WIND TUNNEL STUDY
OF AIR POLLUTANT DISPERSION ON GUAM

Prepared by
David E. Neff

ATMOSPHERIC DISPERSION
COMPARABILITY TESTING DOCUMENTATION
(July 1995)

for

Dr. George Wu, Senior Environmental Scientist
R. W. Beck
1125 Seventeenth St. , Suite 1900
Denver, Colorado 80202-2615

FLUID MECHANICS AND WIND ENGINEERING PROGRAM

Colorado State University

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1 INTRODUCTION

This document summarizes wind tunnel atmospheric dispersion comparability test (ADCT) results as stipulated in "Guideline for Use of Fluid Modeling to Determine Good Engineering Practice Height" (EPA-450/4-81-003, July, 1981), hence forth this document is referred to as EPA-FM-GEP Guideline. The EPA-FM-GEP Guideline requires that the wind tunnel testing facility demonstrate atmospheric dispersion comparability by acquiring and documenting a set of velocity and concentration profiles on a standardized stack plume released into a standardized model boundary layer. The EPA-FM-GEP Guideline outlines in detail the testing requirements for this comparability demonstration.

These wind tunnel simulations are in support of R. W. Beck's effort to demonstrate compliance of the NAAQS for Guam Power Authorities Cabras Units 3 and 4. The report "Wind Tunnel Study of Air Pollutant Dispersion on Guam - Final Report" by D. E. Neff (August 1995) specifies all fluid modeling study design criteria and testing parameters. Table 1, Atmospheric Dispersion Comparability Test Parameters, lists the different prototype and model parameter values for this atmospheric dispersion comparability test program. Table 2, ADCT Field Test Conditions, details the field conditions for each type of data test performed in this test series. Table 3, ADCT Model Test Conditions, details the model conditions for each type of data test performed in this test series. These tables will be discussed more throughly in the following sections.

2 ATMOSPHERIC DISPERSION COMPARABILITY TEST SPECIFICATIONS

2.1 Overview of EPA Guideline Requirements

The EPA-FM-GEP Guideline requires that the wind tunnel testing facility demonstrate atmospheric dispersion comparability by acquiring and documenting a set of velocity and concentration profiles on a standardized stack plume released into a standardized model boundary layer. The EPA-FM-GEP Guideline similarity requirements for these atmospheric dispersion comparability tests (ADCT) are summarized below:

(1) All ADCT length scaling (stack height, study area distances, boundary layer height and roughness length, etc.) should be at the same ratio as for the GEP model tests,

(2) The ADCT flow velocity should match the GEP model design flow velocity at the proposed stack height,

(3) The ADCT stack is to be the field equivalent of 100 meters high with an inside diameter of 5 meters and is placed at the same location within the test facility as the GEP stack tests,

(4) The ADCT wind boundary layer is represented by a characteristic roughness length, z_o, of less than 0.2 meters,

(5) The ADCT stack gas exit velocity is to be 1.5 times the ADCT wind speed at the stack top.

The EPA-FM-GEP Guideline requires that the following ADCT data be acquired and documented:

(6) Vertical profiles of mean velocity, longitudinal turbulent intensity, vertical turbulent intensity and Reynolds stress at the stack location, at the end of the planned study area and midway between these two locations,

(7) Lateral profiles of mean velocity and longitudinal turbulent intensity at three elevations near the stack and at three elevations at the end of the study area,

(8) Vertical and lateral mean concentration profiles through the plume centerline at quarter intervals between the stack and the end of study area,

(9) Ground level longitudinal concentration profile through the ground level plume centerline with lateral points verifying location of ground level plume centerline.

The EPA-FM-GEP Guideline requires that the following ADCT data be analyzed:

(10) The velocity profiles are to be regressed upon to determine their power law index, roughness length, and friction velocity. These values are to be compared to the expected atmospheric values for this site.

(11) The concentration data are to be converted to the equivalent field values of $\chi U_H/Q$ [m^{-2}] and compared to estimates from the Pasquill-Gifford diffusion categories C and D (H = 100m).

(12) The measured model plume rise is to be compared to estimates from the EPA-FM-GEP Guidelines suggested model.

2.2 Similarity Criteria Compliance

The ADCT model scale and flow velocity were set to equal that of the site model test program, i.e. model scale of 1:1000 and U_s = 113.3 cm/s (where s = 61m/1000 =6.1cm). The ADCT boundary layer roughness length, $z_0 \sim 0.5$ meters, is greater the the GEP suggested value but is the same as in the compliance testing program. The model stack represents a field stack of 100 m height and 5 m inside diameter, i.e. 10 cm high with I.D. = 0.5 cm. This stack was placed at the same location in the wind tunnel as that used in the main test program. A neutrally buoyant stack gas (100% ethane) was released at a flow rate such that the exhaust velocity was 1.5 times the mean velocity at the stack top. Table 1, Atmospheric Dispersion Comparability Test Parameters, lists the different prototype and model parameter values for this atmospheric dispersion comparability test program. This table shows that all of the required Guideline similarity criteria are satisfied.

3 ATMOSPHERIC DISPERSION COMPARABILITY TEST RESULTS

3.1 Wind Profile Measurements

The field scale specifications for the EPA-FM-GEP ADCT velocity profile requirements are listed in Table 2. The model scale specifications are listed in Table 3. The lateral profiles were determined from abbreviated vertical velocity profiles at each of the required test positions and thus no run numbers and file names are included in this portion of these tables. Table 4 presents model, normalized, and field values of the average of the three tunnel centerline wind profiles, one at the stack location (X_m = 0 cm), one at the end of the study area (X_m = 800 cm), and one at half way between these two (X_m = 400 cm).

The averaged profile, mentioned in the previous paragraph, was examined to determine the following model boundary layer similarity parameters; the roughness length, the displacement height, the friction velocity, and the power law index. The top graph in Figure 1 displays the test data as symbols and the design power law curve (index = 0.18, see Table 1) as a line. This graph shows that the model profile is representative of the field design power law index value of 0.18. The middle graph in Figure 1 displays the mean velocity profile test data and the design log-lin law on log-lin coordinates. This graph shows that the model profile is representative of the field design values of roughness length equal to 0.5 meters, friction velocity equal to 1.18 meters/second, and a displacement height of 0.0 meters. The bottom graph in Figure 1 displays the longitudinal turbulent intensity profile test data and the EPA-FM-GEP suggested design curve. The EPA-FM-GEP Guideline states that a model turbulent intensity greater than this curve maybe too turbulent of a condition. The measured test data fits the suggested curve, thus it complies with the Guidelines specifications.

Table 5 through Table 7 present model, normalized and field values of the three tunnel centerline wind profiles, one at the stack location (X_m = 0 cm), one at the end of the study area (X_m = 800 cm), and one at half way between these two (X_m = 400 cm). The field values of mean velocity, longitudinal, and vertical turbulent intensity for all three locations are presented in the graphs in Figure 2. The consistency in profile shape between these three measurement locations is demonstrated.

Vertical velocity profiles of four heights each (Z_f = 50, 100, 250 meters) were taken at six different crosswind positions (Y_f = ±900, ±600, ±300 meters) and two different downwind positions (X_f = 0, 8000 meters) to test the flow uniformity of the wind tunnel. These mean velocity and turbulent intensity data along with the appropriate height data from the tunnel centerline velocity profiles (Y_f = 0 meters) are presented in Table 8. Graphs of the lateral mean velocity and lateral turbulent intensity profiles for both downwind distances and for all heights are presented in Figure 3. Here again it is seen that the wind tunnel uniformity is within the bounds of acceptability.

3.2 Stack Plume Visualization

Visualization of the atmospheric dispersion comparability stack plume was documented on the video cassette VHS tape and included with this report in Appendix A. The specifications for this test is listed in Table 2 for field conditions and Table 3 for model conditions. The camera position for this film sequence was directly outside the wind tunnel from the model stack at a height slightly above model ground level. The film test observes the plume trajectories from the model stack down to the end of the study area, approximately 8000 meters field equivalent distance, and zooms in on the stack to document downwash and near stack plume rise characteristics.

The EPA-FM-GEP Guideline states that for the conditions of this test there should be little stack downwash and low plume rise. The ADCT plume visualization shows that the model plume had little stack downwash and low plume rise.

3.3 Concentration Measurements

The specifications for these tests are listed in Table 2 for field conditions and Table 3 for model conditions. Seven concentration profiles of the test plume were measured, lateral and vertical profiles at field downwind distances of 2000, 4000, and 6000 meters and a ground level profile with additional off-centerline line points. Table 9 through Table 15 lists for each of these concentration profiles field and model sample positions, measured model concentrations in both ppm, χ, and normalized model concentrations, $K_m = \chi U_m / Q_m$ [cm^{-2}], the equivalent field normalized concentration, K_f, and Pasquill-Gifford estimates of K_f for both dispersion categories C, D and E. Figure 4 through Figure 10 display plots of each concentration profile for the measured test data converted to field equivalent normalized concentrations and the Pasquill-Gifford dispersion estimates for both stability categories C and D.

The EPA-FM-GEP Guideline desires that the ADCT plume be representative of plume dispersion between Pasquill-Gifford dispersion categories C and D and it requires that the ADCT plume not be more stable then estimates based on dispersion category D. Observation of the test data with respect to the PG dispersion estimates for categories C and D in Figure 4 through Figure 10 for the vertical and lateral plume centerline profiles out to 6000 meters shows that the test plume meets the EPA requirements. The test data ground level concentration profile shown in Figure 10 stays between dispersion classes C and D out to 1500 meters. At distances greater than 1500 meters the test data display greater ground level concentrations than the dispersion classes indicates. This behavior of being outside of the specification on the high side is considered "not critical" in the EPA-FM-GEP Guideline.

4 REYNOLDS NUMBER INDEPENDENCE TESTS

The Reynolds number (Re) invariance of the concentration field should be demonstrated whenever model scaling requirements have reduced the roughness Re# and/or the stack Re# lower then the accepted limits. The method for demonstration of Reynolds number invariance is to measure the ground level longitudinal concentration distribution from a passive plume released at the location of the ADCT stack. This test was done for the five different wind speeds planned in the study. When these concentration profiles are normalized by the form $\chi U/Q$ [m-2] their differences should not be greater than the error acceptable for the study.

Table 16, Reynolds Number Invariance Test Conditions, lists the different field and model test conditions for each type of data test performed in this test series. The concentration results for these tests are listed in Table 17 for the vertical profiles and Table 18 for the lateral profiles. These tables list both model and field distances to concentration measurement locations, the model reference velocity and flow rate used to calculate normalized model concentrations and the normalized model concentrations. Concentration profiles for each of these tests are displayed in Figure 11 for the vertical profiles and Figure 12 for the lateral profiles. These figures show that there is loss of plume similarity at the lowest wind speed tested, 38 cm/s at 6 cm height, and that there is some plume lateral drift at the 75 cm/s wind speed.

5 INSTRUMENTATION AND MEASUREMENT METHODOLOGY

5.1 Boundary Layer Wind Tunnel

All model tests were performed in the Environmental Wind Tunnel (EWT) test facility at Colorado State University (CSU). This tunnel has a 3.66 m by 2.13 m cross section, a 17.4 m length, a wind speed range of 0 to 15 m/s and a flexible test section roof. A complete description of this facility is provided in Appendix D. Appropriate boundary layer development techniques were utilized to accurately represent wind conditions approaching the plant stack from all wind directions. The project model was placed on a 3 meter diameter turntable located ~8.8 meters into the test section. This placement permits convenient changing of wind directions, provide sufficient upwind fetch, and provide a sufficient downwind measurement zone. The zones upwind and downwind of the turntable area were modeled with a generic roughness design to create the desired model boundary layer.

5.2 Velocity Measurements

The techniques employed in the acquisition of velocity profiles are discussed in detail in Appendix D including basic equations and errors associated with each technique. Single-hot-film (TSI 1220 Sensor), cross-film (TSI 1241) probes and pitot-static probes are used to measure velocity statistics. TSI 1125 Velocity Calibrator System and Pitot-static Probes are used for velocity calibration.

The variation of mean wind speed with height above the ground (referred to as the boundary layer) at the study site is deduced from empirical equations known to correlate atmospheric data. The EPA-FM-GEP Guideline states that for heights up 100 meters the log-linear velocity profile relationship be used:

$U/u_* = 2.5*\ln[(z-d)/z_o]$; where

u_* ≡ friction velocity,

d ≡ displacement height,

z_o ≡ roughness length.

Table 1 in the EPA-FM-GEP Guideline lists suggested values of the roughness length for various types of ground cover. The displacement height is estimated from Equation 6 in the

EPA-FM-GEP Guideline: $d = H - z_o/2.5$; where H = the general roof-top level.

The mean velocity through the entire depth of the boundary layer (which the Guideline states to be 600 meters) is represented by the power law equation:

$U/U_\infty = (z/\delta)^p$; where

U ≡ mean wind speed at height z,

U_∞ ≡ wind speed at boundary layer height δ,

δ ≡ boundary layer height = 600 meters

p ≡ power law index.

The EPA-FM-GEP Guideline suggests that the power law index be estimated from the equation $p = 0.24 + 0.096 * \log_{10}(z_o) + 0.016 * [\log_{10}(z_o)]^2$.

Velocity measurements obtained in this study are summarized and presented through plots of vertical profiles of mean velocity, longitudinal and vertical turbulence intensity, and Reynolds stress. The height and velocity coordinates are normalized by a model reference height and the model velocity at the reference height. Since a neutral boundary layer's velocity is invariant with respect to wind speed, the normalized profiles can be converted to any field velocity at a specific height by the appropriate multiplicative constant. Each of the vertical profiles of mean velocity are plotted on linear-linear and log-linear paper to display the best fit regressions.

5.3 Plume Visualization Techniques

Techniques employed to obtain a visible plume are discussed in Appendix D. A Smoke Generator System and a Video Camera System are used for plume visualization. Given a field to model wind speed ratio of 7.965 (= [9 m/s]/[1.13 m/s]) and a model to field length scale ratio of 1000, then the time scale ratio between the model and the field is 1:126. Thus phenomena observed over the model in the wind tunnel will occur 126 times faster than observed at full scale. If the TV tapes were replayed in slow motion (126 times slower than the recorded speed) the observed plume trajectories and motions would appear realistic.

5.4 Concentration Measurements

Techniques employed to obtain the concentration data are discussed in Appendix D. A gas chromatograph with flame ionization detector is used to measure gas concentrations. Figure

5 in Appendix D shows a schematic of stack gas release, sampling, and analyzing methodology.

Concentration data are reported in terms of field scale normalized concentration, K_p, where $K_p = (\chi U_H/Q)_p$ [m^{-2}]. This normalized format is convenient because the concentration results, χ_p [gm/m^3], from a test at one particular combination of wind speed, $(U_H)_p$ [m/s], and source mass flow rate, Q_p [gm/sec], can be extrapolated to other $(U_H)_p$ and Q_p values provided that flow physics, such as plume rise, remains the same. $(U_H)_p$ is the field wind speed at the stack height. The conversion from model units to field units is as follows:

$K_p = K_m * (H_m/H_p)^2$ [m^{-2}]; with $K_m = (\chi U_H/Q)_m$ [cm^{-2}].

χ_m is the source normalized model concentration (ppm),

$(U_H)_m$ [cm/s] is model wind speed at stack height,

Q_m [ccs] is the model stack flow rate,

H_m [cm] is the model stack height, and

H_p [m] is the field stack height.

5.5 Stack Flow Rate and Composition Techniques

An Omega mass flow controlling system was used to monitor and control all stack gas flow settings. This system has four mass flow channels with full scale responses of 0.1, 1, 10, and 100 SLPM for gases with unity gas factors. Different gases will have different gas factors and this must be taken into account when calculating the proper meter setting. The local atmospheric pressure (~631 mmHg at CSU) must also be accounted for in these calculations.

During a visual plume test the proper plume flow rate and specific gravity would be attained by mixing metered quantities of Air (SG = 1) and Helium (SG = 0.14) or Argon (SG = 1.38). This gas mixture is then pass through the smoke generator and then out the model stack. During a plume concentration test a hydrocarbon gas must be in the source mixture so that measurements of sample concentration can be made with a flame ionization type gas chromatograph. Depending upon many experimental considerations, a hydrocarbon, either methane (SG = 0.55), ethane (SG = 1.04), or propane (SG = 1.52) will be mixed with Helium (SG = 0.14), Nitrogen (SG = 0.967), or Argon (SG = 1.38). This mixture is passed directly into the model stack. Table 19 Stack Gas Flow Settings and Composition, lists the settings and type of gas used to achieve the proper model stack effluent discharge velocities and specific gravities.

REFERENCES

Following is a list of reference materials related to this study. This list is not meant to be all inclusive.

1. EPA, Guideline for Use of Fluid Modeling to Determine Good Engineering Practice Stack Height. EPA-450/4-81-003, U.S. Environmental Protection Agency, Research Triangle Park, NC, July, 1981.

2. EPA, Guideline for Determination of Good Engineering Practice Stack Height (Technical Support Document For the Stack Height Regulations (revised). EPA-450/4-80-023R, U.S. Environmental Protection Agency, Research Triangle Park, NC, June 1985.

3. EPA, Determination of Good Engineering Practice Stack Height - A Fluid Model Demonstration Study for a Power Plant. EPA/600/3-85/022, U.S. Environmental Protection Agency, Research Triangle Park, NC, April 1983.

4. EPA, Fluid Model Demonstration of Good Engineering Practice Stack Height in Complex Terrain. EPA/600/3-85/022, U.S. Environmental Protection Agency, Research Triangle Park, NC, April 1985.

5. Snyder, W.H., "Guideline for Fluid Modeling of Atmospheric Diffusion", EPA-600/8-8cl-009. U.S. Environmental Protection Agency, Research Triangle Park, NC, 1981.

6. Turner, D. B.,"Workbook of Atmospheric Dispersion Estimates, 2nd Edition" CRC Press, Inc., 2000 Corporate Blvd., Boca Raton, Florida, ISBN 1-56670-023-X, 1994.

TABLES

Atmospheric Dispersion Comparability Test Parameters

SCALE =	Full	Units	1000	Units
SELECTED HEIGHT DIMENSIONS				
Ref Height 10 m =	10.0	m	1.0	cm
Wind Instr. Height =	60.0	m	6.0	cm
Cabras Stack Height =	61.0	m	6.1	cm
ADCT Stack Height =	100.0	m	10.0	cm
Boundary Layer Height =	600.0	m	60.0	cm
SELECTED DISTANCE DIMENSIONS				
Distance to 2.0 km downwind =	2000.0	m	200.0	cm
Distance to 4.0 km downwind =	4000.0	m	400.0	cm
Distance to 6.0 km downwind =	6000.0	m	600.0	cm
Distance to 8.0 km downwind =	8000.0	m	800.0	cm
APPROACH FLOW CHARACTERISTICS				
Roughness Length < or = to 0.2m	0.20	m	0.020	cm
Power Law Index =	0.18		0.18	
Friction Velocity =	0.67	m/s	7.9	cm/s
Wind Speed @ 10m =	6.5	m/s	81.7	cm/s
Wind Speed @ Wind Instr. Height =	9.0	m/s	113.0	cm/s
Wind Speed @ Cabras Stack =	9.0	m/s	113.3	cm/s
Wind Speed @ ADCT Stack =	9.9	m/s	123.9	cm/s
Wind Speed @ BL =	13.6	m/s	171.3	cm/s
ADCT STACK FLOW CHARACTERISTICS				
Stack I.D. =	5.00	m	0.50	cm
Stack Exit Velocity =	14.8	m/s	185.8	cm/s
Stack Flow Rate =	290.7	m^3/s	36.5	ccs
Stack gas Temp. =	20.0	C	20.0	C
Ambient Temp. =	20.0	C	20.0	C
Stack Gas Equivalent MW =	29.0		29.0	
DIMENSIONLESS PARAMETERS				
Roughness RE # =	89		1.06	
ADCT Stack RE # =	49352		619	
ADCT W/U velocity ratio =	1.50		1.50	
ADCT Stack Gas Specific Gravity =	1.000		1.000	

Table 1 Atmospheric Dispersion Comparability Test Parameters

Field Test Conditions - ADCT Test Series

Measurement Type	Model Config.	Stack Config.	Wind Dir. (deg)	Ref. Velocity (m/s)	Effluent Velocity (m/s)	Position X (m)	Y (m)	Z (m)
ADCT Series								
Vel. Lateral Profile U,u'	Generic	Out	-	9	14.8	0	Profile	40.0
"	"	"	-	"	"	0	Profile	70.0
"	"	"	-	"	"	0	Profile	100.0
"	"	"	-	"	"	8000	Profile	40.0
"	"	"	-	"	"	8000	Profile	70.0
"	"	"	-	"	"	8000	Profile	100.0
Vel. Vertical Profile U,u',w',uw	"	"	-	"	"	0	0	Profile
"	"	"	-	"	"	4000	0	Profile
"	"	"	-	"	"	8000	0	Profile
Visualization of Plume Elevation	"	In	-	"	"	Profile	0	Profile
Concentration Vertical Profile	"	"	-	"	"	2000	0	Profile
"	"	"	-	"	"	4000	0	Profile
"	"	"	-	"	"	6000	0	Profile
Concentration Lateral Profile	"	"	-	"	"	2000	Profile	H_{eff}
"	"	"	-	"	"	4000	Profile	H_{eff}
"	"	"	-	"	"	6000	Profile	H_{eff}
Conc. Ground Level Profile	"	"	-	"	"	Profile	Profile	0.0

Notes: Stack Config.

1) ADCT Stack > 100m stack, ID = 5m, SG = 1, W/U = 1.5

Notes: Ref. Velocity

2) Reference Velocity Height is 60 m

3) Power Law Index is 0.18

Table 2 Field Test Conditions

Model Test Conditions - ADCT Test Series

Vel. Scale = *0.126* *Length Scale =* *1000*

Measurement Type	Model Config.	Stack Config.	Wind Dir. (deg)	Ref. Velocity (cm/s)	Effluent Velocity (m/s)	Position X (cm)	Y (cm)	Z (cm)
ADCT Series								
Vel. Lateral Profile U,u'	Generic	Out	-	113	185.8	0	Profile	4.0
"	"	"	-	"	"	0	Profile	7.0
"	"	"	-	"	"	0	Profile	10.0
"	"	"	-	"	"	800	Profile	4.0
"	"	"	-	"	"	800	Profile	7.0
"	"	"	-	"	"	800	Profile	10.0
Vel. Vertical Profile U,u',w',uw	"	"	-	"	"	0	0	Profile
"	"	"	-	"	"	400	0	Profile
"	"	"	-	"	"	800	0	Profile
Visualization of Plume Elevation	"	In	-	"	"	Profile	0	Profile
Concentration Vertical Profile	"	"	-	"	"	200	0	Profile
"	"	"	-	"	"	400	0	Profile
"	"	"	-	"	"	600	0	Profile
Concentration Lateral Profile	"	"	-	"	"	200	Profile	H_{eff}
"	"	"	-	"	"	400	Profile	H_{eff}
"	"	"	-	"	"	600	Profile	H_{eff}
		"						
Conc. Ground Level Profile	"		-	"	"	Profile	Profile	0.0

Notes: Stack Config.

