88	.09	20.43
1b	81.50	82.75	1.25	1.91	.10	20.59
1c	84.58	85.58	1.00	1.84	.09	20.21
3c	86.00	87.00	1.00	1.90	.10	20.54
2c	87.50	88.50	1.00	1.90	.10	20.54
2b	89.17	90.25	1.08	1.90	.10	20.54
2a	92.00	93.00	1.00	1.90	.10	20.54

ELAPSED TIME (MINUTES) 65.00

AVERAGE SAMPLE TIME 1.10

AVERAGE VELOCITY (ft/sec) 20.60

RANGE .54

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PROBE POSITION	TIME START	STOP	ELAPSED TIME	MANOMETER READING	ACTUAL DELTA P	VELOCITY (FT/SEC)
Pref	26.00	27.00	1.00	1.87	.09	20.38
Pref	34.75	36.00	1.25	1.87	.09	20.38
Pref	46.00	47.10	1.10	1.79	.09	19.94
Pref	47.50	48.50	1.00	1.84	.09	20.21
Pref	56.03	57.07	1.04	1.87	.09	20.38
Pref	67.33	68.33	1.00	1.84	.09	20.21
Pref	74.00	75.00	1.00	1.84	.09	20.21
Pref	83.13	84.17	1.04	1.84	.09	20.21
Pref	93.50	94.50	1.00	1.84	.09	20.21

ELAPSED TIME 68.50

AVERAGE SAMPLE TIME 1.05

AVERAGE VELOCITY (FT/SEC) 20.24

RANGE .44

Table AI.5-5c: Velocity Traverse Results (20 ft/sec)

PROBE POSITION	ELAPSED TIME	DELTA P READING	DELTA P READINGS	AVERAGE VELOCITY	VELOCITY RANGE
1A	49.50	.10	0	20.75	0
1B	52.41	.10	.00	20.70	.16
1C	48.58	.09	.01	20.50	.54
2A	48.78	.10	.00	20.61	.22
2B	47.92	.09	0	20.52	0
2C	47.82	.10	0	20.54	0
3A	50.37	.10	.00	20.70	.05
3B	49.88	.09	.00	20.47	.11
3C	48.17	.10	.00	20.56	.05

Average Stack Temperature (°R)	538.70
Average Stack Pressure (inHg)	29.71
Average Molar Water Content (Bwo)	.0071124829

PROBE POSITION	ACTUAL DELTA P	Q (cfm)	Q (dscfm)	Reynolds Number
1a	.10	1245	1201	124590
3a	.10	1245	1201	124590
3b	.10	1232	1189	123299
1b	.10	1245	1201	124590
1c	.10	1245	1201	124590
3c	.10	1236	1192	123623
2c	.10	1232	1189	123299
2b	.10	1232	1189	123299
2a	.10	1245	1201	124590
1a	.10	1245	1201	124590
3a	.10	1239	1195	123946
3b	.09	1226	1182	122649
1b	.10	1245	1201	124590
1c	.10	1232	1189	123299
3c	.10	1232	1189	123299
2c	.10	1232	1189	123299
2b	.09	1229	1186	122974
2a	.10	1232	1189	123299
1a	.10	1245	1201	124590
3a	.10	1242	1198	124269
3b	.09	1226	1182	122649
1b	.10	1236	1192	123623
1c	.09	1213	1170	121337
3c	.10	1232	1189	123299
2c	.10	1232	1189	123299
2b	.10	1232	1189	123299
2a	.10	1232	1189	123299

Table AI.5-5d: Velocity Traverse Results (20 ft/sec)

PROBE POSITION	ACTUAL DELTA P	Q (cfm)	Q (dscfm)	Reynolds Number
Pref	.09	1223	1179	122322
Pref	.09	1223	1179	122322
Pref	.09	1196	1154	119677
Pref	.09	1213	1170	121337
Pref	.09	1223	1179	122322
Pref	.09	1213	1170	121337
Pref	.09	1213	1170	121337
Pref	.09	1213	1170	121337
Pref	.09	1213	1170	121337

1A	1B	1C
89.07	88.07	87.61
2A	2B	2C
87.24	85.63	86.97
3A	3B	3C
88.64	88.05	87.[illegible]3

Figure AI.4: Results of Velocity Traverse at 90 ft/sec

1A	1B	1C
79.82	79.11	78.86
2A	2B	2C
78.81	78.28	78.56
3A	3B	3C
79.41	78.81	78.73

Figure AI.5: Results of Velocity Traverse at 80 ft/sec

1A	1B	1C
68.95	68.61	68.50
2A	2B	2C
68.61	66.24	68.17
3A	3B	3C
68.61	68.11	68.43

Figure AI.6: Results of Velocity Traverse at 70 ft/sec

1A	1B	1C
52.75	52.55	52.24
2A	2B	2C
52.75	50.84	52.04
3A	3B	3C
52.69	51.64	52.13

Figure AI.7: Results of Velocity Traverse at 50 ft/sec

1A	1B	1C
20.75	20.70	20.50
2A	2B	2C
20.61	20.52	20.54
3A	3B	3C
20.70	20.47	20.56

Figure AI.8: Results of Velocity Traverse at 20 ft/sec

The third conclusion is that the velocity of the gas in the wind tunnel was not stable over time. The velocity decreased from the beginning of an experiment. This effect was most pronounced at the highest velocity, where the deviation was approximately 7 per cent per hour. The decrease was negligable at 20 feet per second. This effect may be of importance if the measured dilution ratio is affected by external flow around the Venturi sampling probe.

This change in velocity may be due to a change in viscosity of the hydraulic fluid which drives the fan in the wind tunnel. The change in viscosity would be due to the increase in temperature of the fluid during operation.

REFERENCES

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2. Gnyp, A.W., C.C. St. Pierre, J. Price, and D.S. Smith, Windsor Stack Sampling School Notes, University of Windsor, Windsor, Ontario. (1974)

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Appendix II: The Determination of the Volume Fraction of Water

To determine the volume fraction of water vapour in the wind tunnel, wet and dry bulb temperatures were recorded at the beginning and end of each experiment.

The wet and dry bulb temperatures were converted into per cent relative humidity values by using the correlation published by Pallady and Henley [1] These values agree closely with those obtained from standard psychrometric charts [2]. The following sample calculation will demonstrate the evaluation of relative humidity given the following values.

Wet Bulb Temperature (tw) = 80 °F
Dry Bulb Temperature (td) = 60 °F
Barometric Pressure (Pb) = 760 mmHg

Using the Pallady and Henley correlation, the calculated relative humidity is 28.9 %. A psychrometric chart provides a value of approximately 29 %.

To determine the volume fraction of water in the airstream, it is necessary to calculate the absolute humidity. This is achieved by the use of the following formula [3]:

$$\mathcal{H} = \frac{Mw \times Pw}{Ma \times (Pb - Pw)}$$

$\mathcal{H}$ = absolute humidity (lbm water/lbm dry air)
Mw = molecular weight of water
= 18.05 (lbm/lbmol)
Ma = molecular weight of air
= 28.85 (lbm/lbmol)
Pw = partial pressure of water vapour
Pb = barometric pressure

By calculation, the value of $\mathcal{H}$ is 0.0063. The absolute humidity from a psychrometric chart is 0.0065.

The volume fraction of water vapour is determined from the following formula [4].

$$Bwo = \left(\frac{Vm}{Vm + Vw}\right)_{ref}$$

where: Bwo = volume fraction of water in stack gas
Vm = volume of gas sample at 760 mmHg, 537°R
Vw = volume of water as a gas, at 760 mmHg, 537°R

Knowing that the volume fraction of a vapour which exhibits ideal gas behaviour is equivalent to the mole fraction, the preceeding formula was converted to the more convenient form:

$$Bwo = \frac{n_w}{n_w + n_a}$$

n_w = number of moles of water vapour
n_a = number of moles of dry air

The value for the number of moles of water was derived by dividing the absolute humidity by the molecular weight of water according to:

$$n_w = \frac{\mathcal{H}}{18.01} \quad \frac{\text{(lbm water/lbm dry air)}}{\text{(lbm water/lbmol water)}}$$

Similarly, the number of moles of dry air was calculated from:

$$n_a = \frac{1}{28.85} \quad \frac{\text{(lbm dry air/lbm dry air)}}{\text{(lbm dry air/lbmol dry air)}}$$

Accordingly the value of Bwo was calculated as 0.00995.

A. Error Analysis

Since the values derived by calculation show sufficient agreement with the values derived from the psychrometric chart, the correlation was used to determine the mole fraction of water during the reduction of all experimental data.

Due to the complexity of the Pallady and Henley correlation, an error calculation using known values was considered more meaningful than a mathematical analysis. Error was estimated using the minimum and maximum parameter values as derived from instrumental error. These errors are listed below.

- Thermometer : 1 °F
- Barometer : 0.005 mmHg

Since a static pressure was not used to correct the barometric pressure in the example calculations, it will not be included in this analysis. It is assumed that this value would have a negligable effect on the magnitude of the error.

In order to calculate the error in the values of Bwo, the instrument error was added or subtracted from the actual values, and the resulting values were placed in the algorithm. This approach is illustrated in Table AII.1.

Table AII.1: Error Analysis of Bwo Values

tw	td	Pb	Bwo
60	80	760.000	0.00995
61	81	760.005	0.01058
59	79	760.005	0.00935
59	81	760.005	0.00860
61	79	760.005	0.01133
61	81	759.995	0.01058
59	79	759.995	0.00935
59	81	759.995	0.00860
61	79	795.995	0.01133

Using the example values, the nominal Bwo was calculated to be 0.00995, the maximum value was 0.01133, and the minimum was 0.00860.

This analysis suggests that a relative error of 13.7% in Bwo is possible. Variations due to barometric readings had no observable effect on the final Bwo value Consequently the exclusion of static pressures was justified.

REFERENCES

1. Pallady, P.H, and P.J. Henley, Evaluating Moist Air Properties, Chemical Engineering, Vol. 19, No. 22, October 29, p. 117. (1984)

2. Perry, R.H., and C.H. Chilton, eds., Chemical Engineers' Handbook, 6th Edition, McGraw-Hill Publishing Co., NY, NY, p. 12-4.

3. Treyball, R.E., Mass-Transfer Operations, 3rd Edition, McGraw-Hill Publishing Co.,NY, NY, p. 227. (1980)

4. Source Testing Code, Report Number ARB-TDA-66-80,Ontario Ministry of the Environment, p. 4-6. (1980)

Appendix III: Miran 1A Calibration

This appendix describes the calibration of the Miran-1A infrared spectrophotometer that was used to determine the concentrations of sulphur hexafluoride gas in both the wind tunnel and the sample bags.

A. Experimental Equipment

The equipment used for this calibration included:

1. Miran-1A Infrared Spectrophotometer
2. Miran Closed Loop Calibration System
3. 100 uL gas tight syringe
4. Sulphur Hexafluoride gas, commercial grade
5. Hewlett-Packard 1703 chart recorder
6. CCAD Analog-to-Digital signal converter
7. Radio Shack TRS-80 Colour Computer

B. Experimental Procedure

The following procedure was used to calibrate the Miran-1A:

1. The Miran was calibrated according to the procedure outlined in the manual provided [1]. Preliminary considerations involved confirmation of pathlength and zero absorbance settings. The instrument was set to the following specified conditions for the optimum detection of SF_6 [1]:

- Pathlength = 20.25 metres
- Slit width = 1.0 millimetres
- Wavelength = 10.7 microns

2. A 125 millilitre polyethylene sampling bulb was filled with commercial grade SF_6 gas by allowing a flow through the bulb for 2 minutes from a source at high pressure. A lower flow rate was maintained during the calibration process to ensure a complete filling of the

sampling bulb.

3. A sample of gas was removed from the sampling bulb with a 100 uL gas-tight syringe.

4. The sample was quickly injected into the septum of the closed loop calibration system which is illustrated in Figure AIII.1 [1].

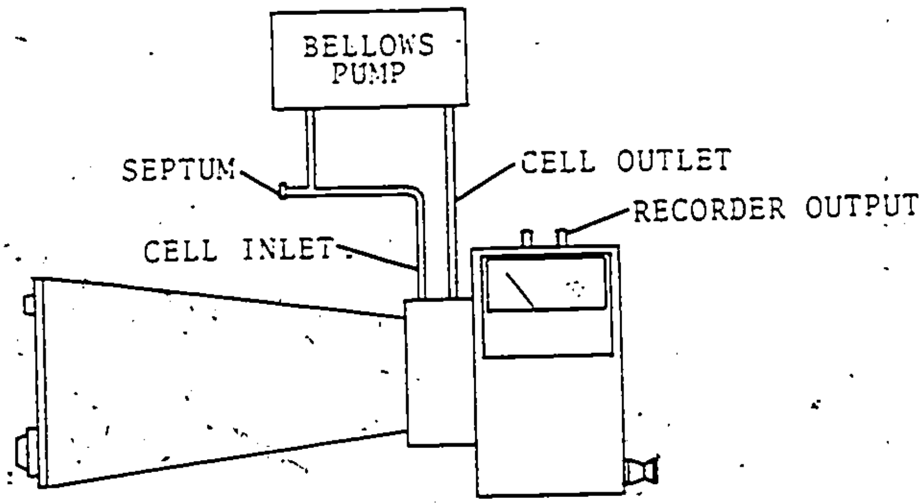

Figure AIII.1: Schematic Representation of Calibration Loop [1]

5. The reading in absorbance units was recorded 30 to 60 seconds after injection when stabilization of the instrument was evident. Absorbance was also recorded by a computerized data collection system.

6. The sequence of steps, 3 to 5, was repeated until a total volume of 1000 microlitres was injected.

7. Steps 3 through 6 were repeated 5 times to ensure precision of results.

C. Results

The results of this calibration are presented in Table AIII.1.

Table AIII.1: Raw Calibration Data for Miran-1A

Total Injected Volume (ul)	Absorbance				
	I	II	III	IV	V
0.0	0.000	0.000	0.000	0.000	0.000
100.0	0.382	0.379	0.383	0.384	0.386
200.0	0.552	0.551	0.553	0.558	0.557
300.0	0.663	0.672	0.673	0.678	0.674
400.0	0.750	0.759	0.757	0.753	0.754
500.0	0.808	0.817	0.815	0.818	0.811
600.0	0.849	0.861	0.858	0.859	0.853
700.0	0.879	0.895	0.888	0.888	0.888
800.0	0.905	0.920	0.912	0.917	0.909
900.0	0.926	0.941	0.930	0.935	0.929
1000.0	0.941	0.955	0.945	0.951	0.945

D. Data Reduction

To facilitate the use of the calibration data for determination of the concentrations of sulphur hexafluoride in either the wind tunnel or a sample bag, it was necessary to fit the average absorbance values to corresponding concentrations. The concentration of the gas was determined by dividing the injected volume in microlitres by the total volume of the closed loop calibration system, in this case 5.6 litres. This division yields a concentration in parts per million (ppm). The relationship between the values of concentration and average absorbance is shown in Table AIII.2.

