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Environmental Research Laboratories

Diffusion Under Low Windspeed, Inversion Conditions

SEP 1

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ENVIRONMENTAL RESEARCH LABORATORIES

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UNITED STATES
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Robert M. White, Administrator

Environmental Research
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Jerrold F. Sagendorf
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ABSTRACT

Recently there has been much interest in diffusion characteristics of a stable atmosphere with light winds. The frequency and characterization of these "poor" diffusion conditions is important in predicting the environmental impact of a power-generating facility.

A series of diffusion tests conducted under stable conditions with windspeeds less than 2 m/sec is described. The results of these tests indicate that diffusion was enhanced by horizontal fluctuations in the wind direction. Measured peak concentrations averaged about 8 times less than the predicted values. Alternate methods of predicting concentrations are explored, which seem to give more realistic results for low windspeed, inversion conditions.

1. INTRODUCTION

In recent years there has been a marked increase in man's awareness of the quality of his environment. At the same time, the energy crisis has made the need for more power-generating facilities only too apparent. To study the impact of a proposed power-generating facility on the environment, it becomes necessary to determine the atmospheric dispersion characteristics in the area surrounding the facility. The common method of calculating dispersion assumes the material is transported in the mean wind direction, at the mean wind speed, while being dispersed by atmospheric turbulence. Under the present diffusion categorization method (NRC Regulatory Guide 1.23) the highest concentrations from a

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[1]Research was carried out under the sponsorship of the Energy Research and Development Administration under Interagency Agreement AT(49-5)-1289.

ground-level source are calculated with a stable atmosphere and near calm winds. In fact, the calculated concentrations approach infinity as the windspeed approaches zero.

This memorandum describes a series of 14 diffusion tests conducted under stable conditions with light winds over flat, even terrain. This is the first of a series in a comprehensive program to experimentally determine actual dispersion characteristics under "limiting" meteorological conditions. The second phase of the program involves assessing diffusion parameters under the same meteorological conditions as above, but over wooded, hilly terrain. The data for this phase has recently been collected in a test series conducted along the Clinch River near Oak Ridge, Tennessee. Phase three will consist of examining the effects of buildings in the flow pattern over flat terrain with a range of windspeeds and stability conditions. It is planned that a fourth stage will consist of tracer tests performed at actual nuclear power plant sites with different topographical features. The uniqueness of this program also involves the use of dual tracer releases (ground and elevated), concentric 360° sampling arcs of from 100 to 400 m in radius, and elevated as well as ground level receptors.

2. METHODS AND INSTRUMENTATION

The field tests were conducted at the Idaho National Engineering Laboratory (INEL), formerly the National Reactor Testing Station, in Southeastern Idaho. The INEL is located in a broad, relatively flat plain at an elevation of about 1500 m above sea level. The climate is dry and the area has semidesert characteristics (Yanskey et al., 1966). The test criteria were a stable lapse rate with winds less than 2 m/sec. These test conditions were most often met in the early morning hours.

Because of wind direction variability, it was felt that a full 360° sampling grid was necessary. Arcs were laid out at radii of 100, 200, and 400 m from the grid center. Samplers were placed at intervals of 6° on each arc for a total of 180 ground level sampling positions. After examining results from the early tests it became apparent that elevated samples would also be desirable. Eight towers, spaced 20° apart on the 200-m arc, were supplied with samplers at the 2, 4.5, 6, and 9 m levels. These provided some elevated measurements during the last four tests. The grid was divided into quadrants and wired so that a single switch could turn on and off all the samplers in a given quadrant. The grid layout of tower and sampler positions is shown in figure 1. A sampler consisted of a battery-operated pump used to pull air into a tedlar bag. The pump, batteries and bag were enclosed in a protective case with the air intake at an elevation of 0.76 m (fig. 2).

The tracer, SF_6, was released at a height of 1.5 m. The 1-hr average concentrations were determined by means of an electron capture gas chromatograph. Lovelock et al., (1971) has reported on this type of system. To provide for visual observation of the plume, a cloud of oil fog was released simultaneously, with the assumption that the oil fog and the SF_6 plumes travelled together. As will be shown later, this appeared to be a valid assumption. The oil fog proved very useful in determining which quadrants to turn on and when to turn the samplers off.

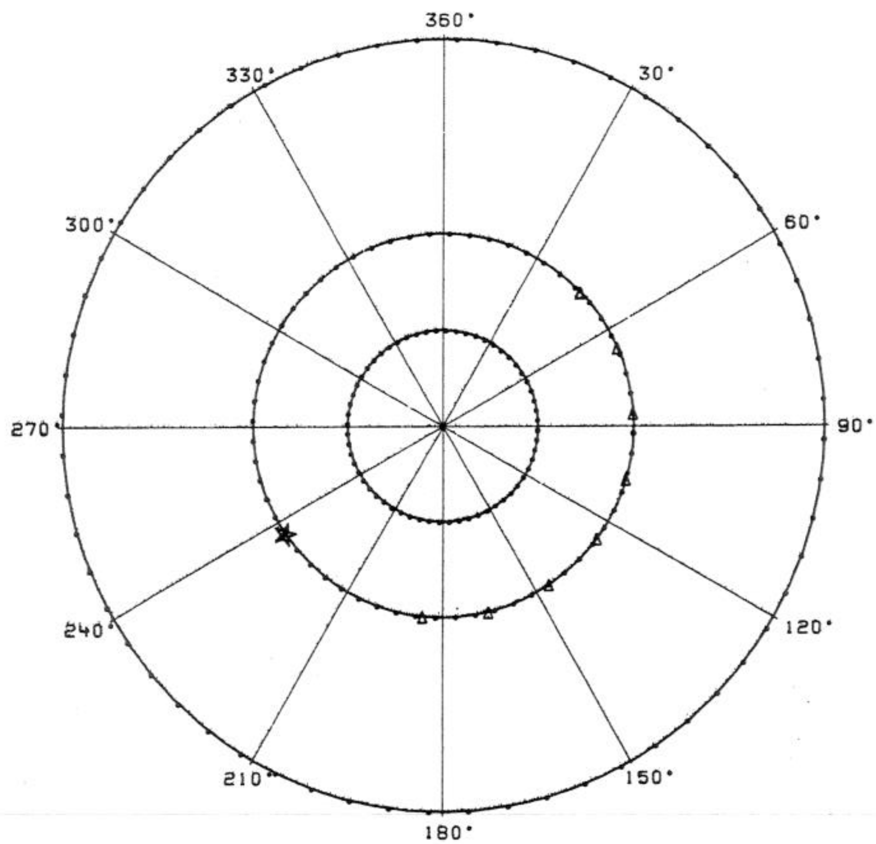


Figure 1. Sampler (•), tower (Δ), and 61-m meteorological tower (☆) locations on the grid.

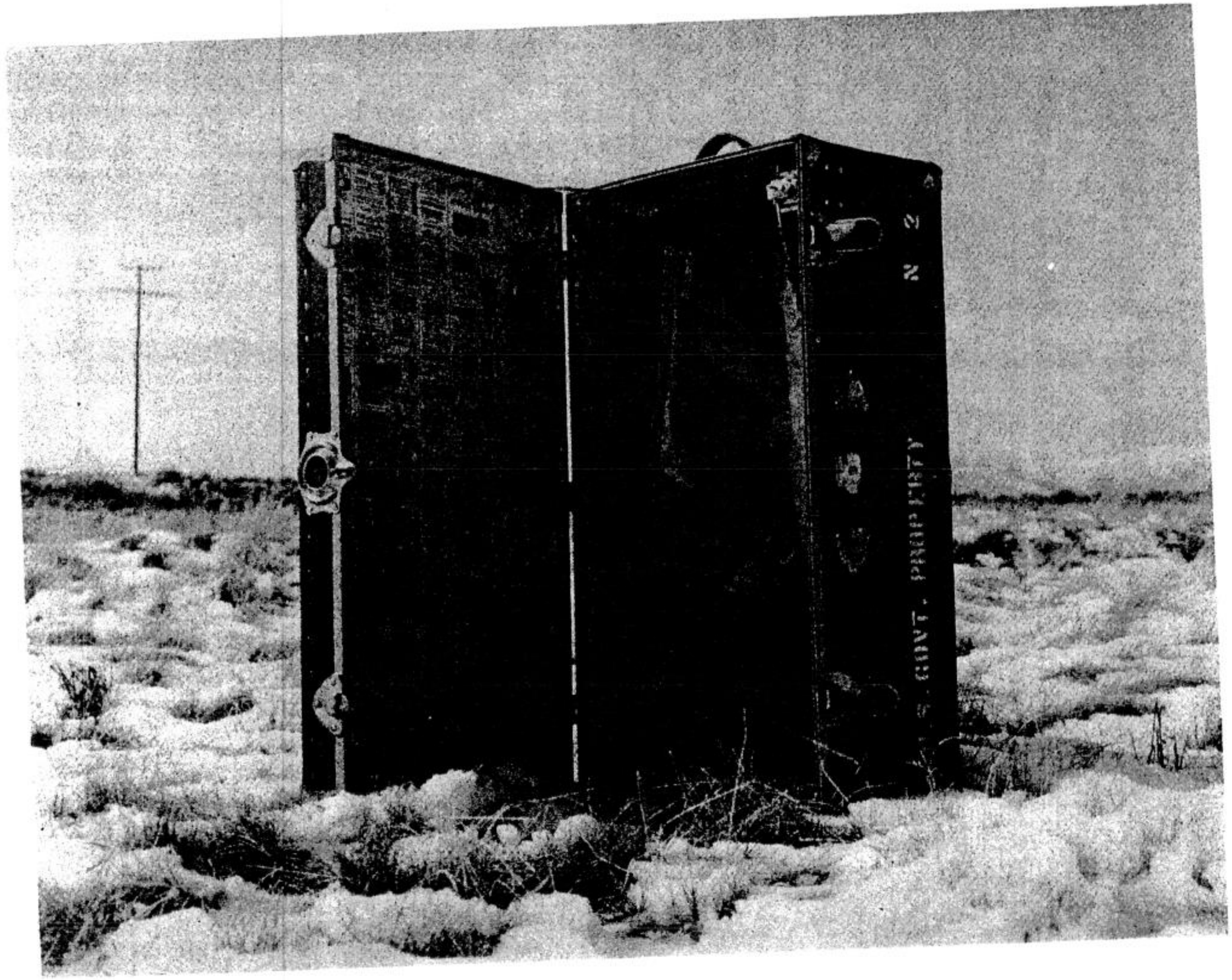


Figure 2. Sampler with the lid open. Inside can be seen the tedlar bag, the battery (bottom of case), the pump (upper right-hand corner of the case), and the air intake going out through the top of the case in the upper right-hand corner.

Wind measurements were provided by lightweight cup anemometers and bivanes at the 2, 4, 8, 16, 32, and 61 m levels of the 61-m tower located on the 200-m arc. The temperature profile was also measured at the 1, 2, 4, 8, 16, 32, and 61 m levels.

Of the total of 14 tests conducted, tests 1, 2, and 3 were shakedown tests of equipment and procedures. Tests 4 through 14 are summarized in table 1. It should be noted that test 6 fell in the neutral rather than a stable atmospheric stability category. The results of test 6 are included for comparison.

Table 1. Test Series

Test	Time (MST)	Date	$\Delta T/\Delta Z$* (C^{o}/100 m) ↓	$\bar{U}$† (m/sec)	σ_θ† (deg)	Plume Spread (deg)††
4	0642-0742	2/7/74	18.1 G 7	1.21	12.01	48
5	0630-0730	2/8/74	21.09 G 7	0.88	28.42	144
6	0646-0746	2/9/74	-1.11 D 4	1.29	11.56	36
7	0630-0730	2/12/74	8.10 G 7	0.90	22.28	96
8	0630-0730	2/21/74	0.67 E 5	0.75	72.08	360
9	0530-0630	3/21/74	0.58 E 5	0.80	17.92	54
10	0458-0547	4/17/74	8.89 G 7	1.66	21.66	102
11	0146-0246	4/30/74	6.67 G 7	1.92	37.91	138
12	0411-0511	4/30/74	5.42 G 7	1.08	60.18	156
13	0422-0522	5/3/74	3.91 F 6	1.61	11.70	84
14	0345-0445	5/22/74	10.02 G 7	1.47	18.69	60

* Measured between 32 and 8 m at the 61-m tower

† Measured at the 4-m level at the 61-m tower

†† Plume spread determined as the sector width in degrees over which SF_6 was detected at the 200-m arc.

3. GAUSSIAN DIFFUSION

To mathematically describe diffusion, a common approach is to assume a Gaussian distribution of material in the plume. The equation becomes

$$\chi(x,y,z;H) = \frac{Q}{2\pi\sigma_y\sigma_z\bar{U}} e^{-\frac{1}{2}\left(\frac{y}{\sigma_y}\right)^2} \left[e^{-\frac{1}{2}\left(\frac{z-H}{\sigma_z}\right)^2} + e^{-\frac{1}{2}\left(\frac{z+H}{\sigma_z}\right)^2} \right] , \quad (1)$$

where χ = concentration of material (units/m^3)

x = distance in mean wind direction (m)

y = distance in crosswind direction (m)

z = distance in vertical direction (m)

Q = source strength (units/sec)

$\bar{U}$ = mean windspeed (m/sec)

σ_y = standard deviation of material in the y direction (m)

σ_z = standard deviation of material in the z direction (m)

H = effective emission height (m).

In addition to the assumption of a Gaussian distribution, (1) assumes no material is removed from the plume, there is total reflection at the surface, and the mean wind is representative of the diffusing layer. By specifying the standard deviations, the concentration of material within the plume can be described.

The work of Pasquill (1961) and Gifford (1961) has simplified the procedure of determining standard deviations by defining atmospheric stability classes dependent upon insolation, cloud cover, and windspeed. Standard deviations of material along the y and z axis can be determined as functions of stability class and distance from the source. Figures 3 and 4 are graphs from Turner (1970) with the G curves added by extrapolation. Objective means to determine the atmospheric stability class are in common use. Two such methods are defined in table 2 (NRC Regulatory Guide 1.23). In table 2, σ_θ is the standard deviation of the horizontal wind direction over a period of 15 min to 1 hr, and $\Delta T/\Delta Z$ is the temperature gradient. Intuitively, it would seem that σ_θ may be related to σ_y and $\Delta T/\Delta Z$ to σ_z in (1). The usual practice, however, is to determine both σ_y and σ_z from only one parameter, either σ_θ or $\Delta T/\Delta Z$. Using $\Delta T/\Delta Z$, for example, implies that if diffusion is restricted in the vertical, as in an inversion case, it should also be restricted in the horizontal. In general, the results from the low windspeed tests indicate that under the test criteria this is not a good assumption. Table 3 summarizes the results of using $\Delta T/\Delta Z$ and σ_θ to determine stability categories as defined in table 2 from the tests summarized in table 1.

Table 2. Stability Categories

Classification	Pasquill Category	σ_θ (degrees)	$\Delta T/\Delta Z$ ($^\circ$C/100 m)
Extremely unstable	A	25.0	-1.9
Moderately unstable	B	20.0	-1.9 to -1.7
Slightly unstable	C	15.0	-1.7 to -1.5
Neutral	D	10.0	-1.5 to -0.5
Slightly stable	E	5.0	-.5 to 1.5
Moderately stable	F	2.5	1.5 to 4.0
Extremely stable	G	1.7	> 4.0

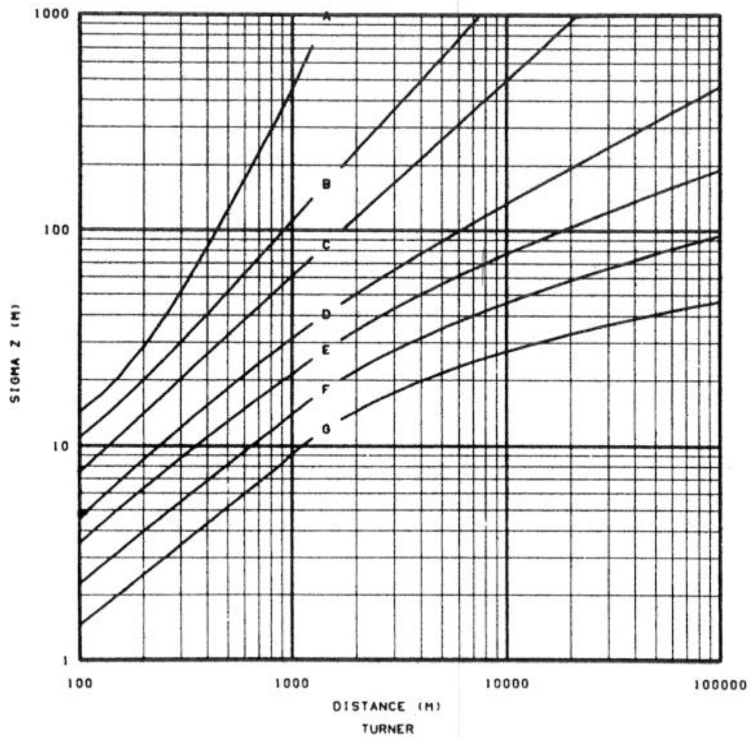


Figure 3. Sigma z from Turner.