1) ADCT Stack > 10cm stack, ID =0.5cm, SG = 1, W/U = 1.5

Notes: Ref. Velocity

2) Reference Velocity Height is 6cm

3) Power Law Index is 0.18

Table 3 Model Test Conditions

Guam Project - ADCT Centerline Velocity and Turbulence Profiles

Average of 0, 4 and 8 km Profiles

Run No. =	Average			Location =	(avg,0,Z)						
FIELD VALUES				**NORMALIZED VALUES**				**MODEL VALUES**			
Height (m)	Velocity (m/s)	Long. T.I. (%)		Height	Velocity	Long. T.I. (%)		Height (cm)	Velocity (cm/s)	Long. T.I. (%)	
0.5											
10.0	9.3	24.8		0.100	0.577	24.8		1.0	69.3	24.8	
20.0	11.1	20.8		0.200	0.686	20.8		2.0	82.4	20.8	
40.0	13.0	17.1		0.400	0.804	17.1		4.0	96.5	17.1	
60.0	14.0	15.7		0.600	0.873	15.7		6.0	104.7	15.7	
80.0	15.0	15.1		0.800	0.933	15.1		8.0	111.9	15.1	
100.0	16.0	13.6		1.000	0.993	13.6		10.0	119.2	13.6	
150.0	16.9	11.3		1.500	1.049	11.3		15.0	125.8	11.3	
200.0	17.6	10.7		2.000	1.095	10.7		20.0	131.4	10.7	
250.0	18.2	9.3		2.500	1.131	9.3		25.0	135.8	9.3	
300.0	18.6	9.2		3.000	1.152	9.2		30.0	138.3	9.2	
400.0	19.1	8.2		4.000	1.188	8.2		40.0	142.6	8.2	
500.0	20.1	7.1		5.000	1.246	7.1		50.0	149.5	7.1	
600.0	20.2	7.0		6.000	1.254	7.0		60.0	150.5	7.0	
800.0	21.7	6.3		8.000	1.347	6.3		80.0	161.7	6.3	
References								References			
100.0	16.1							10.0	120.0		
Roughness Length (m) =			0.50					Roughness Length (cm) =			0.05
Displacement Height (m) =			0.00					Displacement Height (cm) =			0.00
Friction Velocity (m/s) =			1.18					Friction Velocity (cm/s) =			8.80
Power Law Index =			0.18					Power Law Index =			0.18

Table 4 ADCT Reference Velocity and Turbulence Profiles

Guam Project - ADCT Centerline Velocity and Turbulence Profiles

0 km Profile

Run No. =	VER0.PRF			Location =		(0,0,Z)					
FIELD VALUES				NORMALIZED VALUES				MODEL VALUES			
Height (m)	Velocity (m/s)	Long. T.I. (%)		Height	Velocity	Long. T.I. (%)		Height (cm)	Velocity (cm/s)	Long. T.I. (%)	
0.0											
10.0	9.3	27.4		0.100	0.572	27.4		1.0	68.7	27.4	
20.0	11.9	20.4		0.200	0.736	20.4		2.0	88.4	20.4	
40.0	13.7	16.8		0.400	0.846	16.8		4.0	101.5	16.8	
60.0	14.9	14.3		0.600	0.921	14.3		6.0	110.5	14.3	
80.0	15.6	14.7		0.800	0.965	14.7		8.0	115.9	14.7	
100.0	16.4	12.3		1.000	1.013	12.3		10.0	121.6	12.3	
150.0	16.5	11.3		1.500	1.019	11.3		15.0	122.3	11.3	
200.0	17.8	11.4		2.000	1.096	11.4		20.0	131.5	11.4	
250.0	18.6	10.2		2.500	1.147	10.2		25.0	137.7	10.2	
300.0	18.7	9.6		3.000	1.151	9.6		30.0	138.2	9.6	
400.0	19.1	9.3		4.000	1.179	9.3		40.0	141.5	9.3	
500.0	20.0	7.6		5.000	1.232	7.6		50.0	147.9	7.6	
600.0	20.2	8.2		6.000	1.244	8.2		60.0	149.3	8.2	
800.0	21.4	7.5		8.000	1.319	7.5		80.0	158.3	7.5	
References								References			
100.0	16.2							10.0	120.0		

Table 5 Downwind (0 km) Velocity and Turbulence Profile Data

Guam Project - ADCT Centerline Velocity and Turbulence Profiles

4 km Profile

Run No. =	VER4.PRF			Location =	(4000,0,Z)						
FIELD VALUES				NORMALIZED VALUES				MODEL VALUES			
Height (m)	Velocity (m/s)	Long. T.I. (%)		Height	Velocity	Long. T.I. (%)		Height (cm)	Velocity (cm/s)	Long. T.I. (%)	
0.0											
10.0	9.2	23.9		0.100	0.566	23.9		1.0	67.9	23.9	
20.0	10.9	21.3		0.200	0.676	21.3		2.0	81.1	21.3	
40.0	13.0	17.0		0.400	0.802	17.0		4.0	96.2	17.0	
60.0	14.0	15.9		0.600	0.863	15.9		6.0	103.5	15.9	
80.0	15.0	14.2		0.800	0.929	14.2		8.0	111.5	14.2	
100.0	16.7	13.0		1.000	1.029	13.0		10.0	123.4	13.0	
150.0	17.4	11.4		1.500	1.075	11.4		15.0	129.0	11.4	
200.0	17.9	10.0		2.000	1.105	10.0		20.0	132.6	10.0	
250.0	18.1	8.8		2.500	1.117	8.8		25.0	134.1	8.8	
300.0	18.6	9.1		3.000	1.147	9.1		30.0	137.6	9.1	
400.0	19.5	8.3		4.000	1.202	8.3		40.0	144.2	8.3	
500.0	20.2	7.1		5.000	1.249	7.1		50.0	149.9	7.1	
600.0	20.4	6.1		6.000	1.260	6.1		60.0	151.2	6.1	
800.0	21.4	6.0		8.000	1.322	6.0		80.0	158.6	6.0	
References								References			
100.0	16.2							10.0	120.0		

Table 6 Downwind (4 km) Velocity and Turbulence Profile Data

Guam Project - ADCT Centerline Velocity and Turbulence Profiles

8 km Profile

Run No. =	VER8.PRF			Location =	(8000,0,Z)						
FIELD VALUES				NORMALIZED VALUES				MODEL VALUES			
Height (m)	Velocity (m/s)	Long. T.I. (%)		Height	Velocity	Long. T.I. (%)		Height (cm)	Velocity (cm/s)	Long. T.I. (%)	
0.0											
10.0	9.6	23.2		0.100	0.593	23.2		1.0	71.2	23.2	
20.0	10.5	20.8		0.200	0.648	20.8		2.0	77.7	20.8	
40.0	12.4	17.4		0.400	0.766	17.4		4.0	91.9	17.4	
60.0	13.5	16.8		0.600	0.834	16.8		6.0	100.1	16.8	
80.0	14.6	16.3		0.800	0.904	16.3		8.0	108.5	16.3	
100.0	15.2	15.4		1.000	0.937	15.4		10.0	112.4	15.4	
150.0	17.0	11.3		1.500	1.052	11.3		15.0	126.2	11.3	
200.0	17.6	10.6		2.000	1.084	10.6		20.0	130.1	10.6	
250.0	18.3	8.9		2.500	1.129	8.9		25.0	135.5	8.9	
300.0	18.8	8.8		3.000	1.159	8.8		30.0	139.1	8.8	
400.0	19.2	6.9		4.000	1.184	6.9		40.0	142.1	6.9	
500.0	20.3	6.6		5.000	1.256	6.6		50.0	150.7	6.6	
600.0	20.4	6.7		6.000	1.257	6.7		60.0	150.9	6.7	
800.0	22.7	5.4		8.000	1.401	5.4		80.0	168.1	5.4	
References								References			
100.0	16.2							10.0	120.0		

Table 7 Downwind (8 km) Velocity and Turbulence Profile Data

Guam Project - ADCT Lateral Velocity and Turbulence Profiles

Model Mean Wind Speed (cm/s) at X = 0 cm

	Y (cm)							
Z (cm)	-90	-60	-30	0	30	60	90	Avg. Values
5	110	114	104	106	110	109	110	*105.6*
10	124	126	126	118	121	126	131	***121.6***
25	140	143	138	130	137	142	142	*139.6*

Normalized Mean Wind at X = 0 cm (Uref = 121.6 cm/s)

	Y (cm)						
Z (cm)	-90	-60	-30	0	30	60	90
5	0.91	0.94	0.86	0.87	0.90	0.89	0.91
10	1.02	1.04	1.03	0.97	0.99	1.04	1.08
25	1.15	1.18	1.14	1.07	1.12	1.17	1.17

Model Mean Wind Speed (cm/s) at X = 800 cm

	Y (cm)						
Z (cm)	-90	-60	-30	0	30	60	90
5	105	109	100	101	100	104	96
10	121	120	111	114	118	125	121
25	146	137	138	134	142	142	144

Normalized Mean Wind at X = 800 cm (Uref = 121.6 cm/s)

	Y (cm)						
Z (cm)	-90	-60	-30	0	30	60	90
5	0.87	0.90	0.82	0.83	0.82	0.85	0.79
10	1.00	0.99	0.92	0.94	0.97	1.02	1.00
25	1.20	1.12	1.14	1.10	1.17	1.17	1.19

Local Longitudinal Turbulent Intensity (%) at X = 0 cm

	Y (cm)							
Z (cm)	-90	-60	-30	0	30	60	90	Avg. Values
5	18	16	17	17	16	16	16	*16.8*
10	13	12	12	13	14	14	11	***13.2***
25	10	9	9	10	9	9	9	*9.2*

Normalized Local Long. Turb. Int. at X = 0 cm (T.I.ref = 13.2%)

	Y (cm)						
Z (cm)	-90	-60	-30	0	30	60	90
5	1.4	1.2	1.3	1.3	1.2	1.2	1.2
10	1.0	0.9	0.9	1.0	1.0	1.0	0.9
25	0.7	0.7	0.7	0.8	0.7	0.7	0.6

Local Longitudinal Turbulent Intensity (%) at X = 800 cm

	Y (cm)						
Z (cm)	-90	-60	-30	0	30	60	90
5	18	16	17	18	16	17	18
10	13	15	15	13	14	12	14
25	9	9	9	9	9	8	9

Normalized Local Long. Turb. Int. at X = 800 cm (T.I.ref = 13.2%)

	Y (cm)						
Z (cm)	-90	-60	-30	0	30	60	90
5	1.4	1.2	1.3	1.4	1.2	1.3	1.4
10	1.0	1.1	1.2	1.0	1.1	0.9	1.1
25	0.7	0.7	0.7	0.7	0.7	0.6	0.7

Table 8 ADCT Crosswind Velocity and Turbulence Profile Variation

Guam Project - ADCT Stack Concentration Measurements

Vertical Profile at 2 km downwind

Field Values (MKS)	Model Values (CGS)		RUN #	E203
1000		< Length Scale		
	119.2	< Wind Speed		
	37.5	< Flow Rate		
22.0		< Stack Gas Temp. (C)		
22.0		< Ambient Temp. (C)		
100.0	10.0	< Effective Stack Height		

Field Position X (m)	Y (m)	Z (m)	Model Position X (cm)	Y (cm)	Z (cm)	PG-C K*10^6 (m^-2)	Field K*10^6 (m^-2)	PG-D K*10^6 (m^-2)	PG-E K*10^6 (m^-2)	Model K*10^6 (cm^-2)	Model Conc. (ppm)
2000	0	0	200	0	0	9	14	9	2	1362	429
2000	0	20	200	0	2	9	14	10	4	1412	444
2000	0	40	200	0	4	9	15	12	11	1469	462
2000	0	60	200	0	6	9	15	15	22	1495	470
2000	0	80	200	0	8	8	15	17	34	1546	487
2000	0	100	200	0	10	8	15	18	39	1505	474
2000	0	120	200	0	12	7	14	17	34	1442	454
2000	0	140	200	0	14	7	13	15	22	1318	415
2000	0	160	200	0	16	6	12	11	11	1186	373
2000	0	180	200	0	18	6	11	7	4	1070	337
2000	0	200	200	0	20	5	9	5	1	891	281
2000	0	220	200	0	22	4	7	2	0	730	230
2000	0	240	200	0	24	4	6	1	0	568	179
2000	0	260	200	0	26	3	4	1	0	439	138
2000	0	280	200	0	28	3	3	0	0	300	94
2000	0	300	200	0	30	2	2	0	0	238	75
2000	0	320	200	0	32	2	2	0	0	163	51
2000	0	340	200	0	34	1	1	0	0	112	35
2000	0	360	200	0	36	1	1	0	0	82	26
2000	0	380	200	0	38	1	1	0	0	57	18
2000	0	400	200	0	40	1	0	0	0	38	12
2000	0	420	200	0	42	0	0	0	0	22	7
2000	0	440	200	0	44	0	0	0	0	14	4
2000	0	460	200	0	46	0	0	0	0	8	3
2000	0	480	200	0	48	0	0	0	0	7	2
2000	0	500	200	0	50	0	0	0	0	1	0
2000	0	520	200	0	52	0	0	0	0	0	0
2000	0	540	200	0	54	0	0	0	0	0	0
2000	0	560	200	0	56	0	0	0	0	1	0
2000	0	580	200	0	58	0	0	0	0	0	0
2000	0	600	200	0	60	0	0	0	0		
2000	0	620	200	0	62	0	0	0	0		
2000	0	640	200	0	64	0	0	0	0		
2000	0	680	200	0	68	0	0	0	0		
2000	0	700	200	0	70	0	0	0	0		
2000	0	720	200	0	72	0	0	0	0		
2000	0	760	200	0	76	0	0	0	0		
2000	0	800	200	0	80	0	0	0	0		
2000	0	840	200	0	84	0	0	0	0		
2000	0	880	200	0	88	0	0	0	0		
2000	0	920	200	0	92	0	0	0	0		
2000	0	960	200	0	96	0	0	0	0		
2000	0	1000	200	0	100	0	0	0	0		
2000	0	1040	200	0	104	0	0	0	0		
2000	0	1080	200	0	108	0	0	0	0		
2000	0	1120	200	0	112	0	0	0	0		
2000	0	1160	200	0	116	0	0	0	0		

Table 9 ADCT Vertical Concentration Profile Data; X = 2000 meters

Guam Project - ADCT Stack Concentration Measurements

Lateral Profile at 2 km downwind

Field Values (MKS)	Model Values (CGS)		RUN # E208
1000		< Length Scale	
	120.0	< Wind Speed	
	37.5	< Flow Rate	
22.0		< Stack Gas Temp. (C)	
22.0		< Ambient Temp. (C)	
100.0	10.0	< Effective Stack Height	

Field Position			Model Position			PG-C	Field	PG-D	PG-E	Model	Model
X (m)	Y (m)	Z (m)	X (cm)	Y (cm)	Z (cm)	K*10^6 (m^-2)	K*10^6 (m^-2)	K*10^6 (m^-2)	K*10^6 (m^-2)	K*10^6 (cm^-2)	Conc. (ppm)
2000	-80	100	200	-8	10	7	11	16	30	1144	358
2000	-60	100	200	-6	10	7	12	17	33	1228	384
2000	-40	100	200	-4	10	8	13	18	36	1271	397
2000	-20	100	200	-2	10	8	13	18	38	1326	415
2000	0	100	200	0	10	8	14	18	39	1366	427
2000	20	100	200	2	10	8	14	18	38	1373	429
2000	40	100	200	4	10	8	13	18	36	1345	421
2000	60	100	200	6	10	7	13	17	33	1335	417
2000	80	100	200	8	10	7	13	16	30	1279	400
2000	100	100	200	10	10	7	12	14	26	1213	379
2000	120	100	200	12	10	7	11	13	21	1132	354
2000	140	100	200	14	10	6	10	12	17	1035	324
2000	160	100	200	16	10	6	9	10	13	906	283
2000	180	100	200	18	10	5	8	9	10	806	252
2000	200	100	200	20	10	5	7	7	7	689	215
2000	220	100	200	22	10	4	6	6	5	581	182
2000	240	100	200	24	10	4	5	5	4	497	155
2000	260	100	200	26	10	3	4	4	2	404	126
2000	280	100	200	28	10	3	3	3	1	283	89
2000	300	100	200	30	10	3	2	2	1	224	70
2000	320	100	200	32	10	2	1	2	1	135	42
2000	340	100	200	34	10	2	1	1	0	120	38
2000	360	100	200	36	10	2	1	1	0	65	20
2000	380	100	200	38	10	1	0	1	0	49	15
2000	400	100	200	40	10	1	0	0	0	28	9
2000	420	100	200	42	10	1	0	0	0	13	4
2000	440	100	200	44	10	1	0	0	0	13	4
2000	460	100	200	46	10	1	0	0	0	9	3
2000	480	100	200	48	10	0	0	0	0	4	1
2000	500	100	200	50	10	0	0	0	0	6	2
2000	520	100	200	52	10	0	0	0	0		
2000	540	100	200	54	10	0	0	0	0		
2000	560	100	200	56	10	0	0	0	0		
2000	580	100	200	58	10	0	0	0	0		
2000	600	100	200	60	10	0	0	0	0		
2000	620	100	200	62	10	0	0	0	0		
2000	640	100	200	64	10	0	0	0	0		
2000	680	100	200	68	10	0	0	0	0		
2000	700	100	200	70	10	0	0	0	0		
2000	720	100	200	72	10	0	0	0	0		
2000	760	100	200	76	10	0	0	0	0		
2000	800	100	200	80	10	0	0	0	0		
2000	840	100	200	84	10	0	0	0	0		
2000	880	100	200	88	10	0	0	0	0		
2000	920	100	200	92	10	0	0	0	0		
2000	960	100	200	96	10	0	0	0	0		
2000	1000	100	200	100	10	0	0	0	0		

Table 10 ADCT Lateral Concentration Profile Data; X = 2000 meters

Guam Project - ADCT Stack Concentration Measurements

Vertical Profile at 4 km downwind

Field Values (MKS)	Model Values (CGS)		RUN # E003
1000		< Length Scale	
	115.5	< Wind Speed	
	37.5	< Flow Rate	
22.0		< Stack Gas Temp. (C)	
22.0		< Ambient Temp. (C)	
100.0	10.0	< Effective Stack Height	

Field Position			Model Position			PG-C	Field	PG-D	PG-E	Model	Model
X	Y	Z	X	Y	Z	K*10^6	K*10^6	K*10^6	K*10^6	K*10^6	Conc.
(m)	(m)	(m)	(cm)	(cm)	(cm)	(m^-2)	(m^-2)	(m^-2)	(m^-2)	(cm^-2)	(ppm)
4000	0	0	400	0	0	3	8	7	5	821	266
4000	0	20	400	0	2	3	8	7	6	797	259
4000	0	40	400	0	4	3	8	7	8	776	252
4000	0	60	400	0	6	3	8	7	11	750	244
4000	0	80	400	0	8	3	7	7	14	709	230
4000	0	100	400	0	10	3	7	7	14	695	226
4000	0	120	400	0	12	3	7	7	13	659	214
4000	0	140	400	0	14	3	6	6	11	629	204
4000	0	160	400	0	16	3	6	5	8	609	198
4000	0	180	400	0	18	3	6	4	5	573	186
4000	0	200	400	0	20	2	5	4	3	524	170
4000	0	220	400	0	22	2	5	3	1	486	158
4000	0	240	400	0	24	2	4	2	1	441	143
4000	0	260	400	0	26	2	4	1	0	399	130
4000	0	280	400	0	28	2	3	1	0	344	112
4000	0	300	400	0	30	2	3	1	0	318	103
4000	0	320	400	0	32	2	3	0	0	280	91
4000	0	340	400	0	34	1	2	0	0	235	76
4000	0	360	400	0	36	1	2	0	0	205	67
4000	0	380	400	0	38	1	2	0	0	168	55
4000	0	400	400	0	40	1	1	0	0	140	46
4000	0	420	400	0	42	1	1	0	0	116	38
4000	0	440	400	0	44	1	1	0	0	90	29
4000	0	460	400	0	46	1	1	0	0	72	23
4000	0	480	400	0	48	1	1	0	0	57	19
4000	0	500	400	0	50	1	0	0	0	47	15
4000	0	520	400	0	52	0	0	0	0	34	11
4000	0	540	400	0	54	0	0	0	0	26	9
4000	0	560	400	0	56	0	0	0	0	19	6
4000	0	580	400	0	58	0	0	0	0	17	5
4000	0	600	400	0	60	0	0	0	0		
4000	0	620	400	0	62	0	0	0	0		
4000	0	640	400	0	64	0	0	0	0		
4000	0	680	400	0	68	0	0	0	0		
4000	0	700	400	0	70	0	0	0	0		
4000	0	720	400	0	72	0	0	0	0		
4000	0	760	400	0	76	0	0	0	0		
4000	0	800	400	0	80	0	0	0	0		
4000	0	840	400	0	84	0	0	0	0		
4000	0	880	400	0	88	0	0	0	0		
4000	0	920	400	0	92	0	0	0	0		
4000	0	960	400	0	96	0	0	0	0		
4000	0	1000	400	0	100	0	0	0	0		
4000	0	1040	400	0	104	0	0	0	0		
4000	0	1080	400	0	108	0	0	0	0		
4000	0	1120	400	0	112	0	0	0	0		
4000	0	1160	400	0	116	0	0	0	0		

Table 11 ADCT Vertical Concentration Profile Data; X = 4000 meters

Guam Project - ADCT Stack Concentration Measurements

Lateral Profile at 4 km downwind

Field Values (MKS)	Model Values (CGS)		RUN #	E008
1000		< Length Scale		
	112.1	< Wind Speed		
	37.5	< Flow Rate		
22.0		< Stack Gas Temp. (C)		
22.0		< Ambient Temp. (C)		
100.0	10.0	< Effective Stack Height		

Field Position X (m)	Y (m)	Z (m)	Model Position X (cm)	Y (cm)	Z (cm)	PG-C K*10^6 (m^-2)	Field K*10^6 (m^-2)	PG-D K*10^6 (m^-2)	PG-E K*10^6 (m^-2)	Model K*10^6 (cm^-2)	Model Conc. (ppm)
4000	-80	100	400	-8	10	3	6	7	13	633	212
4000	-60	100	400	-6	10	3	7	7	14	664	222
4000	-40	100	400	-4	10	3	7	7	14	702	235
4000	-20	100	400	-2	10	3	7	7	14	707	237
4000	0	100	400	0	10	3	7	7	14	702	235
4000	20	100	400	2	10	3	7	7	14	697	233
4000	40	100	400	4	10	3	7	7	14	695	232
4000	60	100	400	6	10	3	7	7	14	680	227
4000	80	100	400	8	10	3	7	7	13	677	226
4000	100	100	400	10	10	3	6	7	13	647	216
4000	120	100	400	12	10	3	6	6	12	626	209
4000	140	100	400	14	10	3	6	6	11	598	200
4000	160	100	400	16	10	3	6	6	11	577	193
4000	180	100	400	18	10	3	5	6	10	542	181
4000	200	100	400	20	10	3	5	5	9	498	166
4000	220	100	400	22	10	3	5	5	8	464	155
4000	240	100	400	24	10	2	4	5	7	433	145
4000	260	100	400	26	10	2	4	4	6	407	136
4000	280	100	400	28	10	2	4	4	6	375	125
4000	300	100	400	30	10	2	3	4	5	340	114
4000	320	100	400	32	10	2	3	4	4	297	99
4000	340	100	400	34	10	2	3	3	4	265	89
4000	360	100	400	36	10	2	2	3	3	220	74
4000	380	100	400	38	10	2	2	3	2	197	66
4000	400	100	400	40	10	2	2	2	2	173	58
4000	420	100	400	42	10	2	1	2	2	143	48
4000	440	100	400	44	10	2	1	2	1	116	39
4000	460	100	400	46	10	1	1	2	1	93	31
4000	480	100	400	48	10	1	1	1	1	72	24
4000	500	100	400	50	10	1	1	1	1	62	21
4000	520	100	400	52	10	1	0	1	1		
4000	540	100	400	54	10	1	0	1	0		
4000	560	100	400	56	10	1	0	1	0		
4000	580	100	400	58	10	1	0	1	0		
4000	600	100	400	60	10	1	0	1	0		
4000	620	100	400	62	10	1	0	1	0		
4000	640	100	400	64	10	1	0	0	0		
4000	680	100	400	68	10	1	0	0	0		
4000	700	100	400	70	10	1	0	0	0		
4000	720	100	400	72	10	0	0	0	0		
4000	760	100	400	76	10	0	0	0	0		
4000	800	100	400	80	10	0	0	0	0		
4000	840	100	400	84	10	0	0	0	0		
4000	880	100	400	88	10	0	0	0	0		
4000	920	100	400	92	10	0	0	0	0		
4000	960	100	400	96	10	0	0	0	0		
4000	1000	100	400	100	10	0	0	0	0		

Table 12 ADCT Lateral Concentration Profile Data; X = 4000 meters

Guam Project - ADCT Stack Concentration Measurements

Vertical Profile at 6 km downwind

Field Values (MKS)	Model Values (CGS)		RUN #	E603
1000		< Length Scale		
	109.7	< Wind Speed		
	37.5	< Flow Rate		
22.0		< Stack Gas Temp. (C)		
22.0		< Ambient Temp. (C)		
100.0	10.0	< Effective Stack Height		