A plot of concentration versus the average absorbance, yielded a calibration curve for the sulphur hexafluoride for the specific instrument parameters.

Table AIII.2: Reduced Data for Closed Loop Calibration

Total Injected Volume (microlitres)	Calculated Concentration (ppm)	Average Absorbance	Standard Deviation
0.0	0.0	0.000	0.000
100.0	17.8	0.383	0.003
200.0	35.7	0.554	0.003
300.0	53.5	0.672	0.006
400.0	71.4	0.755	0.004
500.0	89.2	0.814	0.004
600.0	107.1	0.856	0.005
700.0	125.0	0.888	0.006
800.0	142.8	0.913	0.006
900.0	160.7	0.932	0.006
1000.0	178.5	0.947	0.006

To facilitate the use of the data logger that was used in conjunction with the Miran-1A, the reduced data were also fitted using a Gaussian Curve fit [2]. This process provided the following mathematical expression for the calibration curve:

$$\text{Concentration} = ((\text{Ln.}(1 - \text{Absorbance}))/0.049225)^{1.27269}$$

This expression made it possible to read the tracer gas concentration from the display of the data logger, along with the absorbance. A plot of the averaged data points and the derived calibration curve is provided in Figure AIII.2.

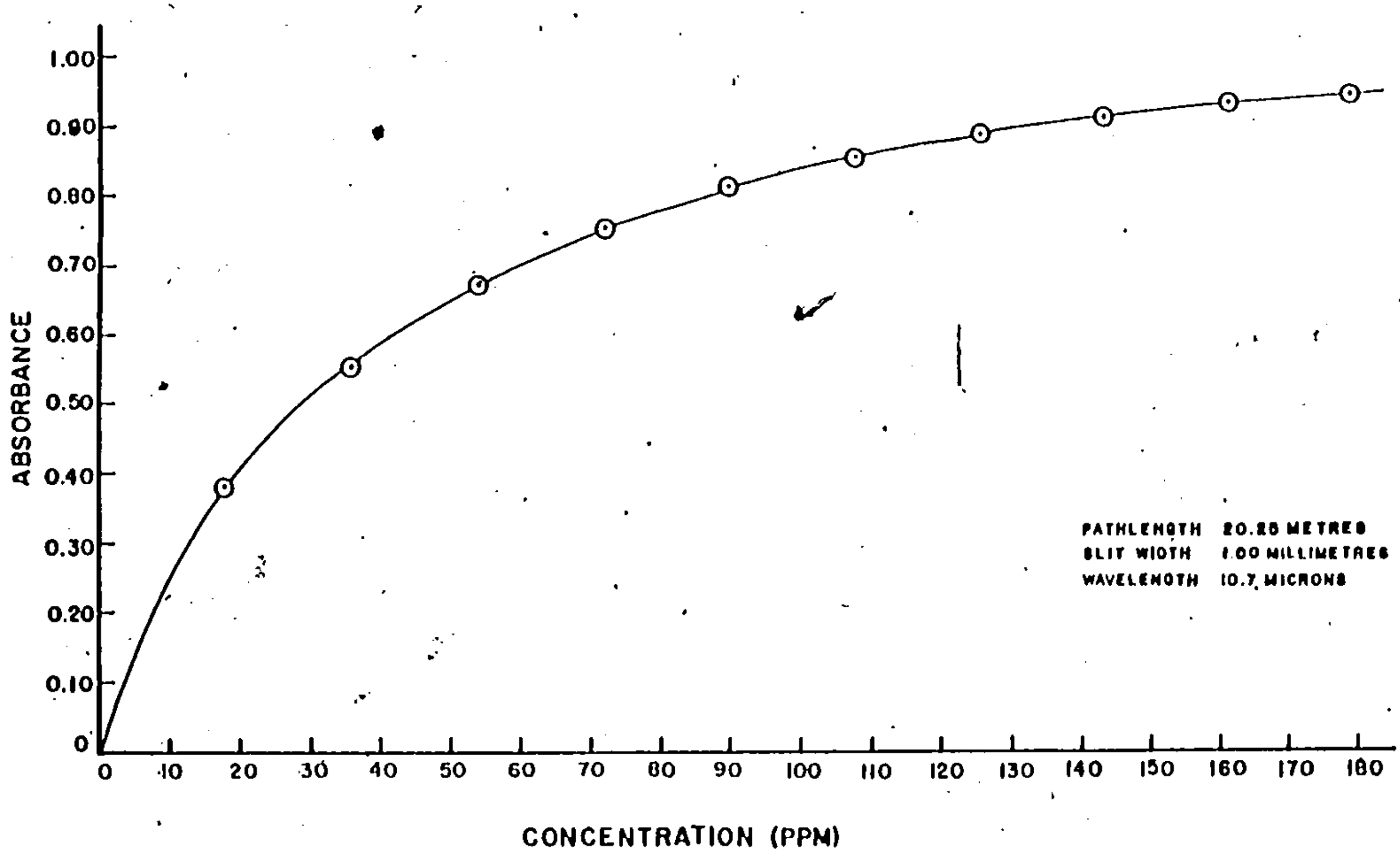

Figure AIII.2: SULFUR HEXAFLOURIDE CALIBRATION CURVE

E. Error Analysis

To determine the random errors inherent in the evaluation of the dilution ratio, DR, the following analysis was performed.

For:

$$DR = \frac{C_{wt}}{C_s} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(1)$$

where: C_{wt} = Concentration of SF_6 in the wind tunnel
C_s = Concentration of SF_6 in the sample

the variance in the measurement is expressed as:

$$\sigma_{DR}^2 = \left[\frac{\partial_{DR}}{\partial_{C_{wt}}}\right]^2 \sigma_{C_{wt}}^2 + \left[\frac{\partial_{DR}}{\partial_{C_s}}\right]^2 \sigma_{C_s}^2 \quad \ldots.(2)$$

The partial derivatives are determined from Equation 1 as:

$$\left[\frac{\partial_{DR}}{\partial_{C_{wt}}}\right] = \frac{1}{C_s}$$

$$\left[\frac{\partial_{DR}}{\partial_{C_s}}\right] = -\frac{C_{wt}}{C_s^2}$$

Substituting into Equation 2 and dividing both sides by $(DR)^2$, yields:

$$\left[\frac{\sigma_{DR}}{DR}\right]^2 = \left[\frac{\sigma_{C_{wt}}}{C_{wt}}\right]^2 + \left[\frac{\sigma_{C_s}}{C_s}\right]^2 \quad \text{........(3)}$$

The absorbance reading is related to the concentration by Beer's Law [3] according to:

$$A = abC \quad \text{.........................(4)}$$

where: A = measured absorbance
a = absorptivity constant
b = path length
C = concentration

The variance involved in calculating the wind tunnel SF_6 concentration is given by:

$$\sigma_{C_{wt}}^2 = \left[\frac{\partial_{C_{wt}}}{\partial_{A_{wt}}}\right]^2 \sigma_{A_{wt}}^2 + \left[\frac{\partial_{C_{wt}}}{\partial_a}\right]^2 \sigma_a^2 + \left[\frac{\partial_{C_{wt}}}{\partial_b}\right]^2 \sigma_b^2 \quad \text{(5)}$$

Since the values of a and b are constant, σ_a^2 and σ_b^2 can be eliminated from the expression to yield:

$$\sigma_{C_{wt}}^2 = \left[\frac{\partial_{C_{wt}}}{\partial_{A_{wt}}}\right]^2 \sigma_{A_{wt}}^2 \quad \text{............(6)}$$

Similarily, the variance in the SF_6 sample concentration can be written as:

$$\sigma_{C_s}^2 = \left[\frac{\partial C_s}{\partial A_s}\right]^2 \sigma_{A_s}^2 \quad \ldots\ldots\ldots\ldots\ldots (7)$$

The required partial derivatives are evaluated from Equation 4 to give:

$$\left[\frac{\partial C_{wt}}{\partial A_{wt}}\right] = \left[\frac{1}{ab}\right]_{wt}$$

$$\left[\frac{\partial C_s}{\partial A_s}\right] = \left[\frac{1}{ab}\right]_s$$

As a result, Equation 6 simplifies to:

$$\left[\frac{\sigma_{C_{wt}}}{C_{wt}}\right]^2 = \left[\frac{\sigma_{A_{wt}}}{A_{wt}}\right]^2 \quad \ldots\ldots\ldots\ldots\ldots (8)$$

and Equation 7 reduces to:

$$\left[\frac{\sigma_{C_s}}{C_s}\right]^2 = \left[\frac{\sigma_{A_s}}{A_s}\right]^2 \quad \ldots\ldots\ldots\ldots\ldots (9)$$

Substituting Equations 8 and 9 into Equation 3 results in:

$$\left[\frac{\sigma_{DR}}{DR}\right]^2 = \left[\frac{\sigma_{A_{wt}}}{A_{wt}}\right]^2 + \left[\frac{\sigma_{A_s}}{A_s}\right]^2 \quad \ldots\ldots\ldots (10)$$

Since the experimental concentrations were not in a linear range of Beer's Law, it was necessary to evaluate the partial derivatives from representative points on the calibration curve. This procedure is illustrated in terms of typical wind tunnel and sample bag SF_6 concentrations.

The standard deviation of each absorbance reading is set at the instrument readibility of 0.005 absorbance units. Using a wind tunnel absorbance reading of 0.888, and a sample bag absorbance reading of 0.383, and substituting these values into Equation 10 yields:

$$\left[\frac{\sigma_{DR}}{DR}\right]^2 = \frac{(0.005)^2}{(0.888)^2} + \frac{(0.005)^2}{(0.383)^2}$$

$$= 2.02 \times 10^{-4}$$

and

$$\left[\frac{\sigma_{DR}}{DR}\right] = 0.014$$

This value corresponds to a relative random error of 1.4 %.

REFERENCES

1. MIRAN-1A General Purpose Gas Analyzer-Operation, Maintenance and Service Manual, #001-4136, Wilks Infrared Center, South Norwalk, Connecticutt, USA. (1980)

2. Ellwood, K.R.J., graduate student, Department of Chemical Engineering, University of Windsor, personal communication, May, 1985.

Appendix IV: Data Records

REPORT NUMBER 1

PROBE CONFIGURATION 1/8 A

VENTURI MANOMETER READING (INCHES OF WATER)

INITIAL	FINAL
21.2	21.1

STACK GAS VELOCITY (ft/sec)

INITIAL	FINAL
72.66	71.36

	WIND TUNNEL ABSORBANCE	WIND TUNNEL CONCENTRATION (ppm)	SAMPLE ABSORBANCE	SAMPLE CONCENTRATION (ppm)	DILUTION RATIO	SAMPLE TIME (min)
1	0.815	90	0.131	4	23.7	25

REPORT NUMBER 2

PROBE CONFIGURATION 1/8 A

VENTURI MANOMETER READING (INCHES OF WATER)

INITIAL	FINAL
15.1	15.2

STACK GAS VELOCITY (ft/sec)

INITIAL	FINAL
71.81	71.54

	WIND TUNNEL ABSORBANCE	WIND TUNNEL CONCENTRATION (ppm)	SAMPLE ABSORBANCE	SAMPLE CONCENTRATION (ppm)	DILUTION RATIO	SAMPLE TIME (min)
1	0.877	118	0.170	5	21.8	33

REPORT NUMBER . 3

PROBE CONFIGURATION 1/8 A

VENTURI MANOMETER READING (INCHES OF WATER)

INITIAL	FINAL
20.9	21.5

STACK GAS VELOCITY (ft/sec)

INITIAL	FINAL
70.82	70.44

	WIND TUNNEL ABSORBANCE	WIND TUNNEL CONCENTRATION (ppm)	SAMPLE ABSORBANCE	SAMPLE CONCENTRATION (ppm)	DILUTION RATIO	SAMPLE TIME (min)
1	0.861	110	0.147	4	24.7	14

REPORT NUMBER 4

PROBE CONFIGURATION. 1/8 A

VENTURI MANOMETER READING (INCHES OF WATER)

INITIAL	FINAL
14.9	14.7

STACK GAS VELOCITY (ft/sec)

INITIAL	FINAL
71.68	70.41

	WIND TUNNEL ABSORBANCE	WIND TUNNEL CONCENTRATION (ppm)	SAMPLE ABSORBANCE	SAMPLE CONCENTRATION (ppm)	DILUTION RATIO	SAMPLE TIME (min)
1	0.898	132	0.203	7	18.9	17

REPORT NUMBER 5

PROBE CONFIGURATION 1/4 A

VENTURI MANOMETER READING (INCHES OF WATER)

INITIAL	FINAL
21.4	21.7

STACK GAS VELOCITY (ft/sec)

INITIAL	FINAL
70.79	70.62

	WIND TUNNEL ABSORBANCE	WIND TUNNEL CONCENTRATION (ppm)	SAMPLE ABSORBANCE	SAMPLE CONCENTRATION (ppm)	DILUTION RATIO	SAMPLE TIME (min)
1	0.868	125	0.264	10	12.2	12

REPORT NUMBER 6

PROBE CONFIGURATION 1/4 A

VENTURI MANOMETER READING (INCHES OF WATER)

INITIAL	FINAL
21.4	21.3

STACK GAS VELOCITY (ft/sec)

INITIAL	FINAL
72.15	71.25

	WIND TUNNEL ABSORBANCE	WIND TUNNEL CONCENTRATION (ppm)	SAMPLE ABSORBANCE	SAMPLE CONCENTRATION (ppm)	DILUTION RATIO	SAMPLE TIME (min)
1	0.905	137	0.267	10	13.2	8

REPORT NUMBER 7

PROBE CONFIGURATION 1/4 A

VENTURI MANOMETER READING (INCHES OF WATER)

INITIAL	FINAL
15.4	14.9

STACK GAS VELOCITY (ft/sec)

INITIAL	FINAL
72.67	72.48

	WIND TUNNEL ABSORBANCE	WIND TUNNEL CONCENTRATION (ppm)	SAMPLE ABSORBANCE	SAMPLE CONCENTRATION (ppm)	DILUTION RATIO	SAMPLE TIME (min)
1	0.887	125	0.283	11	10.9	19

REPORT NUMBER 8

PROBE CONFIGURATION 1/4 A

VENTURI MANOMETER READING (INCHES OF WATER)

INITIAL	FINAL
14.9	14.9

STACK GAS VELOCITY (ft/sec)

INITIAL	FINAL
72.48	71.82

	WIND TUNNEL ABSORBANCE	WIND TUNNEL CONCENTRATION (ppm)	SAMPLE ABSORBANCE	SAMPLE CONCENTRATION (ppm)	DILUTION RATIO	SAMPLE TIME (min)
1	0.920	150	0.312	13	11.4	14

REPORT NUMBER 9

PROBE CONFIGURATION 1/8 C

VENTURI MANOMETER READING (INCHES OF WATER)