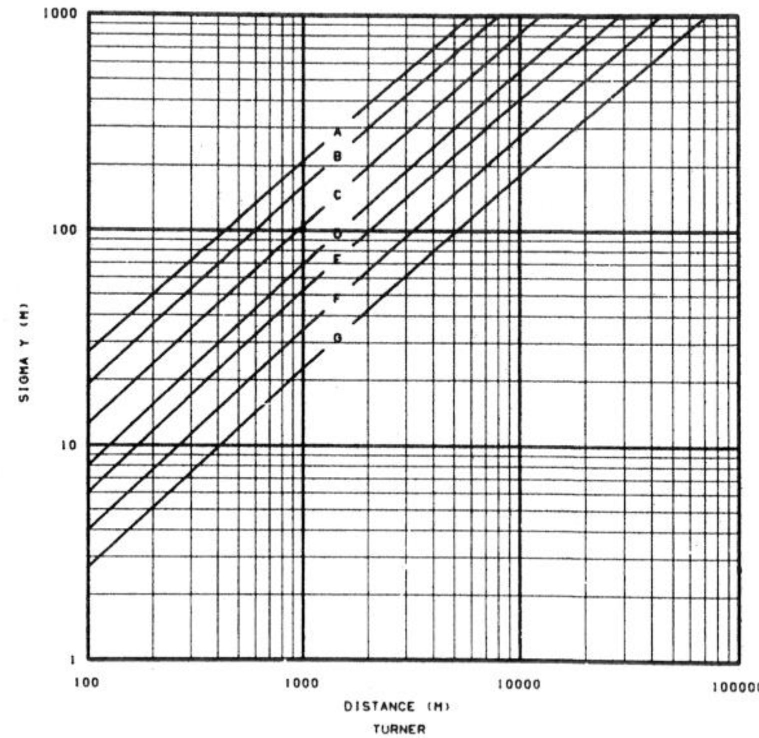


Figure 4. Sigma y from Turner.

Table 3. Comparison of Classification Methods

Rows: Stability Class determined by $\Delta T/\Delta Z$; Columns: Stability class defined by σ_θ

	A	B	C	D	E	F	G
G	3	3		1			
F				1			
E	1	1					
D				1			
C							
B							
A							

As may be seen from table 3, in only one case did the two methods agree on the stability class. The stabilities determined by $\Delta T/\Delta Z$ were never unstable, while the stabilities determined by σ_θ were never stable. Seven of the tests were conducted under type G conditions according to $\Delta T/\Delta Z$. Measurements of σ_θ, however, indicated three of these tests belonged in type A, three in B, and one in D. In other words, 86% of the tests were classified as extremely stable according to $\Delta T/\Delta Z$ measurements were at least moderately unstable according to σ_θ measurements. This seems to indicate that a split sigma approach, where σ_y is determined by σ_θ and σ_z is determined by $\Delta T/\Delta Z$, may be desirable. A second set of curves derived by Markee (Yanskey et al., 1966) from diffusion experiments at the INEL are presented in figures 5 and 6. These curves are based on effluent releases of 15 min to 1 hr and once again G curves are added by extrapolation. It should be noted that unlike figure 4 the values of σ_y in the stable categories in figure 6 increase with increasing stability. This represents the contribution of horizontal plume meander under stable conditions.

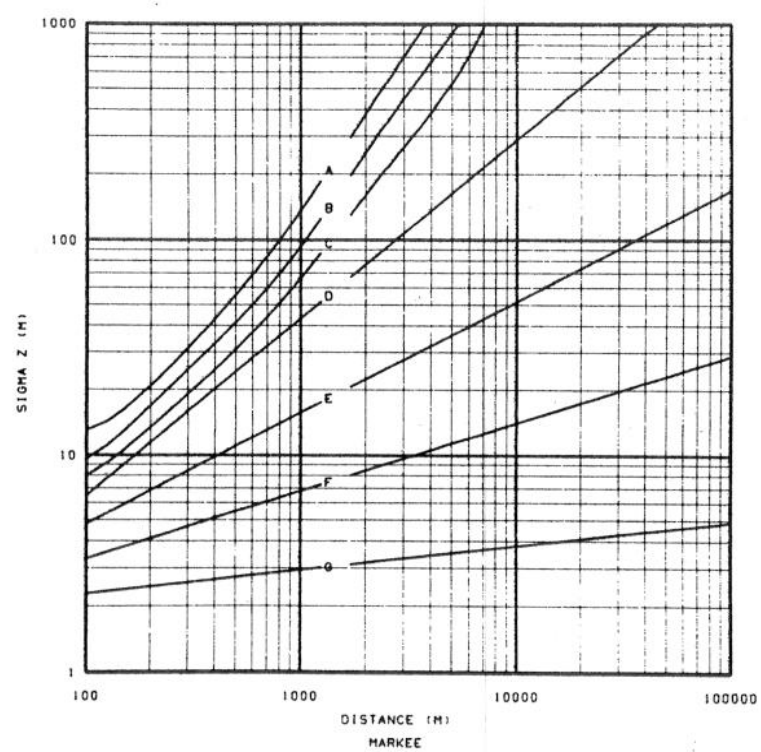


Figure 5. Sigma z from Markee.

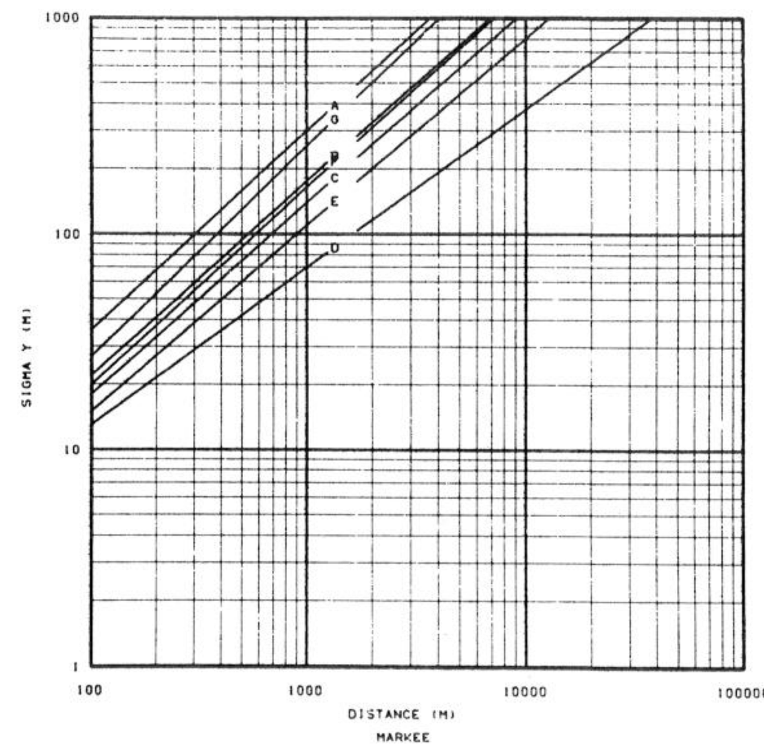


Figure 6. Sigma y from Markee.

4. TEST MEASUREMENTS

Figures 7 through 17 are contour plots of the hourly concentrations for each test. The effect of plume meander becomes very apparent in these figures. The instantaneous oil fog plume was generally observed to be on the order of 10 to 15° in width at the 200-m arc. Over the hourly testing periods under stable conditions, however, SF_6 was detected at the 200-m arc over a range from 48° in test 4 to the full 360° in test 8. It is believed that the oil fog and SF_6 plumes were very nearly coincident.

In each test the SF_6 was released at a rate of 0.032 g/sec, at a height of 1.5 m and sampled on the grid at a height of 0.76 m over a 1-hr period. Initially this arrangement was assumed to approximate a ground-level source and receptor. During the actual tests, however, the oil fog plume was observed to develop a tilt as it traveled downwind. Figures 18 and 19 are photographs showing this tilted behavior. The left side of the plume is on the ground, while the right side is elevated. This tilt developed whenever the wind direction became comparatively steady. Barad and Fuquay (1962) also observed this effect at the Hanford, Washington site. To determine whether the SF_6 plume was coincident with the tilted oil fog plume, a number of attempts were made to obtain simultaneous 30-sec grab samples in and underneath the tilted edge of the plume. These samples were obtained when the tilted plume passed close by one of the 200-m arc towers in such a way that the tower protruded into the lifted edge of the plume. One man would climb 4 or 5 m up the tower and sample in the oil fog while another would obtain a simultaneous sample at the foot of the tower. In practice, it was difficult to catch the plume in position and have it remain steady long enough to obtain the samples. The results of the samples are included in table 4. The sample pairs are designated by the test number during which the sample was obtained, and a letter. The comments recorded at sampling time indicate that only samples 11(a), 12(b), and 13(a) were good tilt cases. The ratios in these samples indicate that the SF_6 concentration was much higher in the oil fog than underneath it. Samples 13(b) and 13(c) are also interesting. In these cases the plume shifted across the tower. The man on the tower obtained a cross-sectional sample of the lifted edge of the plume, while the man at the foot of the tower obtained a similar sample of the lower edge. The concentrations in both samples from both cases are essentially the same. These results imply that the SF_6 and the oil fog plumes were coincident and partially elevated. The tower samples taken on the 200-m arc during tests 10 through 14 also confirmed that the plumes were elevated. The tower samples were rather widely spaced and the information from them is incomplete, but they indicate that the maximum concentrations were usually measured at the 2 or the 4.5-m levels. This agrees with what one would expect from observing the oil fog plumes. The ground and tower sample measurements are included in the data appendix.

Table 5 is a summary of the tower wind measurements. It may be noted from table 5 that during all but two of the tests the wind, at least in the lower levels, veered with height in the manner of the Ekman spiral (Ekman, 1905). The two nonconforming tests were 6 and 14.

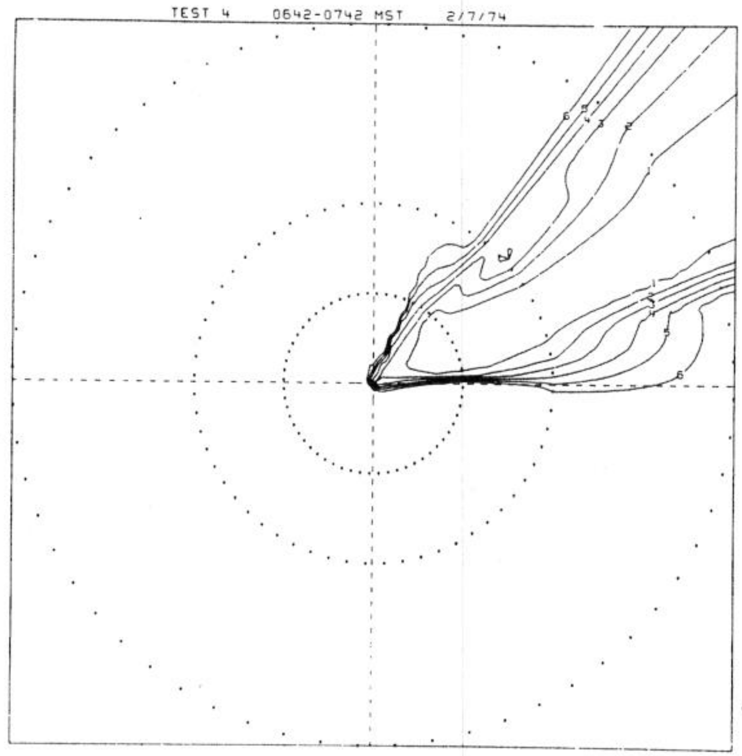


Figure 7. $\chi U/Q$ (sec^{-2}) isolines. The numbers on the isolines designate the values as follows:

1 - $1x10^{-3}$
2 - $3x10^{-4}$
3 - $1x10^{-4}$
4 - $3x10^{-5}$
5 - $1x10^{-5}$
6 - $3x10^{-6}$

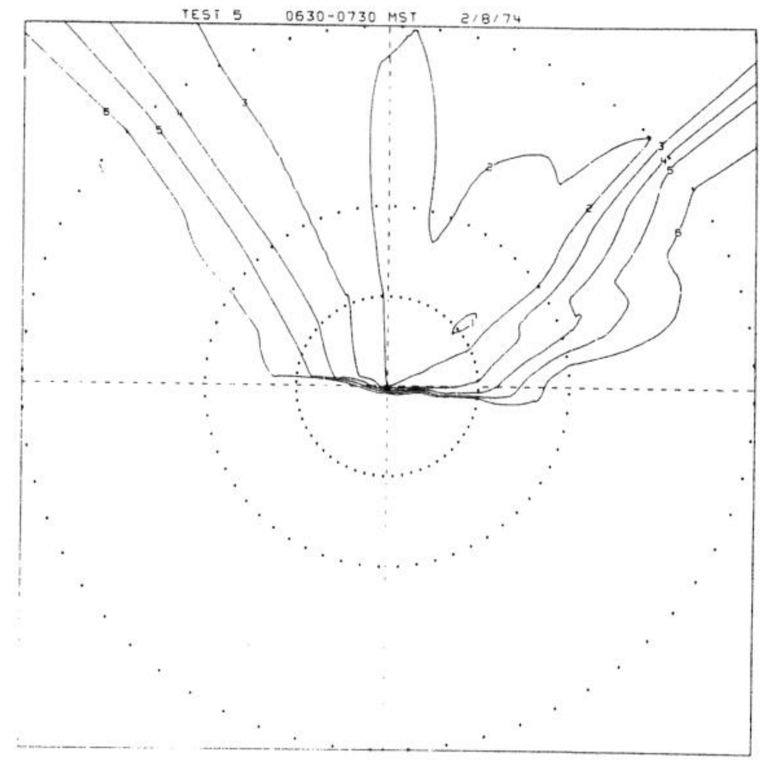


Figure 8. $\chi U/Q$ (sec^{-2}) isolines. Values are designated as in figure 7.

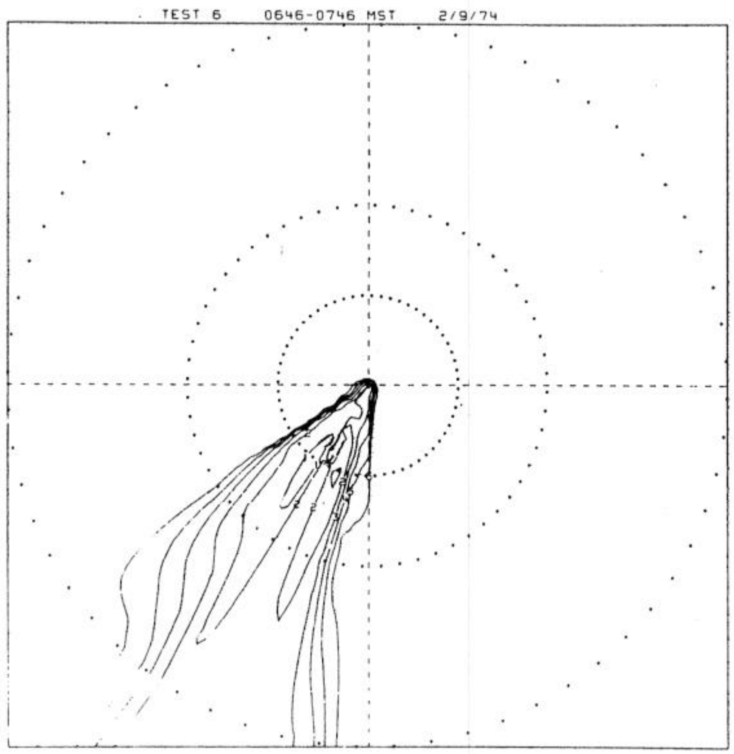


Figure 9. $\chi U/Q$ (sec^{-2}) isolines. Values are designated as in figure 7.

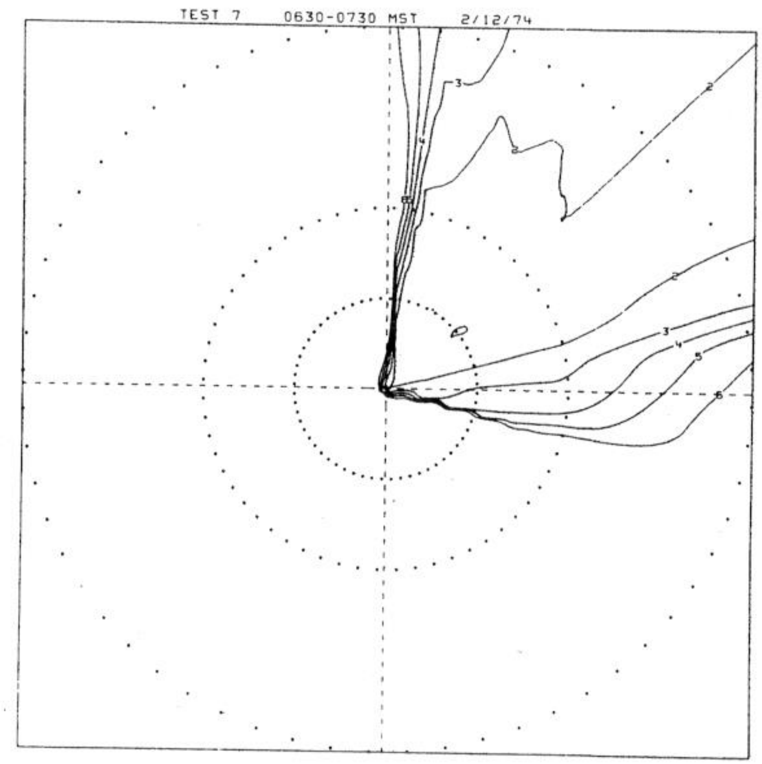


Figure 10. $\chi U/Q$ (sec^{-2}) isolines. Values are designated as in figure 7.