Field Position X (m)	Y (m)	Z (m)	Model Position X (cm)	Y (cm)	Z (cm)	PG-C K*10^6 (m^-2)	Field K*10^6 (m^-2)	PG-D K*10^6 (m^-2)	PG-E K*10^6 (m^-2)	Model K*10^6 (cm^-2)	Model Conc. (ppm)
6000	0	0	600	0	0	2	5	5	5	498	170
6000	0	20	600	0	2	2	5	5	6	490	168
6000	0	40	600	0	4	2	5	5	6	483	165
6000	0	60	600	0	6	2	5	5	8	465	159
6000	0	80	600	0	8	2	5	5	8	451	154
6000	0	100	600	0	10	2	4	4	9	433	148
6000	0	120	600	0	12	2	4	4	8	418	143
6000	0	140	600	0	14	2	4	4	7	398	136
6000	0	160	600	0	16	2	4	3	6	378	129
6000	0	180	600	0	18	2	4	3	4	358	122
6000	0	200	600	0	20	2	3	3	3	336	115
6000	0	220	600	0	22	1	3	2	2	313	107
6000	0	240	600	0	24	1	3	2	1	298	102
6000	0	260	600	0	26	1	3	1	0	279	96
6000	0	280	600	0	28	1	3	1	0	251	86
6000	0	300	600	0	30	1	2	1	0	235	81
6000	0	320	600	0	32	1	2	1	0	214	73
6000	0	340	600	0	34	1	2	0	0	194	66
6000	0	360	600	0	36	1	2	0	0	182	62
6000	0	380	600	0	38	1	2	0	0	156	53
6000	0	400	600	0	40	1	1	0	0	145	50
6000	0	420	600	0	42	1	1	0	0	127	44
6000	0	440	600	0	44	1	1	0	0	114	39
6000	0	460	600	0	46	1	1	0	0	101	35
6000	0	480	600	0	48	1	1	0	0	93	32
6000	0	500	600	0	50	1	1	0	0	84	29
6000	0	520	600	0	52	1	1	0	0	73	25
6000	0	540	600	0	54	1	1	0	0	61	21
6000	0	560	600	0	56	0	1	0	0	55	19
6000	0	580	600	0	58	0	0	0	0	46	16
6000	0	600	600	0	60	0	0	0	0		
6000	0	620	600	0	62	0	0	0	0		
6000	0	640	600	0	64	0	0	0	0		
6000	0	680	600	0	68	0	0	0	0		
6000	0	700	600	0	70	0	0	0	0		
6000	0	720	600	0	72	0	0	0	0		
6000	0	760	600	0	76	0	0	0	0		
6000	0	800	600	0	80	0	0	0	0		
6000	0	840	600	0	84	0	0	0	0		
6000	0	880	600	0	88	0	0	0	0		
6000	0	920	600	0	92	0	0	0	0		
6000	0	960	600	0	96	0	0	0	0		
6000	0	1000	600	0	100	0	0	0	0		
6000	0	1040	600	0	104	0	0	0	0		
6000	0	1080	600	0	108	0	0	0	0		
6000	0	1120	600	0	112	0	0	0	0		
6000	0	1160	600	0	116	0	0	0	0		

Table 13 ADCT Vertical Concentration Profile Data; X = 6000 meters

Guam Project - ADCT Stack Concentration Measurements

Lateral Profile at 6 km downwind

Field Values (MKS)	Model Values (CGS)		RUN # E608
1000		< Length Scale	
	109.0	< Wind Speed	
	37.5	< Flow Rate	
22.0		< Stack Gas Temp. (C)	
22.0		< Ambient Temp. (C)	
100.0	10.0	< Effective Stack Height	

Field Position X (m)	Y (m)	Z (m)	Model Position X (cm)	Y (cm)	Z (cm)	PG-C K*10^6 (m^-2)	Field K*10^6 (m^-2)	PG-D K*10^6 (m^-2)	PG-E K*10^6 (m^-2)	Model K*10^6 (cm^-2)	Model Conc. (ppm)
6000	-80	100	600	-8	10	2	3	4	8	305	105
6000	-60	100	600	-6	10	2	3	4	9	320	110
6000	-40	100	600	-4	10	2	3	4	9	344	118
6000	-20	100	600	-2	10	2	4	4	9	365	126
6000	0	100	600	0	10	2	4	4	9	382	132
6000	20	100	600	2	10	2	4	4	9	399	137
6000	40	100	600	4	10	2	4	4	9	414	142
6000	60	100	600	6	10	2	4	4	9	432	149
6000	80	100	600	8	10	2	4	4	8	448	154
6000	100	100	600	10	10	2	5	4	8	455	157
6000	120	100	600	12	10	2	5	4	8	466	160
6000	140	100	600	14	10	2	5	4	8	470	162
6000	160	100	600	16	10	2	5	4	7	470	162
6000	180	100	600	18	10	2	5	4	7	472	162
6000	200	100	600	20	10	2	5	4	7	468	161
6000	220	100	600	22	10	2	5	4	7	462	159
6000	240	100	600	24	10	2	4	4	6	448	154
6000	260	100	600	26	10	2	4	4	6	436	150
6000	280	100	600	28	10	1	4	3	5	433	149
6000	300	100	600	30	10	1	4	3	5	396	136
6000	320	100	600	32	10	1	4	3	5	395	136
6000	340	100	600	34	10	1	4	3	4	355	122
6000	360	100	600	36	10	1	3	3	4	337	116
6000	380	100	600	38	10	1	3	3	4	310	107
6000	400	100	600	40	10	1	3	3	3	293	101
6000	420	100	600	42	10	1	3	2	3	267	92
6000	440	100	600	44	10	1	2	2	3	234	81
6000	460	100	600	46	10	1	2	2	2	210	72
6000	480	100	600	48	10	1	2	2	2	190	66
6000	500	100	600	50	10	1	2	2	2	168	58
6000	520	100	600	52	10	1	0	2	2		
6000	540	100	600	54	10	1	0	2	1		
6000	560	100	600	56	10	1	0	2	1		
6000	580	100	600	58	10	1	0	1	1		
6000	600	100	600	60	10	1	0	1	1		
6000	620	100	600	62	10	1	0	1	1		
6000	640	100	600	64	10	1	0	1	1		
6000	680	100	600	68	10	1	0	1	1		
6000	700	100	600	70	10	1	0	1	0		
6000	720	100	600	72	10	1	0	1	0		
6000	760	100	600	76	10	1	0	1	0		
6000	800	100	600	80	10	1	0	0	0		
6000	840	100	600	84	10	0	0	0	0		
6000	880	100	600	88	10	0	0	0	0		
6000	920	100	600	92	10	0	0	0	0		
6000	960	100	600	96	10	0	0	0	0		
6000	1000	100	600	100	10	0	0	0	0		

Table 14 ADCT Lateral Concentration Profile Data; X = 6000 meters

Guam Project - ADCT Stack Concentration Measurements

Ground Level Profiles

Field Values (MKS)	Model Values (CGS)		RUN # E000
1000		< Length Scale	
	113.2	< Wind Speed	
	37.5	< Flow Rate	
22.0		< Stack Gas Temp. (C)	
22.0		< Ambient Temp. (C)	
100.0	10.0	< Effective Stack Height	

Field Position			Model Position			PG-C	Field	PG-D	PG-E	Model	Model
X (m)	Y (m)	Z (m)	X (cm)	Y (cm)	Z (cm)	K*10^6 (m^-2)	K*10^6 (m^-2)	K*10^6 (m^-2)	K*10^6 (m^-2)	K*10^6 (cm^-2)	Conc. (ppm)
250	0	0	25	0	0	0	0	0	0	0	0
500	0	0	50	0	0	5	0	0	0	14	5
750	0	0	75	0	0	14	2	1	0	178	59
1000	0	0	100	0	0	16	6	3	0	601	199
1250	0	0	125	0	0	15	9	6	0	903	299
1500	0	0	150	0	0	13	11	8	1	1133	375
1750	0	0	175	0	0	11	13	9	1	1315	436
2000	0	0	200	0	0	9	13	9	2	1349	447
2500	0	0	250	0	0	7	13	9	4	1341	444
3000	0	0	300	0	0	5	11	8	5	1134	376
3500	0	0	350	0	0	4	11	8	5	1094	363
4000	0	0	400	0	0	3	10	7	5	976	323
4500	0	0	450	0	0	3	9	6	5	887	294
5000	0	0	500	0	0	2	8	6	5	809	268
5500	0	0	550	0	0	2	7	5	5	727	241
6000	0	0	600	0	0	2	7	5	5	660	219
6500	0	0	650	0	0	2	6	5	5	602	199
7000	0	0	700	0	0	1	6	4	5	551	182
7500	0	0	750	0	0	1	5	4	5	515	171
8000	0	0	800	0	0	1	5	4	5	485	161
2000	-150	0	200	-15	0	7	7	5	1	667	221
2000	-100	0	200	-10	0	8	11	7	1	1100	364
2000	-50	0	200	-5	0	9	13	9	2	1269	420
2000	50	0	200	5	0	9	13	9	2	1255	416
2000	100	0	200	10	0	8	10	7	1	999	331
2000	150	0	200	15	0	7	8	5	1	812	269
4000	-150	0	400	-15	0	3	6	6	4	633	210
4000	-100	0	400	-10	0	3	8	7	5	784	260
4000	-50	0	400	-5	0	3	9	7	5	901	299
4000	50	0	400	5	0	3	10	7	5	993	329
4000	100	0	400	10	0	3	10	7	5	952	315
4000	150	0	400	15	0	3	8	6	4	840	278
6000	-150	0	600	-15	0	2	5	5	5	461	153
6000	-100	0	600	-10	0	2	5	5	5	521	173
6000	-50	0	600	-5	0	2	6	5	5	612	203
6000	50	0	600	5	0	2	7	5	5	680	225
6000	100	0	600	10	0	2	7	5	5	664	220
6000	150	0	600	15	0	2	6	5	5	633	210
8000	-150	0	800	-15	0	1	3	4	4	345	114
8000	-100	0	800	-10	0	1	4	4	4	394	131
8000	-50	0	800	-5	0	1	4	4	5	438	145
8000	50	0	800	5	0	1	5	4	5	498	165
8000	100	0	800	10	0	1	0	4	4		
8000	150	0	800	15	0	1	5	4	4	484	160

Table 15 ADCT Ground Level Concentration Profile Data

Field Test Conditions - Reynold Number Invariance Test Series

Measurement Type	Model Config.	Stack Config.	Wind Dir. (deg)	Ref. Velocity (cm/s)	Effluent Velocity (m/s)	Position X (cm)	Position Y (cm)	Position Z (cm)
Re Invariance Series								
Conc. Ground Level Profile	Generic	In	-	3	4.9	4000	Profile	0.0
"	"	"	-	6	9.9	"	"	"
"	"	"	-	9	14.8	"	"	"
"	"	"	-	12	19.7	"	"	"
"	"	"	-	15	24.7	"	"	"

Notes: Stack Config.

1) ADCT Stack > 100m stack, ID = 5m, SG = 1, W/U = 1.5

Notes: Ref. Velocity

2) Reference Velocity Height is 60 m

3) Power Law Index is 0.18

Model Test Conditions - Re No. Invariance Test Series

Vel. Scale = *0.126* *Length Scale =* *1000*

Measurement Type	Model Config.	Stack Config.	Wind Dir. (deg)	Ref. Velocity (cm/s)	Effluent Velocity (m/s)	Position X (cm)	Position Y (cm)	Position Z (cm)
Re Invariance Series								
Conc. Ground Level Profile	Generic	In	-	38	61.9	Profile	Profile	0.0
"	"	"	-	75	123.9	"	"	"
"	"	"	-	113	185.8	"	"	"
"	"	"	-	151	247.7	"	"	"
"	"	"	-	188	309.6	"	"	"

Notes: Stack Config.

1) ADCT Stack > 10cm stack, ID =0.5cm, SG = 1, W/U = 1.5

Notes: Ref. Velocity

2) Reference Velocity Height is 6cm

3) Power Law Index is 0.18

Table 16 Reynold Number Invariance Test Conditions

Reynolds Number Invariance Tests (Vertical Profile at 4 km)

Boudary Layer Condition E (8- 200cm high CSU Sprires, 2.5cm trip, smallest chains at 30cm)

RUN NO.						E001		E002		E003		E004		E005	
Stack Height (cm)						10.0		10.0		10.0		10.0		10.0	
Wind Speed at 80cm (cm/s)						50.1		98.9		150.2		200.9		255.8	
Stack Flow Rate (ccs)						12.5		25.0		37.5		50.0		62.5	
Q/U =						0.250		0.253		0.250		0.249		0.244	
Re* =						1.04		2.04		3.10		4.15		5.29	
Field Dist.			Model Dist.			Model Conc. (ppm)	Model K*10^6 (cm^-2)	Model Conc. (ppm)	Model K*10^6 (cm^-2)	Model Conc. (ppm)	Model K*10^6 (cm^-2)	Model Conc. (ppm)	Model K*10^6 (cm^-2)	Model Conc. (ppm)	Model K*10^6 (cm^-2)
X (m)	Y (m)	Z (m)	X (cm)	Y (cm)	Z (cm)										
4000	0	0	400	0	0	412	1651	274	1084	266	1067	244	982	235	960
4000	0	20	400	0	2	392	1570	267	1056	259	1036	240	965	227	931
4000	0	40	400	0	4	356	1428	254	1004	252	1009	240	964	220	900
4000	0	60	400	0	6	324	1298	245	968	244	975	236	948	214	877
4000	0	80	400	0	8	298	1194	242	956	230	921	228	916	207	849
4000	**0**	**100**	**400**	**0**	**10**	**254**	**1018**	**225**	**889**	**226**	**904**	**220**	**883**	**198**	**810**
4000	0	120	400	0	12	221	886	219	864	214	857	205	824	187	763
4000	0	140	400	0	14	189	757	205	809	204	818	190	764	174	711
4000	0	160	400	0	16	155	621	190	752	198	792	174	697	163	669
4000	0	180	400	0	18	133	533	181	714	186	745	161	645	151	619
4000	0	200	400	0	20	110	440	169	667	170	682	149	600	140	572
4000	0	220	400	0	22	86	346	150	595	158	632	138	553	130	533
4000	0	240	400	0	24	62	248	128	504	143	573	122	489	120	492
4000	0	260	400	0	26	54	216	112	444	130	519	110	442	105	429
4000	0	280	400	0	28	37	149	90	355	112	448	96	384	87	357
4000	0	300	400	0	30	29	117	76	301	103	414	87	350	78	320
4000	0	320	400	0	32	21	86	67	263	91	364	77	309	68	278
4000	0	340	400	0	34	13	51	56	223	76	306	64	256	57	232
4000	0	360	400	0	36	9	37	51	200	67	266	56	227	52	214
4000	0	380	400	0	38	7	29	39	156	55	218	49	198	43	176
4000	0	400	400	0	40	4	15	30	117	46	182	42	167	38	156
4000	0	420	400	0	42	3	10	26	104	38	151	36	143	30	122
4000	0	440	400	0	44	1	6	19	77	29	117	31	123	23	95
4000	0	460	400	0	46	1	4	17	69	23	93	24	97	19	77
4000	0	480	400	0	48	1	3	13	51	19	74	21	83	16	64
4000	0	500	400	0	50	0	2	10	38	15	60	17	68	12	49
4000	0	520	400	0	52	1	3	7	29	11	44	13	51	10	39
4000	0	540	400	0	54	0	2	6	22	9	34	10	41	7	28
4000	0	560	400	0	56	0	2	4	16	6	25	8	31	5	22
4000	0	580	400	0	58	0	0	3	11			6	23	4	17

Zo = 0.050 cm

Table 17 Re# Vertical Concentration Profile Data; X = 4000 meters

Reynolds Number Invariance Tests (Lateral Profile at 4 km at Stack Height)

Boudary Layer Condition E (8- 200cm high CSU Sprires, 2.5cm trip, smallest chains at 30cm)

RUN NO.						E006		E007		E008		E009		E010	
Stack Height (cm)						10.0		10.0		10.0		10.0		10.0	
Wind Speed at 80cm (cm/s)						49.2		99.4		145.8		205.7		250.8	
Stack Flow Rate (ccs)						12.5		25.0		37.5		50.0		62.5	
Q/U =						0.254		0.252		0.257		0.243		0.249	
Re* =						1.02		2.05		3.01		4.25		5.18	
Field Dist.			Model Dist.			Model	Model	Model	Model	Model	Model	Model	Model	Model	Model
X (m)	Y (m)	Z (m)	X (cm)	Y (cm)	Z (cm)	Conc. (ppm)	K*10^6 (cm^-2)	Conc. (ppm)	K*10^6 (cm^-2)	Conc. (ppm)	K*10^6 (cm^-2)	Conc. (ppm)	K*10^6 (cm^-2)	Conc. (ppm)	K*10^6 (cm^-2)
4000	-80	100	400	-8	10	309	1237	145	576	212	848	182	748	194	792
4000	-60	100	400	-6	10	321	1287	169	671	222	889	196	806	201	821
4000	-40	100	400	-4	10	325	1301	190	757	235	940	202	832	207	849
4000	-20	100	400	-2	10	320	1282	208	829	237	947	204	838	211	862
4000	**0**	**100**	**400**	**0**	**10**	**330**	**1322**	**232**	**920**	**235**	**940**	**206**	**849**	**215**	**878**
4000	20	100	400	2	10	336	1346	240	955	233	933	203	835	210	861
4000	40	100	400	4	10	341	1365	251	999	232	931	204	841	212	867
4000	60	100	400	6	10	339	1357	260	1032	227	911	201	829	207	848
4000	80	100	400	8	10	330	1322	266	1058	226	907	202	830	206	842
4000	100	100	400	10	10	334	1337	262	1040	216	866	199	819	200	819
4000	120	100	400	12	10	332	1328	270	1075	209	838	196	807	191	783
4000	140	100	400	14	10	322	1292	274	1088	200	800	190	781	179	734
4000	160	100	400	16	10	314	1259	271	1075	193	772	184	758	167	684
4000	180	100	400	18	10	298	1193	268	1065	181	726	175	721	157	643
4000	200	100	400	20	10	280	1120	259	1030	166	666	164	675	144	591
4000	220	100	400	22	10	263	1052	253	1005	155	621	155	637	136	558
4000	240	100	400	24	10	240	963	240	953	145	580	138	567	125	511
4000	260	100	400	26	10	233	934	222	884	136	545	125	516	110	449
4000	280	100	400	28	10	209	839	205	815	125	502	110	452	99	404
4000	300	100	400	30	10	189	756	192	762	114	455	101	414	87	356
4000	320	100	400	32	10	154	618	172	683	99	398	86	356	79	321
4000	340	100	400	34	10	130	520	165	654	89	354	81	335	64	262
4000	360	100	400	36	10	107	427	151	601	74	295	68	281	55	226
4000	380	100	400	38	10	93	373	135	538	66	264	59	244	45	186
4000	400	100	400	40	10	77	308	120	479	58	232	48	199	38	155
4000	420	100	400	42	10	64	258	102	404	48	191	35	144	31	125
4000	440	100	400	44	10	55	221	86	341	39	155	34	138	23	93
4000	460	100	400	46	10	48	193	69	274	31	124	27	110	18	73
4000	480	100	400	48	10	41	163	55	217	24	97	19	80	14	59
4000	500	100	400	50	10	34	136	46	181	21	84	18	73	11	47

Zo = 0.050 cm

Table 18 Re# Lateral Concentration Profile Data; X = 4000 meters

Omega Mass Flow Controller System Settings {FLOW_SET.WK4}

Test Program	Test Type	Config. (Uref or Source)	Total Flow Rate (ccs)	Spec. Gravity	Gas mixture component 1					Gas mixture component 2				
					Type	% Total (%)	Flow Rate (ccs)	Meter FS Range (SLPM)	Meter Setting (%FS)	Type	% Total (%)	Flow Rate (ccs)	Meter FS Range (SLPM)	Meter Setting (%FS)
ADCT	Visual	9 mps	36.5	1.000	Air	100.0	36.5	10	18.2					
ADCT	Conc.	9 mps	36.5	1.036	Ethane	100.0	36.5	10	36.6					
Re Inv.	Conc.	3 mps	12.2	1.036	Ethane	100.0	12.2	10	12.2					
"	"	6 mps	24.3	1.036	Ethane	100.0	24.3	10	24.4					
"	"	9 mps	36.5	1.036	Ethane	100.0	36.5	10	36.6					
"	"	12 mps	48.7	1.036	Ethane	100.0	48.7	10	48.8					
"	"	15 mps	60.8	1.036	Ethane	100.0	60.8	10	61.0					
Cabras 1&2	Visual	A	212.5	0.534	Air	45.9	97.6	10	48.6	Helium	54.1	114.9	10 50slpm	39.3 0.57volt
Cabras 3&4	"	B	255.9	0.350	Air	24.6	62.9	10	31.3	Helium	75.4	193.0	10 50slpm	66.0 0.68volt
Piti 4&5	"	C	98.5	0.507	Air	42.8	42.2	10	21.0	Helium	57.2	56.3	10 50slpm	19.3 0.22volt
Cabras 1&2	Conc.	A	212.5	0.534	Methane	95.5	203.0	100	14.0	Helium	4.5	9.5	1	32.4
Cabras 3&4	"	B	255.9	0.350	Ethane	23.6	60.4	10	60.6	Helium	76.4	195.5	10 50slpm	66.9 0.74volt
Piti 4&5	"	C	98.5	0.507	Propane	26.7	26.3	10 F36 Tube-602	36.7 G146 w/15psi	Helium	73.3	72.2	10 F33 Tube-603	24.7 S74 w/10psi

NOTES:

1) G indicates glass ball, S indicates steel ball

2) Matheson 50slpm Mass Flowmeter

Table 19 Stack Gas Flow Settings and Composition

FIGURES

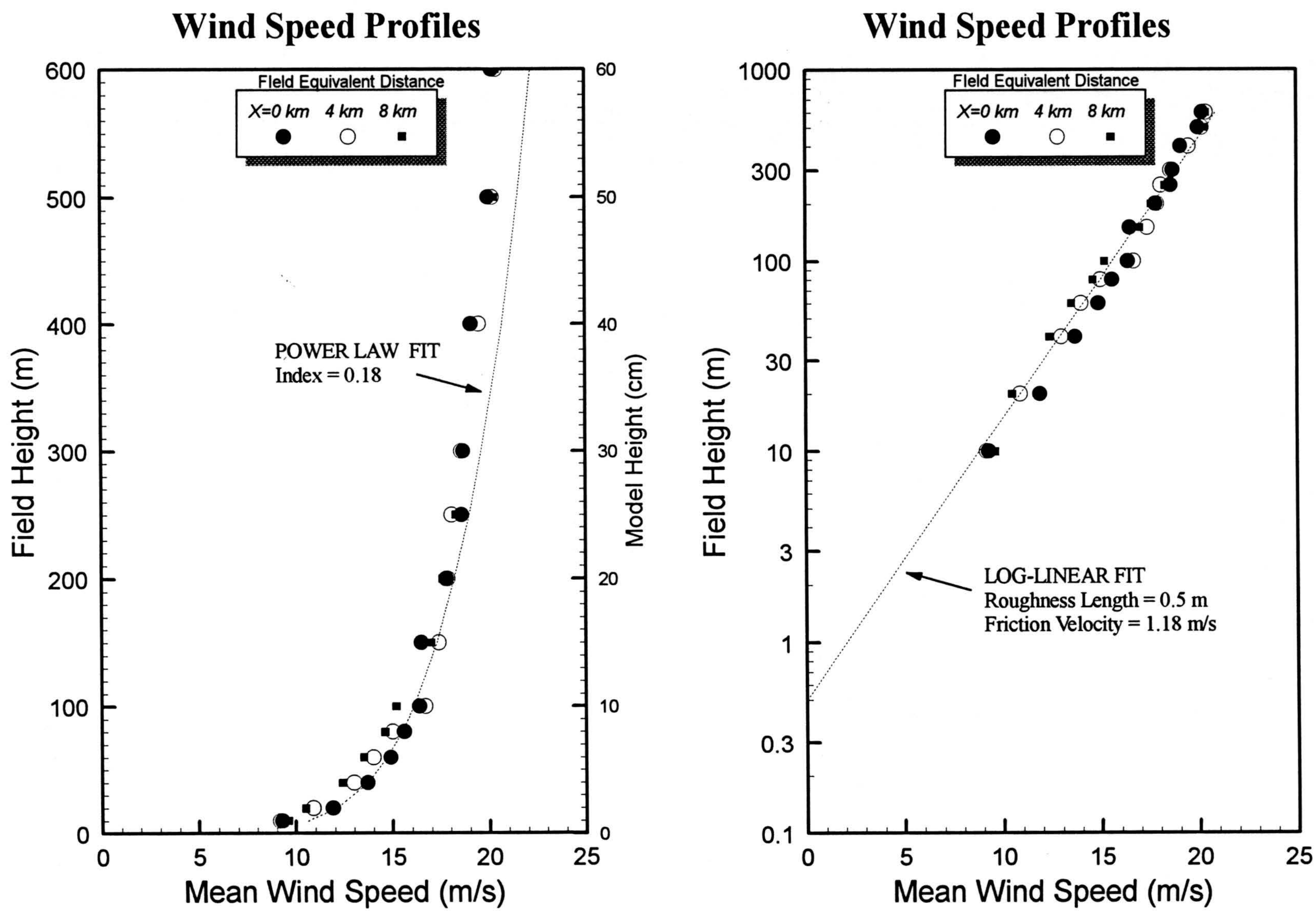


Figure 1 ADCT Reference Velocity Profiles

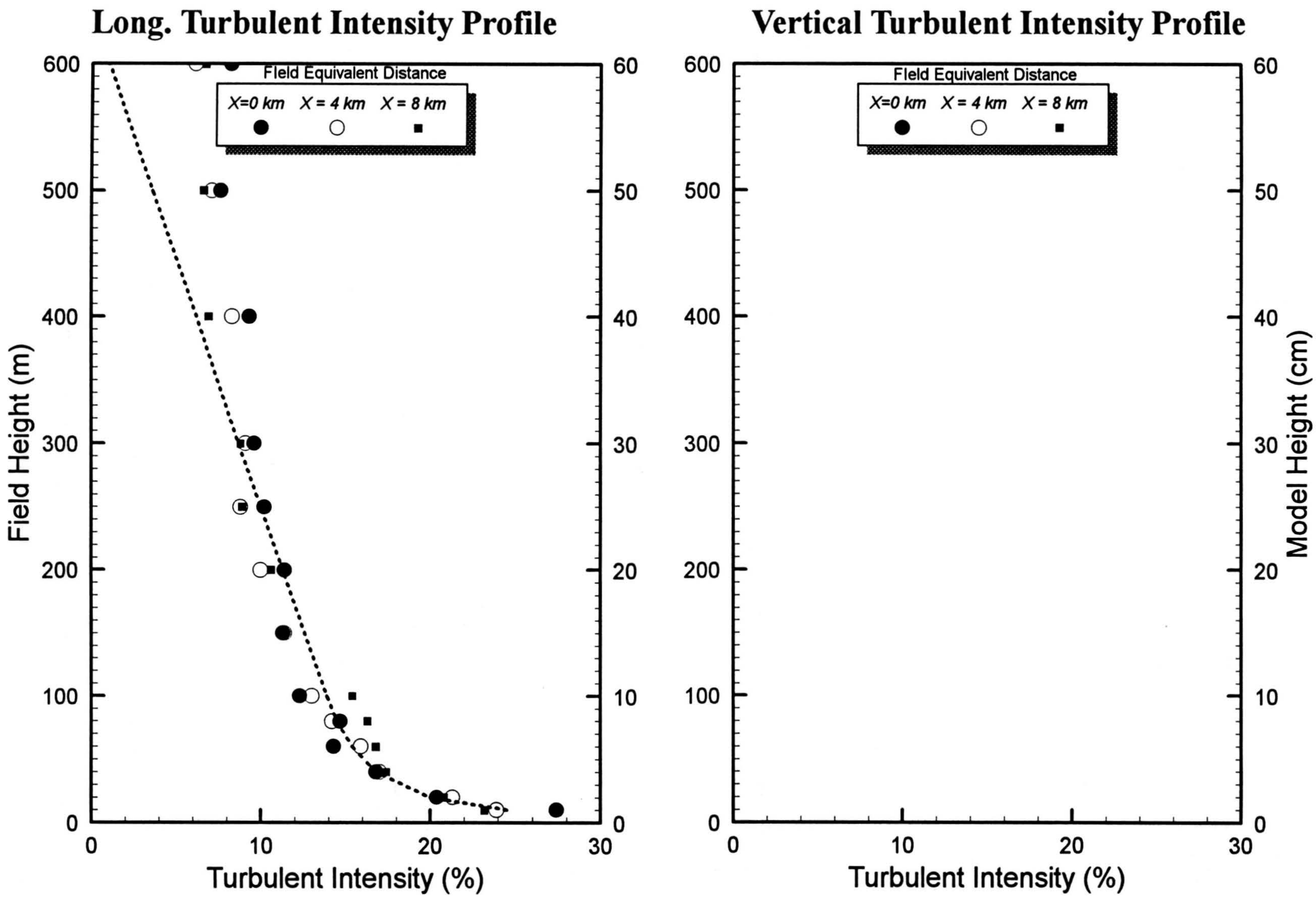
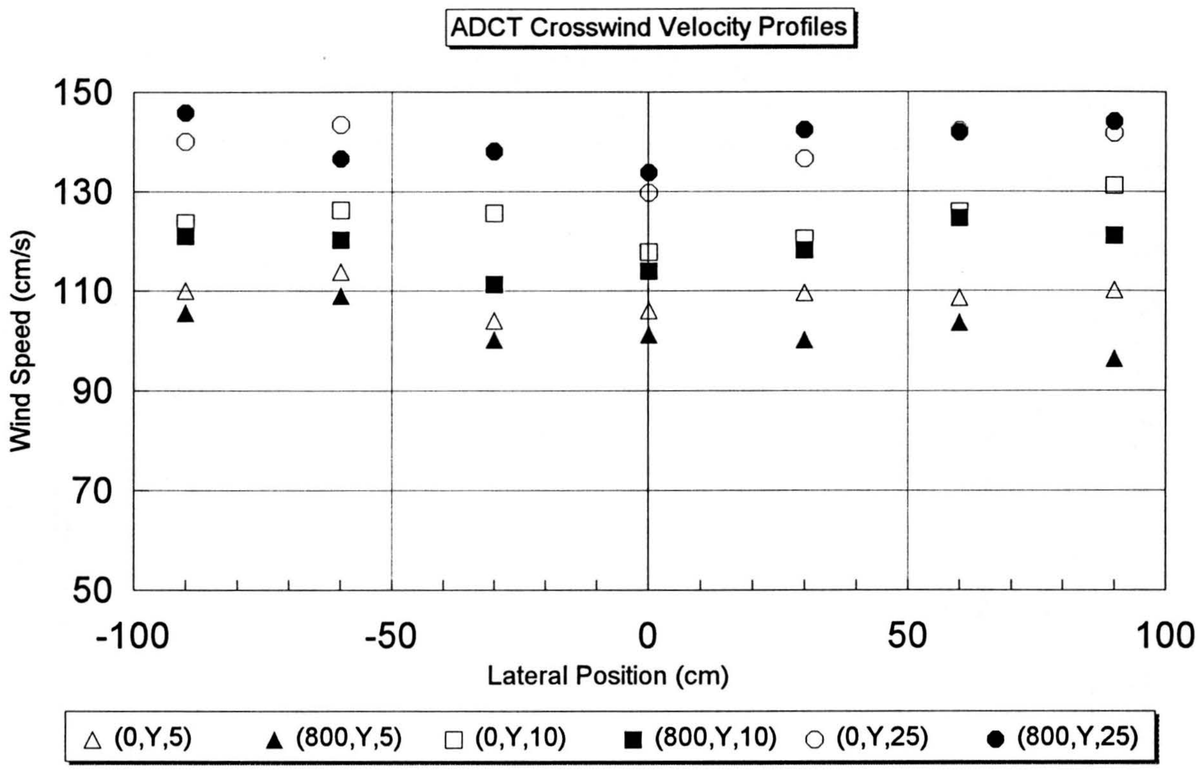