INITIAL	FINAL
22.5	22.6

STACK GAS VELOCITY (ft/sec)

INITIAL	FINAL
72.97	72.54

	WIND TUNNEL ABSORBANCE	WIND TUNNEL CONCENTRATION (ppm)	SAMPLE ABSORBANCE	SAMPLE CONCENTRATION (ppm)	DILUTION RATIO	SAMPLE TIME (min)
1	0.919	149	0.238	9	17.0	9

REPORT NUMBER 10

PROBE CONFIGURATION 1/8 C

VENTURI MANOMETER READING (INCHES OF WATER)

INITIAL	FINAL
15.0	14.8

STACK GAS VELOCITY (ft/sec)

INITIAL	FINAL
72.41	71.81

	WIND TUNNEL ABSORBANCE	WIND TUNNEL CONCENTRATION (ppm)	SAMPLE ABSORBANCE	SAMPLE CONCENTRATION (ppm)	DILUTION RATIO	SAMPLE TIME (min)
1	0.942	175	0.238	9	19.9	28

REPORT NUMBER 11

PROBE CONFIGURATION 1/8 C

VENTURI MANOMETER READING (INCHES OF WATER)

INITIAL	FINAL
22.5	22.5

STACK GAS VELOCITY (ft/sec)

INITIAL	FINAL
71.89	69.32

	WIND TUNNEL ABSORBANCE	WIND TUNNEL CONCENTRATION (ppm)	SAMPLE ABSORBANCE	SAMPLE CONCENTRATION (ppm)	DILUTION RATIO	SAMPLE TIME (min)
1	0.902	135	0.234	9	15.7	11

REPORT NUMBER 11

PROBE CONFIGURATION 1/8 C

VENTURI MANOMETER READING (INCHES OF WATER)

INITIAL	FINAL
14.6	14.5

STACK GAS VELOCITY (ft/sec)

INITIAL	FINAL
71.89	69.32

	WIND TUNNEL ABSORBANCE	WIND TUNNEL CONCENTRATION (ppm)	SAMPLE ABSORBANCE	SAMPLE CONCENTRATION (ppm)	DILUTION RATIO	SAMPLE TIME (min)
1	0.920	150	0.249	9	16.0	23

REPORT NUMBER 12

PROBE CONFIGURATION 1/4 C

VENTURI MANOMETER READING (INCHES OF WATER)

INITIAL	FINAL
14.5	14.2

STACK GAS VELOCITY (ft/sec)

INITIAL	FINAL
71.57	70.47

	WIND TUNNEL ABSORBANCE	WIND TUNNEL CONCENTRATION (ppm)	SAMPLE ABSORBANCE	SAMPLE CONCENTRATION (ppm)	DILUTION RATIO	SAMPLE TIME (min)
1	0.923	153	0.313	13	11.5	22
2	0.932	163	0.337	15	10.9	23

REPORT NUMBER 13

PROBE CONFIGURATION 1/4 C

VENTURI MANOMETER READING (INCHES OF WATER)

INITIAL	FINAL
21.8	22.2

STACK GAS VELOCITY (ft/sec)

INITIAL	FINAL
71.57	70.47

	WIND TUNNEL ABSORBANCE	WIND TUNNEL CONCENTRATION (ppm)	SAMPLE ABSORBANCE	SAMPLE CONCENTRATION (ppm)	DILUTION RATIO	SAMPLE TIME (min)
1	0.923	153	0.315	13	11.4	8
2	0.918	148	0.313	13	11.2	9

REPORT NUMBER 14

PROBE CONFIGURATION 1/8 A

VENTURI MANOMETER READING (INCHES OF WATER)

INITIAL	FINAL
22.3	22.0

STACK GAS VELOCITY (ft/sec)

INITIAL	FINAL
72.59	70.06

	WIND TUNNEL ABSORBANCE	WIND TUNNEL CONCENTRATION (ppm)	SAMPLE ABSORBANCE	SAMPLE CONCENTRATION (ppm)	DILUTION RATIO	SAMPLE TIME (min)
1	0.932	163	0.217	8	21.1	14
2	0.922	152	0.225	8	18.8	14

REPORT NUMBER 15

PROBE CONFIGURATION 1/4 C

VENTURI MANOMETER READING (INCHES OF WATER)

INITIAL	FINAL
14.2	14.1

STACK GAS VELOCITY (ft/sec)

INITIAL	FINAL
72.13	69.99

	WIND TUNNEL ABSORBANCE	WIND TUNNEL CONCENTRATION (ppm)	SAMPLE ABSORBANCE	SAMPLE CONCENTRATION (ppm)	DILUTION RATIO	SAMPLE TIME (min)
1	0.928	158	0.338	15	10.6	32

REPORT NUMBER 16

PROBE CONFIGURATION 1/8 B

VENTURI MANOMETER READING (INCHES OF WATER)

INITIAL	FINAL
22.4	22.3

STACK GAS VELOCITY (ft/sec)

INITIAL	FINAL
71.36	67.62

	WIND TUNNEL ABSORBANCE	WIND TUNNEL CONCENTRATION (ppm)	SAMPLE ABSORBANCE	SAMPLE CONCENTRATION (ppm)	DILUTION RATIO	SAMPLE TIME (min)
1	0.909	140	0.212	7	18.9	10
2	0.917	147	0.216	8	19.3	10

REPORT NUMBER 16

PROBE CONFIGURATION 1/8 B

VENTURI MANOMETER READING (INCHES OF WATER)

INITIAL	FINAL
~~14.5~~	14.4

STACK GAS VELOCITY (ft/sec)

INITIAL	FINAL
71.36	67.62

	WIND TUNNEL ABSORBANCE	WIND TUNNEL CONCENTRATION (ppm)	SAMPLE ABSORBANCE	SAMPLE CONCENTRATION (ppm)	DILUTION RATIO	SAMPLE TIME (min)
1	0.928	158	0.219	8	20.3	17
2	0.923	153	0.218	8	19.8	20

REPORT NUMBER 17

PROBE CONFIGURATION 1/4 B

VENTURI MANOMETER READING (INCHES OF WATER)

INITIAL	FINAL
22.3	22.2

STACK GAS VELOCITY (ft/sec)

INITIAL	FINAL
71.66	69.79

	WIND TUNNEL ABSORBANCE	WIND TUNNEL CONCENTRATION (ppm)	SAMPLE ABSORBANCE	SAMPLE CONCENTRATION (ppm)	DILUTION RATIO	SAMPLE TIME (min)
1	0.910	141	0.265	10	13.7	10
2	0.911	142	0.265	10	13.8	11

REPORT NUMBER 17

PROBE CONFIGURATION 1/4 B

VENTURI MANOMETER READING (INCHES OF WATER)

INITIAL	FINAL
14.2	14.2

STACK GAS VELOCITY (ft/sec)

INITIAL	FINAL
71.66	69.79

	WIND TUNNEL ABSORBANCE	WIND TUNNEL CONCENTRATION (ppm)	SAMPLE ABSORBANCE	SAMPLE CONCENTRATION (ppm)	DILUTION RATIO	SAMPLE TIME (min)
1	0.922	152	0.244	9	16.7	23
2	0.922	152	0.229	8	18.3	20

REPORT NUMBER 18

PROBE CONFIGURATION 1/8 D

VENTURI MANOMETER READING (INCHES OF WATER)

INITIAL	FINAL
22.5	22.2

STACK GAS VELOCITY (ft/sec)

INITIAL	FINAL
71.92	69.37

	WIND TUNNEL ABSORBANCE	WIND TUNNEL CONCENTRATION (ppm)	SAMPLE ABSORBANCE	SAMPLE CONCENTRATION (ppm)	DILUTION RATIO	SAMPLE TIME (min)
1	0.903	136	0.194	7	20.7	12
2	0.909	140	0.200	7	20.5	13

REPORT NUMBER 18

PROBE CONFIGURATION 1/8 D

VENTURI MANOMETER READING (INCHES OF WATER)

INITIAL	FINAL
14.5	14.5

STACK GAS VELOCITY (ft/sec)

INITIAL	FINAL
71.92	69.37

	WIND TUNNEL ABSORBANCE	WIND TUNNEL CONCENTRATION (ppm)	SAMPLE ABSORBANCE	SAMPLE CONCENTRATION (ppm)	DILUTION RATIO	SAMPLE TIME (min)
1	0.928	158	0.202	7	22.8	31
2	0.930	160	0.205	7	22.6	32

REPORT NUMBER 19

PROBE CONFIGURATION 1/4 D

VENTURI MANOMETER READING (INCHES OF WATER)

INITIAL	FINAL
21.4	21.4

STACK GAS VELOCITY (ft/sec)

INITIAL	FINAL
72.16	70.24

	WIND TUNNEL ABSORBANCE	CONCENTRATION (ppm)	SAMPLE ABSORBANCE	CONCENTRATION (ppm)	DILUTION RATIO	SAMPLE TIME (min)
1	0.918	148	0.279	11	13.3	11
2	0.909	140	0.271	11	13.2	14

REPORT NUMBER 19

PROBE CONFIGURATION 1/4 D

VENTURI MANOMETER READING (INCHES OF WATER)

INITIAL	FINAL
14.4	14.4

STACK GAS VELOCITY (ft/sec)

INITIAL	FINAL
72.16	70.24

	WIND TUNNEL ABSORBANCE	CONCENTRATION (ppm)	SAMPLE ABSORBANCE	CONCENTRATION (ppm)	DILUTION RATIO	SAMPLE TIME (min)
1	0.915	146	0.244	9	16.0	24
2	0.915	146	0.270	11	13.7	29

REPORT NUMBER 20

PROBE CONFIGURATION 1/8 ABCD

VENTURI MANOMETER READING (INCHES OF WATER)

INITIAL	FINAL
20.7	20.5

STACK GAS VELOCITY (ft/sec)

INITIAL	FINAL
72.81	72.15

	WIND TUNNEL ABSORBANCE	WIND TUNNEL CONCENTRATION (ppm)	SAMPLE ABSORBANCE	SAMPLE CONCENTRATION (ppm)	DILUTION RATIO	SAMPLE TIME (min)
1	0.906	138	0.375	18	7.8	14
2	0.906	138	0.373	18	7.9	13

REPORT NUMBER 20

PROBE CONFIGURATION 1/8 ABCD

VENTURI MANOMETER READING (INCHES OF WATER)

INITIAL	FINAL
13.3	13.0

STACK GAS VELOCITY (ft/sec)

INITIAL	FINAL
72.81	72.15

	WIND TUNNEL ABSORBANCE	WIND TUNNEL CONCENTRATION (ppm)	SAMPLE ABSORBANCE	SAMPLE CONCENTRATION (ppm)	DILUTION RATIO	SAMPLE TIME (min)
1	0.919	149	0.390	19	7.9	30
2	0.919	149	0.389	19	8.0	29

REPORT NUMBER 21

PROBE CONFIGURATION 1/4 ABCD

VENTURI MANOMETER READING (INCHES OF WATER)

INITIAL	FINAL
20.6	20.7

STACK GAS VELOCITY (ft/sec)

INITIAL	FINAL
72.15	71.48

	WIND TUNNEL ABSORBANCE	WIND TUNNEL CONCENTRATION (ppm)	SAMPLE ABSORBANCE	SAMPLE CONCENTRATION (ppm)	DILUTION RATIO	SAMPLE TIME (min)
1	0.901	134	0.416	21	6.4	13
2	0.898	132	0.415	21	6.3	11

REPORT NUMBER 21

PROBE CONFIGURATION 1/4 ABCD

VENTURI MANOMETER READING (INCHES OF WATER)

INITIAL	FINAL
11.5	11.3

STACK GAS VELOCITY (ft/sec)

INITIAL	FINAL
72.15	71.48

	WIND TUNNEL ABSORBANCE	WIND TUNNEL CONCENTRATION (ppm)	SAMPLE ABSORBANCE	SAMPLE CONCENTRATION (ppm)	DILUTION RATIO	SAMPLE TIME (min)
1	0.914	145	0.433	22	6.4	29
2	0.915	146	0.433	22	6.5	26

REPORT NUMBER 22

PROBE CONFIGURATION 1/8 ABC

VENTURI MANOMETER READING (INCHES OF WATER)

INITIAL	FINAL
21.4	21.4

STACK GAS VELOCITY (ft/sec)

INITIAL	FINAL
72.84	69.29

	WIND TUNNEL ABSORBANCE	WIND TUNNEL CONCENTRATION (ppm)	SAMPLE ABSORBANCE	SAMPLE CONCENTRATION (ppm)	DILUTION RATIO	SAMPLE TIME (min)
1	0.928	158	0.348	16	10.2	18
2	0.929	159	0.358	16	9.7	15

REPORT NUMBER 22

PROBE CONFIGURATION 1/8 ABC

VENTURI MANOMETER READING (INCHES OF WATER)

INITIAL	FINAL
14.5	14.2

STACK GAS VELOCITY (ft/sec)

INITIAL	FINAL
72.84	69.29

	WIND TUNNEL ABSORBANCE	WIND TUNNEL CONCENTRATION (ppm)	SAMPLE ABSORBANCE	SAMPLE CONCENTRATION (ppm)	DILUTION RATIO	SAMPLE TIME (min)
1	0.933	164	0.365	17	9.7	31
2	0.935	166	0.368	17	9.7	27

REPORT NUMBER 23

PROBE CONFIGURATION 1/4 ABC

VENTURI MANOMETER READING (INCHES OF WATER)

INITIAL	FINAL
20.2	20.1

STACK GAS VELOCITY (ft/sec)

INITIAL	FINAL
71.82	69.86

	WIND TUNNEL ABSORBANCE	WIND TUNNEL CONCENTRATION (ppm)	SAMPLE ABSORBANCE	SAMPLE CONCENTRATION (ppm)	DILUTION RATIO	SAMPLE TIME (min)
1	0.924	154	0.427	22	7.0	13
2	0.922	152	0.427	22	6.9	11

REPORT NUMBER 23

PROBE CONFIGURATION 1/4 ABC

VENTURI MANOMETER READING (INCHES OF WATER)

INITIAL	FINAL
10.7	10.3

STACK GAS VELOCITY (ft/sec)

INITIAL	FINAL
71.82	69.86

	WIND TUNNEL ABSORBANCE	WIND TUNNEL CONCENTRATION (ppm)	SAMPLE ABSORBANCE	SAMPLE CONCENTRATION (ppm)	DILUTION RATIO	SAMPLE TIME (min)
1	0.937	168	0.411	21	9.2	39
2	0.937	168	0.453	24	6.9	37

REPORT NUMBER 24

PROBE CONFIGURATION 1/8 ABD

VENTURI MANOMETER READING (INCHES OF WATER)

INITIAL	FINAL
20.6	20.2

STACK GAS VELOCITY (ft/sec)