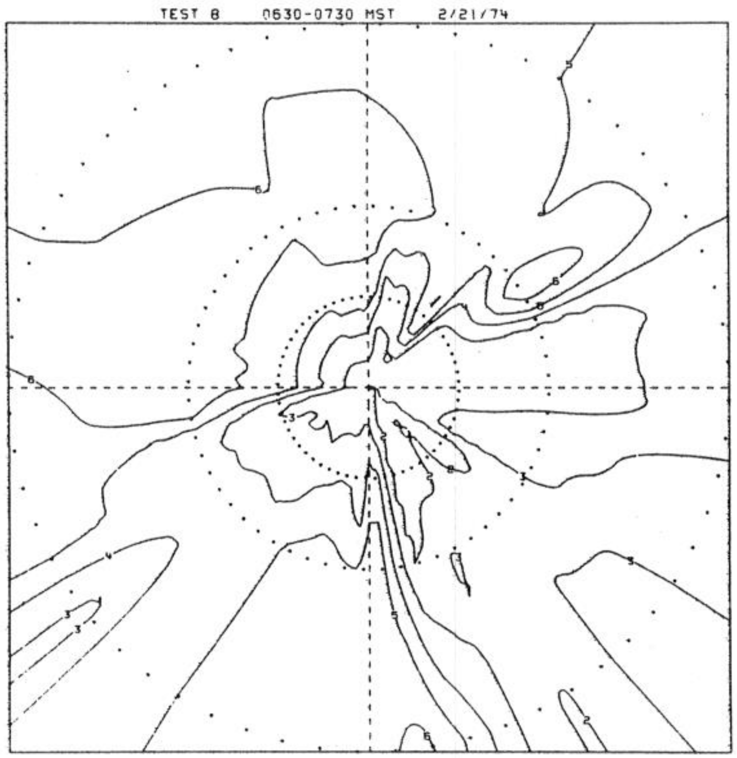


Figure 11. $\chi U/Q$ (sec^{-2}) isolines. Values are designated as in figure 7.

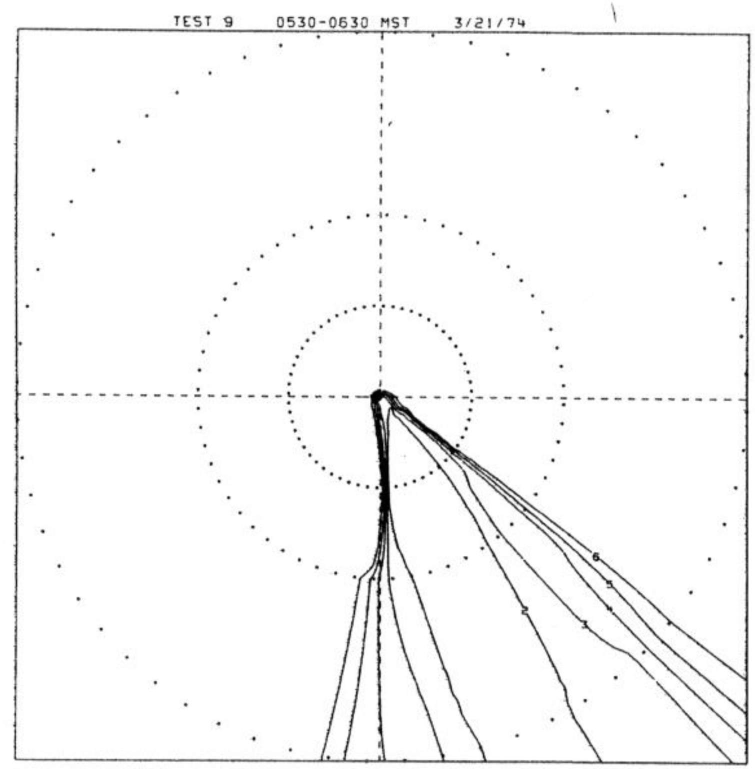


Figure 12. $\chi U/Q$ (sec^{-2}) isolines. Values are designated as in figure 7.

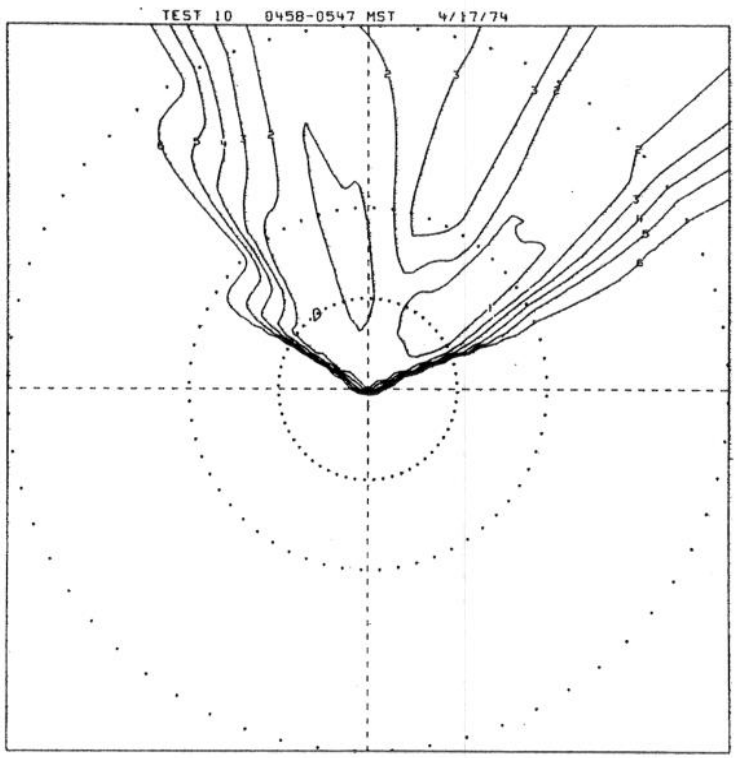


Figure 13. $\chi U/Q$ (sec^{-2}) isolines. Values are designated as in figure 7.

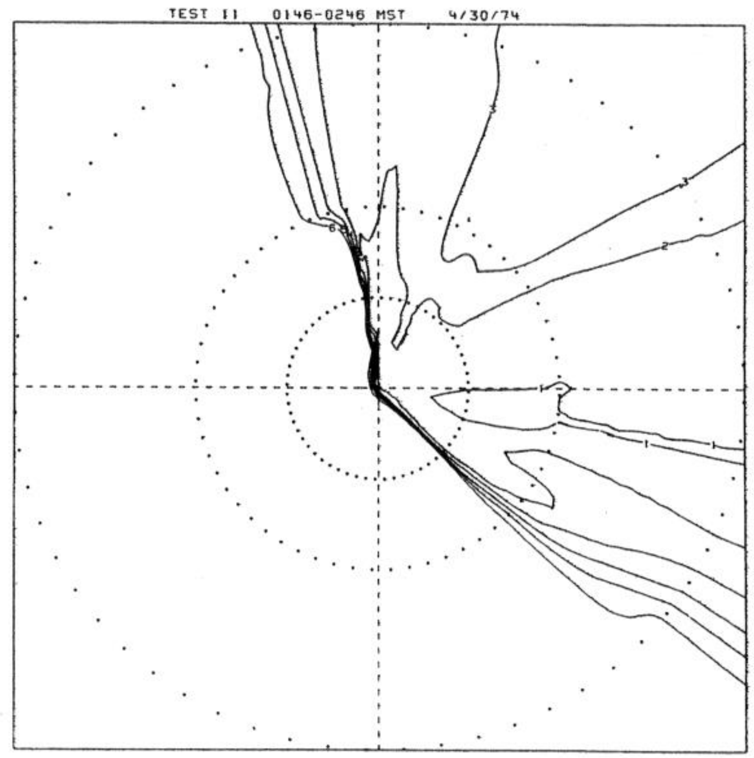


Figure 14. $\chi U/Q$ (sec^{-2}) isolines. Values are designated as in figure 7.

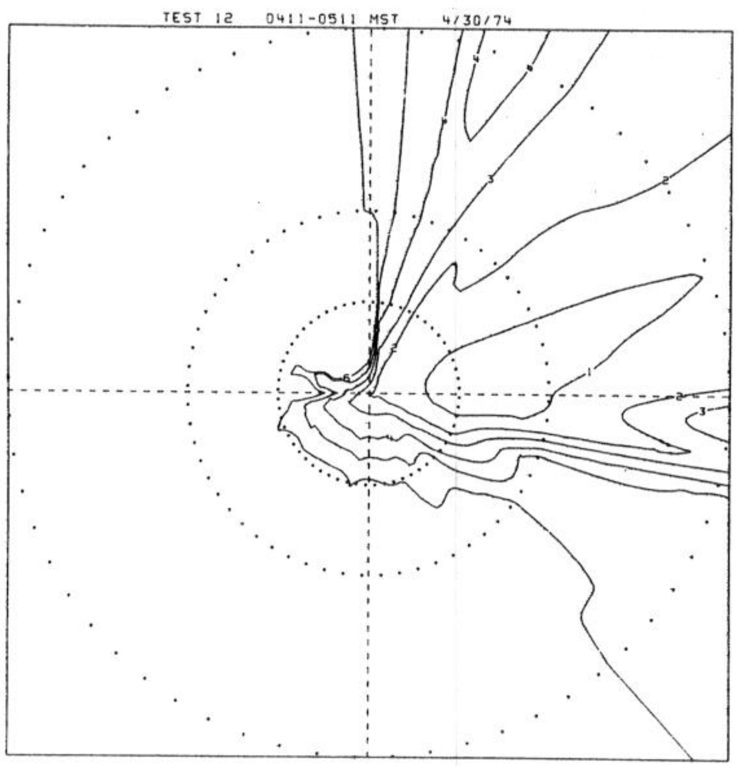


Figure 15. $\chi U/Q$ (sec^{-2}) isolines. Values are designated as in figure 7.

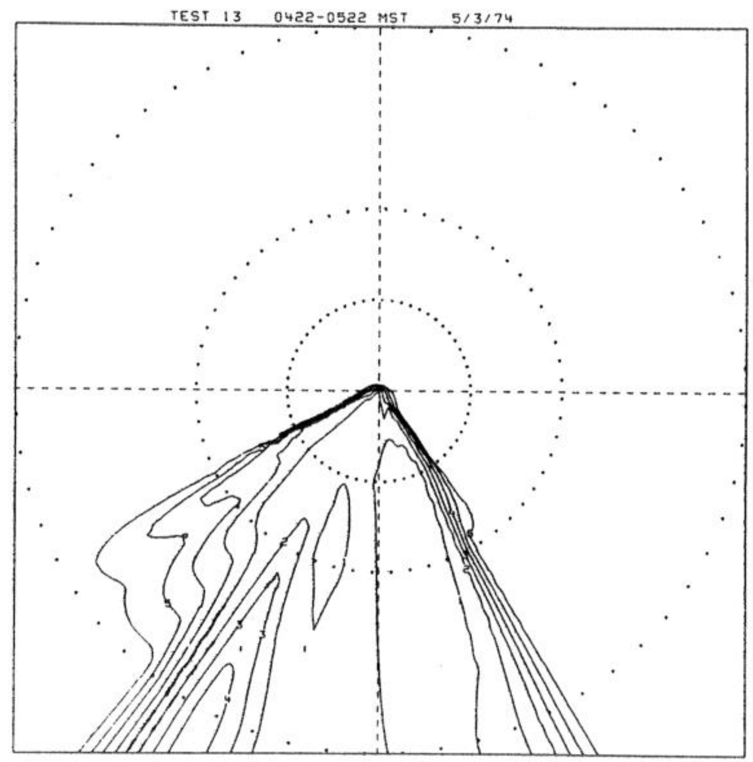


Figure 16. $\chi U/Q$ (sec^{-2}) isolines. Values are designated as in figure 7.

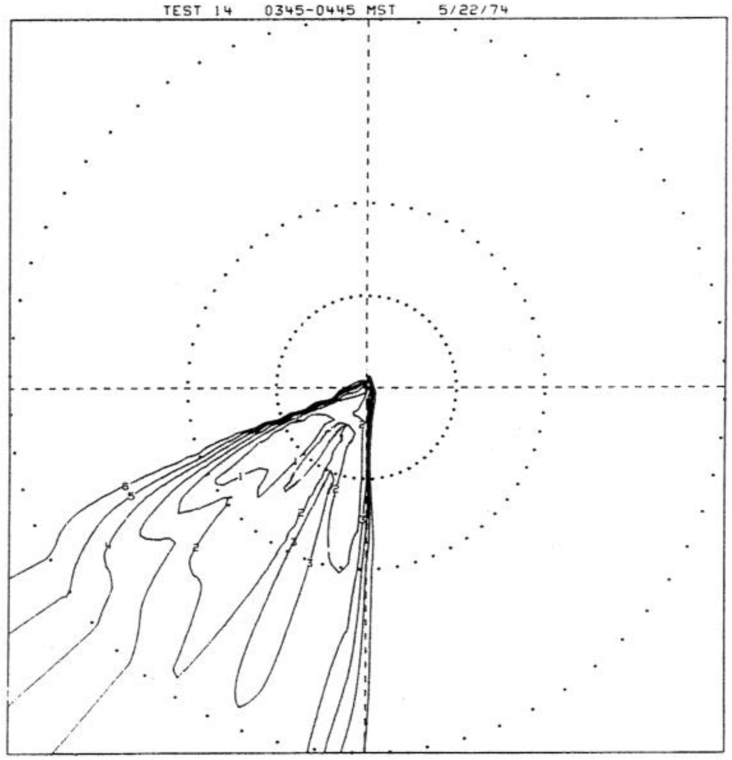


Figure 17. $\chi U/Q$ (sec^{-2}) isolines. Values are designated as in figure 7.

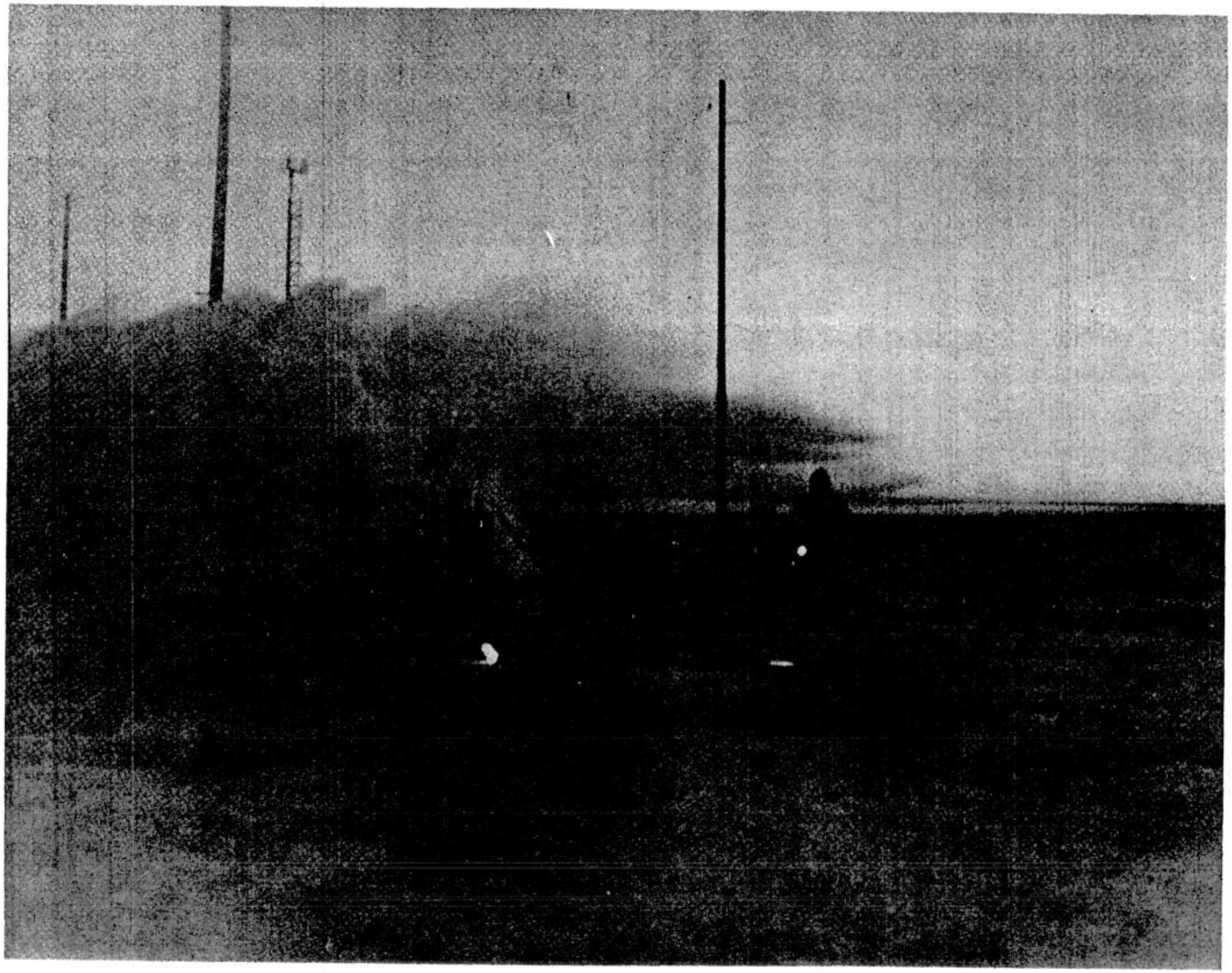


Figure 18. Plume release point. Notice the right side of the plume is elevated.