Figure 2 ADCT Reference Turbulence Profiles



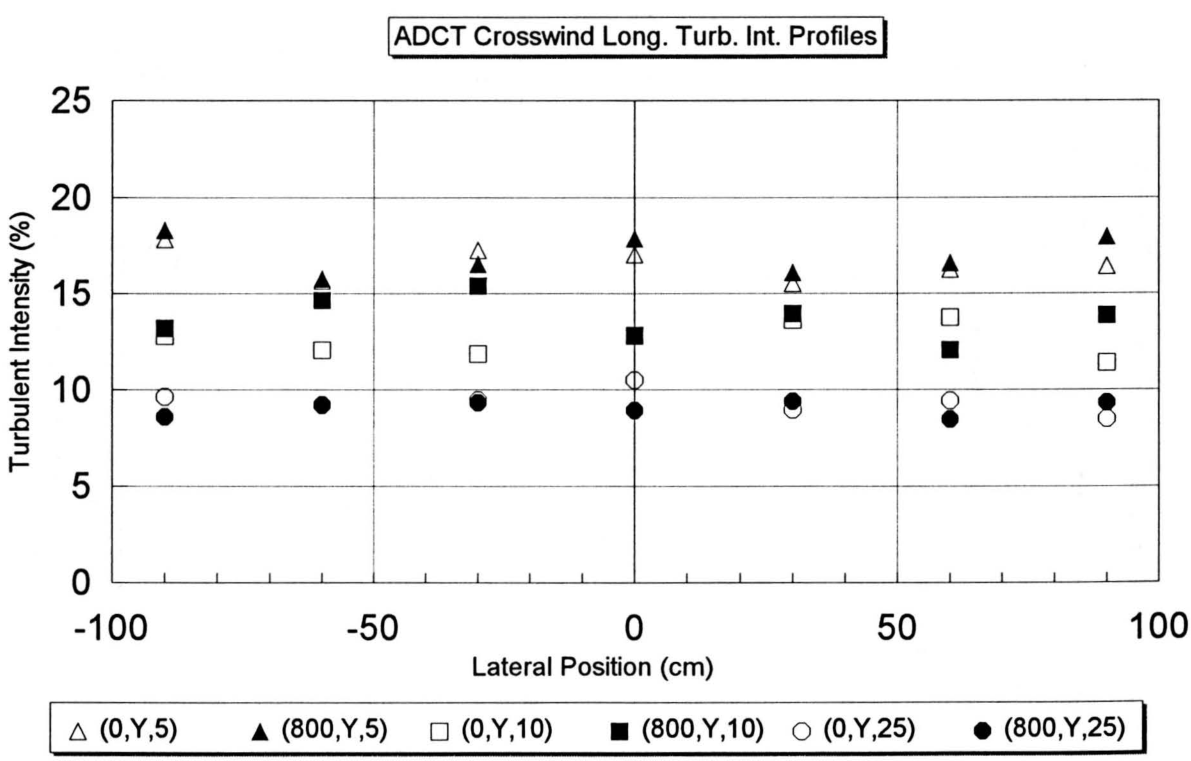


Figure 3 ADCT Crosswind Velocity and Turbulence Profile Variations

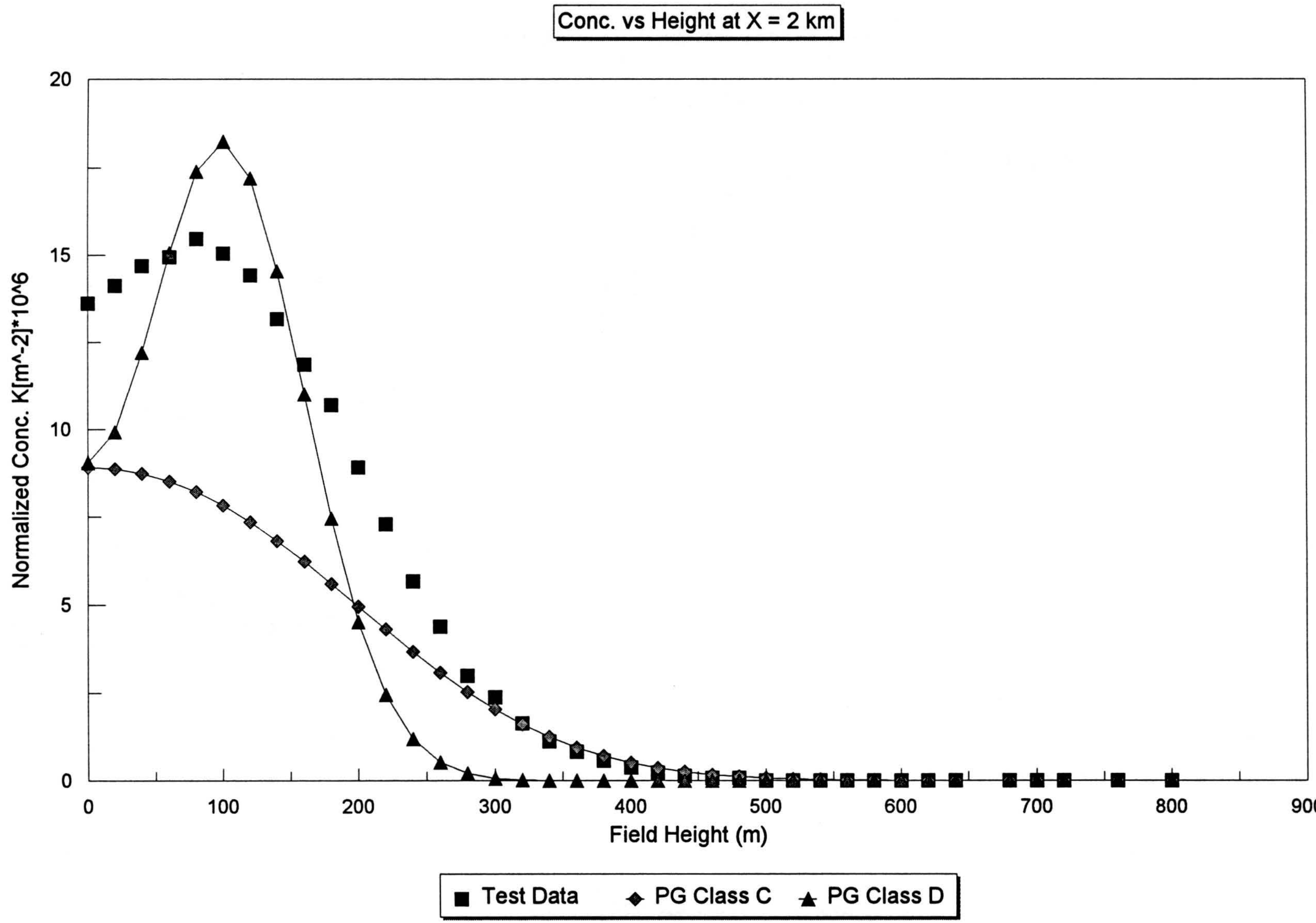


Figure 4 ADCT Vertical Concentration Profile; X = 2000 meters

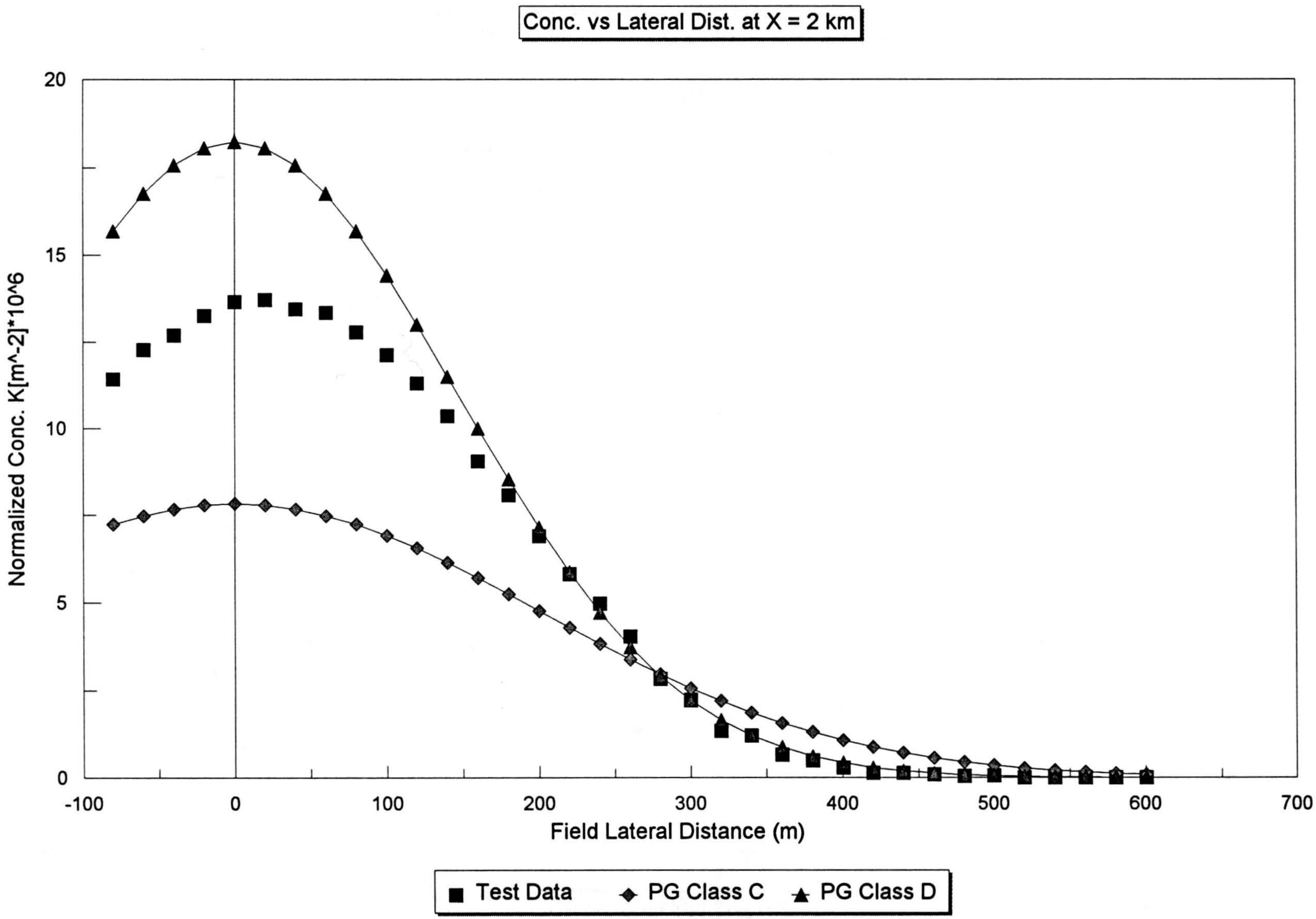


Figure 5 ADCT Lateral Concentration Profile; X = 2000 meters

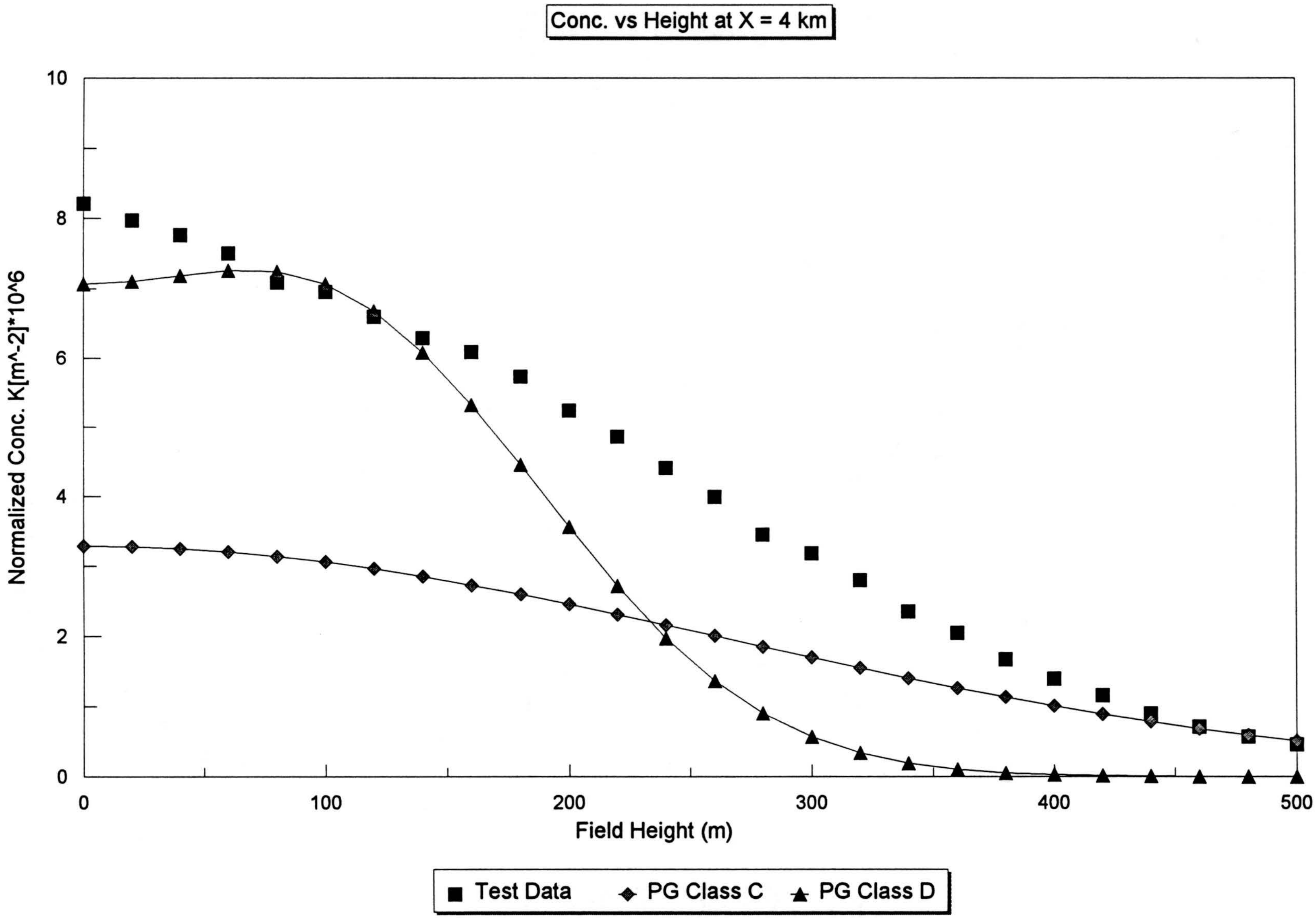


Figure 6 ADCT Vertical Concentration Profile; X = 4000 meters

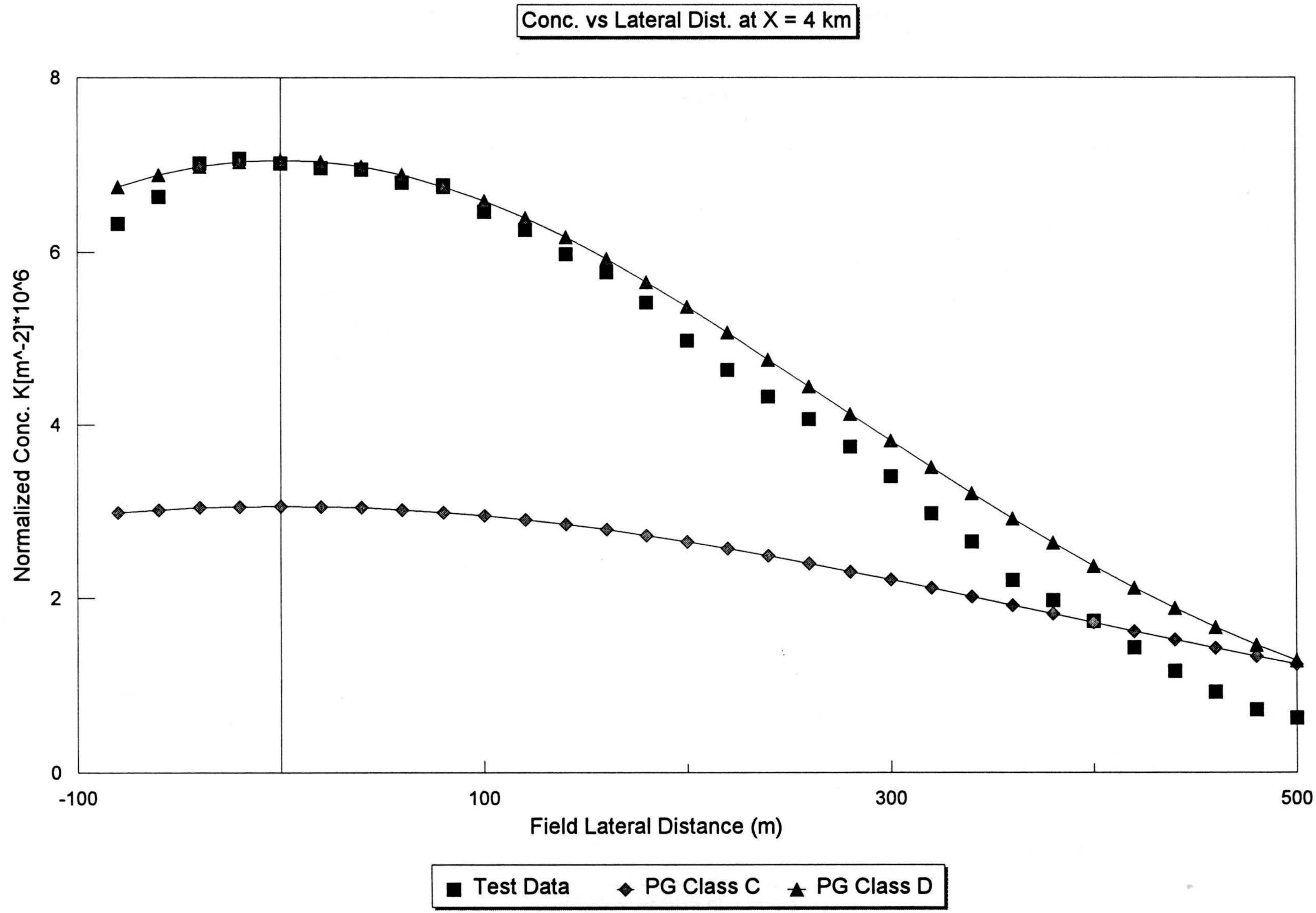


Figure 7 ADCT Lateral Concentration Profile; X = 4000 meters

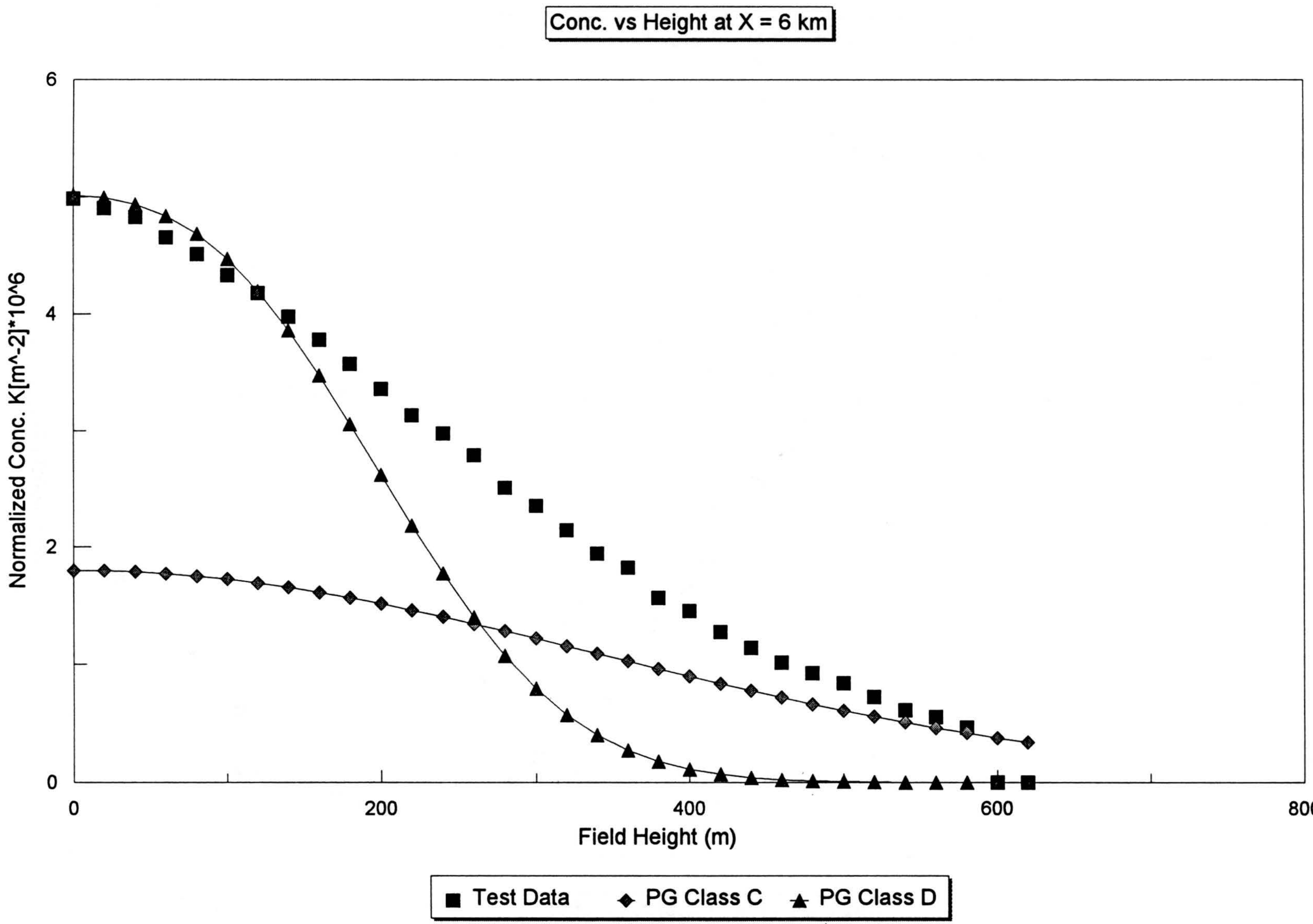


Figure 8 ADCT Vertical Concentration Profile; X = 6000 meters

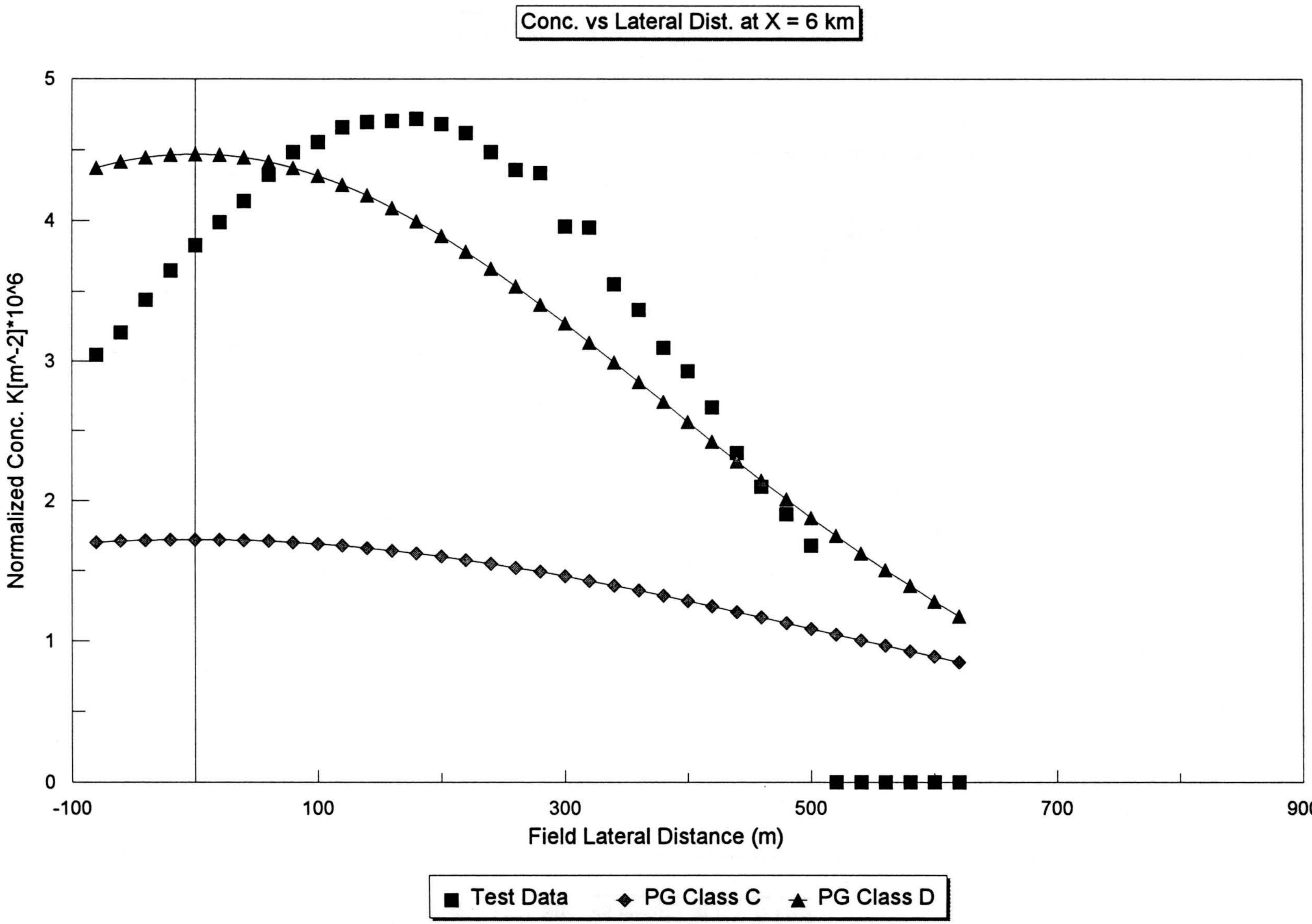


Figure 9 ADCT Lateral Concentration Profile; X = 6000 meters

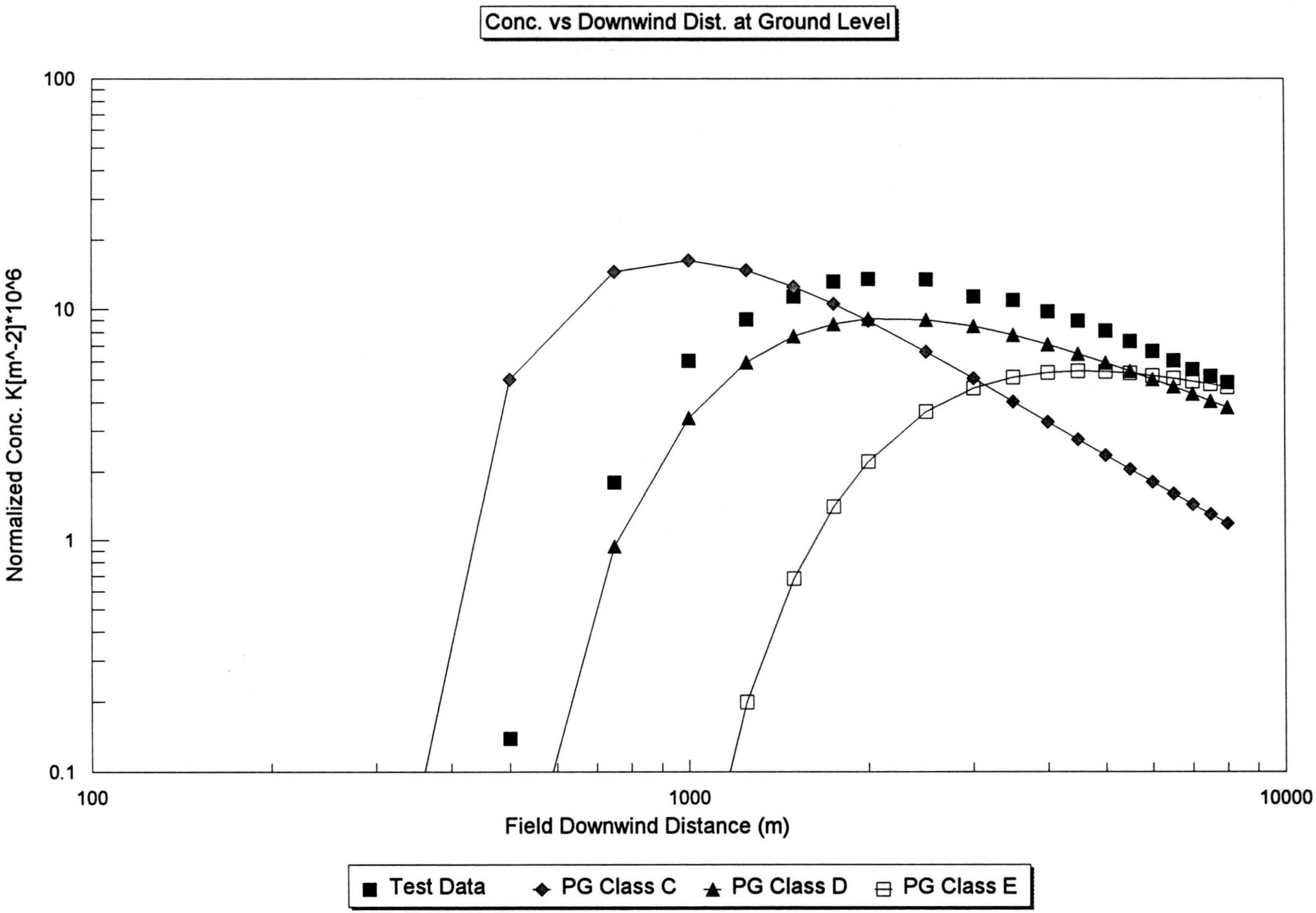


Figure 10 ADCT Ground Level Concentration Profile

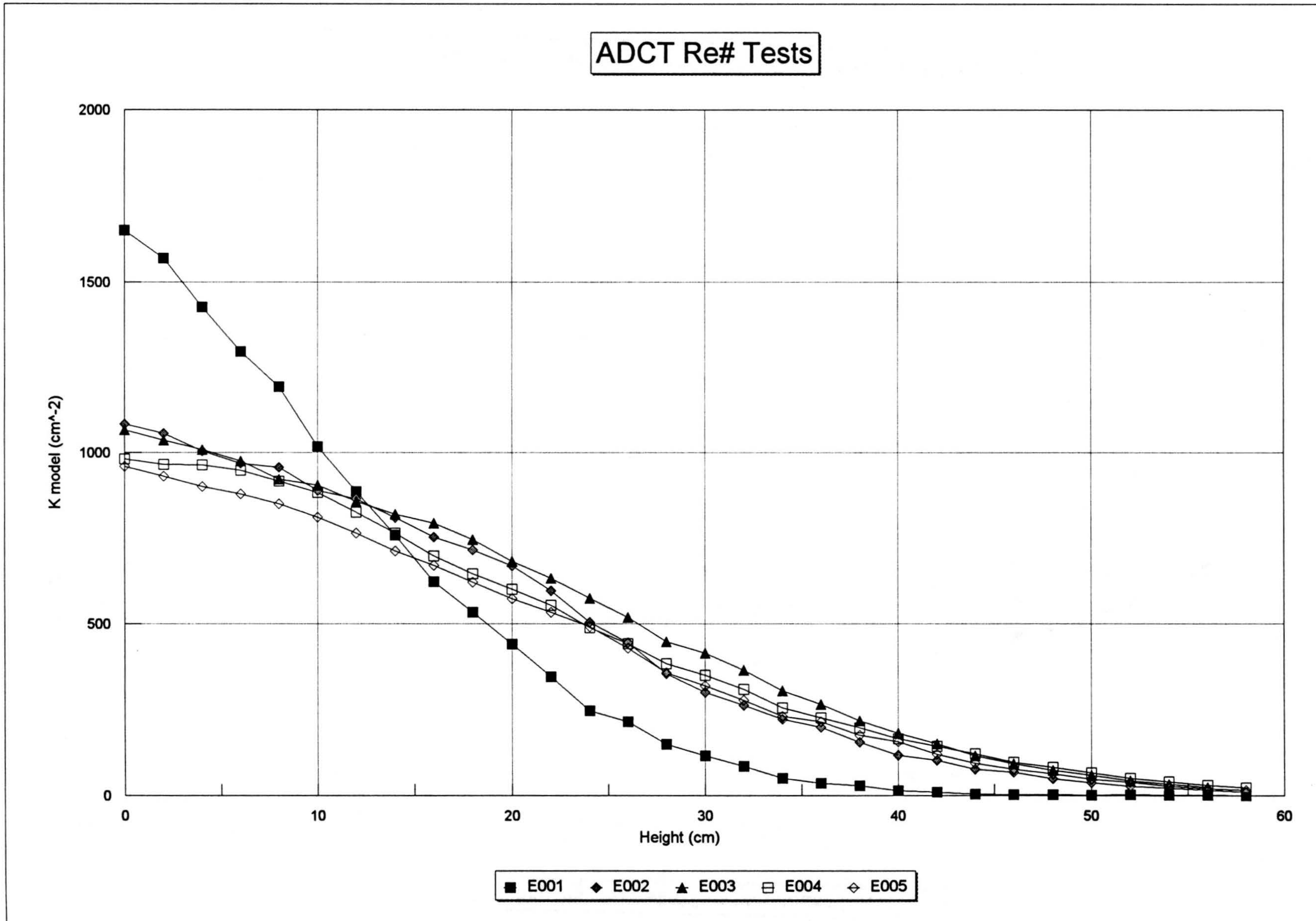


Figure 11 Re# Vertical Concentration Profile; X = 4000 meters

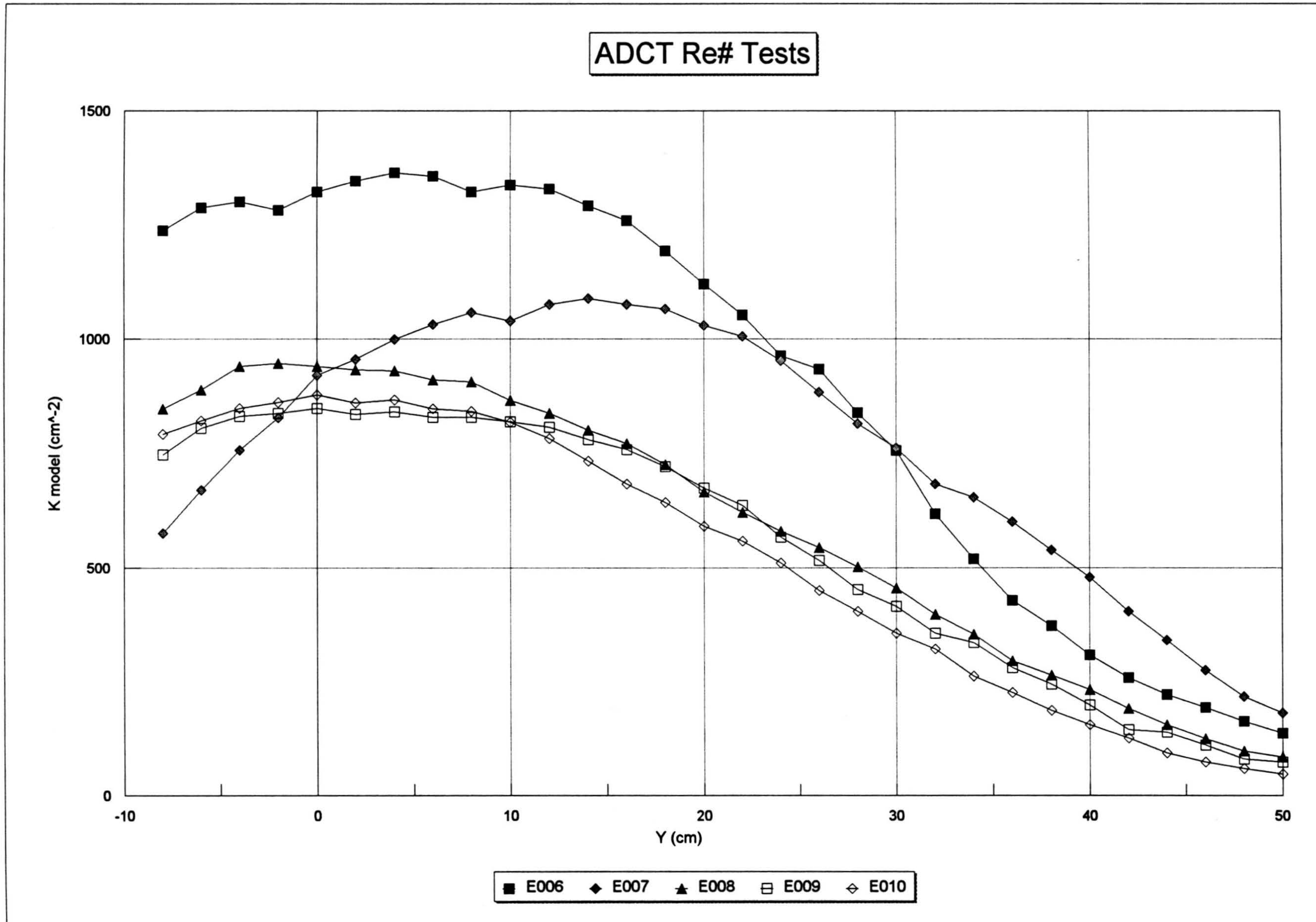


Figure 12 Re# Lateral Concentration Profile; X = 4000 meters

APPENDIX A: VIDEO TAPE ENCLOSURE

APPENDIX B: VELOCITY PROFILE DATA PRINTOUTS

Profile Name = VER0.PRF

Height (cm)	Velocity (cm/s)	Turb.Int. (%)
1.0000	68.681	27.425
2.0000	88.358	20.414
4.0000	101.48	16.830
6.0000	110.49	14.338
8.0000	115.85	14.678
10.000	121.61	12.341
15.000	122.30	11.332
20.000	131.50	11.353
25.000	137.69	10.221
30.000	138.15	9.5836
40.000	141.52	9.3323
50.000	147.88	7.6487
60.000	149.29	8.2243
80.000	158.28	7.4678

Profile Name = VER4.PRF

Height (cm)	Velocity (cm/s)	Turb.Int. (%)
1.0000	67.930	23.872
2.0000	81.072	21.279
4.0000	96.230	17.017
6.0000	103.53	15.947
8.0000	111.48	14.177
10.000	123.44	12.980
15.000	129.04	11.365
20.000	132.62	10.029
25.000	134.09	8.7813
30.000	137.58	9.0652
40.000	144.18	8.3059
50.000	149.86	7.1355
60.000	151.22	6.0849
80.000	158.63	5.9954

Profile Name = VER8.PRF

Height (cm)	Velocity (cm/s)	Turb.Int. (%)
1.0000	71.215	23.217
2.0000	77.702	20.835
4.0000	91.866	17.371
6.0000	100.11	16.784
8.0000	108.45	16.295
10.000	112.41	15.401
15.000	126.20	11.305
20.000	130.06	10.632
25.000	135.51	8.9408
30.000	139.12	8.8236
40.000	142.11	6.8968
50.000	150.67	6.5800
60.000	150.86	6.6543
80.000	168.06	5.4306

Profile Name = LATO-90.PRF

Height (cm)	Velocity (cm/s)	Turb.Int. (%)
5.0000	110.06	17.843
10.000	123.71	12.799
25.000	140.04	9.6421

Profile Name = LATO-60.PRF

Height (cm)	Velocity (cm/s)	Turb.Int. (%)
5.0000	113.90	15.689
10.000	126.34	12.044
25.000	143.49	9.2268

Profile Name = LATO-30.PRF

Height (cm)	Velocity (cm/s)	Turb.Int. (%)
5.0000	103.99	17.288
10.000	125.67	11.869
25.000	138.14	9.4768

Profile Name = LATO_00.PRF

Height (cm)	Velocity (cm/s)	Turb.Int. (%)
5.0000	106.08	17.045
10.000	117.84	12.804
25.000	129.70	10.485

Profile Name = LATO_30.PRF

Height (cm)	Velocity (cm/s)	Turb.Int. (%)
5.0000	109.59	15.551
10.000	120.50	13.631
25.000	136.61	8.9586

Profile Name = LATO_60.PRF

Height (cm)	Velocity (cm/s)	Turb.Int. (%)
5.0000	108.67	16.289
10.000	125.86	13.764
25.000	142.29	9.4467

Profile Name = LATO_90.PRF

Height (cm)	Velocity (cm/s)	Turb.Int. (%)
5.0000	110.17	16.444
10.000	131.23	11.391
25.000	141.78	8.5012