INITIAL	FINAL
72.41	72.10

	WIND TUNNEL ABSORBANCE	WIND TUNNEL CONCENTRATION (ppm)	SAMPLE ABSORBANCE	SAMPLE CONCENTRATION (ppm)	DILUTION RATIO	SAMPLE TIME (min)
1	0.921	151	0.324	14	10.8	13
2	0.922	152	0.323	14	10.9	12

REPORT NUMBER 24

PROBE CONFIGURATION 1/8 ABD

VENTURI MANOMETER READING (INCHES OF WATER)

INITIAL	FINAL
11.7	10.8

STACK GAS VELOCITY (ft/sec)

INITIAL	FINAL
72.41	72.10

	WIND TUNNEL ABSORBANCE	WIND TUNNEL CONCENTRATION (ppm)	SAMPLE ABSORBANCE	SAMPLE CONCENTRATION (ppm)	DILUTION RATIO	SAMPLE TIME (min)
1	0.932	163	0.325	14	11.6	41
2	0.935	166	0.328	14	11.6	40

REPORT NUMBER 25

PROBE CONFIGURATION 1/4 ABD

VENTURI MANOMETER READING (INCHES OF WATER)

INITIAL	FINAL
19.1	19.1

STACK GAS VELOCITY (ft/sec)

INITIAL	FINAL
72.09	71.75

	WIND TUNNEL ABSORBANCE	WIND TUNNEL CONCENTRATION (ppm)	SAMPLE ABSORBANCE	SAMPLE CONCENTRATION (ppm)	DILUTION RATIO	SAMPLE TIME (min)
1	0.927	157	0.379	18	8.7	11
2	0.928	158	0.379	18	8.8	12

REPORT NUMBER 25

PROBE CONFIGURATION 1/4 ABD

VENTURI MANOMETER READING (INCHES OF WATER)

INITIAL	FINAL
11.0	10.7

STACK GAS VELOCITY (ft/sec)

INITIAL	FINAL
72.09	71.75

	WIND TUNNEL ABSORBANCE	WIND TUNNEL CONCENTRATION (ppm)	SAMPLE ABSORBANCE	SAMPLE CONCENTRATION (ppm)	DILUTION RATIO	SAMPLE TIME (min)
1	0.940	172	0.384	18	9.4	31
2	0.942	175	0.382	18	9.6	28

REPORT NUMBER 26

PROBE CONFIGURATION 1/8 ACD

VENTURI MANOMETER READING (INCHES OF WATER)

INITIAL	FINAL
19.1	19.2

STACK GAS VELOCITY (ft/sec)

INITIAL	FINAL
70.56	65.82

	WIND TUNNEL ABSORBANCE	WIND TUNNEL CONCENTRATION (ppm)	SAMPLE ABSORBANCE	SAMPLE CONCENTRATION (ppm)	DILUTION RATIO	SAMPLE TIME (min)
1	0.933	164	0.349	16	10.4	17
2	0.938	170	0.358	16	10.4	15

REPORT NUMBER 26

PROBE CONFIGURATION 1/8 ACD

VENTURI MANOMETER READING (INCHES OF WATER)

INITIAL	FINAL
11.9	11.6

STACK GAS VELOCITY (ft/sec)

INITIAL	FINAL
70.56	65.82

	WIND TUNNEL ABSORBANCE	WIND TUNNEL CONCENTRATION (ppm)	SAMPLE ABSORBANCE	SAMPLE CONCENTRATION (ppm)	DILUTION RATIO	SAMPLE TIME (min)
1	0.954	193	0.375	18	10.9	37
2	0.959	202	0.381	18	11.2	32

REPORT NUMBER 27

PROBE CONFIGURATION 1/4 ACD

VENTURI MANOMETER READING (INCHES OF WATER)

INITIAL	FINAL
18.8	18.7

STACK GAS VELOCITY (ft/sec)

INITIAL	FINAL
72.70	68.33

	WIND TUNNEL ABSORBANCE	WIND TUNNEL CONCENTRATION (ppm)	SAMPLE ABSORBANCE	SAMPLE CONCENTRATION (ppm)	DILUTION RATIO	SAMPLE TIME (min)
1	0.911	142	0.414	21	6.8	13
2	0.914	145	0.426	22	6.[illegible]	14

REPORT NUMBER 27

PROBE CONFIGURATION 1/4 ACD

VENTURI MANOMETER READING (INCHES OF WATER)

INITIAL	FINAL
11.5	11.3

STACK GAS VELOCITY (ft/sec)

INITIAL	FINAL
72.70	68.33

	WIND TUNNEL ABSORBANCE	WIND TUNNEL CONCENTRATION (ppm)	SAMPLE ABSORBANCE	SAMPLE CONCENTRATION (ppm)	DILUTION RATIO	SAMPLE TIME (min)
1	0.931	161	0.451	24	6.7	40
2	0.935	166	0.434	23	7.4	35

REPORT NUMBER 28

PROBE CONFIGURATION 1/8 BCD

VENTURI MANOMETER READING (INCHES OF WATER)

INITIAL	FINAL
19.6	19.5

STACK GAS VELOCITY (ft/sec)

INITIAL	FINAL
72.71	70.81

	WIND TUNNEL ABSORBANCE	WIND TUNNEL CONCENTRATION (ppm)	SAMPLE ABSORBANCE	SAMPLE CONCENTRATION (ppm)	DILUTION RATIO	SAMPLE TIME (min)
1	0.908	140	0.367	17	8.2	11
2	0.908	140	0.387	16	8.6	12

REPORT NUMBER 28

PROBE CONFIGURATION 1/8 BCD

VENTURI MANOMETER READING (INCHES OF WATER)

INITIAL	FINAL
11.3	10.3

STACK GAS VELOCITY (ft/sec)

INITIAL	FINAL
72.71	70.81

	WIND TUNNEL ABSORBANCE	WIND TUNNEL CONCENTRATION (ppm)	SAMPLE ABSORBANCE	SAMPLE CONCENTRATION (ppm)	DILUTION RATIO	SAMPLE TIME (min)
1	0.924	154	0.334	15	10.5	34
2	0.923	153	0.374	18	8.7	29

REPORT NUMBER 29

PROBE CONFIGURATION 1/4 BCD

VENTURI MANOMETER READING (INCHES OF WATER)

INITIAL	FINAL
19.1	18.7

STACK GAS VELOCITY (ft/sec)

INITIAL	FINAL
72.06	67.10

	WIND TUNNEL ABSORBANCE	WIND TUNNEL CONCENTRATION (ppm)	SAMPLE ABSORBANCE	SAMPLE CONCENTRATION (ppm)	DILUTION RATIO	SAMPLE TIME (min)
1	0.929	159	0.425	22	7.3	23
2	0.926	156	0.433	22	7.0	24

REPORT NUMBER 29

PROBE CONFIGURATION 1/4 BCD

VENTURI MANOMETER READING (INCHES OF WATER)

INITIAL	FINAL
9.4	9.1

STACK GAS VELOCITY (ft/sec)

INITIAL	FINAL
72.06	67.10

	WIND TUNNEL ABSORBANCE	WIND TUNNEL CONCENTRATION (ppm)	SAMPLE ABSORBANCE	SAMPLE CONCENTRATION (ppm)	DILUTION RATIO	SAMPLE TIME (min)
1	0.945	179	0.444	23	7.6	36
2	0.946	181	0.444	23	7.7	37

REPORT NUMBER 30

PROBE CONFIGURATION 1/8 AB

VENTURI MANOMETER READING (INCHES OF WATER)

INITIAL	FINAL
19.5	19.8

STACK GAS VELOCITY (ft/sec)

INITIAL	FINAL
71.45	69.58

	WIND TUNNEL ABSORBANCE	WIND TUNNEL CONCENTRATION (ppm)	SAMPLE ABSORBANCE	SAMPLE CONCENTRATION (ppm)	DILUTION RATIO	SAMPLE TIME (min)
1	0.916	146	0.271	11	13.7	13
2	0.912	143	0.267	10	13.7	15

REPORT NUMBER 30

PROBE CONFIGURATION 1/8 AB

VENTURI MANOMETER READING (INCHES OF WATER)

INITIAL	FINAL
12.4	12.0

STACK GAS VELOCITY (ft/sec)

INITIAL	FINAL
71.45	69.59

	WIND TUNNEL ABSORBANCE	WIND TUNNEL CONCENTRATION (ppm)	SAMPLE ABSORBANCE	SAMPLE CONCENTRATION (ppm)	DILUTION RATIO	SAMPLE TIME (min)
1	0.926	156	0.252	10	16.3	36
2	0.928	158	0.280	11	14.1	36

REPORT NUMBER 31

PROBE CONFIGURATION 1/4 AB

VENTURI MANOMETER READING (INCHES OF WATER)

INITIAL	FINAL
19.0	19.4

STACK GAS VELOCITY (ft/sec)

INITIAL	FINAL
73.06	71.05

	WIND TUNNEL ABSORBANCE	WIND TUNNEL CONCENTRATION (ppm)	SAMPLE ABSORBANCE	SAMPLE CONCENTRATION (ppm)	DILUTION RATIO	SAMPLE TIME (min)
1	0.916	146	0.337	15	9.8	13
2	0.916	146	0.339	15	9.7	13

REPORT NUMBER 31

PROBE CONFIGURATION 1/4 AB

VENTURI MANOMETER READING (INCHES OF WATER)

INITIAL	FINAL
10.4	10.3

STACK GAS VELOCITY (ft/sec)

INITIAL	FINAL
73.07	71.05

	WIND TUNNEL ABSORBANCE	WIND TUNNEL CONCENTRATION (ppm)	SAMPLE ABSORBANCE	SAMPLE CONCENTRATION (ppm)	DILUTION RATIO	SAMPLE TIME (min)
1	0.930	160	0.373	18	9.2	33
2	0.930	160	0.375	18	9.1	31

REPORT NUMBER 32

PROBE CONFIGURATION 1/8 AC

VENTURI MANOMETER READING (INCHES OF WATER)

INITIAL	FINAL
19.7	19.6

STACK GAS VELOCITY (ft/sec)

INITIAL	FINAL
71.70	69.10

	WIND TUNNEL ABSORBANCE	WIND TUNNEL CONCENTRATION (ppm)	SAMPLE ABSORBANCE	SAMPLE CONCENTRATION (ppm)	DILUTION RATIO	SAMPLE TIME (min)
1	0.907	139	0.304	13	10.9	20
2	0.908	140	0.308	13	10.8	17

REPORT NUMBER 32

PROBE CONFIGURATION 1/8 AC

VENTURI MANOMETER READING (INCHES OF WATER)

INITIAL	FINAL
14.8	14.7

STACK GAS VELOCITY (ft/sec)

INITIAL	FINAL
71.70	69.10

	WIND TUNNEL ABSORBANCE	WIND TUNNEL CONCENTRATION (ppm)	SAMPLE ABSORBANCE	SAMPLE CONCENTRATION (ppm)	DILUTION RATIO	SAMPLE TIME (min)
1	0.921	151	0.320	14	11.0	31
2	0.920	150	0.319	14	11.0	28

REPORT NUMBER 33

PROBE CONFIGURATION 1/4 AC

VENTURI MANOMETER READING (INCHES OF WATER)

INITIAL	FINAL
18.8	18.8

STACK GAS VELOCITY (ft/sec)

INITIAL	FINAL
72.83	66.00

	WIND TUNNEL		SAMPLE		DILUTION	SAMPLE
	ABSORBANCE	CONCENTRATION (ppm)	ABSORBANCE	CONCENTRATION (ppm)	RATIO	TIME (min)
1	0.940	172	0.365	17	10.2	18
2	0.947	182	0.407	20	9.0	13

REPORT NUMBER 33

PROBE CONFIGURATION 1/4 AC

VENTURI MANOMETER READING (INCHES OF WATER)

INITIAL	FINAL
10.8	10.7

STACK GAS VELOCITY (ft/sec)

INITIAL	FINAL
72.83	66.00

	WIND TUNNEL		SAMPLE		DILUTION	SAMPLE
	ABSORBANCE	CONCENTRATION (ppm)	ABSORBANCE	CONCENTRATION (ppm)	RATIO	TIME (min)
1	0.963	211	0.450	24	8.8	32
2	0.961	206	0.457	25	8.4	26

REPORT NUMBER 34

PROBE CONFIGURATION 1/4 AD

VENTURI MANOMETER READING (INCHES OF WATER)

INITIAL	FINAL
19.4	19.3

STACK GAS VELOCITY (ft/sec)

INITIAL	FINAL
70.90	67.58

	WIND TUNNEL ABSORBANCE	WIND TUNNEL CONCENTRATION (ppm)	SAMPLE ABSORBANCE	SAMPLE CONCENTRATION (ppm)	DILUTION RATIO	SAMPLE TIME (min)
1	0.908	140	0.324	14	10.0	13
2	0.934	165	0.361	17	9.9	13

REPORT NUMBER 34

PROBE CONFIGURATION 1/4 AD

VENTURI MANOMETER READING (INCHES OF WATER)

INITIAL	FINAL
12.7	12.4

STACK GAS VELOCITY (ft/sec)

INITIAL	FINAL
70.90	67.58

	WIND TUNNEL ABSORBANCE	WIND TUNNEL CONCENTRATION (ppm)	SAMPLE ABSORBANCE	SAMPLE CONCENTRATION (ppm)	DILUTION RATIO	SAMPLE TIME (min)
1	0.947	182	0.374	18	10.3	29
2	0.948	183	0.376	18	10.3	28

REPORT NUMBER 35

PROBE CONFIGURATION 1/8 AD

VENTURI MANOMETER READING (INCHES OF WATER)

INITIAL	FINAL
20.0	20.0

STACK GAS VELOCITY (ft/sec)

INITIAL	FINAL
71.59	70.43

	WIND TUNNEL ABSORBANCE	WIND TUNNEL CONCENTRATION (ppm)	SAMPLE ABSORBANCE	SAMPLE CONCENTRATION (ppm)	DILUTION RATIO	SAMPLE TIME (min)
1	0.933	164	0.317	14	12.1	13
2	0.935	166	0.319	14	12.1	13

REPORT NUMBER 35

PROBE CONFIGURATION 1/8 AD

VENTURI MANOMETER READING (INCHES OF WATER)

INITIAL	FINAL
12.3	12.2

STACK GAS VELOCITY (ft/sec)

INITIAL	FINAL
71.59	70.43

	WIND TUNNEL ABSORBANCE	WIND TUNNEL CONCENTRATION (ppm)	SAMPLE ABSORBANCE	SAMPLE CONCENTRATION (ppm)	DILUTION RATIO	SAMPLE TIME (min)
1	0.948	183	0.313	13	13.8	36
2	0.948	183	0.337	15	12.3	27

REPORT NUMBER 36

PROBE CONFIGURATION 1/8 BC

VENTURI MANOMETER READING (INCHES OF WATER)

INITIAL	FINAL
20.2	20.2

STACK GAS VELOCITY (ft/sec)