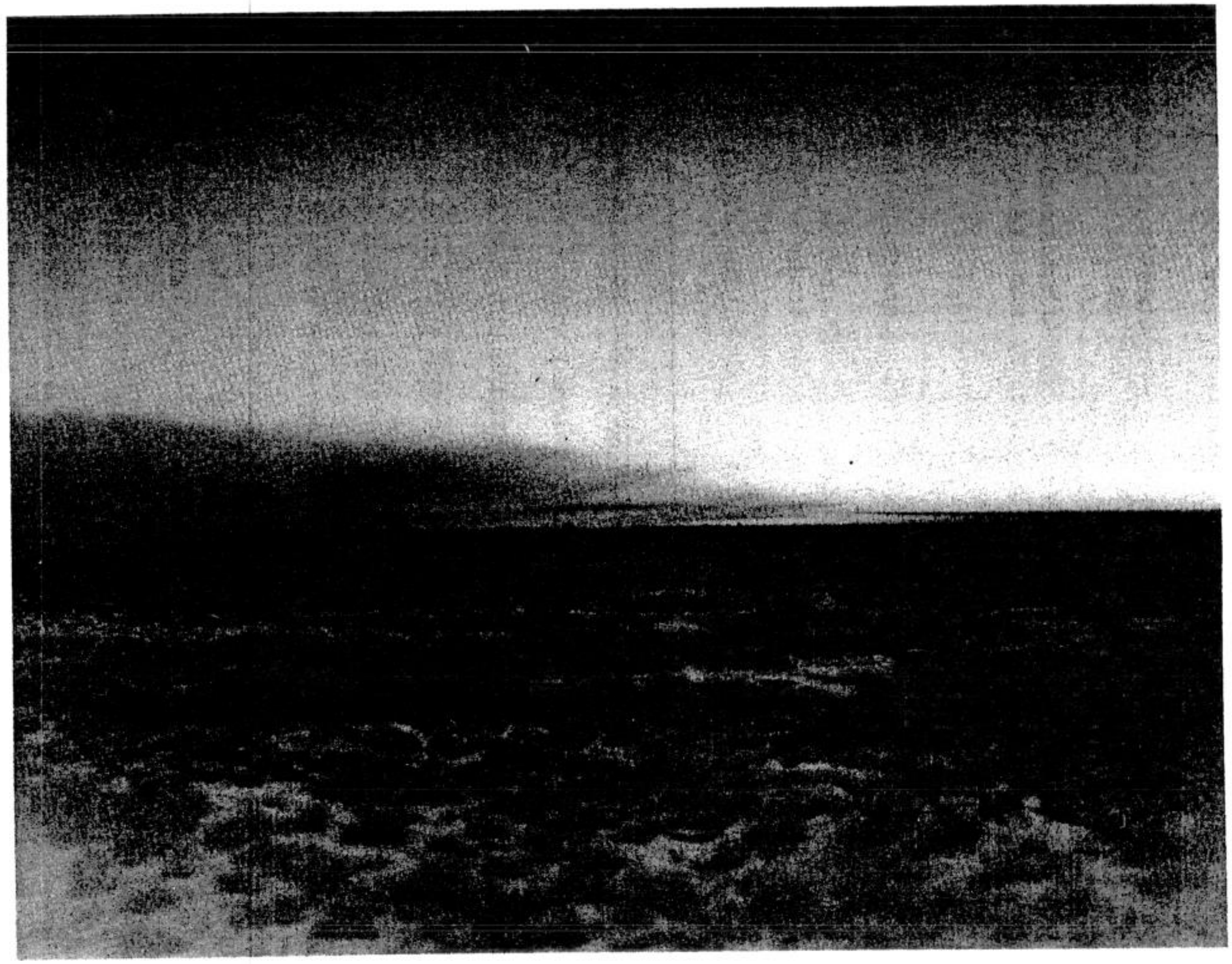


Figure 19. Photograph of the tilted oil fog plume. This is taken along the side of the plume, in the general direction of the plume travel. The left side of the plume is on the ground and the right side is elevated. Notice the bottom of the tower underneath the oil fog in about the center of the photograph.

Table 4. Tilted Plume Grab Samples

Sample pair	Ground (g/m^3)	Tower (g/m^3)	Ratio Tower/ground	Comments
11 (a)	2.00×10^{-7}	6.63×10^{-5}	332	Very good tilt case
11 (b)	6.29×10^{-5}	5.99×10^{-5}	0.95	Questionable, plume not steady
12 (a)	5.47×10^{-6}	6.76×10^{-5}	12.4	Questionable, plume not steady
12 (b)	3.31×10^{-6}	1.05×10^{-4}	31.7	Good tilt case
13 (a)	1.07×10^{-7}	2.69×10^{-6}	25.1	Good tilt case
13 (b)	8.13×10^{-5}	8.45×10^{-5}	1.04	Plume passed across tower
13 (c)	8.00×10^{-5}	8.26×10^{-5}	1.03	Plume passed across tower

Test 6 was the neutral case, and one might expect the more thorough mixing in this case to reduce the vertical directional wind shear. There is a small knoll, about 5 m in elevation, located about 800 m north-northeast of the grid apex. The flow coming around this knoll may be responsible for the backing of the wind with height evident in test 14.

On occasions during the test series, segments of the oil fog plume were observed to become stationary smoke puddles. This was believed to be caused by winds becoming calm in the area of the puddle. One might expect this puddling to result in localized areas of higher concentrations.

5. MODEL COMPARISONS

The measured concentrations from this test series are compared with concentrations predicted by (1). Based on the tower measurements and

Table 5. Wind Measurements

Test #		2-m	4-m	8-m	16-m	32-m	61-m
	DD	234	245	252	230	215	35
4	VV	0.7	1.2	-	1.5	0.9	2.1
	σ_θ	13.6	12.0	7.7	11.5	34.7	18.2
	DD	210	215	247	263	263	273
5	VV	0.8	0.9	1.2	2.2	3.0	2.1
	σ_θ	28.4	28.4	22.3	16.6	20.5	34.3
	DD	20	25	18	17	18	18
6	VV	1.2	1.3	1.2	1.6	1.7	1.8
	σ_θ	11.4	11.6	9.4	8.8	6.5	6.4
	DD	227	228	240	354	-	25
7	VV	0.6	0.9	0.4	0.5	0.9	2.4
	σ_θ	23.9	22.3	34.4	20.1	-	9.0
	DD	297	314	337	10	33	40
8	VV	0.5	0.8	0.6	1.2	1.6	2.7
	σ_θ	49.6	72.1	25.5	15.3	9.8	10.9
	DD	327	340	355	10	28	41
9	VV	0.5	0.8	0.9	1.6	2.2	2.7
	σ_θ	21.4	17.9	14.6	13.9	10.0	4.2
	DD	181	197	207	212	205	184
10	VV	1.1	1.7	2.1	3.2	4.7	3.1
	σ_θ	24.8	21.7	13.0	6.2	3.7	2.9
	DD	265	271	279	291	304	331
11	VV	1.4	1.9	2.3	2.9	-	3.6
	σ_θ	37.6	37.9	35.1	31.5	32.0	47.6
	DD	260	278	334	335	344	51
12	VV	0.7	1.1	1.1	1.6	1.6	1.9
	σ_θ	28.8	60.2	92.6	74.2	65.3	26.8
	DD	2	5	16	30	41	45
13	VV	1.0	1.6	2.0	3.0	4.0	6.0
	σ_θ	12.0	11.7	11.7	11.2	6.2	4.6
	DD	39	37	29	24	16	17
14	VV	1.0	1.5	2.0	3.5	5.1	7.1
	σ_θ	17.2	18.7	15.7	12.2	6.8	5.3

DD is wind direction in degrees
VV is wind velocity in m/sec
σ_θ is standard deviation of wind direction

All values are averaged over the test period the observed oil fog plume, an average effective emission height (H) of 3 m is assumed and wind measurements from the 4-m level are used. The receptor height (Z) was .76 m. As has already been noted there are a number of methods available for selecting σ_z and σ_y values. Some of these different approaches are compared. In the first, the standard method, the stability class is determined by the average temperature gradient during the test period as defined in table 2. Both σ_z and σ_y are determined from this single stability class using the curves from figures 3 and 4. Normalized concentrations ($X\bar{U}/Q$) calculated by this approach are compared to the measured results in figures 20 through 30. These figures portray the $X\bar{U}/Q$ values versus bearing in degrees from the release point. The solid lines connect the measured values, while the dashed lines represent the calculated values. It should be mentioned that samplers were not available for the northwest quadrant of the 100-m arc for tests 4 through 8. Concentration values were linearly interpolated into this sector for tests 5 and 8, the only cases where the oil fog indicated material was transported into the sector.

Using this approach, the calculated plume is consistently more narrow with peak values higher. In some cases it is even difficult to determine an average direction of transport over the test period. Note for example, test 8 (fig. 24) where material was spread in every direction; an average wind direction then becomes meaningless.

The second method is the split sigma approach. In this method σ_z is determined by the temperature gradient as in the standard method, but σ_y is based on a stability class determined by the standard deviation of azimuth angle over the test period, as defined in table 2. Figures 31 through 41 contain the results of these calculations. Significant improvement is shown over the standard method. The calculated peak values are now much closer to the measured values and the calculated plume widths, though generally still too narrow, and more closely approximate the measured plume.

The third procedure is similar to the standard method, except that the values of σ_y and σ_z are derived from Markee's curves (figs. 5 and 6) developed at the INEL (Yanskey et al., 1966). This is termed the standard (INEL) method. The results of these calculations are illustrated in figures 42 through 52. Overall, this procedure gives results that are quite comparable with the split sigma method. In test 4 the standard (INEL) method plume is too wide and therefore underpredicts the peak concentration, but in tests 6 and 7 it gives remarkably good results. Evidently the use of this method, which allows for plume meander, significantly improved the standard method under the test conditions, however, Markee's curves were developed at the INEL and, therefore, may not be applicable in other areas.

The final approach considered is the segmented plume method. A simple way to account for plume meander is to divide each test into small intervals and make separate calculations for each interval. Eq. (1), again with H = 3 m and Z = .76 m, was used to calculate the concentrations received at each sampler position from the plume segment during 2-min intervals and the results summed to determine the total concentration. The 2-min time interval was thought to be short enough to describe the meandering flow patterns and yet contain enough data points (40) to calculate reasonable means and standard deviations. The stability class for each test was determined from the average temperature gradient measured over the test period and σ_z was determined from figure 4 as in the other models. It was desired to obtain σ_y for the 2-min intervals from measurements using a relation of the form

$$\sigma_y = a\sigma_\theta x^b. \qquad (2)$$

The above relation has been used at the INEL for 15-min to 1-hr releases with a = .035 and b = .87 (Yanskey, et al., 1966). It is assumed that the 2-min interval mean wind directions would more closely follow the plume centerline than mean wind directions based on 15-min to 1-hr data. Therefore, comparing concentrations from 2-min plume segments to concentrations received over periods of 15 min to 1 hr would be similar to comparing peak-to-mean concentrations (Gifford, 1960). Hilst (1957) found an average peak-to-mean ratio of 2.28 at a distance of 200 m. Using this as a guide, it was felt reasonable to reduce the values of a in (2) by a factor of 2. The equation used to relate σ_y to σ_θ for the 2-min intervals was thus,

$$\sigma_y = .017\ \sigma_\theta\ x^{.87}. \qquad (3)$$

Table 6 contains the calculated 2-min values of σ_θ averaged for each windspeed class. For windspeeds greater than 0.8 m/sec, σ_θ generally averaged between 4 and 5 m. For winds less than 0.8 m/sec, σ_θ values became more variable but tended to increase with decreasing windspeed Average windspeeds less than 0.2 m/sec were likely below the instrument's

Table 6. Calculated 2-min values of σ_θ

Number of cases	Wind speed (m/sec)	Average σ_θ (m)	Standard deviation (m)
6	0.0 - 0.2	6.0	7.0
10	0.2 - 0.4	15.3	8.2
20	0.4 - 0.6	10.1	8.6
29	0.6 - 0.8	6.2	5.1
52	0.8 - 1.0	4.5	2.8
42	1.0 - 1.2	5.7	4.9
39	1.2 - 1.4	4.8	2.5
45	1.4 - 1.6	4.4	2.3
36	1.6 - 1.8	4.8	2.3
29	1.8 - 2.0	4.1	2.0
10	2.0 - 2.2	4.3	2.5
1	2.2 - 2.4	6.5	-
2	2.4 - 2.6	7.0	3.5
2	2.6 - 2.8	4.5	0.0
1	2.8 - 3.0	4.5	-

threshold much of the time and therefore the σ_θ values show a sharp decline for this windspeed class. To handle this difficulty in the segmented plume model, σ_θ was not allowed to be less than 10° when $\bar{U}$ was less than 0.2 m/sec. As a further precaution, any values of $\bar{U}$ less than 0.2 m/sec were increased to 0.2 m/sec to avoid dividing by a value approaching zero in (1). Figures 53 through 63 contain the results of the segmented plume calculations. This model shows considerable improvement in test 8 over the other models. Notice also the rather fine details the model picks out in tests 10, 11 and 14. The model assumed that a plume segment would continue in the direction it started and cross all three arcs. In test 12 this assumption is invalid. It can be seen from figure 61 that some SF_6 reached the 100-m arc in the sector between 180° and 340°, but it never reached the 200 or 400-m arcs. The model predicted a significant amount of SF_6 in this sector at all three arcs.

Tables 7, 8, and 9 compare the calculated with the measured peak values at the 100, 200, and 400-m arcs, respectively. It is apparent from these tables that the standard method, which may be the approach most generally in use, significantly over-predicted concentrations for the diffusion conditions under which these tests were conducted. Using either a split sigma approach or the INEL standard sigma curves significantly improved the centerline concentration calculations. The segmented plume method was the most realistic in both predicting centerline values, as well as the horizontal spread of the plume.

It may be noted from tables 8 and 9 that during tests 7, 8, and 11 higher centerline concentrations were measured at 400 than at 200 m. Stagnation or "puddling" may have been responsible.

Table 7. 100-m arc

	$\chi\bar{U}/Qx10^{-3}$ (m^{-2})								
	a	b	c	d	e	b/a	c/a	d/a	e/a
4	5.81	14.9	4.98	2.27	2.28	2.57	0.86	0.39	0.39
5	1.36	14.9	1.48	2.27	2.04	10.96	1.09	1.67	1.50
6	2.61	6.94	6.94	3.67	3.40	2.66	2.66	1.41	1.30
7	1.26	14.9	2.10	2.27	1.29	11.83	1.67	1.80	1.02
8	.586	10.4	2.32	3.61	1.76	17.75	3.96	6.16	3.00
9	1.09	10.4	3.23	3.61	2.76	9.54	2.96	3.31	2.53
10	2.41	14.9	2.10	2.27	1.60	6.18	0.87	0.94	0.66
11	2.32	14.9	1.48	2.27	1.59	6.42	0.64	0.98	0.69
12	2.00	14.9	1.48	2.27	1.52	7.45	0.74	1.14	0.76
13	3.16	15.3	7.66	3.18	2.99	4.84	2.42	1.01	0.95
14	2.81	14.9	2.10	2.27	1.62	5.30	0.75	0.81	0.58
						7.77	1.69	1.78	1.22

Measured = a
Standard = b
Split Sigma = c
Standard (INEL) = d
Segmented plume = e

Table 8. 200-m arc

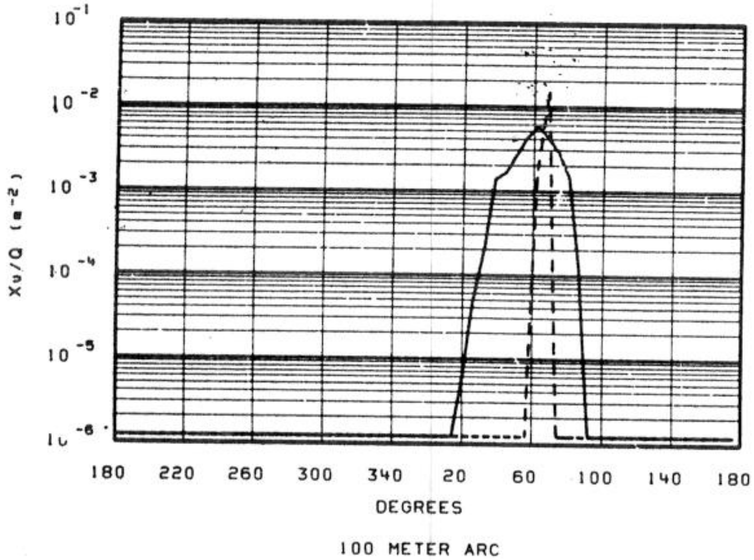
	$\chi\bar{U}/Q \times 10^{-3}$ (m^{-2})								
	a	b	c	d	e	b/a	c/a	d/a	e/a
4	2.99	12.6	4.13	1.19	1.83	4.21	1.38	0.40	0.61
5	.867	12.6	1.26	1.19	1.71	14.53	1.45	1.37	1.97
6	.972	2.29	2.29	1.24	1.08	2.36	2.36	1.28	1.11
7	.709	12.6	1.75	1.19	1.07	17.77	2.47	1.68	1.51
8	.315	3.85	.886	1.53	.665	12.22	2.81	4.86	2.11
9	.568	3.85	1.23	1.53	.966	6.78	2.17	2.69	1.70
10	1.80	12.6	1.75	1.19	1.27	7.00	0.97	0.66	0.71
11	1.09	12.6	1.26	1.19	1.26	11.56	1.16	1.09	1.16
12	1.77	12.6	1.26	1.19	1.25	7.12	0.71	0.67	0.71
13	2.30	7.84	3.90	1.56	1.45	3.41	1.70	0.68	0.63
14	1.59	12.6	1.75	1.19	1.30	7.92	1.10	0.75	0.82
						8.63	1.66	1.47	1.19

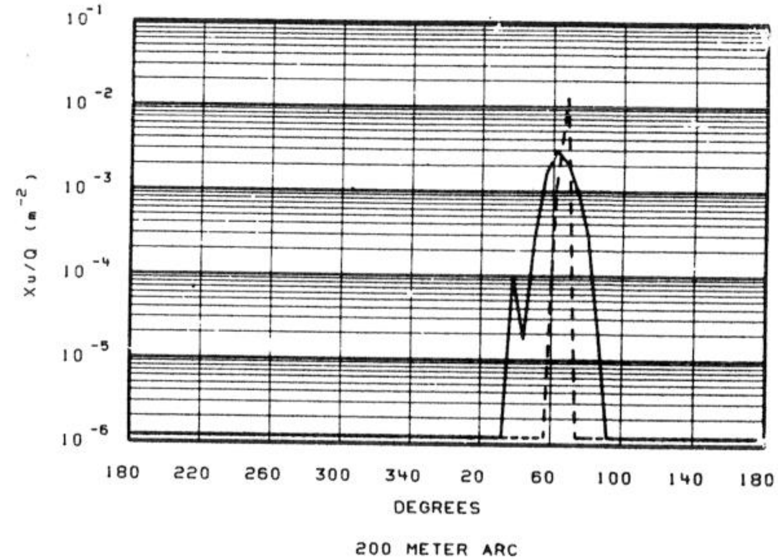
Measured = a
Standard = b
Split Sigma = c
Standard (INEL) = d
Segmented plume = e