Profile Name = LAT8-90.PRF

Height (cm)	Velocity (cm/s)	Turb.Int. (%)
5.0000	105.49	18.301
10.000	121.08	13.196
25.000	145.87	8.6023

Profile Name = LAT8-60.PRF

Height (cm)	Velocity (cm/s)	Turb.Int. (%)
5.0000	109.03	15.764
10.000	120.31	14.657
25.000	136.66	9.2130

Profile Name = LAT8-30.PRF

Height (cm)	Velocity (cm/s)	Turb.Int. (%)
5.0000	100.10	16.535
10.000	111.35	15.418
25.000	138.12	9.3318

Profile Name = LAT8_00.PRF

Height (cm)	Velocity (cm/s)	Turb.Int. (%)
5.0000	101.17	17.889
10.000	113.93	12.821
25.000	133.87	8.9438

Profile Name = LAT8_30.PRF

Height (cm)	Velocity (cm/s)	Turb.Int. (%)
5.0000	100.20	16.110
10.000	118.28	13.938
25.000	142.46	9.4052

Profile Name = LAT8_60.PRF

Height (cm)	Velocity (cm/s)	Turb.Int. (%)
5.0000	103.62	16.624
10.000	124.55	12.065
25.000	141.94	8.4861

Profile Name = LAT8_90.PRF

Height (cm)	Velocity (cm/s)	Turb.Int. (%)
5.0000	96.271	17.978
10.000	121.22	13.845
25.000	144.08	9.3549

APPENDIX C: CONCENTRATION DATA FILE PRINTOUTS

```
File Name E001.GC
Run# E001      DEN          06-10-95    16:10:25
Wind Speed (cm/s)       =     50.09  Hr (cm) =      6.00
Air Temp.  (C)          =     26.90  Hr (cm) =      6.00
Source Designation      =  1
Source Flow Rate (ccs)  =        12.50
Source Gas Temp. (C)    =        26.90
Tracer Type             =        C2H6
Tracer Conc. (ppm)      =   1000000.0
Background Conc. (ppm)  =          4.0
Position Grid Filename  >     POS_VER2.INP
```

Tube No.	X (cm)	Y (cm)	Z (cm)	Meas.#1 (ppm)	Norm.#1 (ppm)	K1*10^6 (cm^-2)
1	400.00	.00	.00	416.1	412.1	1651.3
2	400.00	.00	2.00	395.7	391.7	1569.6
3	400.00	.00	4.00	360.3	356.3	1427.7
4	400.00	.00	6.00	327.8	323.8	1297.5
5	400.00	.00	8.00	302.0	298.0	1194.2
6	400.00	.00	10.00	258.1	254.1	1018.3
7	400.00	.00	12.00	225.1	221.1	885.9
8	400.00	.00	14.00	193.0	189.0	757.5
9	400.00	.00	16.00	158.9	155.0	620.9
10	400.00	.00	18.00	136.9	132.9	532.5
11	400.00	.00	20.00	113.8	109.8	440.0
12	400.00	.00	22.00	90.2	86.3	345.6
13	400.00	.00	24.00	65.8	61.8	247.8
14	400.00	.00	26.00	57.7	53.8	215.4
15	400.00	.00	28.00	41.2	37.3	149.3
16	400.00	.00	30.00	33.2	29.2	117.0
17	400.00	.00	32.00	25.3	21.4	85.6
18	400.00	.00	34.00	16.7	12.7	51.0
19	400.00	.00	36.00	13.2	9.2	36.9
20	400.00	.00	38.00	11.3	7.3	29.3
21	400.00	.00	40.00	7.6	3.7	14.6
22	400.00	.00	42.00	6.5	2.5	10.1
23	400.00	.00	44.00	5.4	1.4	5.7
24	400.00	.00	46.00	5.1	1.1	4.6
25	400.00	.00	48.00	4.6	.7	2.7
26	400.00	.00	50.00	4.4	.4	1.5
27	400.00	.00	52.00	4.7	.7	2.9
28	400.00	.00	54.00	4.4	.4	1.5
29	400.00	.00	56.00	4.3	.4	1.5
30	400.00	.00	58.00	4.1	.1	.4

File Name E002.GC
Run# E002 DEN 06-10-95 17: 0:41
Wind Speed (cm/s) = 98.85 Hr (cm) = 6.00
Air Temp. (C) = 26.90 Hr (cm) = 6.00
Source Designation = 1
Source Flow Rate (ccs) = 25.00
Source Gas Temp. (C) = 26.90
Tracer Type = C2H6
Tracer Conc. (ppm) = 1000000.0
Background Conc. (ppm) = 4.5
Position Grid Filename > POS_VER2.INP

Tube No.	X (cm)	Y (cm)	Z (cm)	Meas.#1 (ppm)	Norm.#1 (ppm)	K1*10^6 (cm^-2)
1	400.00	.00	.00	278.7	274.2	1084.2
2	400.00	.00	2.00	271.6	267.1	1056.2
3	400.00	.00	4.00	258.4	253.9	1003.9
4	400.00	.00	6.00	249.4	244.9	968.4
5	400.00	.00	8.00	246.2	241.8	955.9
6	400.00	.00	10.00	229.3	224.8	888.7
7	400.00	.00	12.00	222.9	218.5	863.8
8	400.00	.00	14.00	209.1	204.6	808.9
9	400.00	.00	16.00	194.6	190.1	751.8
10	400.00	.00	18.00	185.1	180.6	714.0
11	400.00	.00	20.00	173.3	168.8	667.5
12	400.00	.00	22.00	154.9	150.4	594.6
13	400.00	.00	24.00	131.9	127.5	503.9
14	400.00	.00	26.00	116.7	112.2	443.7
15	400.00	.00	28.00	94.2	89.7	354.8
16	400.00	.00	30.00	80.7	76.2	301.3
17	400.00	.00	32.00	71.1	66.6	263.5
18	400.00	.00	34.00	60.8	56.3	222.6
19	400.00	.00	36.00	54.9	50.5	199.5
20	400.00	.00	38.00	43.9	39.4	155.8
21	400.00	.00	40.00	34.2	29.7	117.5
22	400.00	.00	42.00	30.7	26.3	103.9
23	400.00	.00	44.00	23.9	19.4	76.9
24	400.00	.00	46.00	21.9	17.4	68.8
25	400.00	.00	48.00	17.2	12.8	50.5
26	400.00	.00	50.00	14.2	9.7	38.5
27	400.00	.00	52.00	11.8	7.3	29.0
28	400.00	.00	54.00	10.0	5.5	21.8
29	400.00	.00	56.00	8.5	4.0	15.7
30	400.00	.00	58.00	7.1	2.7	10.5

```
File Name E003.GC
Run# E003       DEN          06-10-95    17:40: 5
Wind Speed (cm/s)       =     150.16  Hr (cm) =      6.00
Air Temp.  (C)          =      26.90  Hr (cm) =      6.00
Source Designation      =  1
Source Flow Rate (ccs)  =        37.50
Source Gas Temp. (C)    =        26.90
Tracer Type             =        C2H6
Tracer Conc. (ppm)      =    1000000.0
Background Conc. (ppm)  =          6.2
Position Grid Filename  >    POS_VER2.INP
```

Tube No.	X (cm)	Y (cm)	Z (cm)	Meas.#1 (ppm)	Norm.#1 (ppm)	K1*10^6 (cm^-2)
1	400.00	.00	.00	272.6	266.4	1066.9
2	400.00	.00	2.00	264.9	258.7	1035.8
3	400.00	.00	4.00	258.0	251.9	1008.5
4	400.00	.00	6.00	249.7	243.5	975.1
5	400.00	.00	8.00	236.3	230.1	921.5
6	400.00	.00	10.00	231.9	225.7	903.7
7	400.00	.00	12.00	220.3	214.1	857.1
8	400.00	.00	14.00	210.5	204.3	818.3
9	400.00	.00	16.00	204.0	197.8	792.2
10	400.00	.00	18.00	192.2	186.0	745.0
11	400.00	.00	20.00	176.4	170.2	681.7
12	400.00	.00	22.00	164.0	157.8	631.9
13	400.00	.00	24.00	149.4	143.2	573.3
14	400.00	.00	26.00	135.7	129.5	518.5
15	400.00	.00	28.00	118.0	111.8	447.7
16	400.00	.00	30.00	109.5	103.3	413.7
17	400.00	.00	32.00	97.2	91.0	364.4
18	400.00	.00	34.00	82.5	76.3	305.5
19	400.00	.00	36.00	72.7	66.5	266.2
20	400.00	.00	38.00	60.7	54.5	218.3
21	400.00	.00	40.00	51.7	45.5	182.1
22	400.00	.00	42.00	43.9	37.7	151.0
23	400.00	.00	44.00	35.4	29.2	116.8
24	400.00	.00	46.00	29.5	23.3	93.4
25	400.00	.00	48.00	24.8	18.6	74.4
26	400.00	.00	50.00	21.3	15.1	60.4
27	400.00	.00	52.00	17.2	11.0	44.1
28	400.00	.00	54.00	14.8	8.6	34.4
29	400.00	.00	56.00	12.5	6.3	25.4
30	400.00	.00	58.00	11.5	5.4	21.4

File Name E004.GC
Run# E004 DEN 06-10-95 18:18:26
Wind Speed (cm/s) = 200.86 Hr (cm) = 6.00
Air Temp. (C) = 26.90 Hr (cm) = 6.00
Source Designation = 1
Source Flow Rate (ccs) = 50.00
Source Gas Temp. (C) = 26.90
Tracer Type = C2H6
Tracer Conc. (ppm) = 1000000.0
Background Conc. (ppm) = 8.9
Position Grid Filename > POS_VER2.INP

Tube No.	X (cm)	Y (cm)	Z (cm)	Meas.#1 (ppm)	Norm.#1 (ppm)	K1*10^6 (cm^-2)
1	400.00	.00	.00	253.3	244.4	981.9
2	400.00	.00	2.00	249.0	240.1	964.4
3	400.00	.00	4.00	248.8	239.9	963.8
4	400.00	.00	6.00	244.8	235.9	947.7
5	400.00	.00	8.00	236.9	228.0	915.9
6	400.00	.00	10.00	228.6	219.7	882.4
7	400.00	.00	12.00	214.1	205.2	824.3
8	400.00	.00	14.00	199.1	190.2	763.9
9	400.00	.00	16.00	182.4	173.5	696.8
10	400.00	.00	18.00	169.4	160.5	644.6
11	400.00	.00	20.00	158.1	149.3	599.6
12	400.00	.00	22.00	146.6	137.7	553.3
13	400.00	.00	24.00	130.6	121.7	488.9
14	400.00	.00	26.00	118.9	110.0	441.9
15	400.00	.00	28.00	104.4	95.5	383.8
16	400.00	.00	30.00	96.1	87.2	350.3
17	400.00	.00	32.00	85.8	76.9	308.9
18	400.00	.00	34.00	72.7	63.8	256.5
19	400.00	.00	36.00	65.3	56.4	226.5
20	400.00	.00	38.00	58.3	49.4	198.6
21	400.00	.00	40.00	50.4	41.5	166.6
22	400.00	.00	42.00	44.6	35.7	143.3
23	400.00	.00	44.00	39.4	30.5	122.5
24	400.00	.00	46.00	33.1	24.2	97.3
25	400.00	.00	48.00	29.6	20.7	83.1
26	400.00	.00	50.00	25.8	16.9	68.0
27	400.00	.00	52.00	21.6	12.7	51.0
28	400.00	.00	54.00	19.0	10.1	40.5
29	400.00	.00	56.00	16.6	7.7	31.1
30	400.00	.00	58.00	14.7	5.8	23.1

```
File Name E006.GC
Run# E006       DEN          06-10-95    12:42:36
Wind Speed (cm/s)          =    49.19   Hr (cm) =     6.00
Air Temp.  (C)             =    25.60   Hr (cm) =     6.00
Source Designation         =  1
Source Flow Rate (ccs)     =       12.50
Source Gas Temp. (C)       =       25.60
Tracer Type                =       C2H6
Tracer Conc. (ppm)         =   1000000.0
Background Conc. (ppm)     =          .0
Position Grid Filename >      POS_LAT2.INP
```

Tube No.	X (cm)	Y (cm)	Z (cm)	Meas.#1 (ppm)	Norm.#1 (ppm)	K1*10^6 (cm^-2)
1	400.00	-8.00	10.00	308.8	308.8	1215.3
2	400.00	-6.00	10.00	321.1	321.1	1263.9
3	400.00	-4.00	10.00	324.6	324.6	1277.7
4	400.00	-2.00	10.00	319.9	319.9	1258.8
5	400.00	.00	10.00	330.0	330.0	1298.9
6	400.00	2.00	10.00	335.9	335.9	1321.8
7	400.00	4.00	10.00	340.7	340.7	1340.9
8	400.00	6.00	10.00	338.7	338.7	1332.8
9	400.00	8.00	10.00	329.9	329.9	1298.4
10	400.00	10.00	10.00	333.7	333.7	1313.2
11	400.00	12.00	10.00	331.5	331.5	1304.8
12	400.00	14.00	10.00	322.4	322.4	1268.7
13	400.00	16.00	10.00	314.3	314.3	1237.0
14	400.00	18.00	10.00	297.7	297.7	1171.5
15	400.00	20.00	10.00	279.5	279.5	1100.0
16	400.00	22.00	10.00	262.6	262.6	1033.6
17	400.00	24.00	10.00	240.4	240.4	946.0
18	400.00	26.00	10.00	233.1	233.1	917.3
19	400.00	28.00	10.00	209.4	209.4	824.3
20	400.00	30.00	10.00	188.7	188.7	742.8
21	400.00	32.00	10.00	154.3	154.3	607.3
22	400.00	34.00	10.00	129.7	129.7	510.3
23	400.00	36.00	10.00	106.6	106.6	419.6
24	400.00	38.00	10.00	93.0	93.0	365.9
25	400.00	40.00	10.00	76.9	76.9	302.6
26	400.00	42.00	10.00	64.3	64.3	253.1
27	400.00	44.00	10.00	55.1	55.1	217.0
28	400.00	46.00	10.00	48.2	48.2	189.8
29	400.00	48.00	10.00	40.6	40.6	159.6
30	400.00	50.00	10.00	33.9	33.9	133.5

```
File Name E007.GC
Run# E007      DEN          06-10-95    13:23: 9
Wind Speed (cm/s)       =     99.39  Hr (cm) =     6.00
Air Temp.  (C)          =     25.60  Hr (cm) =     6.00
Source Designation      =  1
Source Flow Rate (ccs)  =      25.00
Source Gas Temp. (C)    =      25.60
Tracer Type             =      C2H6
Tracer Conc. (ppm)      =   1000000.0
Background Conc. (ppm)  =        1.6
Position Grid Filename  >    POS_LAT2.INP
```

Tube No.	X (cm)	Y (cm)	Z (cm)	Meas.#1 (ppm)	Norm.#1 (ppm)	K1*10^6 (cm^-2)
1	400.00	-8.00	10.00	146.3	144.8	575.5
2	400.00	-6.00	10.00	170.3	168.8	671.0
3	400.00	-4.00	10.00	191.9	190.4	756.9
4	400.00	-2.00	10.00	209.9	208.4	828.4
5	400.00	.00	10.00	233.0	231.5	920.3
6	400.00	2.00	10.00	241.8	240.2	955.1
7	400.00	4.00	10.00	252.9	251.3	999.1
8	400.00	6.00	10.00	261.1	259.6	1031.9
9	400.00	8.00	10.00	267.5	266.0	1057.4
10	400.00	10.00	10.00	263.1	261.5	1039.8
11	400.00	12.00	10.00	272.0	270.4	1075.2
12	400.00	14.00	10.00	275.2	273.6	1087.8
13	400.00	16.00	10.00	272.1	270.5	1075.6
14	400.00	18.00	10.00	269.4	267.9	1065.0
15	400.00	20.00	10.00	260.7	259.1	1030.1
16	400.00	22.00	10.00	254.3	252.8	1005.0
17	400.00	24.00	10.00	241.2	239.6	952.8
18	400.00	26.00	10.00	223.8	222.3	883.7
19	400.00	28.00	10.00	206.6	205.0	815.2
20	400.00	30.00	10.00	193.2	191.7	762.0
21	400.00	32.00	10.00	173.5	171.9	683.6
22	400.00	34.00	10.00	166.1	164.6	654.3
23	400.00	36.00	10.00	152.8	151.2	601.2
24	400.00	38.00	10.00	136.9	135.4	538.2
25	400.00	40.00	10.00	121.9	120.4	478.6
26	400.00	42.00	10.00	103.1	101.6	403.8
27	400.00	44.00	10.00	87.4	85.8	341.3
28	400.00	46.00	10.00	70.5	69.0	274.2
29	400.00	48.00	10.00	56.1	54.6	216.9
30	400.00	50.00	10.00	47.1	45.6	181.1

```
File Name E008.GC
Run# E008      DEN          06-10-95    14: 1:25
Wind Speed (cm/s)       =    145.78  Hr (cm) =    6.00
Air Temp.  (C)          =     25.60  Hr (cm) =    6.00
Source Designation      =  1
Source Flow Rate (ccs)  =        37.50
Source Gas Temp. (C)    =        25.60
Tracer Type             =        C2H6
Tracer Conc. (ppm)      =    1000000.0
Background Conc. (ppm)  =          2.6
Position Grid Filename  >     POS_LAT2.INP
```

Tube No.	X (cm)	Y (cm)	Z (cm)	Meas.#1 (ppm)	Norm.#1 (ppm)	K1*10^6 (cm^-2)
1	400.00	-8.00	10.00	214.4	211.7	823.2
2	400.00	-6.00	10.00	224.7	222.0	863.1
3	400.00	-4.00	10.00	237.3	234.7	912.3
4	400.00	-2.00	10.00	239.2	236.5	919.6
5	400.00	.00	10.00	237.3	234.7	912.4
6	400.00	2.00	10.00	235.6	233.0	905.8
7	400.00	4.00	10.00	235.1	232.4	903.6
8	400.00	6.00	10.00	230.0	227.4	884.0
9	400.00	8.00	10.00	229.1	226.4	880.2
10	400.00	10.00	10.00	218.9	216.3	840.9
11	400.00	12.00	10.00	212.0	209.3	813.8
12	400.00	14.00	10.00	202.5	199.9	777.0
13	400.00	16.00	10.00	195.5	192.8	749.7
14	400.00	18.00	10.00	183.8	181.2	704.4
15	400.00	20.00	10.00	169.1	166.4	647.0
16	400.00	22.00	10.00	157.9	155.2	603.5
17	400.00	24.00	10.00	147.6	144.9	563.4
18	400.00	26.00	10.00	138.7	136.1	529.0
19	400.00	28.00	10.00	128.0	125.3	487.3
20	400.00	30.00	10.00	116.4	113.7	442.1
21	400.00	32.00	10.00	101.9	99.3	385.9
22	400.00	34.00	10.00	91.1	88.5	344.0
23	400.00	36.00	10.00	76.3	73.7	286.5
24	400.00	38.00	10.00	68.6	66.0	256.5
25	400.00	40.00	10.00	60.6	57.9	225.2
26	400.00	42.00	10.00	50.3	47.7	185.3
27	400.00	44.00	10.00	41.4	38.8	150.7
28	400.00	46.00	10.00	33.7	31.0	120.7
29	400.00	48.00	10.00	26.8	24.2	94.1
30	400.00	50.00	10.00	23.5	20.9	81.2

```
File Name E009.GC
Run# E009      DEN          06-10-95    14:41:12
Wind Speed (cm/s)       =    205.74  Hr (cm) =     6.00
Air Temp.  (C)          =     26.20  Hr (cm) =     6.00
Source Designation      =  1
Source Flow Rate (ccs) =        50.00
Source Gas Temp. (C)    =       26.20
Tracer Type             =        C2H6
Tracer Conc. (ppm)      =   1000000.0
Background Conc. (ppm) =          5.9
Position Grid Filename >    POS_LAT2.INP
```

Tube No.	X (cm)	Y (cm)	Z (cm)	Meas.#1 (ppm)	Norm.#1 (ppm)	K1*10^6 (cm^-2)
1	400.00	-8.00	10.00	187.6	181.7	747.8
2	400.00	-6.00	10.00	201.7	195.8	805.8
3	400.00	-4.00	10.00	208.0	202.1	831.6
4	400.00	-2.00	10.00	209.6	203.7	838.1
5	400.00	.00	10.00	212.2	206.3	848.8
6	400.00	2.00	10.00	208.9	203.0	835.2
7	400.00	4.00	10.00	210.2	204.3	840.8
8	400.00	6.00	10.00	207.3	201.4	828.6
9	400.00	8.00	10.00	207.5	201.6	829.4
10	400.00	10.00	10.00	204.9	199.0	818.9
11	400.00	12.00	10.00	202.1	196.2	807.5
12	400.00	14.00	10.00	195.7	189.8	781.1
13	400.00	16.00	10.00	190.1	184.2	758.1
14	400.00	18.00	10.00	181.1	175.3	721.1
15	400.00	20.00	10.00	169.9	164.0	675.0
16	400.00	22.00	10.00	160.6	154.7	636.5
17	400.00	24.00	10.00	143.7	137.8	566.9
18	400.00	26.00	10.00	131.3	125.4	515.9
19	400.00	28.00	10.00	115.8	109.9	452.2
20	400.00	30.00	10.00	106.6	100.7	414.4
21	400.00	32.00	10.00	92.3	86.4	355.5
22	400.00	34.00	10.00	87.3	81.4	334.9
23	400.00	36.00	10.00	74.1	68.2	280.8
24	400.00	38.00	10.00	65.3	59.4	244.5
25	400.00	40.00	10.00	54.2	48.3	198.7
26	400.00	42.00	10.00	40.9	35.0	144.0
27	400.00	44.00	10.00	39.5	33.6	138.1
28	400.00	46.00	10.00	32.6	26.7	109.7
29	400.00	48.00	10.00	25.3	19.4	79.8
30	400.00	50.00	10.00	23.6	17.7	72.7

```
File Name E010.GC
Run# E010      DEN          06-10-95    15:21: 5
Wind Speed (cm/s)       =    250.83  Hr (cm) =     6.00
Air Temp.  (C)          =     26.20  Hr (cm) =     6.00
Source Designation      =  1
Source Flow Rate (ccs)  =       62.50
Source Gas Temp. (C)    =       26.20
Tracer Type             =       C2H6
Tracer Conc. (ppm)      =    1000000.0
Background Conc. (ppm)  =         7.5
Position Grid Filename  >    POS_LAT2.INP
```

Tube No.	X (cm)	Y (cm)	Z (cm)	Meas.#1 (ppm)	Norm.#1 (ppm)	K1*10^6 (cm^-2)
1	400.00	-8.00	10.00	201.0	193.5	776.5
2	400.00	-6.00	10.00	208.2	200.7	805.4
3	400.00	-4.00	10.00	214.9	207.3	832.1
4	400.00	-2.00	10.00	218.2	210.6	845.3
5	400.00	.00	10.00	222.1	214.6	861.2
6	400.00	2.00	10.00	217.9	210.3	844.1
7	400.00	4.00	10.00	219.4	211.8	850.0
8	400.00	6.00	10.00	214.6	207.1	831.0
9	400.00	8.00	10.00	213.3	205.8	825.9
10	400.00	10.00	10.00	207.5	200.0	802.5
11	400.00	12.00	10.00	198.7	191.2	767.2
12	400.00	14.00	10.00	186.8	179.3	719.4
13	400.00	16.00	10.00	174.7	167.1	670.7
14	400.00	18.00	10.00	164.7	157.2	630.9
15	400.00	20.00	10.00	151.8	144.3	579.0
16	400.00	22.00	10.00	143.9	136.4	547.4
17	400.00	24.00	10.00	132.5	124.9	501.3
18	400.00	26.00	10.00	117.3	109.7	440.3
19	400.00	28.00	10.00	106.3	98.7	396.2
20	400.00	30.00	10.00	94.4	86.9	348.6
21	400.00	32.00	10.00	86.0	78.5	314.9
22	400.00	34.00	10.00	71.5	63.9	256.6
23	400.00	36.00	10.00	62.7	55.1	221.2
24	400.00	38.00	10.00	52.9	45.4	182.1
25	400.00	40.00	10.00	45.3	37.8	151.5
26	400.00	42.00	10.00	38.1	30.6	122.7
27	400.00	44.00	10.00	30.2	22.6	90.9
28	400.00	46.00	10.00	25.4	17.9	71.6
29	400.00	48.00	10.00	21.9	14.3	57.5
30	400.00	50.00	10.00	19.0	11.4	45.9

```
File Name E000.GC
Run# E000       DDR            06-11-95    18:13:42
Wind Speed (cm/s)          =    147.18  Hr (cm) =     6.00
Air Temp.  (C)             =     28.20  Hr (cm) =     6.00
Source Designation         =  1
Source Flow Rate (ccs)     =       37.50
Source Gas Temp. (C)       =       28.20
Tracer Type                =       C2H6
Tracer Conc. (ppm)         =    1000000.0
Background Conc. (ppm)     =         1.0
Position Grid Filename >     POS_GRD.INP
```