INITIAL	FINAL
69.69	66.61

	WIND TUNNEL ABSORBANCE	WIND TUNNEL CONCENTRATION (ppm)	SAMPLE ABSORBANCE	SAMPLE CONCENTRATION (ppm)	DILUTION RATIO	SAMPLE TIME (min)
1	0.915	146	0.296	12	12.0	16
2	0.909	140	0.294	12	11.7	8

REPORT NUMBER 36

PROBE CONFIGURATION 1/8 BC

VENTURI MANOMETER READING (INCHES OF WATER)

INITIAL	FINAL
12.1	12.1

STACK GAS VELOCITY (ft/sec)

INITIAL	FINAL
69.69	66.61

	WIND TUNNEL ABSORBANCE	WIND TUNNEL CONCENTRATION (ppm)	SAMPLE ABSORBANCE	SAMPLE CONCENTRATION (ppm)	DILUTION RATIO	SAMPLE TIME (min)
1	0.913	144	0.300	12	11.6	30
2	0.912	143	0.302	13	11.4	32

REPORT NUMBER 37

PROBE CONFIGURATION 1/4 BC

VENTURI MANOMETER READING (INCHES OF WATER)

INITIAL	FINAL
19.5	19.6

STACK GAS VELOCITY (ft/sec)

INITIAL	FINAL
71.36	69.63

	WIND TUNNEL ABSORBANCE	WIND TUNNEL CONCENTRATION (ppm)	SAMPLE ABSORBANCE	SAMPLE CONCENTRATION (ppm)	DILUTION RATIO	SAMPLE TIME (min)
1	0.913	144	0.372	17	8.2	32
2	0.913	144	0.374	18	8.2	32
3	0.915	146	0.347	16	9.3	32
4	0.913	144	0.384	18	7.8	29

REPORT NUMBER 38

PROBE CONFIGURATION 1/4 BD

VENTURI MANOMETER READING (INCHES OF WATER)

INITIAL	FINAL
19.7	19.3

STACK GAS VELOCITY (ft/sec)

INITIAL	FINAL
71.42	67.66

	WIND TUNNEL ABSORBANCE	WIND TUNNEL CONCENTRATION (ppm)	SAMPLE ABSORBANCE	SAMPLE CONCENTRATION (ppm)	DILUTION RATIO	SAMPLE TIME (min)
1	0.899	133	0.349	16	8.4	12
2	0.897	131	0.350	16	8.3	17

REPORT NUMBER 38

PROBE CONFIGURATION 1/4 BD

VENTURI MANOMETER READING (INCHES OF WATER)

INITIAL	FINAL
12.5	12.2

STACK GAS VELOCITY (ft/sec)

INITIAL	FINAL
71.42	67.66

	WIND TUNNEL		SAMPLE		DILUTION RATIO	SAMPLE TIME (min)
	ABSORBANCE	CONCENTRATION (ppm)	ABSORBANCE	CONCENTRATION (ppm)		
1	0.906	138	0.355	16	8.5	21
2	0.910	141	0.368	17	8.2	23

REPORT NUMBER 39

PROBE CONFIGURATION 1/4 CD

VENTURI MANOMETER READING (INCHES OF WATER)

INITIAL	FINAL
19.4	19.0

STACK GAS VELOCITY (ft/sec)

INITIAL	FINAL
71.87	71.54

	WIND TUNNEL		SAMPLE		DILUTION RATIO	SAMPLE TIME (min)
	ABSORBANCE	CONCENTRATION (ppm)	ABSORBANCE	CONCENTRATION (ppm)		
1	0.928	158	0.398	19	8.1	20
2	0.932	163	0.403	20	8.2	23

REPORT NUMBER 39

PROBE CONFIGURATION 1/4 CD

VENTURI MANOMETER READING (INCHES OF WATER)

INITIAL	FINAL
14.6	14.1

STACK GAS VELOCITY (ft/sec)

INITIAL	FINAL
71.87	71.54

	WIND TUNNEL ABSORBANCE	WIND TUNNEL CONCENTRATION (ppm)	SAMPLE ABSORBANCE	SAMPLE CONCENTRATION (ppm)	DILUTION RATIO	SAMPLE TIME (min)
1	0.939	171	0.411	21	8.3	35
2	0.937	168	0.415	21	8.1	39

REPORT NUMBER 40

PROBE CONFIGURATION 1/8 BD

VENTURI MANOMETER READING (INCHES OF WATER)

INITIAL	FINAL
20.5	20.2

STACK GAS VELOCITY (ft/sec)

INITIAL	FINAL
72.38	68.91

	WIND TUNNEL ABSORBANCE	WIND TUNNEL CONCENTRATION (ppm)	SAMPLE ABSORBANCE	SAMPLE CONCENTRATION (ppm)	DILUTION RATIO	SAMPLE TIME (min)
1	0.924	154	0.271	11	14.4	13
2	0.919	149	0.281	11	13.3	11

REPORT NUMBER 40

PROBE CONFIGURATION 1/8 BD

VENTURI MANOMETER READING (INCHES OF WATER)

INITIAL	FINAL
11.1	11.0

STACK GAS VELOCITY (ft/sec)

INITIAL	FINAL
72.38	68.91

	WIND TUNNEL ABSORBANCE	WIND TUNNEL CONCENTRATION (ppm)	SAMPLE ABSORBANCE	SAMPLE CONCENTRATION (ppm)	DILUTION RATIO	SAMPLE TIME (min)
1	0.928	158	0.284	11	13.8	31
2	0.928	158	0.284	11	13.8	32.

REPORT NUMBER 41

PROBE CONFIGURATION 1/8 CD

VENTURI MANOMETER READING (INCHES OF WATER)

INITIAL	FINAL
20.3	20.3

STACK GAS VELOCITY (ft/sec)

INITIAL	FINAL
72.71	70.17

	WIND TUNNEL ABSORBANCE	WIND TUNNEL CONCENTRATION (ppm)	SAMPLE ABSORBANCE	SAMPLE CONCENTRATION (ppm)	DILUTION RATIO	SAMPLE TIME (min)
1	0.898	132	0.297	12	10.8	15
2	0.898	132	0.297	12	10.8	17

REPORT NUMBER 41

PROBE CONFIGURATION 1/8 CD

VENTURI MANOMETER READING (INCHES OF WATER)

INITIAL	FINAL
13.7	13.3

STACK GAS VELOCITY (ft/sec)

INITIAL	FINAL
72.71	70.17

	WIND TUNNEL ABSORBANCE	WIND TUNNEL CONCENTRATION (ppm)	SAMPLE ABSORBANCE	SAMPLE CONCENTRATION (ppm)	DILUTION RATIO	SAMPLE TIME (min)
1	0.912	143	0.279	11	12.8	37
2	0.912	143	0.312	13	10.8	31

REPORT NUMBER 42

PROBE CONFIGURATION 1/8 ABCD

VENTURI MANOMETER READING (INCHES OF WATER)

INITIAL	FINAL
19.3	19.1

STACK GAS VELOCITY (ft/sec)

INITIAL	FINAL
34.16	32.36

	WIND TUNNEL ABSORBANCE	WIND TUNNEL CONCENTRATION (ppm)	SAMPLE ABSORBANCE	SAMPLE CONCENTRATION (ppm)	DILUTION RATIO	SAMPLE TIME (min)
1	0.875	117	0.356	16	7.2	9
2	0.873	116	0.357	16	7.1	10
3	0.872	116	0.360	17	7.0	13
4	0.870	114	0.358	16	7.0	14

REPORT NUMBER 43

PROBE CONFIGURATION 1/8 ABCD

VENTURI MANOMETER READING (INCHES OF WATER)

INITIAL	FINAL
5.1	4.6

STACK GAS VELOCITY (ft/sec)

INITIAL	FINAL
34.16	32.36

	WIND TUNNEL ABSORBANCE	WIND TUNNEL CONCENTRATION (ppm)	SAMPLE ABSORBANCE	SAMPLE CONCENTRATION (ppm)	DILUTION RATIO	SAMPLE TIME (min)
1	0.944	178	0.403	20	8.9	33
2	0.955	195	0.459	25	7.8	30
3	0.954	193	0.461	25	7.7	30
4	0.955	195	0.461	25	7.8	25

REPORT NUMBER 44

PROBE CONFIGURATION 1/4 ABCD

VENTURI MANOMETER READING (INCHES OF WATER)

INITIAL	FINAL
3.7	3.7

STACK GAS VELOCITY (ft/sec)

INITIAL	FINAL
35.22	35.15

	WIND TUNNEL ABSORBANCE	WIND TUNNEL CONCENTRATION (ppm)	SAMPLE ABSORBANCE	SAMPLE CONCENTRATION (ppm)	DILUTION RATIO	SAMPLE TIME (min)
1	0.927	157	0.468	26	6.1	41
2	0.930	160	0.470	26	6.2	37
3	0.929	159	0.474	26	6.1	36
4	0.926	156	0.470	26	6.0	53

REPORT NUMBER 45

PROBE CONFIGURATION 1/4 ABCD

VENTURI MANOMETER READING (INCHES OF WATER)

INITIAL	FINAL
18.8	19.0

STACK GAS VELOCITY (ft/sec)

INITIAL	FINAL
35.22	35.15

	WIND TUNNEL ABSORBANCE	WIND TUNNEL CONCENTRATION (ppm)	SAMPLE ABSORBANCE	SAMPLE CONCENTRATION (ppm)	DILUTION RATIO	SAMPLE TIME (min)
1	0.868	113	0.382	18	6.2	10
2	0.840	100	0.378	18	5.6	9
3	0.838	99	0.373	18	5.7	10
4	0.838	99	0.376	18	5.6	9

REPORT NUMBER 46

PROBE CONFIGURATION 1/8 A

VENTURI MANOMETER READING (INCHES OF WATER)

INITIAL	FINAL
20.2	20.1

STACK GAS VELOCITY (ft/sec)

INITIAL	FINAL
36.11	34.84

	WIND TUNNEL ABSORBANCE	WIND TUNNEL CONCENTRATION (ppm)	SAMPLE ABSORBANCE	SAMPLE CONCENTRATION (ppm)	DILUTION RATIO	SAMPLE TIME (min)
1	0.886	124	0.218	8	16.0	11
2	0.880	120	0.215	8	15.8	10
3	0.877	118	0.216	8	15.5	11
4	0.879	120	0.213	7	16.0	12

REPORT NUMBER 47

PROBE CONFIGURATION 1/8 A

VENTURI MANOMETER READING (INCHES OF WATER)

INITIAL	FINAL
7.8	7.4

STACK GAS VELOCITY (ft/sec)

INITIAL	FINAL
36.11	34.84

	WIND TUNNEL ABSORBANCE	WIND TUNNEL CONCENTRATION (ppm)	SAMPLE ABSORBANCE	SAMPLE CONCENTRATION (ppm)	DILUTION RATIO	SAMPLE TIME (min)
1	0.932	163	0.225	8	20.0	29
2	0.937	168	0.247	9	18.1	32
3	0.936	167	0.255	10	17.2	32
4	0.934	165	0.260	10	16.4	33

REPORT NUMBER 48

PROBE CONFIGURATION 1/4 A

VENTURI MANOMETER READING (INCHES OF WATER)

INITIAL	FINAL
5.8	5.8

STACK GAS VELOCITY (ft/sec)

INITIAL	FINAL
36.23	35.69

	WIND TUNNEL ABSORBANCE	WIND TUNNEL CONCENTRATION (ppm)	SAMPLE ABSORBANCE	SAMPLE CONCENTRATION (ppm)	DILUTION RATIO	SAMPLE TIME (min)
1	0.917	147	0.295	12	12.2	31
2	0.910	141	0.289	12	12.0	34
3	0.906	138	0.284	11	12.1	32
4	0.906	138	0.283	11	12.1	38

REPORT NUMBER 49

PROBE CONFIGURATION 1/4 A

VENTURI MANOMETER READING (INCHES OF WATER)

INITIAL	FINAL
19.4	19.8

STACK GAS VELOCITY (ft/sec)

INITIAL	FINAL
35.69	35.60

	WIND TUNNEL ABSORBANCE	WIND TUNNEL CONCENTRATION (ppm)	SAMPLE ABSORBANCE	SAMPLE CONCENTRATION (ppm)	DILUTION RATIO	SAMPLE TIME (min)
1	0.826	94	0.208	7	13.0	16
2	0.796	83	0.211	7	11.3	14
3	0.793	82	0.210	7	11.2	13
4	0.794	83	0.220	8	10.5	13

REPORT NUMBER 50

PROBE CONFIGURATION 1/8 C

VENTURI MANOMETER READING (INCHES OF WATER)

INITIAL	FINAL
5.9	5.8

STACK GAS VELOCITY (ft/sec)

INITIAL	FINAL
35.33	34.17

	WIND TUNNEL ABSORBANCE	WIND TUNNEL CONCENTRATION (ppm)	SAMPLE ABSORBANCE	SAMPLE CONCENTRATION (ppm)	DILUTION RATIO	SAMPLE TIME (min)
1	0.949	185	0.280	11	16.5	35
2	0.944	178	0.271	11	16.7	45
3	0.941	174	0.271	11	16.3	40
4	0.944	178	0.275	11	16.3	45

REPORT NUMBER 51

PROBE CONFIGURATION 1/8 C

VENTURI MANOMETER READING (INCHES OF WATER)

INITIAL	FINAL
20.1	20.5

STACK GAS VELOCITY (ft/sec)

INITIAL	FINAL
34.18	33.90

	WIND TUNNEL ABSORBANCE	WIND TUNNEL CONCENTRATION (ppm)	SAMPLE ABSORBANCE	SAMPLE CONCENTRATION (ppm)	DILUTION RATIO	SAMPLE TIME (min)
1	0.876	118	0.217	8	15.3	15
2	0.864	111	0.226	8	13.6	12
3	0.865	112	0.224	8	13.9	14
4	0.863	111	0.227	8	13.5	16

REPORT NUMBER 52

PROBE CONFIGURATION 1/16 C

VENTURI MANOMETER READING (INCHES OF WATER)

INITIAL	FINAL
4.9	4.6

STACK GAS VELOCITY (ft/sec)

INITIAL	FINAL
35.75	34.38

	WIND TUNNEL ABSORBANCE	WIND TUNNEL CONCENTRATION (ppm)	SAMPLE ABSORBANCE	SAMPLE CONCENTRATION (ppm)	DILUTION RATIO	SAMPLE TIME (min)
1	0.910	141	0.111	3	46.6	53
2	0.911	142	0.112	3	46.3	44
3	0.912	143	0.117	3	43.9	34
4	0.913	144	0.117	3	44.2	35

REPORT NUMBER 53

PROBE CONFIGURATION 1/16 C

VENTURI MANOMETER READING (INCHES OF WATER)

INITIAL	FINAL
20.5	20.9

STACK GAS VELOCITY (ft/sec)