Table 9. 400-m arc

	$\chi\bar{U}/Q \times 10^{-3}$ (m^{-2})								
	a	b	c	d	e	b/a	c/a	d/a	e/a
4	1.47	5.69	1.92	.615	.822	3.87	1.31	0.42	0.56
5	.304	5.69	.592	.615	.800	18.72	1.95	2.02	2.63
6	.293	.694	.694	.433	.308	2.37	2.37	1.48	1.05
7	1.01	12.6	.818	.615	.492	12.48	0.81	0.61	0.49
8	.328	1.29	.296	.622	.224	3.93	0.90	1.90	0.68
9	.392	1.29	.409	.622	.296	3.29	1.04	1.59	0.76
10	.708	5.69	.818	.615	.560	8.04	1.16	0.87	0.79
11	1.10	5.69	.592	.615	.549	5.17	0.54	0.56	0.50
12	.994	5.69	.592	.615	.566	5.72	0.60	0.62	0.57
13	1.37	2.82	1.41	.733	.502	2.06	1.03	0.54	0.37
14	0.302	5.67	.818	.615	.584	18.77	2.71	2.04	1.93
						7.67	1.31	1.15	0.94

Measured = a
Standard = b
Split Sigma = c
Standard (INEL) = d
Segmented plume = e





TEST 4 STANDARD METHOD

06:42 - 07:42 2/7/74

u = 1.2 m/sec

Q = 0.032 gm/sec

———— Measured

- - - - - - - - Calculated

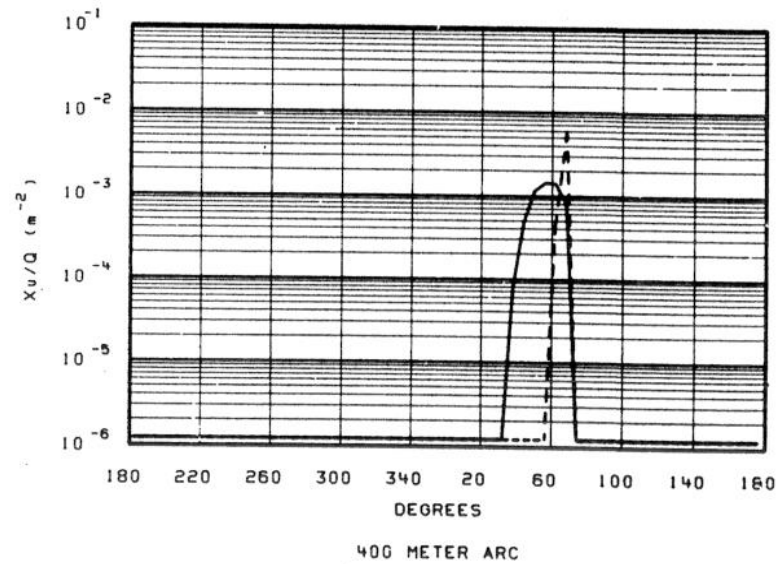
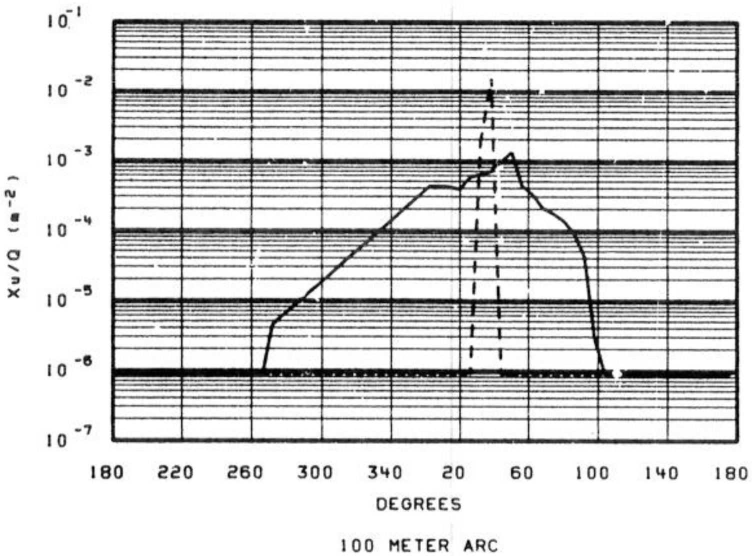
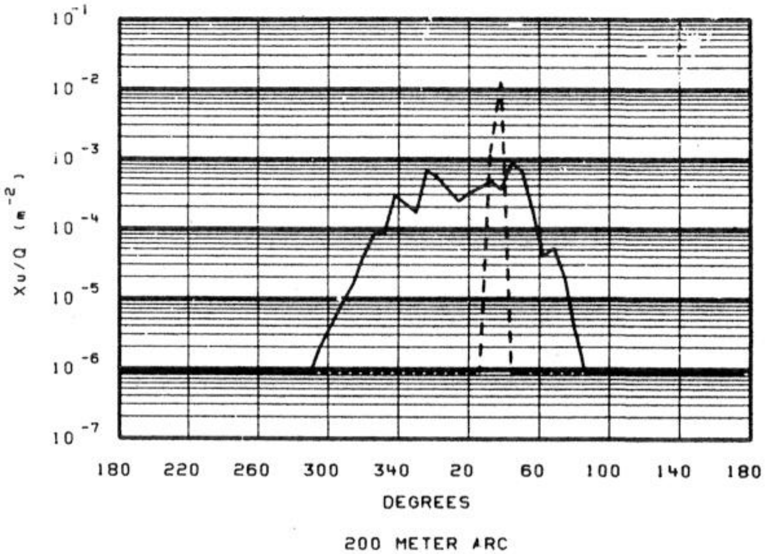


FIG. 20





TEST 5 STANDARD METHOD

06:30 - 07:30 2/8/74

u = 0.9 m/sec

Q = 0.032 gm/sec

———— Measured

-------- Calculated

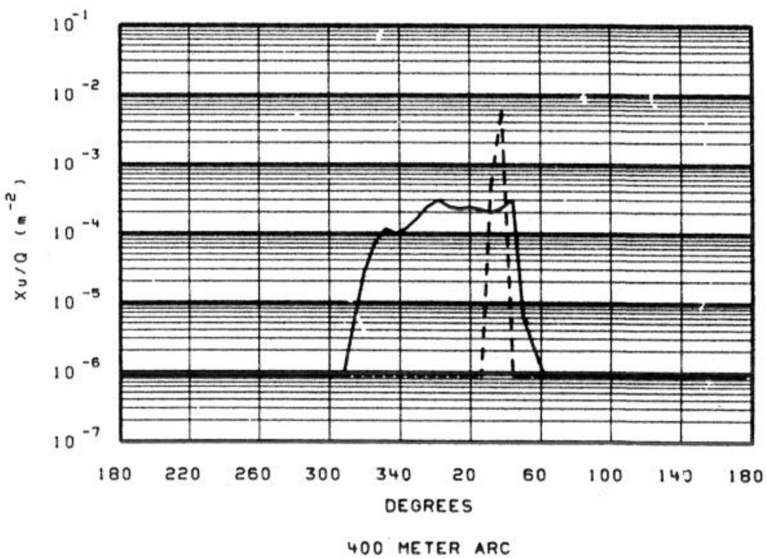
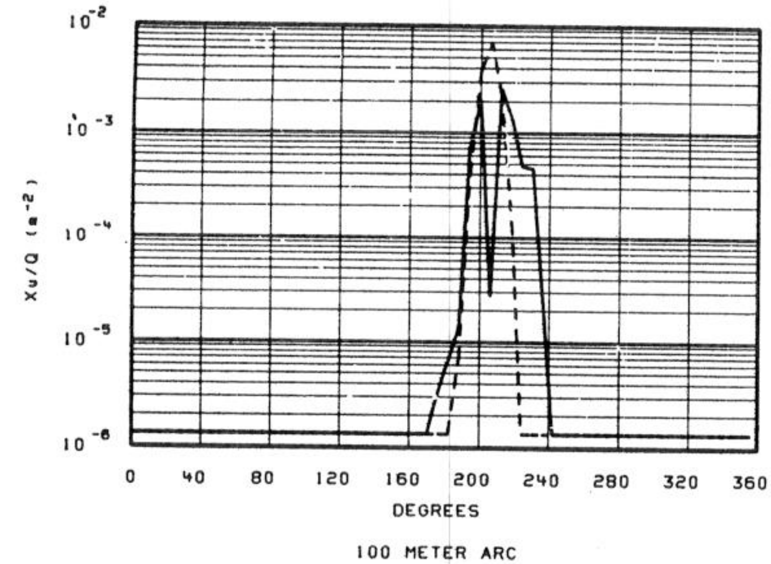
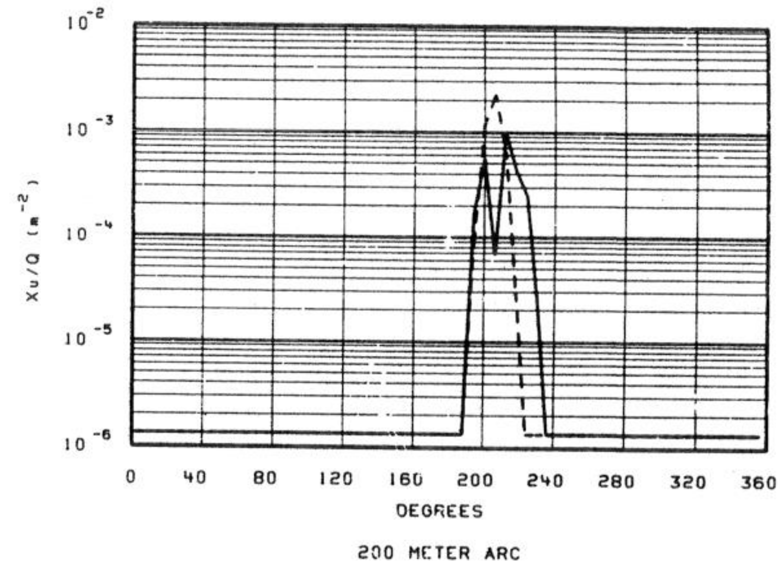


FIG. 21





TEST 6 STANDARD METHOD

06:46 - 07:46 2/9/74

u = 1.3 m/sec

Q = 0.031 gm/sec

——— Measured

- - - - - - - Calculated

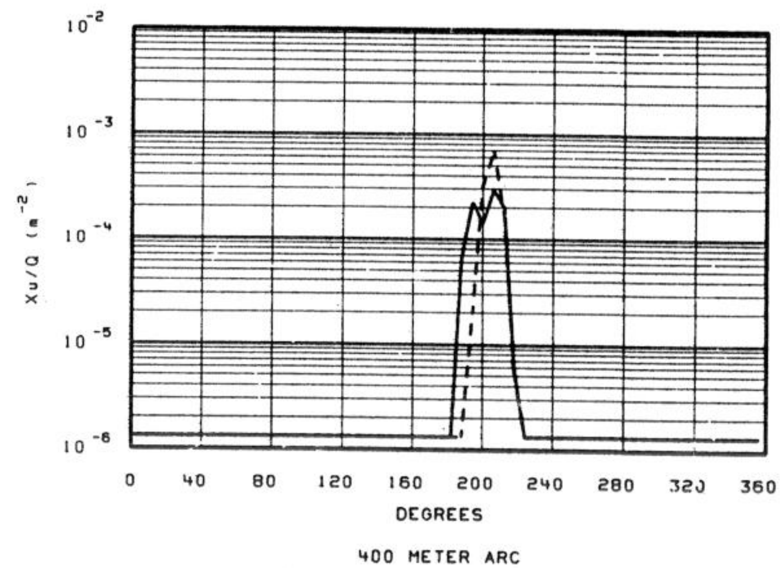
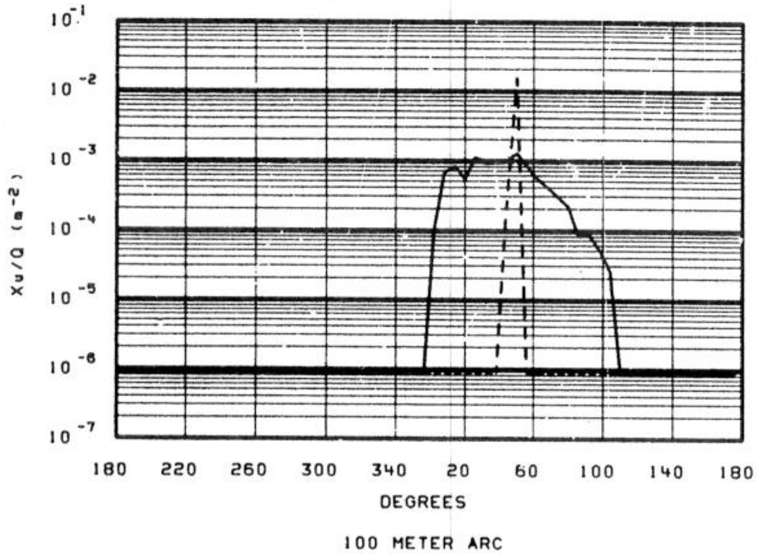
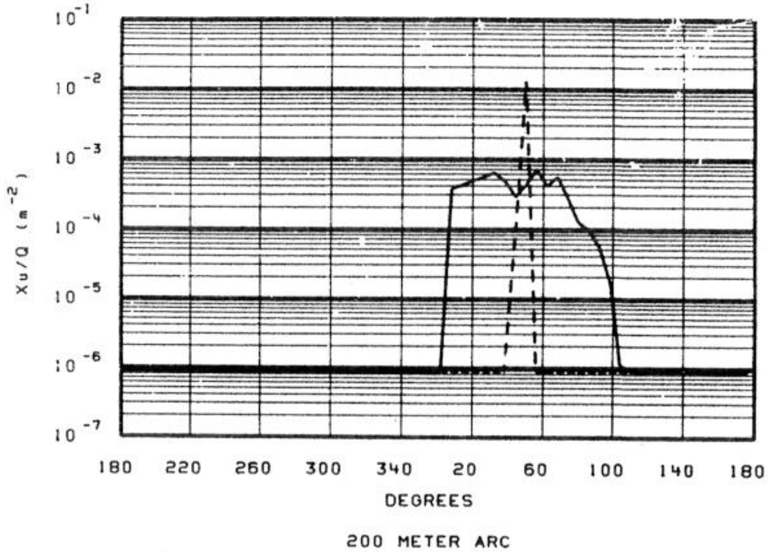


FIG. 22





TEST 7 STANDARD METHOD

06:30 - 07:30 2/12/74

u = 0.9 m/sec

Q = 0.033 gm/sec

——— Measured

-------- Calculated

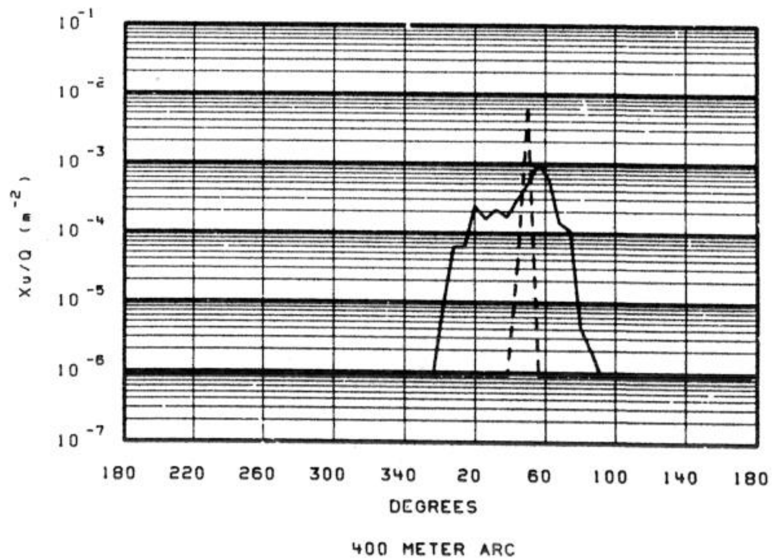
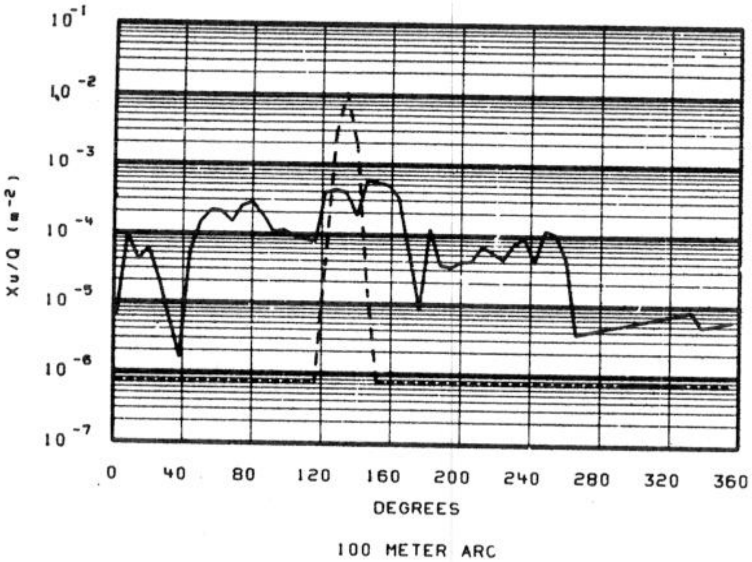
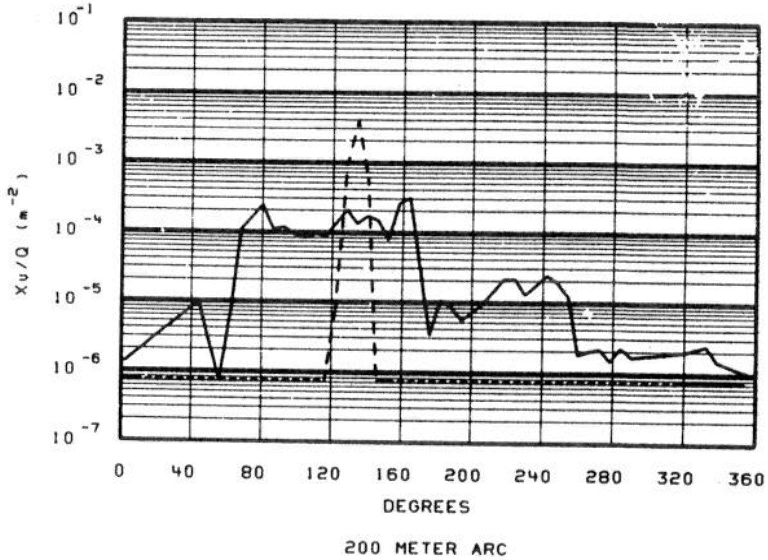