Tube No.	X (cm)	Y (cm)	Z (cm)	Meas.#1 (ppm)	Norm.#1 (ppm)	K1*10^6 (cm^-2)
1	25.00	.00	.00	1.0	.0	.0
2	50.00	.00	.00	5.6	4.6	18.2
3	75.00	.00	.00	60.1	59.1	231.9
4	100.00	.00	.00	200.1	199.2	781.7
5	125.00	.00	.00	300.0	299.0	1173.5
6	150.00	.00	.00	376.2	375.3	1472.8
7	175.00	.00	.00	436.5	435.5	1709.2
8	200.00	.00	.00	447.6	446.7	1753.0
9	250.00	.00	.00	445.0	444.1	1742.9
10	300.00	.00	.00	376.6	375.6	1474.2
11	350.00	.00	.00	363.5	362.5	1422.8
12	400.00	.00	.00	324.2	323.2	1268.6
13	450.00	.00	.00	294.8	293.8	1153.3
14	500.00	.00	.00	268.9	267.9	1051.3
15	550.00	.00	.00	241.9	240.9	945.5
16	600.00	.00	.00	219.6	218.6	858.0
17	650.00	.00	.00	200.4	199.4	782.7
18	700.00	.00	.00	183.4	182.4	715.9
19	750.00	.00	.00	171.5	170.5	669.3
20	800.00	.00	.00	161.7	160.7	630.7
21	200.00	-15.00	.00	221.8	220.9	866.8
22	200.00	-10.00	.00	365.1	364.2	1429.2
23	200.00	-5.00	.00	421.2	420.2	1649.1
24	200.00	5.00	.00	416.8	415.8	1631.8
25	200.00	10.00	.00	331.8	330.8	1298.5
26	200.00	15.00	.00	270.1	269.1	1056.3
27	400.00	-15.00	.00	210.7	209.7	823.0
28	400.00	-10.00	.00	260.7	259.7	1019.2
29	400.00	-5.00	.00	299.4	298.5	1171.3
30	400.00	5.00	.00	329.8	328.8	1290.5
31	400.00	10.00	.00	316.4	315.4	1238.0
32	400.00	15.00	.00	279.3	278.3	1092.3
33	600.00	-15.00	.00	153.6	152.6	598.8
34	600.00	-10.00	.00	173.7	172.7	677.9
35	600.00	-5.00	.00	203.8	202.8	796.0
36	600.00	5.00	.00	226.4	225.4	884.5
37	600.00	10.00	.00	220.8	219.8	862.6
38	600.00	15.00	.00	210.7	209.8	823.3
39	800.00	-15.00	.00	115.3	114.3	448.6
40	800.00	-10.00	.00	131.5	130.6	512.4
41	800.00	-5.00	.00	146.1	145.1	569.5
42	800.00	5.00	.00	166.1	165.1	648.1
43	800.00	10.00	.00	81.7	80.7	316.8
44	800.00	15.00	.00	161.4	160.4	629.5

```
File Name E203.GC
Run# E203      DEN          06-11-95    12: 9: 9
Wind Speed (cm/s)       =    154.92  Hr (cm) =     6.00
Air Temp.  (C)          =     26.10  Hr (cm) =     6.00
Source Designation      =  1
Source Flow Rate (ccs)  =       37.50
Source Gas Temp. (C)    =       26.10
Tracer Type             =       C2H6
Tracer Conc. (ppm)      =    1000000.0
Background Conc. (ppm)  =         2.0
Position Grid Filename  >     POS_VER1.INP
```

Tube No.	X (cm)	Y (cm)	Z (cm)	Meas.#1 (ppm)	Norm.#1 (ppm)	K1*10^6 (cm^-2)
1	200.00	.00	.00	430.7	428.7	1771.2
2	200.00	.00	2.00	446.4	444.4	1835.9
3	200.00	.00	4.00	464.3	462.3	1909.7
4	200.00	.00	6.00	472.3	470.3	1942.8
5	200.00	.00	8.00	488.6	486.6	2010.2
6	200.00	.00	10.00	475.5	473.5	1956.1
7	200.00	.00	12.00	455.8	453.8	1874.9
8	200.00	.00	14.00	416.7	414.7	1713.3
9	200.00	.00	16.00	375.2	373.2	1541.6
10	200.00	.00	18.00	338.7	336.7	1391.0
11	200.00	.00	20.00	282.5	280.5	1158.9
12	200.00	.00	22.00	231.7	229.7	949.0
13	200.00	.00	24.00	180.7	178.7	738.3
14	200.00	.00	26.00	140.2	138.2	570.8
15	200.00	.00	28.00	96.3	94.3	389.4
16	200.00	.00	30.00	76.8	74.8	308.9
17	200.00	.00	32.00	53.4	51.4	212.5
18	200.00	.00	34.00	37.3	35.3	145.9
19	200.00	.00	36.00	27.7	25.7	106.0
20	200.00	.00	38.00	19.8	17.8	73.7
21	200.00	.00	40.00	13.9	11.9	49.3
22	200.00	.00	42.00	9.0	7.0	28.8
23	200.00	.00	44.00	6.4	4.4	18.2
24	200.00	.00	46.00	4.6	2.6	10.8
25	200.00	.00	48.00	4.3	2.3	9.5
26	200.00	.00	50.00	2.2	.2	.7
27	200.00	.00	52.00	1.9	.0	.0
28	200.00	.00	54.00	1.9	.0	.0
29	200.00	.00	56.00	2.3	.3	1.2
30	200.00	.00	58.00	1.5	.0	.0

```
File Name E208.GC
Run# E208      DDR          06-11-95    13:15:11
Wind Speed (cm/s)         =   155.94  Hr (cm) =      6.00
Air Temp.  (C)            =    26.10  Hr (cm) =      6.00
Source Designation        =  1
Source Flow Rate (ccs)    =        37.50
Source Gas Temp. (C)      =        26.10
Tracer Type               =         C2H6
Tracer Conc. (ppm)        =    1000000.0
Background Conc. (ppm)    =          2.2
Position Grid Filename >     POS_LAT1.INP
```

Tube No.	X (cm)	Y (cm)	Z (cm)	Meas.#1 (ppm)	Norm.#1 (ppm)	K1*10^6 (cm^-2)
1	200.00	-8.00	10.00	359.8	357.7	1487.2
2	200.00	-6.00	10.00	386.0	383.9	1596.3
3	200.00	-4.00	10.00	399.4	397.2	1651.8
4	200.00	-2.00	10.00	416.8	414.6	1724.2
5	200.00	.00	10.00	429.1	426.9	1775.3
6	200.00	2.00	10.00	431.3	429.1	1784.4
7	200.00	4.00	10.00	422.8	420.6	1749.1
8	200.00	6.00	10.00	419.3	417.2	1734.6
9	200.00	8.00	10.00	401.9	399.8	1662.3
10	200.00	10.00	10.00	381.5	379.3	1577.3
11	200.00	12.00	10.00	355.9	353.8	1471.0
12	200.00	14.00	10.00	325.9	323.7	1346.0
13	200.00	16.00	10.00	285.3	283.2	1177.4
14	200.00	18.00	10.00	254.3	252.1	1048.5
15	200.00	20.00	10.00	217.5	215.4	895.5
16	200.00	22.00	10.00	183.8	181.6	755.1
17	200.00	24.00	10.00	157.5	155.3	645.8
18	200.00	26.00	10.00	128.3	126.2	524.6
19	200.00	28.00	10.00	90.8	88.6	368.5
20	200.00	30.00	10.00	72.2	70.0	291.1
21	200.00	32.00	10.00	44.2	42.1	174.9
22	200.00	34.00	10.00	39.8	37.6	156.3
23	200.00	36.00	10.00	22.6	20.4	84.9
24	200.00	38.00	10.00	17.6	15.4	64.1
25	200.00	40.00	10.00	10.9	8.7	36.3
26	200.00	42.00	10.00	6.3	4.1	17.1
27	200.00	44.00	10.00	6.3	4.1	17.0
28	200.00	46.00	10.00	4.8	2.7	11.2
29	200.00	48.00	10.00	3.5	1.4	5.8
30	200.00	50.00	10.00	4.2	2.0	8.5

```
File Name E603.GC
Run# E603       DEN          06-11-95    11: 4:59
Wind Speed (cm/s)        =    151.32  Hr (cm) =      6.00
Air Temp.  (C)           =     26.10  Hr (cm) =      6.00
Source Designation       =  1
Source Flow Rate (ccs) =        37.50
Source Gas Temp. (C)     =      26.10
Tracer Type              =      C2H6
Tracer Conc. (ppm)       =   1000000.0
Background Conc. (ppm) =          1.7
Position Grid Filename >     POS_VER3.INP
```

Tube No.	X (cm)	Y (cm)	Z (cm)	Meas.#1 (ppm)	Norm.#1 (ppm)	K1*10^6 (cm^-2)
1	600.00	.00	.00	172.1	170.4	687.8
2	600.00	.00	2.00	169.2	167.6	676.2
3	600.00	.00	4.00	166.8	165.1	666.2
4	600.00	.00	6.00	160.8	159.1	641.9
5	600.00	.00	8.00	156.0	154.3	622.7
6	600.00	.00	10.00	149.8	148.2	597.9
7	600.00	.00	12.00	144.6	143.0	576.9
8	600.00	.00	14.00	137.8	136.1	549.3
9	600.00	.00	16.00	131.0	129.3	521.9
10	600.00	.00	18.00	124.0	122.3	493.6
11	600.00	.00	20.00	116.5	114.9	463.5
12	600.00	.00	22.00	108.9	107.2	432.7
13	600.00	.00	24.00	103.5	101.8	410.9
14	600.00	.00	26.00	97.2	95.5	385.4
15	600.00	.00	28.00	87.4	85.8	346.1
16	600.00	.00	30.00	82.1	80.5	324.7
17	600.00	.00	32.00	75.0	73.3	295.9
18	600.00	.00	34.00	68.0	66.4	267.8
19	600.00	.00	36.00	64.0	62.3	251.5
20	600.00	.00	38.00	55.0	53.4	215.4
21	600.00	.00	40.00	51.2	49.6	200.0
22	600.00	.00	42.00	45.1	43.5	175.3
23	600.00	.00	44.00	40.7	39.0	157.3
24	600.00	.00	46.00	36.4	34.7	140.2
25	600.00	.00	48.00	33.4	31.7	128.0
26	600.00	.00	50.00	30.4	28.7	116.0
27	600.00	.00	52.00	26.5	24.8	100.2
28	600.00	.00	54.00	22.6	21.0	84.6
29	600.00	.00	56.00	20.6	18.9	76.4
30	600.00	.00	58.00	17.6	15.9	64.1

File Name E608.GC
Run# E608 DDR 06-11-95 14:11:43
Wind Speed (cm/s) = 150.41 Hr (cm) = 6.00
Air Temp. (C) = 26.10 Hr (cm) = 6.00
Source Designation = 1
Source Flow Rate (ccs) = 37.50
Source Gas Temp. (C) = 26.10
Tracer Type = C2H6
Tracer Conc. (ppm) = 1000000.0
Background Conc. (ppm) = 2.1
Position Grid Filename > POS_LAT3.INP

Tube No.	X (cm)	Y (cm)	Z (cm)	Meas.#1 (ppm)	Norm.#1 (ppm)	K1*10^6 (cm^-2)
1	600.00	-8.00	10.00	106.9	104.8	420.4
2	600.00	-6.00	10.00	112.3	110.2	441.9
3	600.00	-4.00	10.00	120.3	118.3	474.3
4	600.00	-2.00	10.00	127.6	125.5	503.4
5	600.00	.00	10.00	133.6	131.6	527.8
6	600.00	2.00	10.00	139.3	137.2	550.4
7	600.00	4.00	10.00	144.5	142.4	571.2
8	600.00	6.00	10.00	150.8	148.8	596.7
9	600.00	8.00	10.00	156.3	154.2	618.6
10	600.00	10.00	10.00	158.8	156.7	628.6
11	600.00	12.00	10.00	162.4	160.3	642.9
12	600.00	14.00	10.00	163.6	161.6	648.0
13	600.00	16.00	10.00	163.9	161.8	649.0
14	600.00	18.00	10.00	164.3	162.3	650.8
15	600.00	20.00	10.00	163.1	161.1	646.0
16	600.00	22.00	10.00	160.9	158.9	637.1
17	600.00	24.00	10.00	156.2	154.2	618.3
18	600.00	26.00	10.00	151.9	149.9	601.1
19	600.00	28.00	10.00	151.2	149.1	598.0
20	600.00	30.00	10.00	138.3	136.3	546.6
21	600.00	32.00	10.00	138.1	136.0	545.6
22	600.00	34.00	10.00	124.3	122.2	490.2
23	600.00	36.00	10.00	117.9	115.9	464.7
24	600.00	38.00	10.00	108.6	106.5	427.2
25	600.00	40.00	10.00	102.9	100.8	404.3
26	600.00	42.00	10.00	93.9	91.8	368.3
27	600.00	44.00	10.00	82.6	80.5	323.0
28	600.00	46.00	10.00	74.3	72.2	289.7
29	600.00	48.00	10.00	67.6	65.5	262.8
30	600.00	50.00	10.00	59.9	57.8	231.8

APPENDIX D:
FACILITIES AND TECHNIQUES

1 FLUID DYNAMICS AND DIFFUSION LABORATORY

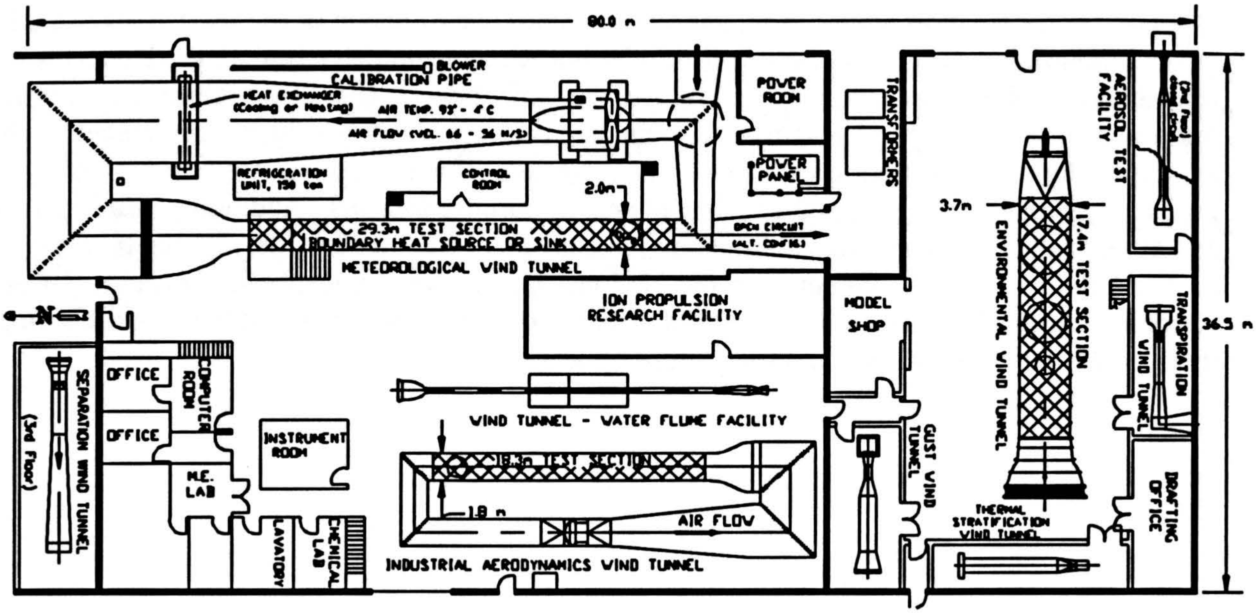
Engineering Research Center (ERC) is located at Foothills Campus of Colorado State University in Fort Collins, Colorado. This ERC has facilities for Agricultural & Chemical Engineering, Civil Engineering, Electrical Engineering and Mechanical Engineering Department including Groundwater Laboratory, Geotechnical Laboratory, Hydraulics Laboratory, Fluid Dynamics and Diffusion Laboratory (FDDL), Thermofluid Laboratory, Laser laboratory, Aerosol Science Laboratory and Heat Transfer Laboratory.

The FDDL is an integral part of the Fluid Mechanics and Wind Engineering Program, and houses facilities with unique research capabilities. Special boundary layer wind tunnels for simulation of atmospheric motions provide a capability for unique research on wind engineering and environmental problems of state, national and international concerns. Modern instrumentation and a variety of flow facilities support fundamental investigations on turbulence and turbulent diffusion. The Fluid Mechanics and Wind Engineering Program was awarded in 1989 from National Society of Professional Engineers for its distinguished research.

Research developed during the first three decades has revolved around basic fluid dynamics - turbulence, heat and mass transfer, boundary layers, jets and wakes, vortex dynamics, and flow separation; physical modeling - winds near the surface of Earth (atmospheric boundary layers), atmospheric diffusion, and mountain and urban winds; basic studies in aerosol mechanics - particle generation techniques, sampling and collection investigations, development of ambient aerosol samplers and fractional systems, behavior of particles in turbulent shear flows, deposition of particles in plant canopies; wind engineering - air pollution control, behavior of smoke plumes from power plant stacks, hazard analysis of liquid natural gas (LNG) storage, industrial aerodynamics, environmental design for urban centers, wind power, heat transfer from buildings, and wind forces on buildings and bridges; turbomachinery - effects of turbulence on the performance of blade cascades; and instrumentation - aerosol and tracer gas concentration sensors and hot wire anemometry. Research in these areas is sponsored primarily by the National Science Foundation, the Office of Naval Research, Project SQUID, the National Aeronautics and Space Administration, the Department of Energy, the Gas Research Institute, the Department of Transportation, the Nuclear Regulatory Commission, the Environmental Protection Agency, and the Electric Power Research Institute.

Research in the Program is complemented by a wide variety of laboratory investigations of wind forces on structures, atmospheric diffusion, and other wind engineering problems associated with the design and planning of major engineering projects. These investigations, sponsored by leading consulting and industrial firms throughout the country, utilize many of the research results obtained by the Program staff and students and help identify areas that will be productive for new research.

The following figure shows the plan view layout of the FDDL laboratory facilities including the meteorological wind tunnel, environmental wind tunnel and industrial aerodynamics wind tunnel.



Fluid Dynamics and Diffusion Laboratory Layout

The unique meteorological wind tunnel has an overall length of 200 feet with a 6-foot by 6-foot test or working section 100 feet long. Heating and cooling of air in the 18-foot by 18-foot return flow section of the recirculating tunnel provides extreme flexibility for simulating a wide range of atmospheric thermal stratifications, as well as elevated inversions. This thermal control, coupled with well-controlled flow speeds from 0.0 to 100 miles per hour and a long test section, enables boundary layer flows similar to those found in the real atmosphere to be modeled with accuracy. Thus, this facility provides an ideal medium for fundamental studies on the relationship of mean wind speed and turbulence to surface roughness, thermal stratification and topography. On the other hand, the simulation of natural winds for specific sites provides an ideal means for physical modeling of wind effects on existing or proposed buildings, urban developments, or any other of man's activities on earth's surface.

The FDDL houses an environmental wind tunnel with working section 60 feet long and a cross section of 12 by 8 feet. Using wind speed from 0.5 miles per hour up to 34 miles per hour, this facility provides excellent capability for investigation of wind effects on large areas. Dispersion of cloud seeding materials over mountain ranges, dispersion of automobile exhaust in new urban developments and existing cities, effects of buildings and topography on power plant plumes, and heat island effects over large urban areas have been investigated successfully in this facility.

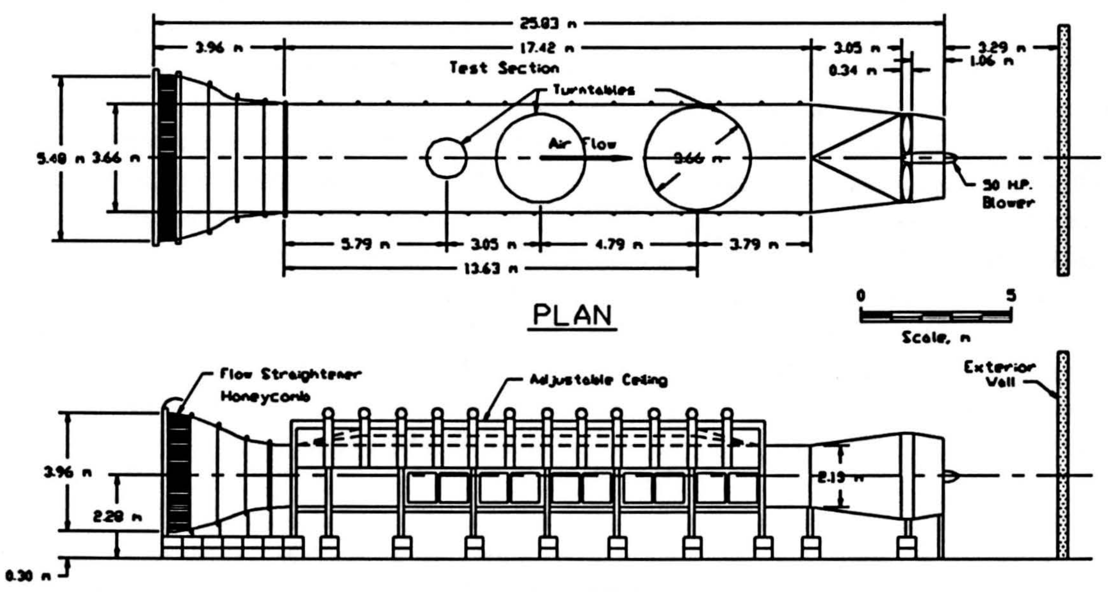
The industrial aerodynamics wind tunnel with a working section 60 feet long and 6 feet by 6 feet in cross section provides additional capabilities for basic studies of boundary layer characteristics. Many studies of evaporation from soil and water surfaces, wind pressures on model structures, ventilation of buildings, and the movement of soil and snow by wind have been made in this wind tunnel, which has a speed range of 1 to 70 miles per hour.

A gust wind tunnel equipped with two arrays of oscillating air foils provides opportunities for research on the effects of turbulence scale on the aerodynamics of bluff bodies and aerodynamic stability of long-span bridge decks.

Instrumentation for measurement of flow variables and tracer gas concentrations is available to support either the most advanced studies on turbulence and diffusion or the applied investigations of wind engineering. This instrumentation includes hot wire anemometer system; electronic pressure transducers and meters; aerosol, radioactive gas, and helium and hydrocarbon concentration measurement systems; optical systems; and strain gage balances. Data processing equipment includes analog-to-digital converters connected to PC, AT and 386 type computer, spectral analyzers, probability density analyzers, and a variety of special purpose systems. Additional data processing and numerical analyses are accomplished on the University CDC 170 model 720 digital computer, or the CRAY 1 digital computer of the National Center for Atmospheric Research (NCAR). Recording capabilities are provided by 50 FM magnetic tape channels, 25 digital tape channels, floppy disks, and a variety of motion and still picture cameras.

2 ENVIRONMENTAL WIND TUNNEL DESCRIPTION

This wind tunnel, especially designed to study atmospheric flow phenomena, incorporates special features such as an adjustable ceiling, a rotating turntable and a long test section to permit adequate reproduction of micrometeorological behavior. Mean wind speeds of 0 to 15 m/sec in the EWT can be obtained. A boundary-layer thickness up to 1.5 m can be developed over the downwind portion of the EWT test section by using vortex generators at the test section entrance and surface roughness on the floor. The flexible test section on the EWT roof is adjustable in height to permit the longitudinal pressure gradient to be set at zero.