INITIAL	FINAL
34.39	34.61

	WIND TUNNEL		SAMPLE		DILUTION RATIO	SAMPLE TIME (min)
	ABSORBANCE	CONCENTRATION (ppm)	ABSORBANCE	CONCENTRATION (ppm)		
1	0.815	90	0.101	3	33.7	9
2	0.797	84	0.098	3	32.6	10
3	0.793	82	0.091	2	35.5	10
4	0.791	82	0.098	3	31.9	10

REPORT NUMBER 54

PROBE CONFIGURATION 1/16 A

VENTURI MANOMETER READING (INCHES OF WATER)

INITIAL	FINAL
5.6	5.2

STACK GAS VELOCITY (ft/sec)

INITIAL	FINAL
34.54	33.70

	WIND TUNNEL		SAMPLE		DILUTION RATIO	SAMPLE TIME (min)
	ABSORBANCE	CONCENTRATION (ppm)	ABSORBANCE	CONCENTRATION (ppm)		
1	0.952	190	0.097	3	75.1	33
2	0.949	185	0.100	3	70.2	33
3	0.951	188	0.106	3	66.[illegible]	35
4	0.952	190	0.109	3	64.2	35

REPORT NUMBER 55

PROBE CONFIGURATION 1/16 A

VENTURI MANOMETER READING (INCHES OF WATER)

INITIAL	FINAL
20.1	20.4

STACK GAS VELOCITY (ft/sec)

INITIAL	FINAL
34.04	33.76

	WIND TUNNEL ABSORBANCE	WIND TUNNEL CONCENTRATION (ppm)	SAMPLE ABSORBANCE	SAMPLE CONCENTRATION (ppm)	DILUTION RATIO	SAMPLE TIME (min)
1	0.869	114	0.111	3	37.6	14
2	0.851	105	0.110	3	35.0	19
3	0.848	103	0.096	2	41.5	14
4	0.849	104	0.118	3	31.5	13

REPORT NUMBER 56

PROBE CONFIGURATION 1/16 ABCD

VENTURI MANOMETER READING (INCHES OF WATER)

INITIAL	FINAL
5.4	5.1

STACK GAS VELOCITY (ft/sec)

INITIAL	FINAL
35.03	33.86

	WIND TUNNEL ABSORBANCE	WIND TUNNEL CONCENTRATION (ppm)	SAMPLE ABSORBANCE	SAMPLE CONCENTRATION (ppm)	DILUTION RATIO	SAMPLE TIME (min)
1	0.931	161	0.197	7	24.1	36
2	0.928	158	0.203	7	22.6	50
3	0.921	151	0.200	7	22.1	38
4	0.919	149	0.195	7	22.6	38

REPORT NUMBER 57

PROBE CONFIGURATION 1/16 ABCD

VENTURI MANOMETER READING (INCHES OF WATER)

INITIAL	FINAL
20.0	20.1

STACK GAS VELOCITY (ft/sec)

INITIAL	FINAL
34.13	33.94

	WIND TUNNEL ABSORBANCE	WIND TUNNEL CONCENTRATION (ppm)	SAMPLE ABSORBANCE	SAMPLE CONCENTRATION (ppm)	DILUTION RATIO	SAMPLE TIME (min)
1	0.831	96	0.176	6	16.8	12
2	0.802	85	0.169	5	15.8	12
3	0.797	84	0.160	5	16.7	11
4	0.794	83	0.170	5	15.2	10

REPORT NUMBER 58

PROBE CONFIGURATION 1/4 C

VENTURI MANOMETER READING (INCHES OF WATER)

INITIAL	FINAL
8.7	8.9

STACK GAS VELOCITY (ft/sec)

INITIAL	FINAL
35.91	35.02

	WIND TUNNEL ABSORBANCE	WIND TUNNEL CONCENTRATION (ppm)	SAMPLE ABSORBANCE	SAMPLE CONCENTRATION (ppm)	DILUTION RATIO	SAMPLE TIME (min)
1	0.932	163	0.329	14	11.3	24
2	0.931	161	0.341	15	10.6	34
3	0.929	159	0.336	15	10.7	21
4	0.928	158	0.334	15	10.8	22

REPORT NUMBER 59

PROBE CONFIGURATION 1/4 C

VENTURI MANOMETER READING (INCHES OF WATER)

INITIAL	FINAL
20.1	20.4

STACK GAS VELOCITY (ft/sec)

INITIAL	FINAL
35.02	35.03

	WIND TUNNEL ABSORBANCE	WIND TUNNEL CONCENTRATION (ppm)	SAMPLE ABSORBANCE	SAMPLE CONCENTRATION (ppm)	DILUTION RATIO	SAMPLE TIME (min)
1	0.885	123	0.297	12	10.1	9
2	0.876	118	0.293	12	9.8	13
3	0.875	117	0.268	10	11.2	12
4	0.876	118	0.300	12	9.5	18

REPORT NUMBER 60

PROBE CONFIGURATION 1/16 ABCD

VENTURI MANOMETER READING (INCHES OF WATER)

INITIAL	FINAL
13.4	13.3

STACK GAS VELOCITY (ft/sec)

INITIAL	FINAL
69.86	66.20

	WIND TUNNEL ABSORBANCE	WIND TUNNEL CONCENTRATION (ppm)	SAMPLE ABSORBANCE	SAMPLE CONCENTRATION (ppm)	DILUTION RATIO	SAMPLE TIME (min)
1	0.932	163	0.330	14	11.3	35
2	0.931	161	0.340	15	10.7	35
3	0.929	159	0.336	15	10.7	32
4	0.928	158	0.333	15	10.8	35

REPORT NUMBER 61

PROBE CONFIGURATION 1/16 ABCD

VENTURI MANOMETER READING (INCHES OF WATER)

INITIAL	FINAL
20.6	20.7

STACK GAS VELOCITY (ft/sec)

INITIAL	FINAL
71.10	70.16

	WIND TUNNEL ABSORBANCE	WIND TUNNEL CONCENTRATION (ppm)	SAMPLE ABSORBANCE	SAMPLE CONCENTRATION (ppm)	DILUTION RATIO	SAMPLE TIME (min)
1	0.885	123	0.297	12	10.1	18
2	0.876	118	0.292	12	9.9	18
3	0.875	117	0.268	10	11.2	19
4	0.876	118	0.300	12	9.5	19

REPORT NUMBER 62

PROBE CONFIGURATION 1/16 ABCD

VENTURI MANOMETER READING (INCHES OF WATER)

INITIAL	FINAL
20.7	20.7

STACK GAS VELOCITY (ft/sec)

INITIAL	FINAL
88.27	81.20

	WIND TUNNEL ABSORBANCE	WIND TUNNEL CONCENTRATION (ppm)	SAMPLE ABSORBANCE	SAMPLE CONCENTRATION (ppm)	DILUTION RATIO	SAMPLE TIME (min)
1	0.899	133	0.216	8	17.4	40
2	0.895	130	0.224	8	16.1	40
3	0.894	129	0.215	8	17.0	22
4	0.891	127	0.211	7	17.2	40

REPORT NUMBER 63

PROBE CONFIGURATION 1/16 A

VENTURI MANOMETER READING (INCHES OF WATER)

INITIAL	FINAL
16.9	17.2

STACK GAS VELOCITY (ft/sec)

INITIAL	FINAL
69.23	70.15

	WIND TUNNEL ABSORBANCE	WIND TUNNEL CONCENTRATION (ppm)	SAMPLE ABSORBANCE	SAMPLE CONCENTRATION (ppm)	DILUTION RATIO	SAMPLE TIME (min)
1	0.873	116	0.114	3	36.9	28
2	0.872	116	0.108	3	39.6	32
3	0.870	114	0.096	2	45.9	38
4	0.868	113	0.107	3	39.3	28

REPORT NUMBER 64

PROBE CONFIGURATION 1/16 A

VENTURI MANOMETER READING (INCHES OF WATER)

INITIAL	FINAL
21.0	20.9

STACK GAS VELOCITY (ft/sec)

INITIAL	FINAL
70.15	70.15

	WIND TUNNEL ABSORBANCE	WIND TUNNEL CONCENTRATION (ppm)	SAMPLE ABSORBANCE	SAMPLE CONCENTRATION (ppm)	DILUTION RATIO	SAMPLE TIME (min)
1	0.892	128	0.112	3	41.7	23
2	0.893	129	0.114	3	40.9	21
3	0.893	129	0.117	3	39.5	18
4	0.891	127	0.121	3	37.3	19

REPORT NUMBER 65

PROBE CONFIGURATION 1/16 C

VENTURI MANOMETER READING (INCHES OF WATER)

INITIAL	FINAL
12.2	12.8

STACK GAS VELOCITY (ft/sec)

INITIAL	FINAL
67.43	63.57

	WIND TUNNEL ABSORBANCE	WIND TUNNEL CONCENTRATION (ppm)	SAMPLE ABSORBANCE	SAMPLE CONCENTRATION (ppm)	DILUTION RATIO	SAMPLE TIME (min)
1	0.911	142	0.095	2	57.8	56
2	0.910	141	0.114	3	45.0	45
3	0.911	142	0.104	3	51.2	36
4	0.909	140	0.115	3	44.2	35

REPORT NUMBER 66

PROBE CONFIGURATION 1/16 C

VENTURI MANOMETER READING (INCHES OF WATER)

INITIAL	FINAL
21.1	21.0

STACK GAS VELOCITY (ft/sec)

INITIAL	FINAL
69.82	68.56

	WIND TUNNEL ABSORBANCE	WIND TUNNEL CONCENTRATION (ppm)	SAMPLE ABSORBANCE	SAMPLE CONCENTRATION (ppm)	DILUTION RATIO	SAMPLE TIME (min)
1	0.883	122	0.099	3	47.0	22
2	0.881	121	0.098	3	47.1	17
3	0.881	121	0.088	2	54.4	25
4	0.880	120	0.104	3	43.3	23

REPORT NUMBER 67

PROBE CONFIGURATION 1/16 C

VENTURI MANOMETER READING (INCHES OF WATER)

INITIAL	FINAL
21.2	21.4

STACK GAS VELOCITY (ft/sec)

INITIAL	FINAL
89.19	83.45

	WIND TUNNEL ABSORBANCE	WIND TUNNEL CONCENTRATION (ppm)	SAMPLE ABSORBANCE	SAMPLE CONCENTRATION (ppm)	DILUTION RATIO	SAMPLE TIME (min)
1	0.881	121	0.107	3	41.9	30
2	0.874	117	0.112	3	38.0	29
3	0.877	118	0.116	3	36.8	25
4	0.879	120	0.113	3	38.5	20

REPORT NUMBER 68

PROBE CONFIGURATION 1/16 A

VENTURI MANOMETER READING (INCHES OF WATER)

INITIAL	FINAL
21.2	21.7

STACK GAS VELOCITY (ft/sec)

INITIAL	FINAL
87.59	80.74

	WIND TUNNEL ABSORBANCE	WIND TUNNEL CONCENTRATION (ppm)	SAMPLE ABSORBANCE	SAMPLE CONCENTRATION (ppm)	DILUTION RATIO	SAMPLE TIME (min)
1	0.882	121	0.112	3	39.6	29
2	0.864	111	0.123	3	31.9	38
3	0.868	113	0.125	4	31.8	50
4	0.877	118	0.126	4	32.9	25

REPORT NUMBER 69

PROBE CONFIGURATION 1/16 B

VENTURI MANOMETER READING (INCHES OF WATER)

INITIAL	FINAL
21.7	21.4

STACK GAS VELOCITY (ft/sec)

INITIAL	FINAL
70.60	71.43

	WIND TUNNEL ABSORBANCE	WIND TUNNEL CONCENTRATION (ppm)	SAMPLE ABSORBANCE	SAMPLE CONCENTRATION (ppm)	DILUTION RATIO	SAMPLE TIME (min)
1	0.892	128	0.130	4	34.0	18
2	0.893	129	0.140	4	30.9	16
3	0.892	125	0.133	4	33.0	22
4	0.891	127	0.129	4	34.2	15

REPORT NUMBER 70

PROBE CONFIGURATION 1/16 B

VENTURI MANOMETER READING (INCHES OF WATER)

INITIAL	FINAL
13.6	14.1

STACK GAS VELOCITY (ft/sec)

INITIAL	FINAL
71.74	71.62

	WIND TUNNEL ABSORBANCE	WIND TUNNEL CONCENTRATION (ppm)	SAMPLE ABSORBANCE	SAMPLE CONCENTRATION (ppm)	DILUTION RATIO	SAMPLE TIME (min)
1	0.903	136	0.127	4	37.3	29
2	0.903	136	0.127	4	37.3	29
3	0.899	133	0.127	4	36.5	35
4	0.898	132	0.131	4	34.8	26

REPORT NUMBER 71

PROBE CONFIGURATION 1/16 B

VENTURI MANOMETER READING (INCHES OF WATER)

INITIAL	FINAL
22.3	20.5

STACK GAS VELOCITY (ft/sec)

INITIAL	FINAL
91.99	82.43

	WIND TUNNEL ABSORBANCE	WIND TUNNEL CONCENTRATION (ppm)	SAMPLE ABSORBANCE	SAMPLE CONCENTRATION (ppm)	DILUTION RATIO	SAMPLE TIME (min)
1	0.884	123	0.088	2	55.2	32
2	0.892	128	0.119	3	38.4	18
3	0.897	131	0.119	3	39.4	16
4	0.903	136	0.121	3	39.8	16

REPORT NUMBER 72

PROBE CONFIGURATION 1/16 D

VENTURI MANOMETER READING (INCHES OF WATER)

INITIAL	FINAL
20.5	20.5

STACK GAS VELOCITY (ft/sec)

INITIAL	FINAL
71.03	70.33

	WIND TUNNEL ABSORBANCE	WIND TUNNEL CONCENTRATION (ppm)	SAMPLE ABSORBANCE	SAMPLE CONCENTRATION (ppm)	DILUTION RATIO	SAMPLE TIME (min)
1	0.906	138	0.133	4	35.6	19
2	0.906	138	0.134	4	35.3	23
3	0.908	140	0.129	4	37.6	17
4	0.907	139	0.142	4	32.8	21

REPORT NUMBER 73

PROBE CONFIGURATION 1/16 D

VENTURI MANOMETER READING (INCHES OF WATER)

INITIAL	FINAL
14.6	15.0

STACK GAS VELOCITY (ft/sec)

INITIAL	FINAL
70.32	70.44

	WIND TUNNEL ABSORBANCE	WIND TUNNEL CONCENTRATION (ppm)	SAMPLE ABSORBANCE	SAMPLE CONCENTRATION (ppm)	DILUTION RATIO	SAMPLE TIME (min)
1	0.917	147	0.137	4	36.5	28
2	0.917	147	0.142	4	34.8	30
3	0.917	147	0.141	4	35.1	29
4	0.916	146	0.146	4	33.3	28