FIG. 23





TEST 8 STANDARD METHOD

06:30 - 07:30 2/21/74

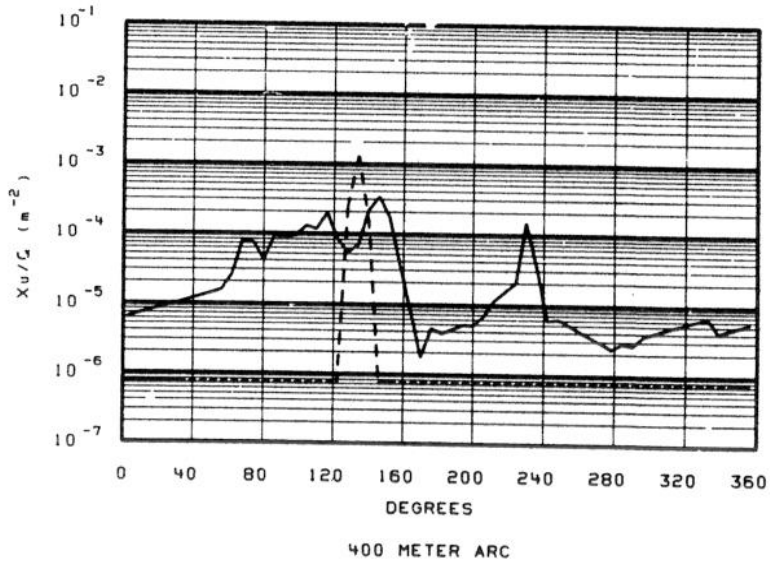
u = 0.8 m/sec

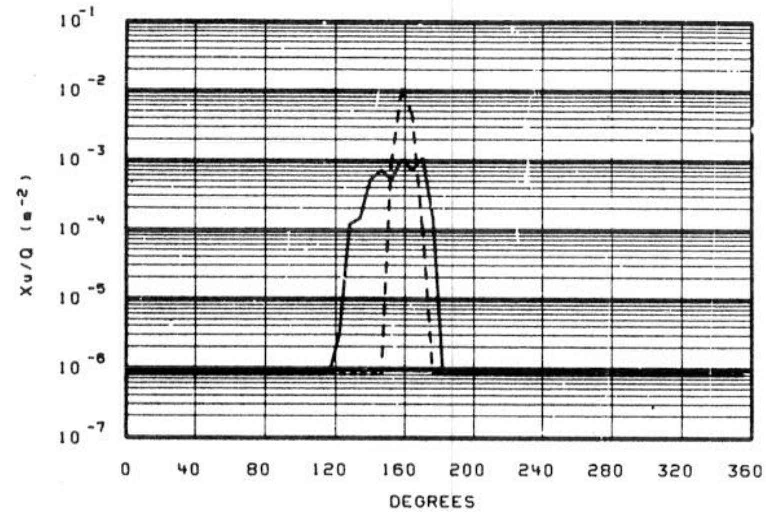
Q = 0.033 gm/sec

——— Measured

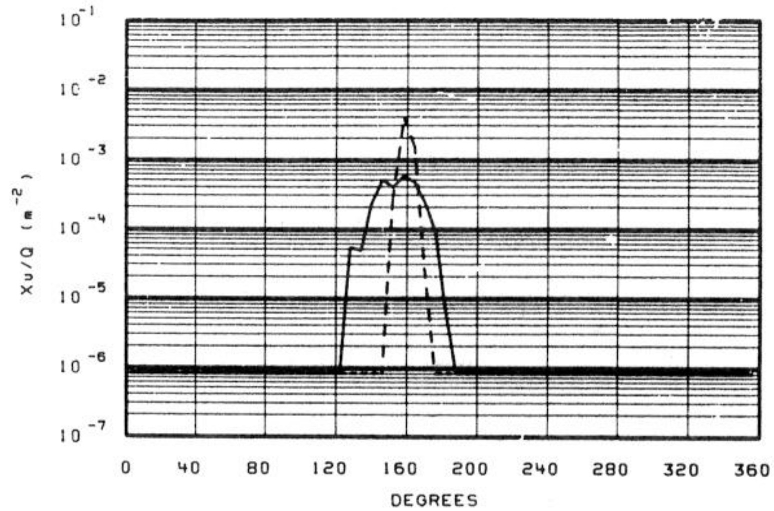
- - - - - - - Calculated

FIG. 24





100 METER ARC



200 METER ARC

TEST 9 STANDARD METHOD

05:30 - 06:30 3/21/74

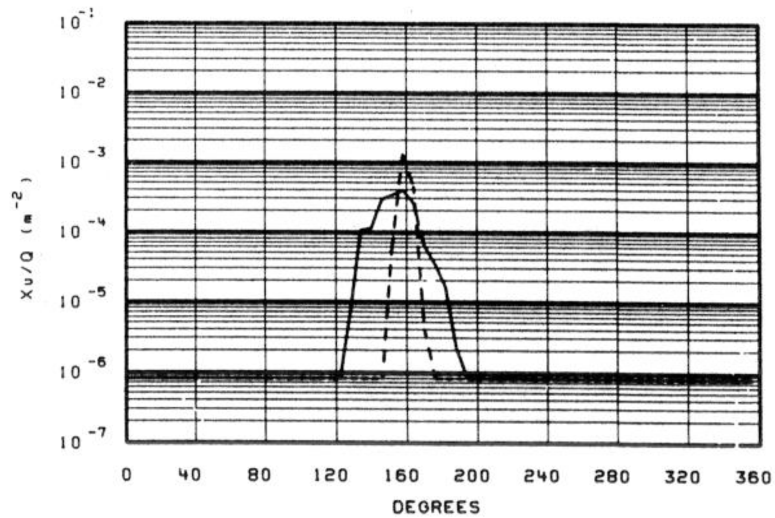
u = 0.8 m/sec

Q = 0.032 gm/sec

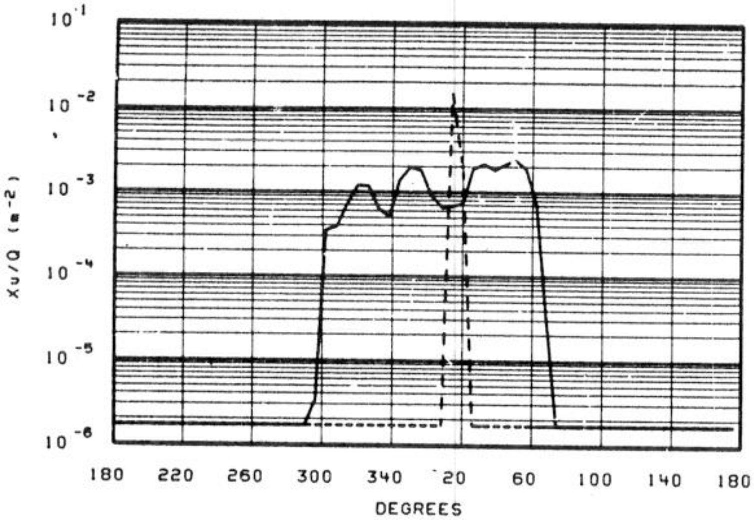
——— Measured

- - - - Calculated

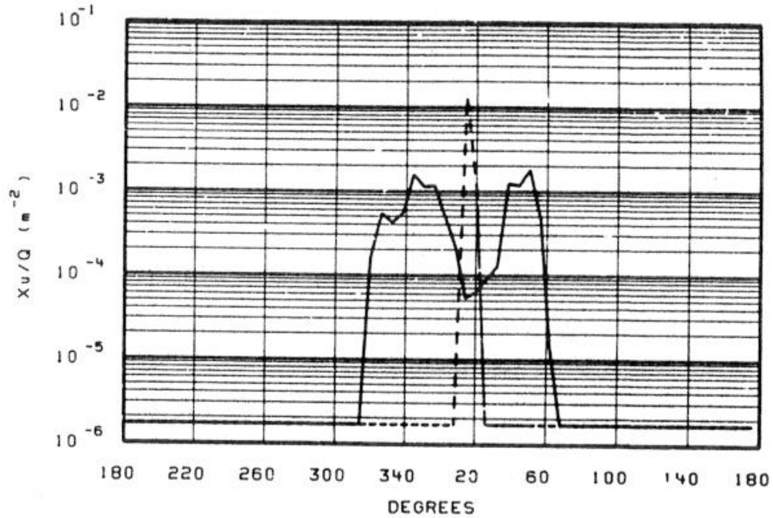
FIG. 25



400 METER ARC



100 METER ARC



200 METER ARC

TEST 10 STANDARD

04:58 - 05:47 4/17/74

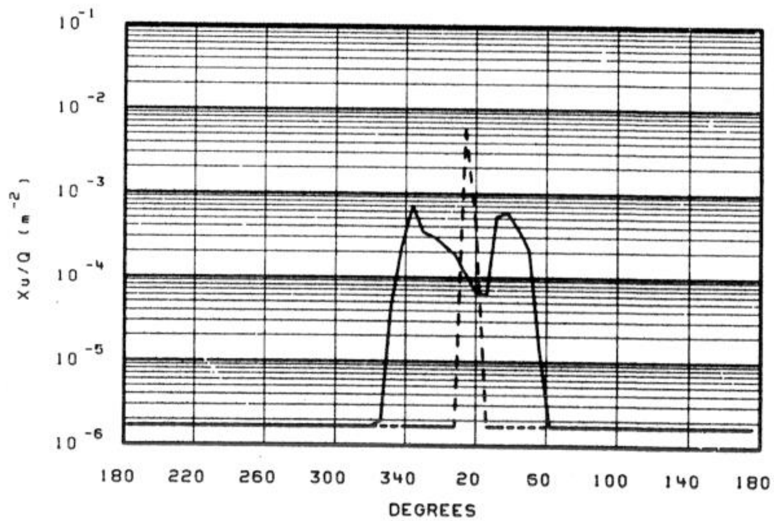
u = 1.7 m/sec

Q = 0.032 gm/sec

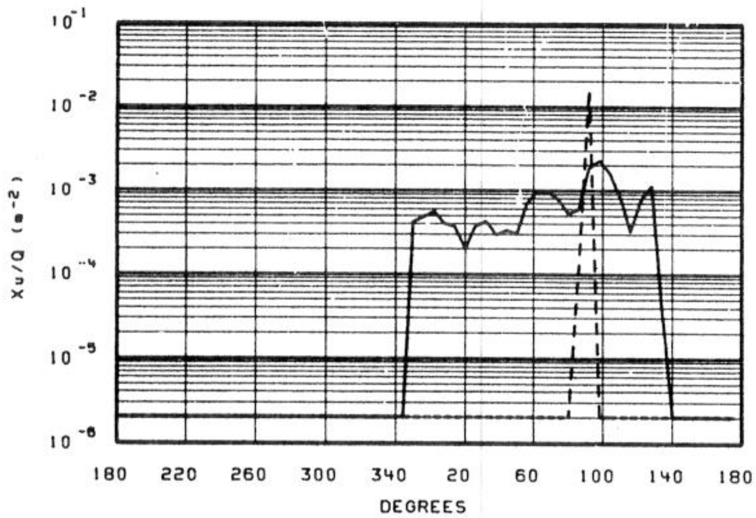
——— Measured

- - - - - Calculated

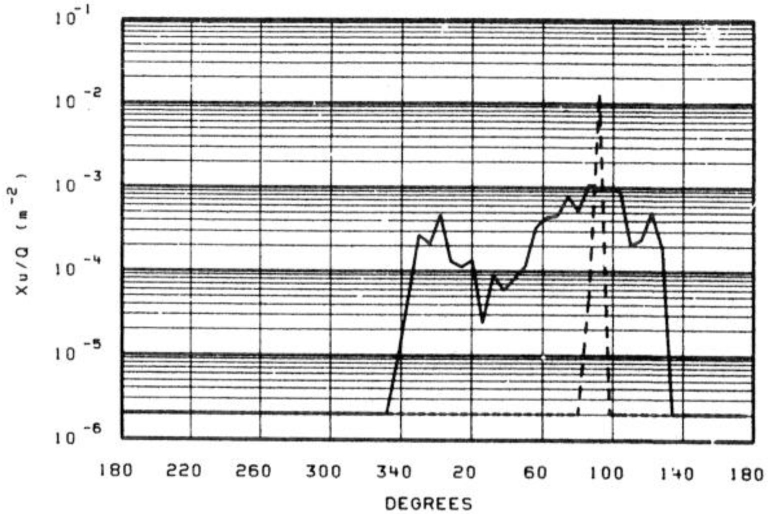
FIG. 26



400 METER ARC



100 METER ARC



200 METER ARC

TEST 11 STANDARD

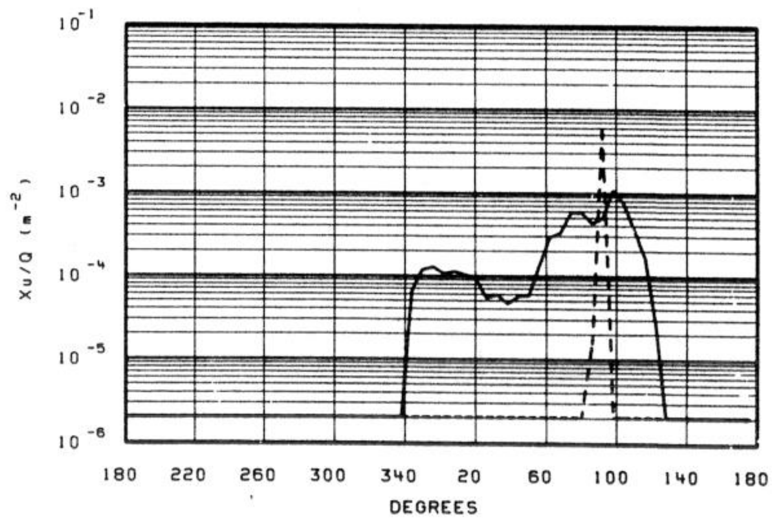
01:46 - 02:46 4/30/74

u = 1.9 m/sec

Q = 0.031 gm/sec

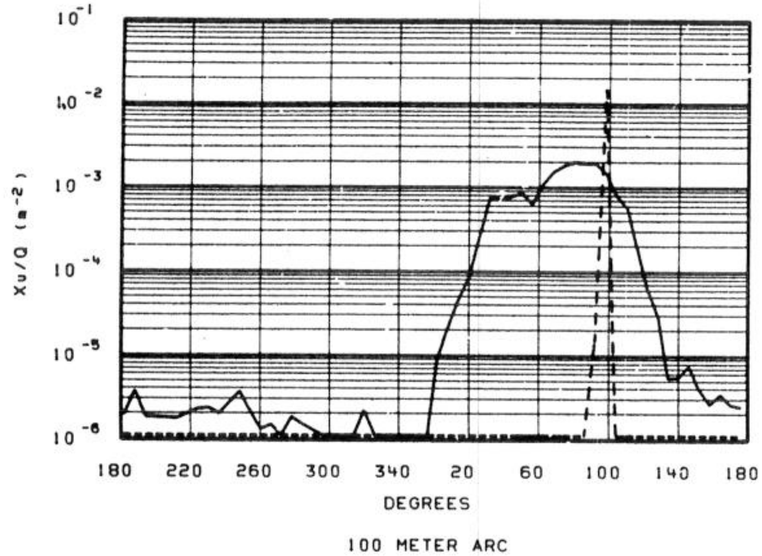
——————— Measured