Environmental Wind Tunnel Schematic

3 WIND SPEED MEASUREMENT DESCRIPTION

3.1 Velocity Standards

3.1.1 *CSU Mass Flow System*

The velocity standard used in the present study consisted of a Omega Model FMA-78P4 mass controller and a profile conditioning section designed and calibrated by the Fluid Dynamics and Diffusion (FDDL) staff at Colorado State University (CSU). The mass flow controller sets mass flow rate independent of temperature and pressure. The profile conditioning section forms a flat velocity profile of very low turbulence at the position where the hot-film-probe is located. Incorporating a measurement of the ambient atmospheric pressure, temperature and a profile correction factor permits the calibration of velocity at the measurement station from 0.1 - 2.0 m/s to within ± 5 percent and from 2.0 - 4.7 m/s to within ± 3 percent. This calibration nozzle is mounted on two computer controlled rotary tables for precise flow angle calibrations of multi-film probes.

3.1.2 *TSI Calibrator*

The TSI Model 1125 Velocity Calibrator System is designed to calibrate hot wire and hot film sensors over wide ranges of velocities. It is primarily for air but can also be modified for use in water and other fluids. In air the velocity range is from approximately 0.1 m/s to 305 m/s. This wide range can be covered using manometers with a range of 0.5 inch of water to approximately 400 inch of water (30 inch of mercury). The calibrator has been designed to be as simple and flexible as possible, while still maintaining good calibration accuracy.

In using the calibrator for air, the unit can be connected to a shop compressed air line. An On-Off line valve, pressure regulator, needle valve, and a heat exchanger are installed in line with the calibrator. This arrangement gives good control of the velocity through the calibrator. Essentially the same arrangement can be used for calibrating in other gases. Rather than the compressed air line the source can be a tank of bottled gas or other convenient supply.

The accuracy of the system is primarily dependent on the accuracy of the pressure measurement. When using the inside chambers with the exterior nozzle in place, the accuracy is ± 2 percent down to 3 m/s. Below 3 m/s, the accuracy is ± 5 percent down to approximately 0.1 m/s. Below 0.1 m/s, approximately ± 10 percent accuracy can be expected.

3.1.3 *Pitot Probe*

Pitot-static probes are used as a velocity standard during the calibration of the different hot film systems and to provide the reference upwind velocity measurement. The principles of operation of pitot-static probes are described in any fundamental text on fluid mechanics and will not be discussed in detail here. The operational relationship for these probes is $U = (2g_c\Delta P/\rho)^{1/2}$, where U = velocity, g_c = gravitational conversion constant, ΔP = difference between static and stagnation pressures, and ρ is the air density. ρ is calculated from ideal gas law and ΔP is measured using a Datametrics Electronic Manometer. The pitot-static probe measurements are accurate to within ± 2 percent of the actual velocity.

3.2 Single-Hot-Film Probe Measurements

Single-hot-film (TSI 1220 Sensor) measurements are used to document the longitudinal turbulence levels. During calibration the probe voltages are recorded at several velocities covering the range of interest. These voltage-velocity (E,U) pairs are then regressed to the equation $E^2 = A + BU^c$ via a least squares approach for various assumed values of the exponent c. Convergence to the minimum residual error was accelerated by using the secant method to find the best new estimate for the exponent c.

The hot-film-probe is mounted on a vertical traverse and positioned over the measurement location in the wind tunnel. The anemometer's output voltage is digitized and stored within an IBM AT computer. This voltage time series was converted to a velocity time series using the inverse of the calibration equation; $U = [(E^2 - A)/B]^{1/c}$. The velocity time series is then analyzed for pertinent statistical quantities, such as mean velocity and root-mean-square turbulent velocity fluctuations. The computer system moves the velocity probe to a vertical position, acquire the data, then moves on to the next vertical positions, thus obtaining an entire vertical velocity profile automatically.

Error Statement

The calibration curve yields hot film anemometer velocities that were always within 2 percent of the known calibrator velocity. Considering the accumulative effect of calibrator, calibration curve fit and other errors the model velocity time series should be accurate to within 5 percent.

3.3 Cross-Film Probe Measurements

Cross-film measurements are used to document longitudinal, lateral and vertical turbulence levels along with cross-component correlations such as Reynolds stresses.

During the calibration of the TSI 1241 X-film probe it is placed at the nozzle of the calibrator with the probe support axis parallel to air flow. In this position the angle between each sensor and the flow vector is 45°. Thus, the yaw angles for each sensor are 45°. The voltage from each anemometer channel are digitized for several velocities covering the range of interest. These voltage-velocity pairs (E_i, U_i; i = 1,2), at a fixed angle, are fit to the equation

$$E_{i,j}^2 = A_i + B_i'(U_j)^{ci} \; ; \; i = 1,2; \; j = 1,n$$

where $B_i' = B_i(\cos^2\phi_i + k^2\sin^2\phi_i)^{ci/2}$

ϕ_i = yaw angle between velocity vector and film i

k = yaw factor

n = number of the calibration points

via a least squares fit with the secant method to find the best new estimate of exponent, c_i.

Note that if the yaw factor, k, equals zero then a sample cosine law dependence of the heat flux exists. To determine the yaw factor, k, the air velocity is set at a constant value, and the probe is rotated about its third axis so that voltage samples are taken for a wide range of yaw angle variation on both films. These voltage-yaw angle pairs, (E_i, ϕ_i; i = 1,2) are regressed to the equation

$$B_i' = (E_{i,j}^2 - A_i)/U^{ci} = B_i(\cos^2\phi_{i,j} + k_i^2\sin^2\phi_{i,j})^{ci/2}$$

where i = 1,2 and j = 1,n

via a least squares approach with the secant method to find the best new estimate for the yaw factor,

k_i. A_i, B_i, c_i and k_i for both films are thus obtained. For the reduction algorithm used, k_i must be equal for both films and not a function of velocity. Providing that both films have similar aspect ratio, then both k_i values should be of similar magnitude; hence, setting them equal does not introduce large errors. Once a value for k is specified then a least squares fit will determine the optimal values for B_i. Once the value of k is determined for a specific probe, it is no longer necessary to perform further angle calibrations.

Given the calibration constants A_i, B_i, and c_i, then the equations

$$E_i^2 = A_i + B_i(V_{eff,i})^{ci} \; ; \; i = 1,2;$$
where $V_{eff,i} = V(\cos^2\phi_i + k^2\sin^2\phi_i)^{1/2}$; $i = 1,2$;
$V_{eff,i}$ = effective cooling velocity for film i, and
V = total velocity vector approaching sensor array

are defined. To take measurements with this calibrated X-film probe, both anemometer signals and the temperature signal are digitized and stored on a disk file within an IBM AT computer. These voltage time series are converted to u and v (or w) velocity time series using the following algorithm proposed by Brunn [1978],

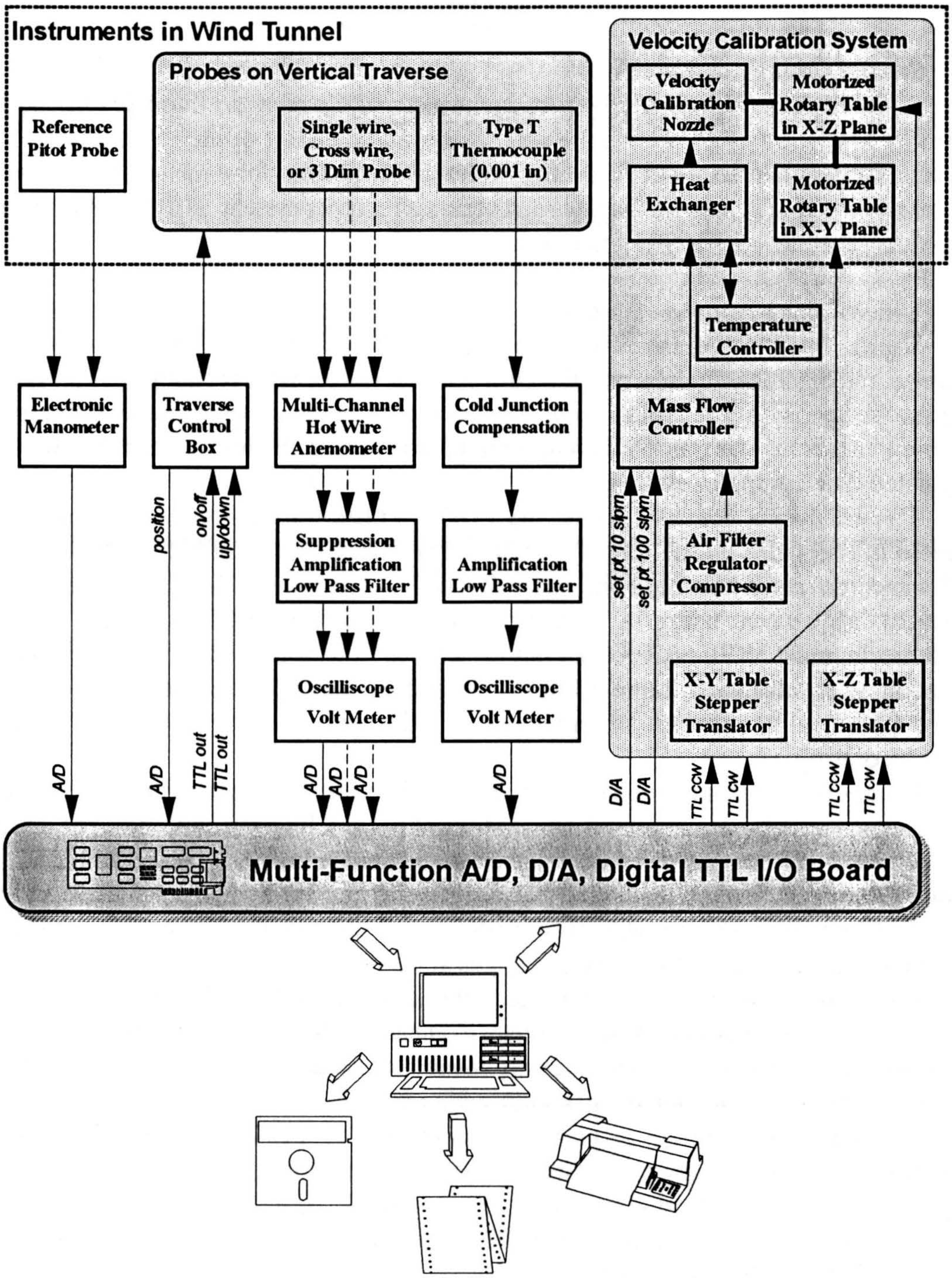
$$u = (V_{eff,1} + V_{eff,2})/[2(\cos^2\alpha + k^2\sin^2\alpha)^{1/2}],$$
$$v \text{ (or } w) = (V_{eff,1} - V_{eff,2})/[(\cos^2\alpha + k^2\sin^2\alpha)^{1/2} A \tan\alpha],$$
where $A = \cos^2\alpha(1-k^2)/[\cos^2\alpha(1 - k^2) + k^2]$,
$\alpha = 45°$,
$V_{eff,i} = [E_i^2 - A_i^*)/B_i^*]^{1/ci}$,
$A_i^* = A_i T_{factor}$, $B_i^* = B_i T_{factor}$,
$T_{factor} = (T_{sensor} - T_{environment})/(T_{sensor} - T_{calibration})$.

Error Statement

The accuracy of X-film velocity measurements and associated reduction algorithms can be estimated by directing different known mean velocity vectors at the probe. Tests at calibration temperature determine that the mean velocity magnitude is generally within ±5 percent of the calibration value. The error in angle calculation was approximately ±2° for angular deviations of 15° or less and somewhat larger than this for greater deviations. Considering cumulative effect of calibrator, calibration curve fit and temperature correction errors, the model longitudinal velocity time series should be accurate to within ±10 percent. The lateral or vertical velocity time series errors are greater than those of the longitudinal component but should be accurate to within ±15 percent.

3.4 Velocity Measurement System

A flow-logic chart of velocity calibration system, velocity measurement system, and the positioning system with the wind tunnel is displayed in the following figure.



Velocity Calibration and Measurement System

4 FLOW VISUALIZATION TECHNIQUES

4.1 Smoke Generator System

A visible plume is produced by passing the metered simulant gas through a Rosco Model 8215 Fog/Smoke Machine located outside the wind tunnel and then out of the model stack. The plume is illuminated with high intensity back lighting. The visible plumes for each test are recorded on VHS video cassettes with a Panasonic Omnivision II camera/recorder system. Run number titles are placed on the video cassette with a title generator.

4.2 Video Image Analysis System

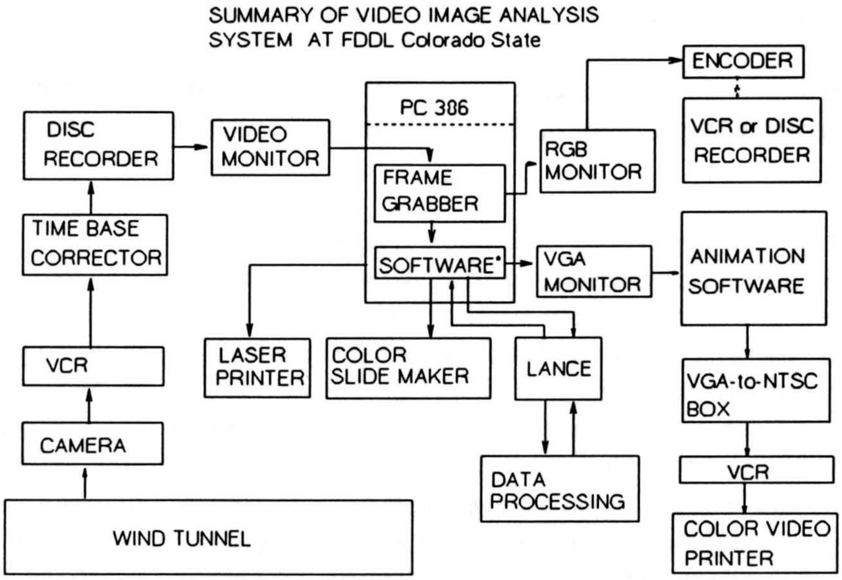
Digital image processing and computer aided enhancement methods provide a means to modernize and significantly improve the conventional smoke wire technique. The visible behavior of the smoke line is now recorded on by a high-resolution television camera system on VCR tape. The analog images may be transformed into digital arrays, and the images can then be enhanced and manipulated by a computer system.

The hardware components of the FDDL Video Image Processing System (VIPS) are presented in the figure on the following page. The image capturing part of the system includes a SVHS camcorder and a four-head one-half inch tape VCR recorder. These images may be edited into convenient sequences using a dual-monitor, dual-SVHS VCR recorder editing system. Unfortunately, most VCR systems can not be controlled well enough to maintain adequate picture registration when advancing frame-by-frame under computer control. Hence, the edited VCR tape must be additionally recorded onto a video disk. Currently this transfer is being accomplished at another laboratory.

Computer control may be used to command a video-disk player to project each individual video frame to a high-resolution video monitor. We use a high-resolution image capturing board installed in a PC-386 compatible microcomputer to digitize the image. A standard NTSC video signal (30 frames/sec) can be digitized with 8-bit precision. The board we use produces an intensity field of 512 x 512 pixels at 256 possible grey levels. Given the image interweaving typical of an NTSC signal the frames can be split to provide images at 60 frames/sec.

Once the video picture is digitized, the image may be enhanced by a) subtracting the background, b) overlaying a coordinate system, c) enhancing front, center, or back edge of the image, or d) assigning colors to different intensity levels. One can also extract edge pixel locations to calculate velocities or combine images to provide animation.

Often it is appropriate to print or restore enhanced images. The FDDL VIPS includes hardware to project the image to a RGB or VGA monitor; store the digital image to floppy or hard disks, streaming tapes, optical digital disk, or on network file-servers; or print to a laser printer or color slide maker. Alternatively, a VGA-to-NTSC hardware card can reformulate the signal to record to a conventional VCR or a color video printer.



Video Image Analysis System

5 CONCENTRATION MEASUREMENT DESCRIPTION

The experimental measurements of concentration were performed using a Hewlett Packard gas-chromatograph and a sampling systems designed by Fluid Dynamics and Diffusion Laboratory staff.

5.1 Gas Chromatograph

A gas chromatograph (Hewlett-Packard Model 5710A) (GC) with flame ionization detector (FID) operates on the principle that the electrical conductivity of a gas is directly proportional to the concentration of charged particles within the gas. The ions in this case are formed by the burning a mixture of hydrogen and the sample gas in the FID. The ions and electrons formed pass between an electrode gap and decrease the gap resistance. The resulting voltage drop is amplified by an electrometer and passed to a Hewlett-Packard Model 3390A integrator. When no effluent gas is flowing, a carrier gas (nitrogen) flows through the FID. Due to certain impurities in the carrier, some ions and electrons are formed creating a background voltage or zero shift. When the effluent gas enters the FID, the voltage increase above this zero shift is proportional to the degree of ionization or correspondingly the amount of tracer gas present. Since the chromatograph used in this study features a temperature control on the flame and electrometer, there is very low drift of the zero shift. Even given any zero drift, the HP 3390A, which integrates the effluent peak, also subtracts out the zero drift.

The lower limit of measurement is imposed by the instrument sensitivity and the background concentration of tracer within the air in the wind tunnel. Background concentrations are measured and subtracted from all data.

5.2 Sampling System

The tracer gas sampling system consists of a series of fifty 30 cc syringes mounted between two circular aluminum plates. A variable-speed motor raises a third plate, which lifts the plunger on all 50 syringes, simultaneously. Computer controlled valves and tubing are connected such that airflow from each tunnel sampling point passes over the top of each designated syringe. When the syringe plunger is raised, a sample from the tunnel is drawn into the syringe container. The sampling procedure consists of flushing (taking and expending a sample) the syringe three times after which the test sample is taken. The draw rate is variable and generally set to be approximately 6 cc/min.

The sampling system is periodically calibrated to insure proper function of each of the valves and tubing assemblies. To calibrate the sampler each intake is connected to a manifold. The manifold, in turn, is connected to a gas cylinder having a known concentration of tracer gas. The gas is turned on, and a valve on the manifold is opened to release the pressure produced in the manifold. The manifold is allowed to flush for about one minute. Normal sampling procedures are carried out during calibration to insure exactly the same procedure is reproduced as when taking a sample from the tunnel. Each sample is then analyzed for tracer gas concentration. Percent error is calculated, and "bad" syringe/tube systems (error > 2 percent) are not used or repaired.

Test Procedure

The test procedure consisted of:

1) Setting the proper tunnel wind speed,
2) Releasing the metered mixtures of source gas from the plant stack,

3) Withdrawing samples of air from the tunnel designated locations, and
4) Analyzing the samples with a FID.

The samples were drawn into each syringe over an ~200 second (adjustable) time period and then consecutively injected into the GC.

The procedure for analyzing the samples from the tunnel is:

1) Introduce the sample into the GC which separates the ethane tracer gas from other hydrocarbons,
2) The voltage output from the chromatograph FID electrometer is sent to the HP 3390A Integrator,
3) the HP 3390A communicates the measured concentration in ppm to an IBM computer for storage, and
4) These values, χ_{mea}, along with the response levels for the background χ_{bg} and source χ_{source} are converted into source normalized model concentration by the equation:

$$\chi_m = (\chi_{mea}-\chi_{bg})/(\chi_{source}-\chi_{bg})$$

5) Field equivalent concentration values are related to model values by the equation:

$$\chi_p = \frac{\chi_m}{\chi_m + (1-\chi_m)[V(T_a/T_s)]_m/[V(T_a/T_s)]_p}$$

where $V = Q/U_H L^2$,

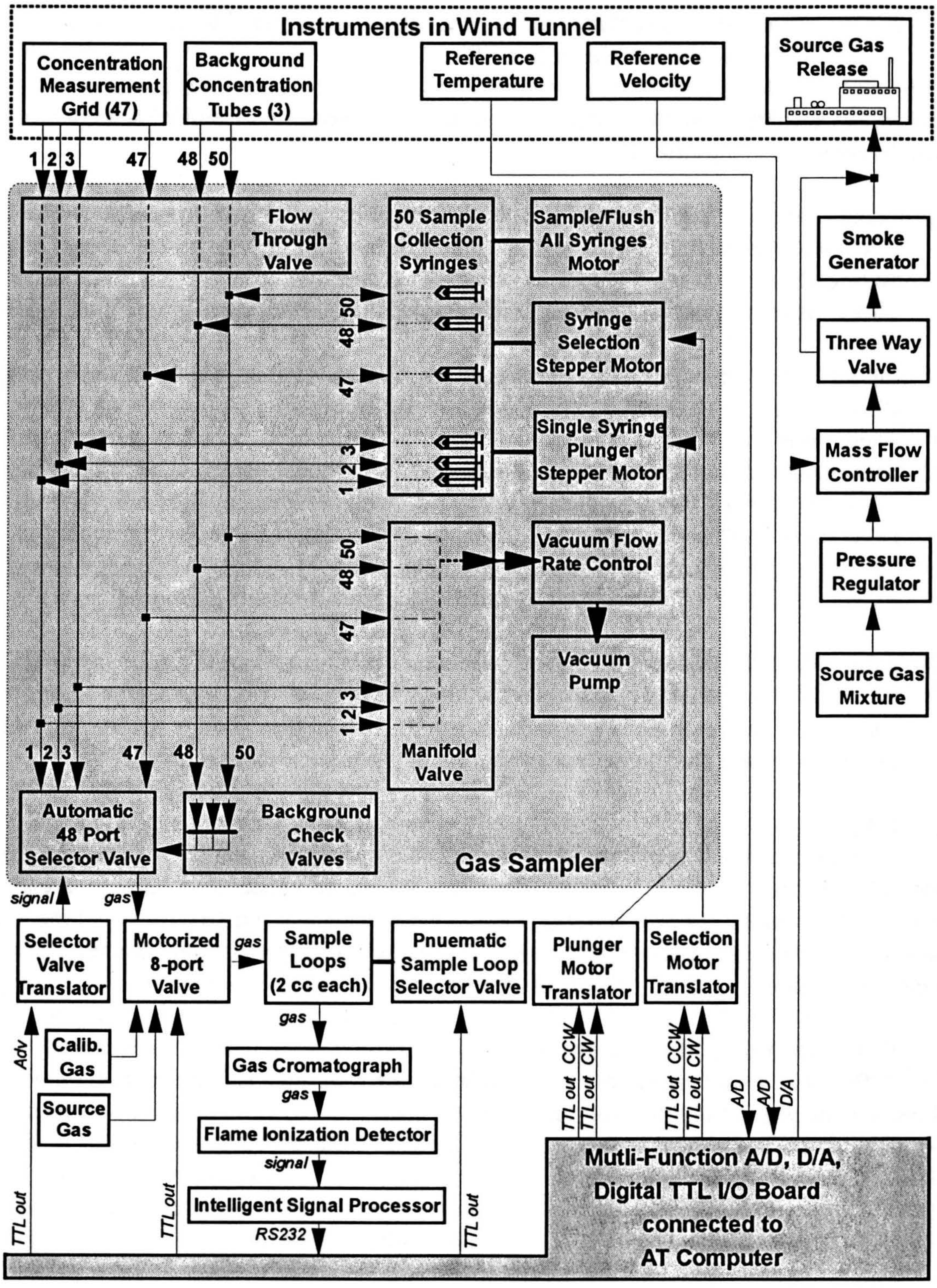
and L is the characteristic length scale. When there is no distortion in the model-field volume flux ratio, V, and the plumes are isothermal this equation reduces to $\chi_p = \chi_m$.

Error Statement

Background concentrations, χ_{bg}, (the result of previous tests within the laboratory), are measured to an accuracy of 20 percent. The larger measured concentrations, χ_{mea}, are accurate to 2 percent. The source gas concentration, χ_{source}, is known to within 10 percent. Thus the source normalized concentration for $\chi_{mea} >> \chi_g$ is accurate to approximately 3 percent. For low concentration values, $\chi_{mea} > \chi_{bg}$, the errors are larger.

5.3 Concentration Measurement System

A flow-logic chart of the source gas release, gas sampling, and concentration measurement systems is displayed in the following figure.



Concentration Sampling and Measurement System Schematic