REPORT NUMBER 74

PROBE CONFIGURATION 1/16 D

VENTURI MANOMETER READING (INCHES OF WATER)

INITIAL	FINAL
22.3	21.8

STACK GAS VELOCITY (ft/sec)

INITIAL	FINAL
88.79	83.33

	WIND TUNNEL ABSORBANCE	WIND TUNNEL CONCENTRATION (ppm)	SAMPLE ABSORBANCE	SAMPLE CONCENTRATION (ppm)	DILUTION RATIO	SAMPLE TIME (min)
1	0.860	109	0.106	3	38.3	17
2	0.868	113	0.133	4	29.2	18
3	0.875	117	0.147	4	26.4	17
4	0.881	121	0.146	4	27.4	16

REPORT NUMBER 75

PROBE CONFIGURATION 1/4 D

VENTURI MANOMETER READING (INCHES OF WATER)

INITIAL	FINAL
19.9	20.1

STACK GAS VELOCITY (ft/sec)

INITIAL	FINAL
34.92	34.73

	WIND TUNNEL ABSORBANCE	WIND TUNNEL CONCENTRATION (ppm)	SAMPLE ABSORBANCE	SAMPLE CONCENTRATION (ppm)	DILUTION RATIO	SAMPLE TIME (min)
1	0.898	132	0.287	12	11.4	11
2	0.900	133	0.286	12	11.5	10
3	0.899	133	0.293	12	11.1	10
4	0.899	133	0.293	12	11.1	10

REPORT NUMBER 76

PROBE CONFIGURATION 1/4 D

VENTURI MANOMETER READING (INCHES OF WATER)

INITIAL	FINAL
10.5	10.4

STACK GAS VELOCITY (ft/sec)

INITIAL	FINAL
34.73	34.18

	WIND TUNNEL ABSORBANCE	WIND TUNNEL CONCENTRATION (ppm)	SAMPLE ABSORBANCE	SAMPLE CONCENTRATION (ppm)	DILUTION RATIO	SAMPLE TIME (min)
1	0.919	149	0.305	13	11.7	23
2	0.924	154	0.311	13	11.7	25
3	0.925	155	0.296	12	12.7	30
4	0.924	154	0.321	14	11.2	41

REPORT NUMBER 77

PROBE CONFIGURATION 1/8 D

VENTURI MANOMETER READING (INCHES OF WATER)

INITIAL	FINAL
8.1	8.1

STACK GAS VELOCITY (ft/sec)

INITIAL	FINAL
34.05	34.30

	WIND TUNNEL ABSORBANCE	WIND TUNNEL CONCENTRATION (ppm)	SAMPLE ABSORBANCE	SAMPLE CONCENTRATION (ppm)	DILUTION RATIO	SAMPLE TIME (min)
1	0.934	165	0.246	9	17.8	29
2	0.933	164	0.249	9	17.4	25
3	0.931	161	0.254	10	16.7	26
4	0.930	160	0.257	10	16.3	27

REPORT NUMBER 78

PROBE CONFIGURATION 1/8 D

VENTURI MANOMETER READING (INCHES OF WATER)

INITIAL	FINAL
20.4	20.5

STACK GAS VELOCITY (ft/sec)

INITIAL	FINAL
34.21	34.14

	WIND TUNNEL ABSORBANCE	WIND TUNNEL CONCENTRATION (ppm)	SAMPLE ABSORBANCE	SAMPLE CONCENTRATION (ppm)	DILUTION RATIO	SAMPLE TIME (min)
1	0.895	130	0.200	7	19.0	9
2	0.889	126	0.199	7	18.5	3
3	0.889	126	0.198	7	18.6	12
4	0.887	125	0.205	7	17.6	8

REPORT NUMBER 79

PROBE CONFIGURATION 1/4 B

VENTURI MANOMETER READING (INCHES OF WATER)

INITIAL	FINAL
7.9	7.7

STACK GAS VELOCITY (ft/sec)

INITIAL	FINAL
34.60	34.53

	WIND TUNNEL ABSORBANCE	WIND TUNNEL CONCENTRATION (ppm)	SAMPLE ABSORBANCE	SAMPLE CONCENTRATION (ppm)	DILUTION RATIO	SAMPLE TIME (min)
1	0.930	160	0.307	13	12.4	23
2	0.931	161	0.331	15	11.1	23
3	0.936	167	0.299	12	13.5	28
4	0.935	166	0.326	14	11.7	28

REPORT NUMBER 80

PROBE CONFIGURATION 1/4 B

VENTURI MANOMETER READING (INCHES OF WATER)

INITIAL	FINAL
19.9	20.0

STACK GAS VELOCITY (ft/sec)

INITIAL	FINAL
34.54	34.21

	WIND TUNNEL ABSORBANCE	WIND TUNNEL CONCENTRATION (ppm)	SAMPLE ABSORBANCE	SAMPLE CONCENTRATION (ppm)	DILUTION RATIO	SAMPLE TIME (min)
1	0.894	129	0.283	11	11.4	8
2	0.889	126	0.282	11	11.1	9
3	0.888	125	0.283	11	11.0	8
4	0.888	125	0.288	12	10.7	9

REPORT NUMBER 81

PROBE CONFIGURATION 1/8 B

VENTURI MANOMETER READING (INCHES OF WATER)

INITIAL	FINAL
20.8	20.3

STACK GAS VELOCITY (ft/sec)

INITIAL	FINAL
35.27	35.47

	WIND TUNNEL ABSORBANCE	WIND TUNNEL CONCENTRATION (ppm)	SAMPLE ABSORBANCE	SAMPLE CONCENTRATION (ppm)	DILUTION RATIO	SAMPLE TIME (min)
1	0.910	141	0.228	8	17.1	12
2	0.895	130	0.224	8	16.1	9
3	0.891	127	0.221	8	16.1	10
4	0.889	126	0.219	8	16.1	27

REPORT NUMBER 82

PROBE CONFIGURATION 1/8 B

VENTURI MANOMETER READING (INCHES OF WATER)

INITIAL	FINAL
8.7	8.7

STACK GAS VELOCITY (ft/sec)

INITIAL	FINAL
35.46	35.07

	WIND TUNNEL ABSORBANCE	WIND TUNNEL CONCENTRATION (ppm)	SAMPLE ABSORBANCE	SAMPLE CONCENTRATION (ppm)	DILUTION RATIO	SAMPLE TIME (min)
1	0.923	153	0.236	9	17.6	31
2	0.921	151	0.237	9	17.3	26
3	0.919	149	0.231	8	17.7	32
4	0.920	150	0.247	9	16.2	32

REPORT NUMBER 83

PROBE CONFIGURATION 1/16 B

VENTURI MANOMETER READING (INCHES OF WATER)

INITIAL	FINAL
20.5	20.2

STACK GAS VELOCITY (ft/sec)

INITIAL	FINAL
35.18	34.68

	WIND TUNNEL ABSORBANCE	WIND TUNNEL CONCENTRATION (ppm)	SAMPLE ABSORBANCE	SAMPLE CONCENTRATION (ppm)	DILUTION RATIO	SAMPLE TIME (min)
1	0.879	120	0.121	3	35.1	10
2	0.878	119	0.114	3	37.9	12
3	0.877	118	0.121	3	34.8	12
4	0.877	118	0.131	4	31.2	11

REPORT NUMBER 84

PROBE CONFIGURATION 1/16 B

VENTURI MANOMETER READING (INCHES OF WATER)

INITIAL	FINAL
8.3	8.1

STACK GAS VELOCITY (ft/sec)

INITIAL	FINAL
35.18	34.44

	WIND TUNNEL ABSORBANCE	WIND TUNNEL CONCENTRATION (ppm)	SAMPLE ABSORBANCE	SAMPLE CONCENTRATION (ppm)	DILUTION RATIO	SAMPLE TIME (min)
1	0.945	179	0.141	4	42.6	32
2	0.948	183	0.127	4	50.4	34
3	0.948	183	0.121	3	53.9	29
4	0.948	183	0.126	4	51.0	33

REPORT NUMBER 85

PROBE CONFIGURATION 1/16 D

VENTURI MANOMETER READING (INCHES OF WATER)

INITIAL	FINAL
10.7	10.7

STACK GAS VELOCITY (ft/sec)

INITIAL	FINAL
34.76	34.35

	WIND TUNNEL ABSORBANCE	WIND TUNNEL CONCENTRATION (ppm)	SAMPLE ABSORBANCE	SAMPLE CONCENTRATION (ppm)	DILUTION RATIO	SAMPLE TIME (min)
1	0.934	165	0.143	4	38.5	29
2	0.933	164	0.142	4	38.6	30
3	0.933	164	0.132	4	42.7	36
4	0.933	164	0.154	5	34.5	27

REPORT NUMBER 86

PROBE CONFIGURATION 1/16 D

VENTURI MANOMETER READING (INCHES OF WATER)

INITIAL	FINAL
20.3	20.4

STACK GAS VELOCITY (ft/sec)

INITIAL	FINAL
34.16	34.55

	WIND TUNNEL ABSORBANCE	WIND TUNNEL CONCENTRATION (ppm)	SAMPLE ABSORBANCE	SAMPLE CONCENTRATION (ppm)	DILUTION RATIO	SAMPLE TIME (min)
1	0.909	140	0.145	4	32.2	18
2	0.905	137	0.146	4	31.2	13
3	0.905	137	0.147	4	30.9	13
4	0.906	138	0.154	5	29.1	25

REPORT NUMBER 87

PROBE CONFIGURATION 1/8 A

VENTURI MANOMETER READING (INCHES OF WATER)

INITIAL	FINAL
20.0	20.2

STACK GAS VELOCITY (ft/sec)

INITIAL	FINAL
68.47	64.97

	WIND TUNNEL ABSORBANCE	WIND TUNNEL CONCENTRATION (ppm)	SAMPLE ABSORBANCE	SAMPLE CONCENTRATION (ppm)	DILUTION RATIO	SAMPLE TIME (min)
1	0.881	121	0.175	6	21.3	30
2	0.890	126	0.188	6	20.2	33

REPORT NUMBER 87

PROBE CONFIGURATION 1/8 A

VENTURI MANOMETER READING (INCHES OF WATER)

INITIAL	FINAL
16.1	16.5

STACK GAS VELOCITY (ft/sec)

INITIAL	FINAL
68.47	64.97

	WIND TUNNEL ABSORBANCE	WIND TUNNEL CONCENTRATION (ppm)	SAMPLE ABSORBANCE	SAMPLE CONCENTRATION (ppm)	DILUTION RATIO	SAMPLE TIME (min)
1	0.895	130	0.195	7	19.7	29
2	0.894	129	0.198	7	19.1	41

REPORT NUMBER 88

PROBE CONFIGURATION 1/4 A

VENTURI MANOMETER READING (INCHES OF WATER)

INITIAL	FINAL
19.5	19.5

STACK GAS VELOCITY (ft/sec)

INITIAL	FINAL
69.80	67.80

	WIND TUNNEL ABSORBANCE	WIND TUNNEL CONCENTRATION (ppm)	SAMPLE ABSORBANCE	SAMPLE CONCENTRATION (ppm)	DILUTION RATIO	SAMPLE TIME (min)
1	0.889	126	0.269	11	11.9	30
2	0.888	125	0.269	11	11.9	24

REPORT NUMBER 88

PROBE CONFIGURATION 1/4 A

VENTURI MANOMETER READING (INCHES OF WATER)

INITIAL	FINAL
16.7	16.9

STACK GAS VELOCITY (ft/sec)

INITIAL	FINAL
69.80	67.80

	WIND TUNNEL ABSORBANCE	WIND TUNNEL CONCENTRATION (ppm)	SAMPLE ABSORBANCE	SAMPLE CONCENTRATION (ppm)	DILUTION RATIO	SAMPLE TIME (min)
1	0.892	128	0.253	10	13.3	42
2	0.895	130	0.278	11	11.7	27

REPORT NUMBER 89

PROBE CONFIGURATION 1/4 B

VENTURI MANOMETER READING (INCHES OF WATER)

INITIAL	FINAL
20.1	20.1

STACK GAS VELOCITY (ft/sec)

INITIAL	FINAL
68.02	67.36

	WIND TUNNEL ABSORBANCE	WIND TUNNEL CONCENTRATION (ppm)	SAMPLE ABSORBANCE	SAMPLE CONCENTRATION (ppm)	DILUTION RATIO	SAMPLE TIME (min)
1	0.883	122	0.245	9	13.3	34
2	0.864	123	0.245	9	13.4	14

REPORT NUMBER 89

PROBE CONFIGURATION 1/4 B

VENTURI MANOMETER READING (INCHES OF WATER)

INITIAL	FINAL
13.1	13.0

STACK GAS VELOCITY (ft/sec)

INITIAL	FINAL
68.02	67.36

	WIND TUNNEL ABSORBANCE	WIND TUNNEL CONCENTRATION (ppm)	SAMPLE ABSORBANCE	SAMPLE CONCENTRATION (ppm)	DILUTION RATIO	SAMPLE TIME (min)
1	0.895	130	0.256	10	13.3	34
2	0.893	129	0.261	10	12.7	32

REPORT NUMBER 90

PROBE CONFIGURATION 1/8 B

VENTURI MANOMETER READING (INCHES OF WATER)

INITIAL	FINAL
20.7	20.7

STACK GAS VELOCITY (ft/sec)

INITIAL	FINAL
68.18	64.91

	WIND TUNNEL ABSORBANCE	WIND TUNNEL CONCENTRATION (ppm)	SAMPLE ABSORBANCE	SAMPLE CONCENTRATION (ppm)	DILUTION RATIO	SAMPLE TIME (min)
1	0.880	120	0.186	6	19.5	30
2	0.878	119	0.194	7	18.2	31

REPORT NUMBER 90

PROBE CONFIGURATION 1/8 B

VENTURI MANOMETER READING (INCHES OF WATER)

INITIAL	FINAL
15.1	15.3

STACK GAS VELOCITY (ft/sec)

INITIAL	FINAL
68.18	64.91

	WIND TUNNEL ABSORBANCE	WIND TUNNEL CONCENTRATION (ppm)	SAMPLE ABSORBANCE	SAMPLE CONCENTRATION (ppm)	DILUTION RATIO	SAMPLE TIME (min)
1	0.892	128	0.203	7	18.3	44
2	0.896	131	0.210	7	17.8	32

REPORT NUMBER 91

PROBE CONFIGURATION 1/8 C

VENTURI MANOMETER READING (INCHES OF WATER)

INITIAL	FINAL
20.0	20.0

STACK GAS VELOCITY (ft/sec)

INITIAL	FINAL
69.34	67.81

	WIND TUNNEL		SAMPLE		DILUTION RATIO	SAMPLE TIME (min)
	ABSORBANCE	CONCENTRATION (ppm)	ABSORBANCE	CONCENTRATION (ppm)		
1	0.887	125	0.243	9	13.7	24
2	0.888	125	0.246	9	13.6	25