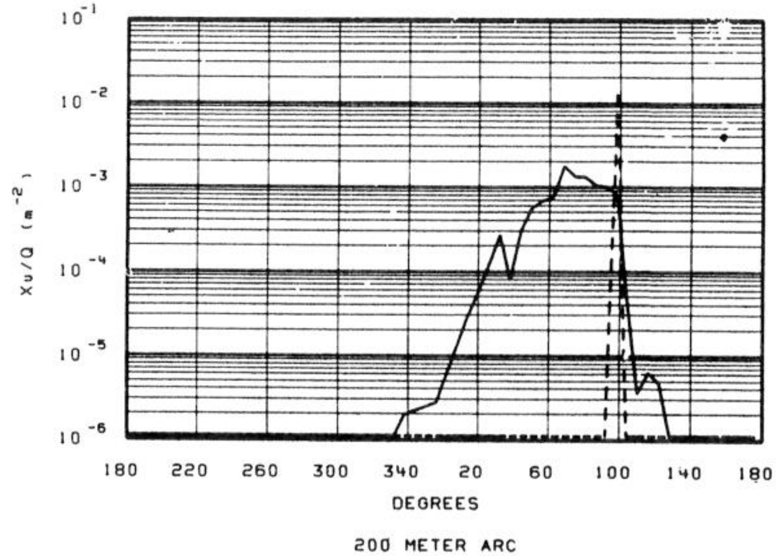
- - - - - - - Calculated



400 METER ARC

FIG. 27





TEST 12 STANDARD

04:11 - 05:11 4/30/74

u = 1.1 m/sec

Q = 0.032 gm/sec

——— Measured

- - - - - - - Calculated

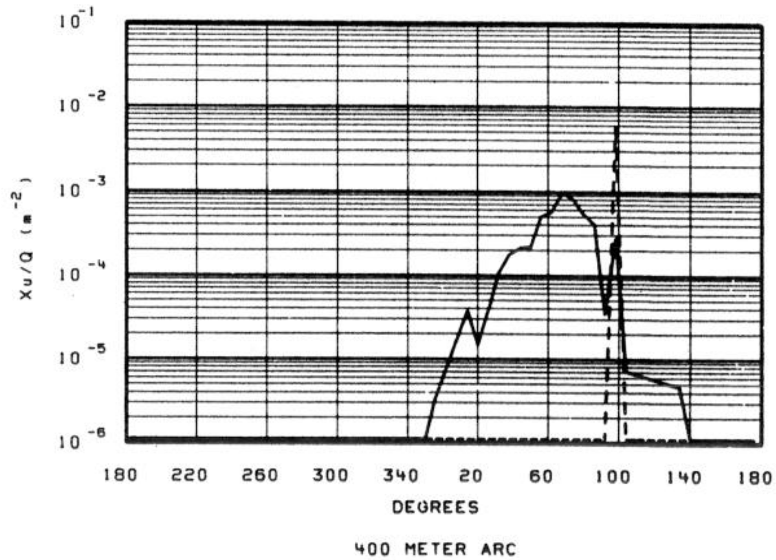
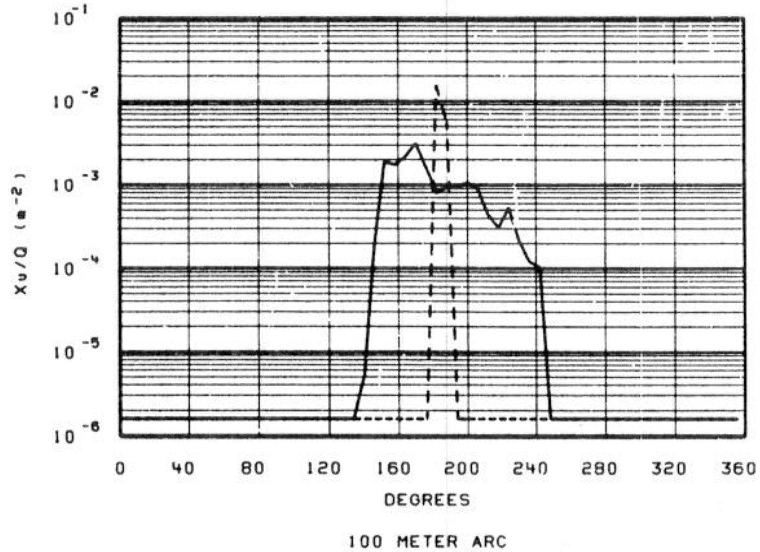
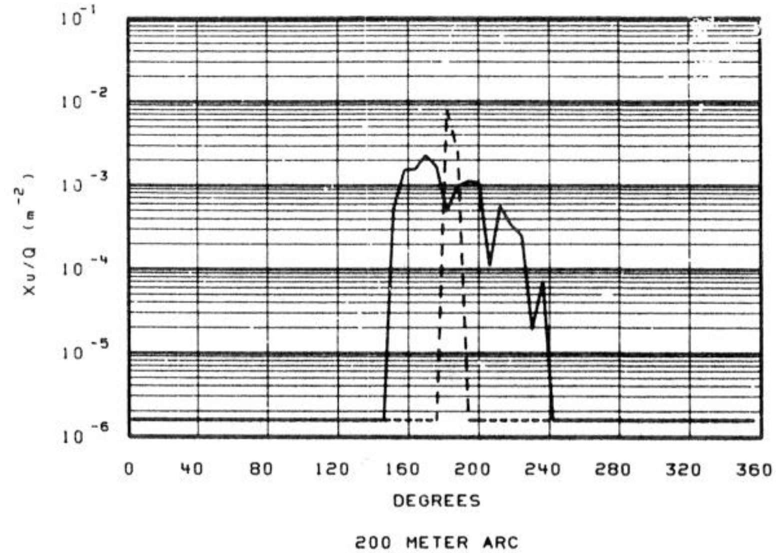


FIG. 28





TEST 13 STANDARD

04:22 - 05:22 5/3/74

u = 1.6 m/sec

Q = 0.033 gm/sec

——— Measured

- - - - - - - - Calculated

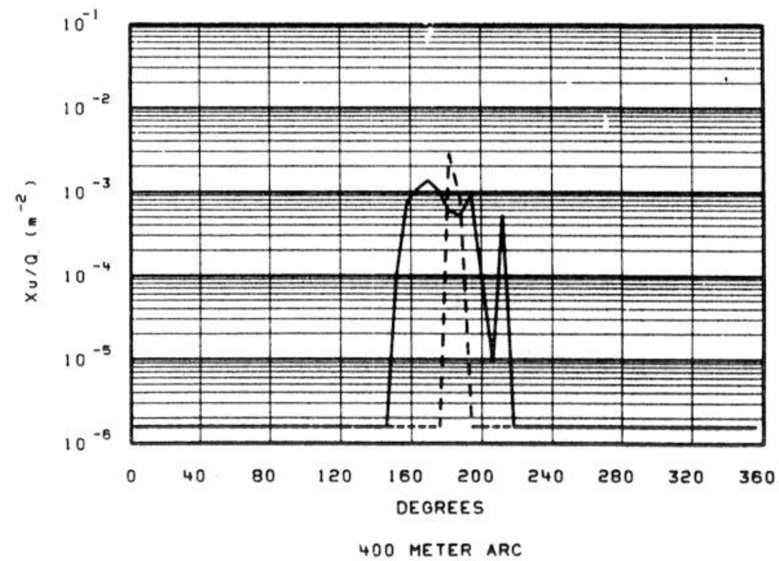
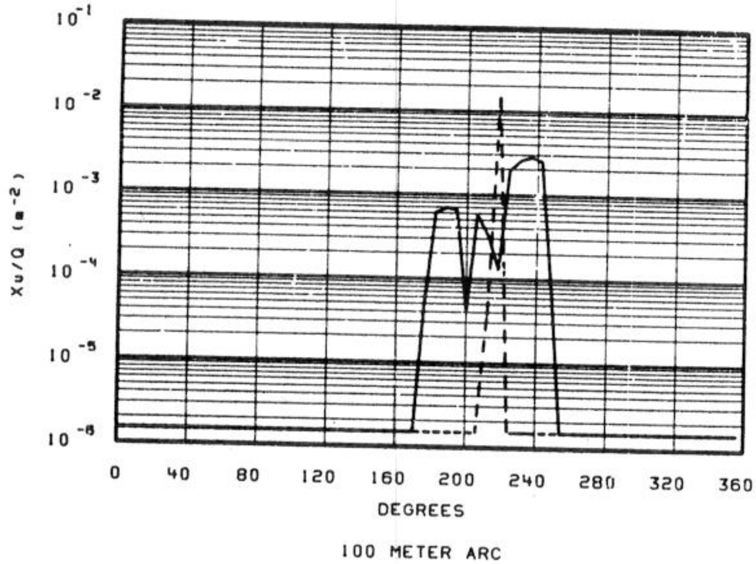
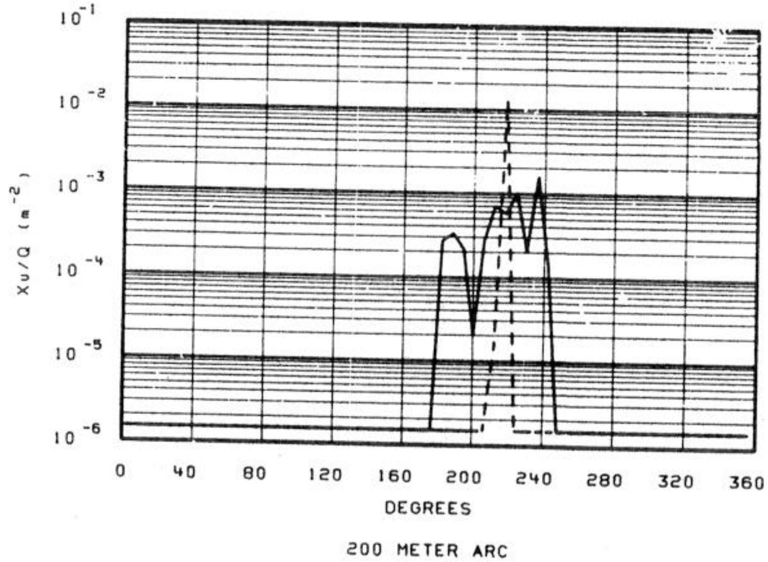


FIG. 29





TEST 14 STANDARD

03:45 - 04:45 5/22/74

u = 1.5 m/sec

Q = 0.032 gm/sec

——— Measured

- - - - - - - - Calculated

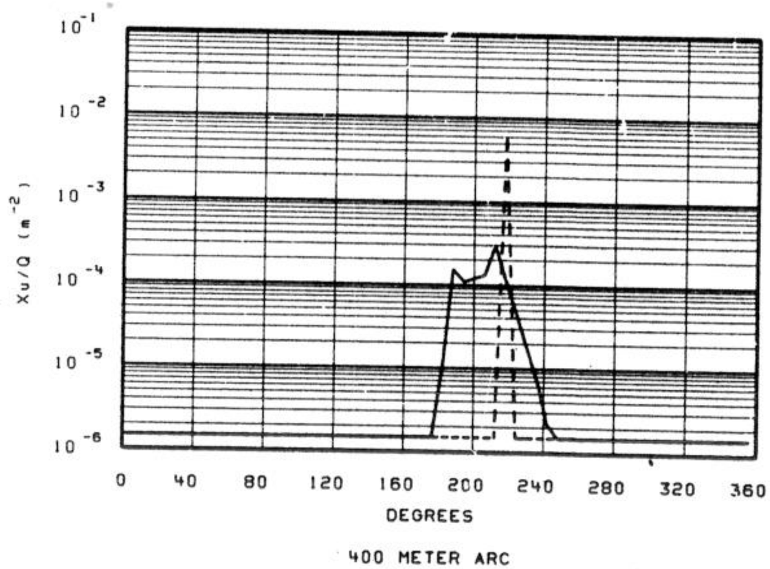
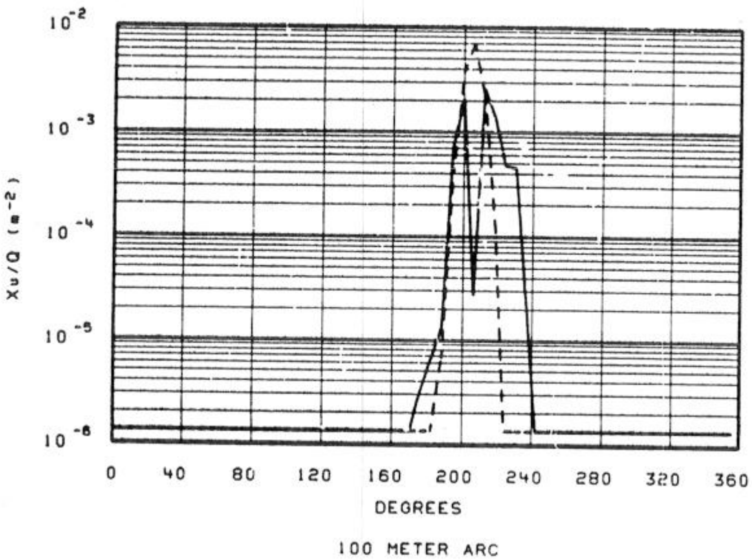
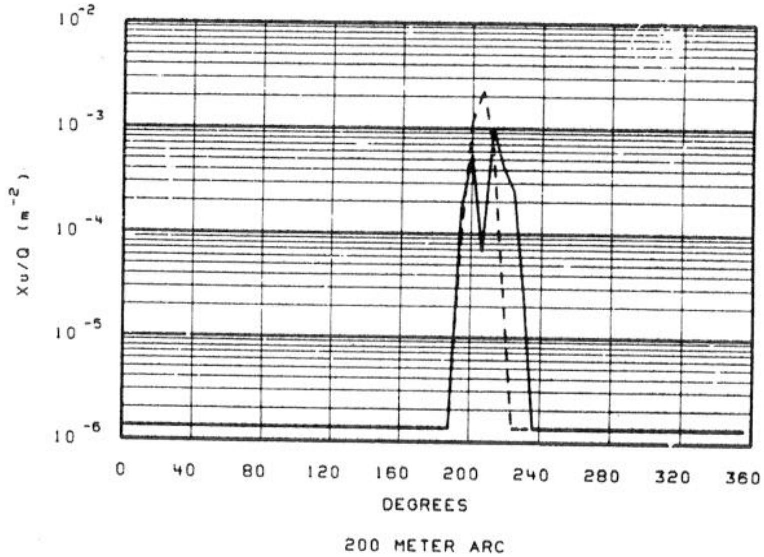


FIG. 30





TEST 6 SPLIT SIGMA

06:46 - 07:46 2/9/74

u = 1.3 m/sec

Q = 0.031 gm/sec

——————Measured

- - - - - - - -Calculated

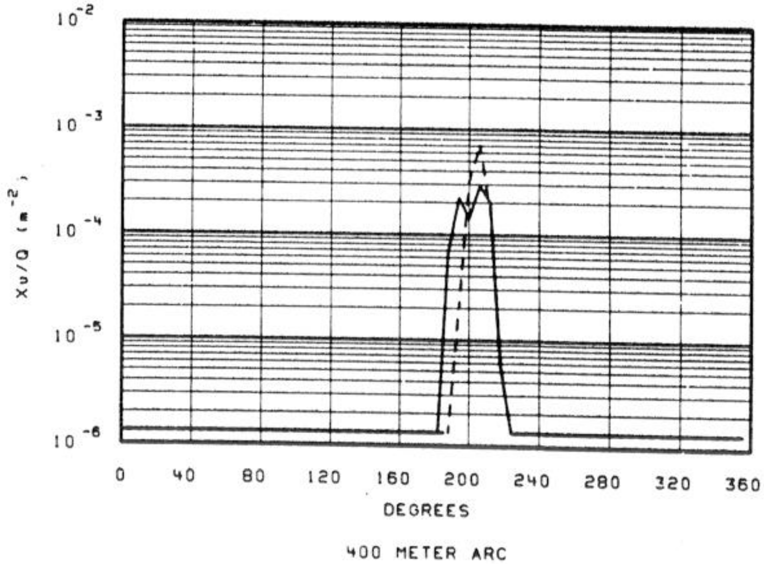
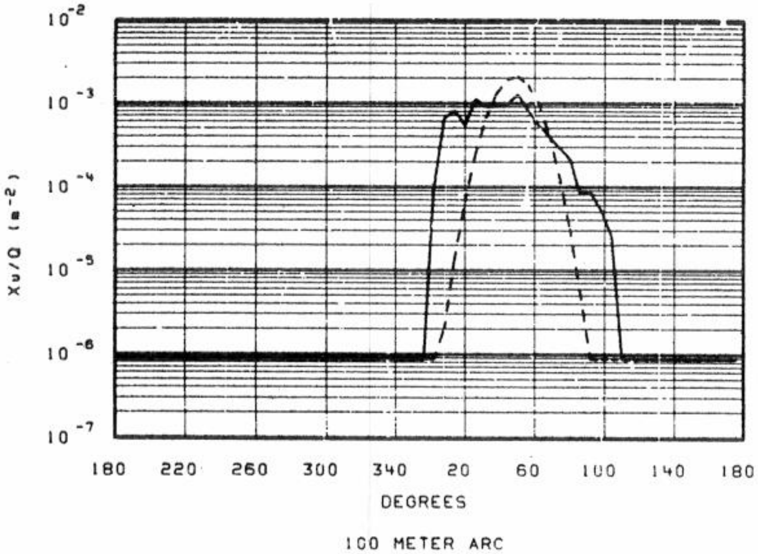
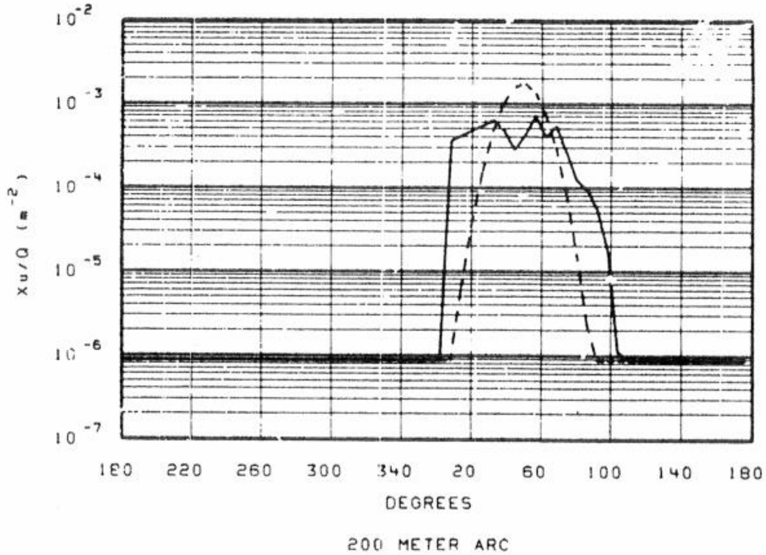