REPORT NUMBER 91

PROBE CONFIGURATION 1/8 C

VENTURI MANOMETER READING (INCHES OF WATER)

INITIAL	FINAL
17.3	17.9

STACK GAS VELOCITY (ft/sec)

INITIAL	FINAL
69.34	67.81

	WIND TUNNEL		SAMPLE		DILUTION RATIO	SAMPLE TIME (min)
	ABSORBANCE	CONCENTRATION (ppm)	ABSORBANCE	CONCENTRATION (ppm)		
1	0.891	127	0.221	8	16.1	47
2	0.890	126	0.243	9	13.9	39

REPORT NUMBER 92

PROBE CONFIGURATION 1/4 C

VENTURI MANOMETER READING (INCHES OF WATER)

INITIAL	FINAL
20.0	19.9

STACK GAS VELOCITY (ft/sec)

INITIAL	FINAL
68.48	68.15

	WIND TUNNEL ABSORBANCE	WIND TUNNEL CONCENTRATION (ppm)	SAMPLE ABSORBANCE	SAMPLE CONCENTRATION (ppm)	DILUTION RATIO	SAMPLE TIME (min)
1	0.884	123	0.339	15	8.2	24
2	0.886	124	0.341	15	8.2	34

REPORT NUMBER 92

PROBE CONFIGURATION 1/4 C

VENTURI MANOMETER READING (INCHES OF WATER)

INITIAL	FINAL
15.7	16.0

STACK GAS VELOCITY (ft/sec)

INITIAL	FINAL
68.48	68.15

	WIND TUNNEL ABSORBANCE	WIND TUNNEL CONCENTRATION (ppm)	SAMPLE ABSORBANCE	SAMPLE CONCENTRATION (ppm)	DILUTION RATIO	SAMPLE TIME (min)
1	0.894	129	0.352	16	8.1	37
2	0.894	129	0.361	17	7.8	31

REPORT NUMBER 93

PROBE CONFIGURATION 1/16 D

VENTURI MANOMETER READING (INCHES OF WATER)

INITIAL	FINAL
20.6	20.9

STACK GAS VELOCITY (ft/sec)

INITIAL	FINAL
69.66	66.31

	WIND TUNNEL ABSORBANCE	WIND TUNNEL CONCENTRATION (ppm)	SAMPLE ABSORBANCE	SAMPLE CONCENTRATION (ppm)	DILUTION RATIO	SAMPLE TIME (min)
1	0.856	108	0.091	2	46.6	23
2	0.868	113	0.097	3	44.8	64

REPORT NUMBER 93

PROBE CONFIGURATION 1/16 D

VENTURI MANOMETER READING (INCHES OF WATER)

INITIAL	FINAL
17.1	17.0

STACK GAS VELOCITY (ft/sec)

INITIAL	FINAL
69.66	66.31

	WIND TUNNEL ABSORBANCE	WIND TUNNEL CONCENTRATION (ppm)	SAMPLE ABSORBANCE	SAMPLE CONCENTRATION (ppm)	DILUTION RATIO	SAMPLE TIME (min)
1	0.881	121	0.109	3	40.8	34
2	0.879	120	0.109	3	40.4	32

REPORT NUMBER 94

PROBE CONFIGURATION 1/8 D

VENTURI MANOMETER READING (INCHES OF WATER)

INITIAL	FINAL
20.1	20.1

STACK GAS VELOCITY (ft/sec)

INITIAL	FINAL
71.27	69.80

	WIND TUNNEL ABSORBANCE	WIND TUNNEL CONCENTRATION (ppm)	SAMPLE ABSORBANCE	SAMPLE CONCENTRATION (ppm)	DILUTION RATIO	SAMPLE TIME (min)
1	0.876	118	0.208	7	16.3	21
2	0.877	118	0.209	7	16.2	18

REPORT NUMBER 94

PROBE CONFIGURATION 1/8 D

VENTURI MANOMETER READING (INCHES OF WATER)

INITIAL	FINAL
16.2	16.4

STACK GAS VELOCITY (ft/sec)

INITIAL	FINAL
71.27	69.80

	WIND TUNNEL ABSORBANCE	WIND TUNNEL CONCENTRATION (ppm)	SAMPLE ABSORBANCE	SAMPLE CONCENTRATION (ppm)	DILUTION RATIO	SAMPLE TIME (min)
1	0.882	121	0.189	6	19.2	37
2	0.882	121	0.209	7	16.7	62

REPORT NUMBER 95

PROBE CONFIGURATION 1/4 D

VENTURI MANOMETER READING (INCHES OF WATER)

INITIAL	FINAL
19.8	19.7

STACK GAS VELOCITY (ft/sec)

INITIAL	FINAL
70.46	69.18

	WIND TUNNEL		SAMPLE			
	ABSORBANCE	CONCENTRATION (ppm)	ABSORBANCE	CONCENTRATION (ppm)	DILUTION RATIO	SAMPLE TIME (min)
1	0.878	119	0.268	10	11.3	24
2	0.879	120	0.268	10	11.4	32

REPORT NUMBER 95

PROBE CONFIGURATION 1/4 D

VENTURI MANOMETER READING (INCHES OF WATER)

INITIAL	FINAL
16.5	16.6

STACK GAS VELOCITY (ft/sec)

INITIAL	FINAL
70.46	69.18

	WIND TUNNEL		SAMPLE			
	ABSORBANCE	CONCENTRATION (ppm)	ABSORBANCE	CONCENTRATION (ppm)	DILUTION RATIO	SAMPLE TIME (min)
1	0.884	123	0.273	11	11.4	59
2	0.884	123	0.281	11	10.9	49

REPORT NUMBER 96

PROBE CONFIGURATION 1/8 ABCD

VENTURI MANOMETER READING (INCHES OF WATER)

INITIAL	FINAL
19.8	19.5

STACK GAS VELOCITY (ft/sec)

INITIAL	FINAL
70.94	67.81

	WIND TUNNEL ABSORBANCE	WIND TUNNEL CONCENTRATION (ppm)	SAMPLE ABSORBANCE	SAMPLE CONCENTRATION (ppm)	DILUTION RATIO	SAMPLE TIME (min)
1	0.872	116	0.365	17	6.8	18
2	0.867	113	0.359	16	6.9	40

REPORT NUMBER 96

PROBE CONFIGURATION 1/8 ABCD

VENTURI MANOMETER READING (INCHES OF WATER)

INITIAL	FINAL
10.7	10.8

STACK GAS VELOCITY (ft/sec)

INITIAL	FINAL
70.94	67.81

	WIND TUNNEL ABSORBANCE	WIND TUNNEL CONCENTRATION (ppm)	SAMPLE ABSORBANCE	SAMPLE CONCENTRATION (ppm)	DILUTION RATIO	SAMPLE TIME (min)
1	0.886	124	0.382	18	6.8	36
2	0.887	125	0.384	18	6.8	32

REPORT NUMBER 97

PROBE CONFIGURATION 1/4 ABCD

VENTURI MANOMETER READING (INCHES OF WATER)

INITIAL	FINAL
18.9	18.9

STACK GAS VELOCITY (ft/sec)

INITIAL	FINAL
70.24	68.82

	WIND TUNNEL ABSORBANCE	WIND TUNNEL CONCENTRATION (ppm)	SAMPLE ABSORBANCE	SAMPLE CONCENTRATION (ppm)	DILUTION RATIO	SAMPLE TIME (min)
1	0.881	121	0.422	21	5.6	21
2	0.879	120	0.420	21	5.6	43

REPORT NUMBER 97

PROBE CONFIGURATION 1/4 ABCD

VENTURI MANOMETER READING (INCHES OF WATER)

INITIAL	FINAL
10.5	10.5

STACK GAS VELOCITY (ft/sec)

INITIAL	FINAL
70.24	68.82

	WIND TUNNEL ABSORBANCE	WIND TUNNEL CONCENTRATION (ppm)	SAMPLE ABSORBANCE	SAMPLE CONCENTRATION (ppm)	DILUTION RATIO	SAMPLE TIME (min)
1	0.894	129	0.404	20	6.5	36
2	0.895	130	0.441	23	5.6	28

REPORT NUMBER 98

PROBE CONFIGURATION 1/4 ABCD

VENTURI MANOMETER READING (INCHES OF WATER)

INITIAL	FINAL
19.1	19.3

STACK GAS VELOCITY (ft/sec)

INITIAL	FINAL
92.88	83.89

	WIND TUNNEL ABSORBANCE	WIND TUNNEL CONCENTRATION (ppm)	SAMPLE ABSORBANCE	SAMPLE CONCENTRATION (ppm)	DILUTION RATIO	SAMPLE TIME (min)
1	0.900	133	0.394	19	7.0	23
2	0.896	131	0.411	21	6.4	20
3	0.900	133	0.415	21	6.4	20
4	0.888	125	0.416	21	6.0	38

REPORT NUMBER 99

PROBE CONFIGURATION 1/8 ABCD

VENTURI MANOMETER READING (INCHES OF WATER)

INITIAL	FINAL
19.4	19.1

STACK GAS VELOCITY (ft/sec)

INITIAL	FINAL
92.53	83.62

	WIND TUNNEL ABSORBANCE	WIND TUNNEL CONCENTRATION (ppm)	SAMPLE ABSORBANCE	SAMPLE CONCENTRATION (ppm)	DILUTION RATIO	SAMPLE TIME (min)
1	0.874	117	0.330	14	8.1	33
2	0.874	117	0.354	16	7.2	27
3	0.873	116	0.361	17	7.0	30
4	0.872	116	0.360	17	7.0	21

REPORT NUMBER 100

PROBE CONFIGURATION 1/4 A

VENTURI MANOMETER READING (INCHES OF WATER)

INITIAL	FINAL
19.8	19.6

STACK GAS VELOCITY (ft/sec)

INITIAL	FINAL
91.07	81.77

	WIND TUNNEL ABSORBANCE	WIND TUNNEL CONCENTRATION (ppm)	SAMPLE ABSORBANCE	SAMPLE CONCENTRATION (ppm)	DILUTION RATIO	SAMPLE TIME (min)
1	0.899	133	0.290	12	11.2	55
2	0.896	131	0.289	12	11.1	30
3	0.891	127	0.296	12	10.4	38
4	0.891	127	0.289	12	10.8	25

REPORT NUMBER 101

PROBE CONFIGURATION 1/4 B

VENTURI MANOMETER READING (INCHES OF WATER)

INITIAL	FINAL
19.9	19.8

STACK GAS VELOCITY (ft/sec)

INITIAL	FINAL
91.83	81.58

	WIND TUNNEL ABSORBANCE	WIND TUNNEL CONCENTRATION (ppm)	SAMPLE ABSORBANCE	SAMPLE CONCENTRATION (ppm)	DILUTION RATIO	SAMPLE TIME (min)
1	0.888	125	0.249	9	13.3	53
2	0.886	124	0.258	10	12.5	33
3	0.890	126	0.266	10	12.2	11
4	0.893	129	0.286	12	11.1	22

REPORT NUMBER 102

PROBE CONFIGURATION 1/8 B

VENTURI MANOMETER READING (INCHES OF WATER)

INITIAL	FINAL
20.1	19.1

STACK GAS VELOCITY (ft/sec)

INITIAL	FINAL
92.47	83.96

	WIND TUNNEL ABSORBANCE	WIND TUNNEL CONCENTRATION (ppm)	SAMPLE ABSORBANCE	SAMPLE CONCENTRATION (ppm)	DILUTION RATIO	SAMPLE TIME (min)
1	0.899	133	0.172	6	24.0	27
2	0.905	137	0.189	6	21.7	23
3	0.910	141	0.191	6	22.0	26
4	0.900	133	0.198	7	19.8	30

REPORT NUMBER 103

PROBE CONFIGURATION 1/8 D

VENTURI MANOMETER READING (INCHES OF WATER)

INITIAL	FINAL
18.8	18.6

STACK GAS VELOCITY (ft/sec)

INITIAL	FINAL
91.68	83.46

	WIND TUNNEL ABSORBANCE	WIND TUNNEL CONCENTRATION (ppm)	SAMPLE ABSORBANCE	SAMPLE CONCENTRATION (ppm)	DILUTION RATIO	SAMPLE TIME (min)
1	0.911	142	0.222	8	17.9	35
2	0.906	138	0.239	9	15.6	32
3	0.910	141	0.226	8	17.3	35
4	0.909	140	0.244	9	15.4	31

REPORT NUMBER 104

PROBE CONFIGURATION 1/4 D

VENTURI MANOMETER READING (INCHES OF WATER)

INITIAL	FINAL
18.9	18.4

STACK GAS VELOCITY (ft/sec)

INITIAL	FINAL
91.49	84.97

	WIND TUNNEL ABSORBANCE	WIND TUNNEL CONCENTRATION (ppm)	SAMPLE ABSORBANCE	SAMPLE CONCENTRATION (ppm)	DILUTION RATIO	SAMPLE TIME (min)
1	0.887	125	0.252	10	13.0	35
2	0.882	121	0.257	10	12.3	30
3	0.883	122	0.258	10	12.3	30
4	0.880	120	0.264	10	11.7	35

REPORT NUMBER 105

PROBE CONFIGURATION 1/8 C

VENTURI MANOMETER READING (INCHES OF WATER)

INITIAL	FINAL
19.2	18.4

STACK GAS VELOCITY (ft/sec)

INITIAL	FINAL
84.75	78.27

	WIND TUNNEL ABSORBANCE	WIND TUNNEL CONCENTRATION (ppm)	SAMPLE ABSORBANCE	SAMPLE CONCENTRATION (ppm)	DILUTION RATIO	SAMPLE TIME (min)
1	0.900	133	0.266	10	12.9	42
2	0.897	131	0.287	12	11.3	35
3	0.897	131	0.278	11	11.9	32
4	0.896	131	0.275	11	12.0	40

REPORT NUMBER 106

PROBE CONFIGURATION 1/4 C

VENTURI MANOMETER READING (INCHES OF WATER)

INITIAL	FINAL
18.3	17.6

STACK GAS VELOCITY (ft/sec)

INITIAL	FINAL
87.65	80.31

	WIND TUNNEL ABSORBANCE	WIND TUNNEL CONCENTRATION (ppm)	SAMPLE ABSORBANCE	SAMPLE CONCENTRATION (ppm)	DILUTION RATIO	SAMPLE TIME (min)
1	0.890	126	0.309	13	9.7	40
2	0.891	127	0.313	13	9.6	41
3	0.887	125	0.317	14	9.2	35
4	0.884	123	0.319	14	9.0	29

VITA AUCTORIS

1955	Born in Toronto, Ontario, Canada
1973	Completed High School at Frontenac Secondary School, Kingston, Ontario
1980	Received Bachelor of Arts (Biology) from Queen's University, Kingston, Ontario
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1987	Presently a candidate for the degree of Master of Applied Science in Chemical Engineering at the University of Windsor, Windsor, Ontario