FIG. 33





TEST 7 SPLIT SIGMA

06:30 - 07:30 2/12/74

u = 0.9 m/sec

Q = 0.033 gm/sec

——————— Measured

- - - - - - - - Calculated

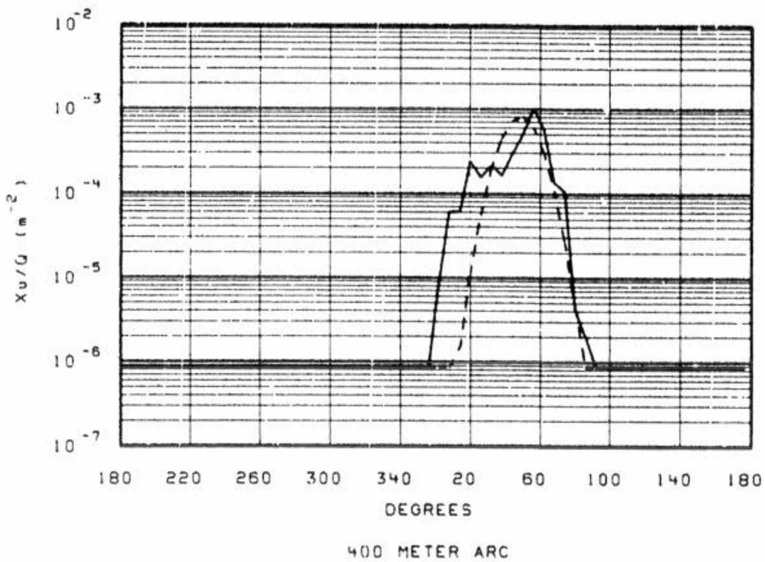
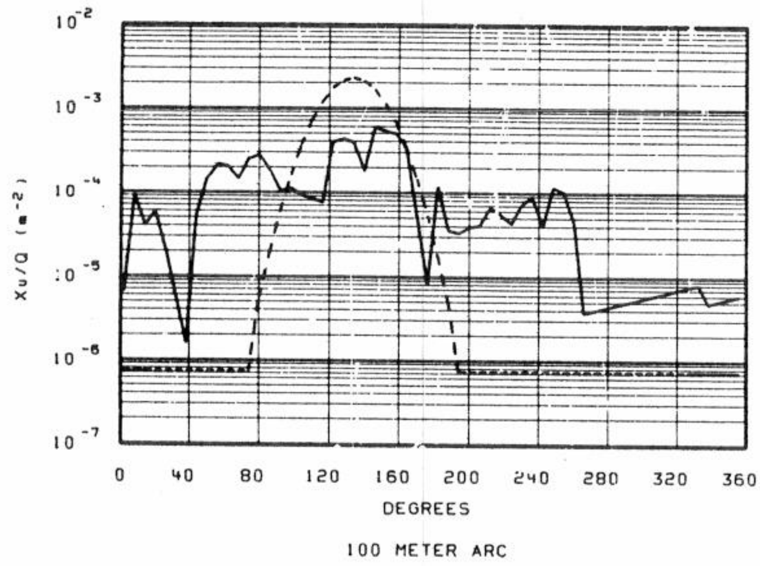
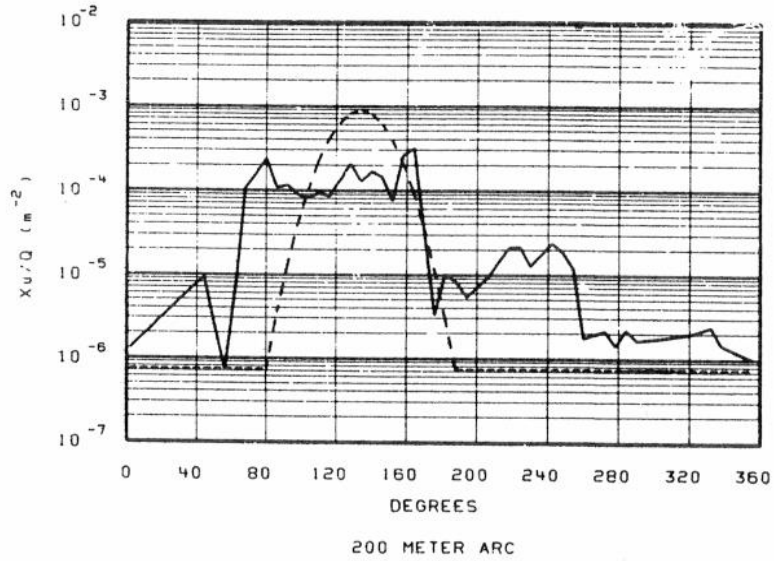


FIG. 34





TEST 8 SPLIT SIGMA

06:30 - 07:30 2/21/74

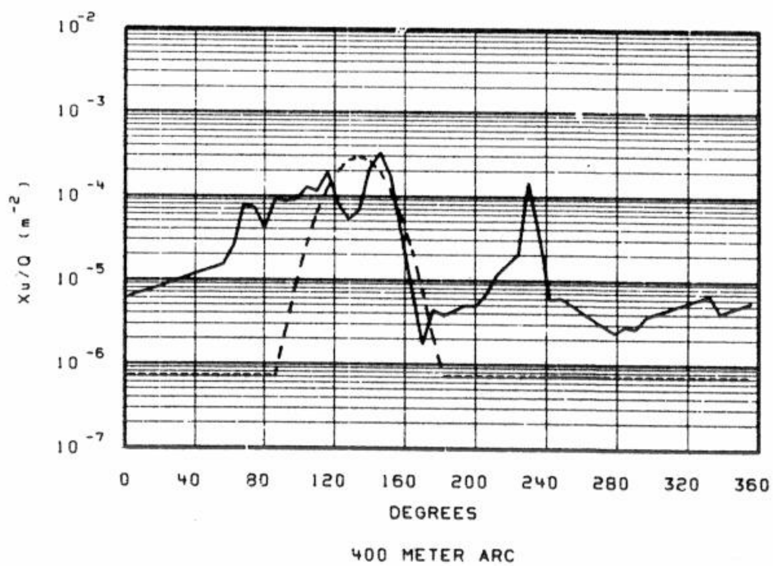
$u = 0.8$ m/sec

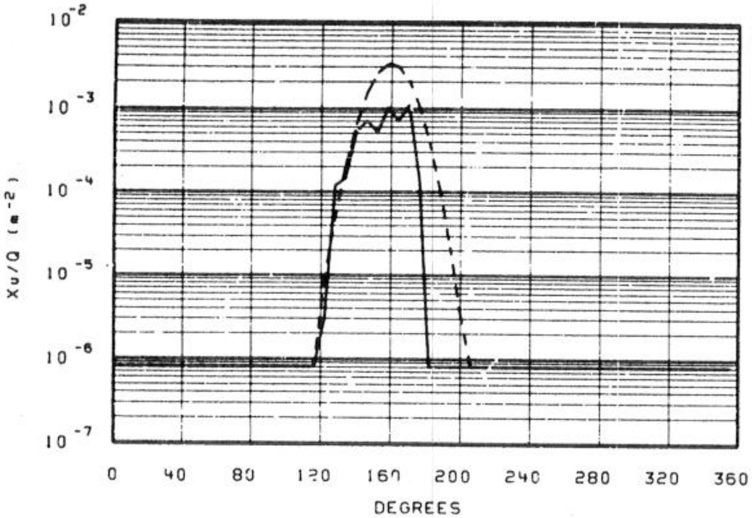
$Q = 0.033$ gm/sec

——— Measured

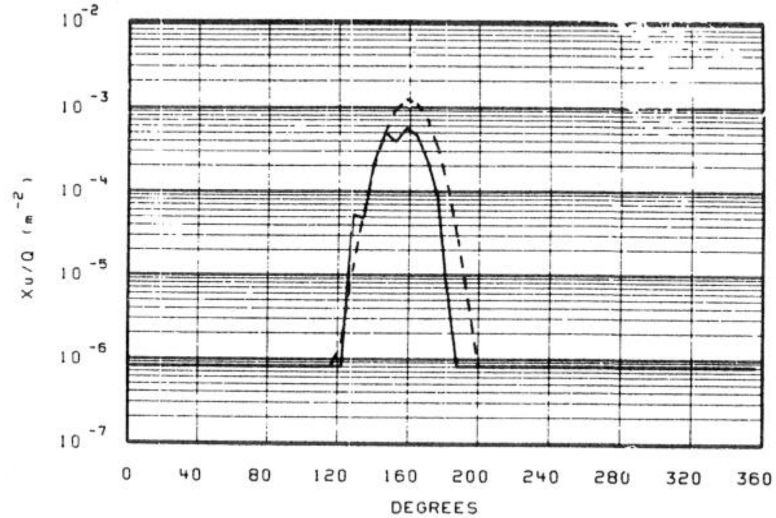
- - - - - - - - Calculated

FIG. 35





100 METER ARC



200 METER ARC

TEST 9 SPLIT SIGMA

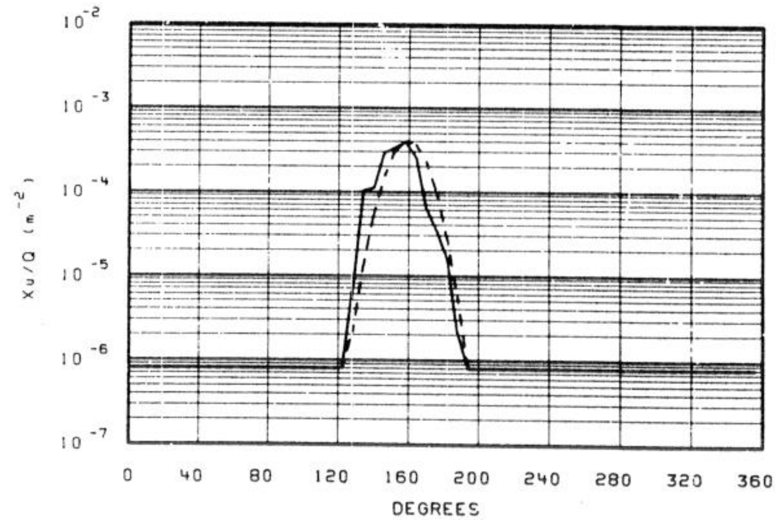
05:30 - 06:30 3/21/74

u = 0.8 m/sec

Q = 0.032 gm/sec

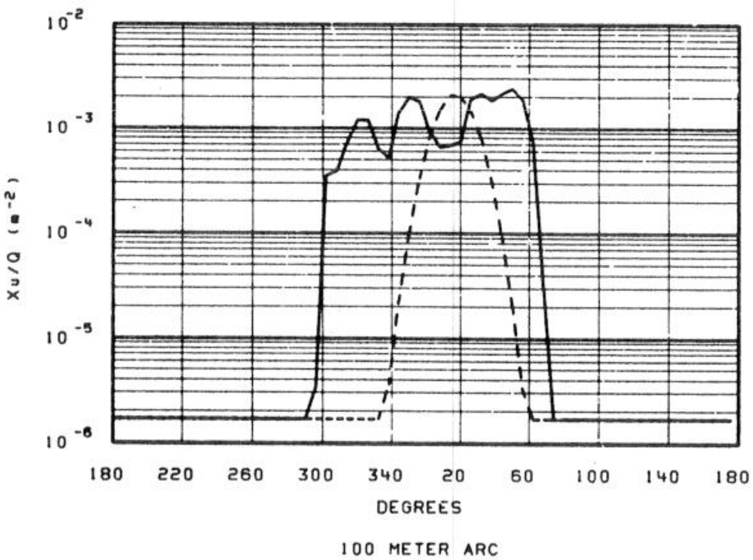
——————— Measured

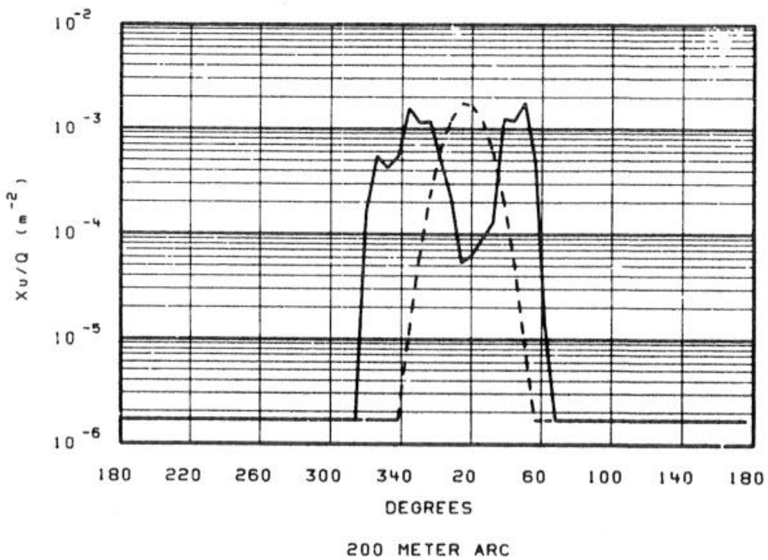
- - - - - - - Calculated



400 METER ARC

FIG. 36





TEST 10 SPLIT SIGMA

04:58 - 05:47 4/17/74

u = 1.7 m/sec

Q = 0.032 gm/sec

——— Measured

- - - - - - - - Calculated

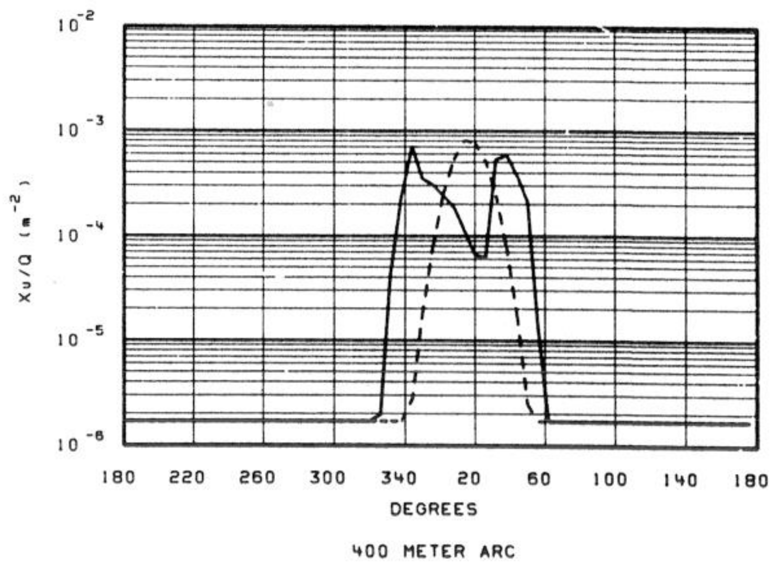
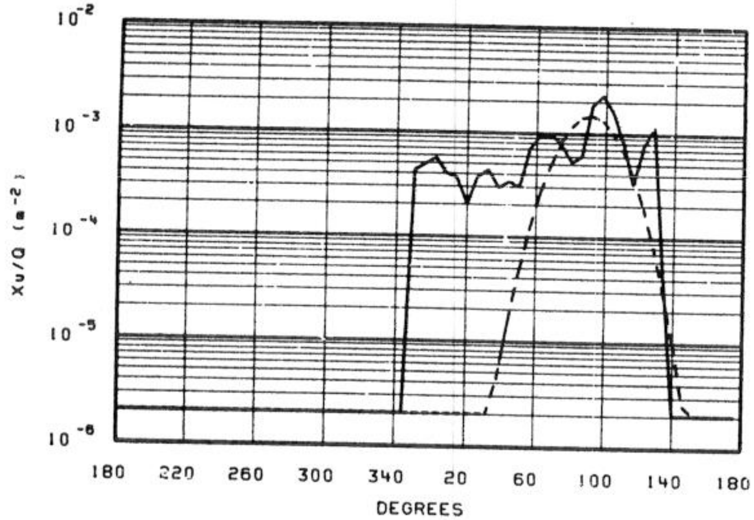
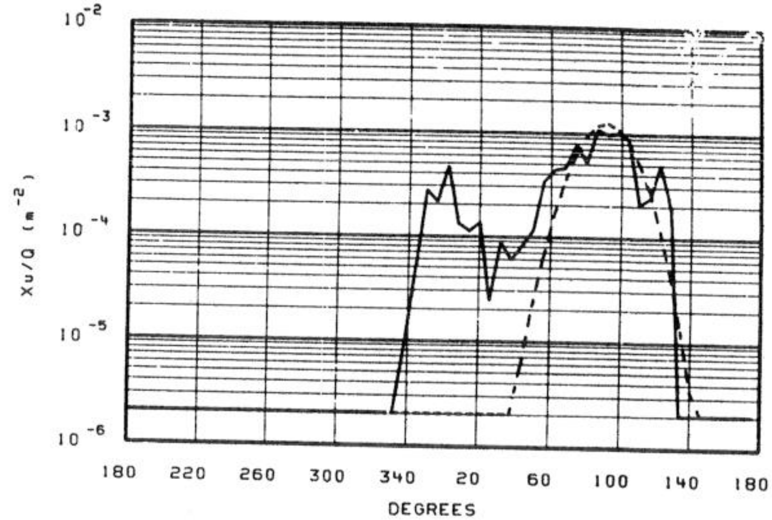


FIG. 37



100 METER ARC



200 METER ARC

TEST 11 SPLIT SIGMA

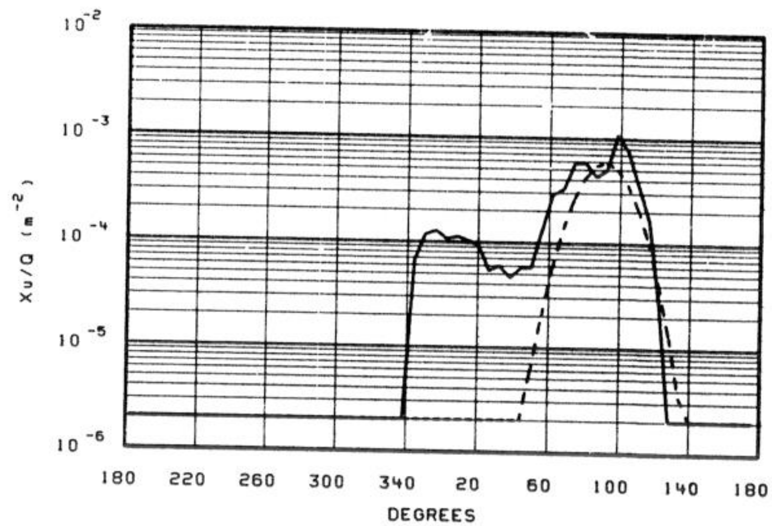
01:46 - 02:46 4/30/74

u = 1.9 m/sec

Q = 0.031 gm/sec

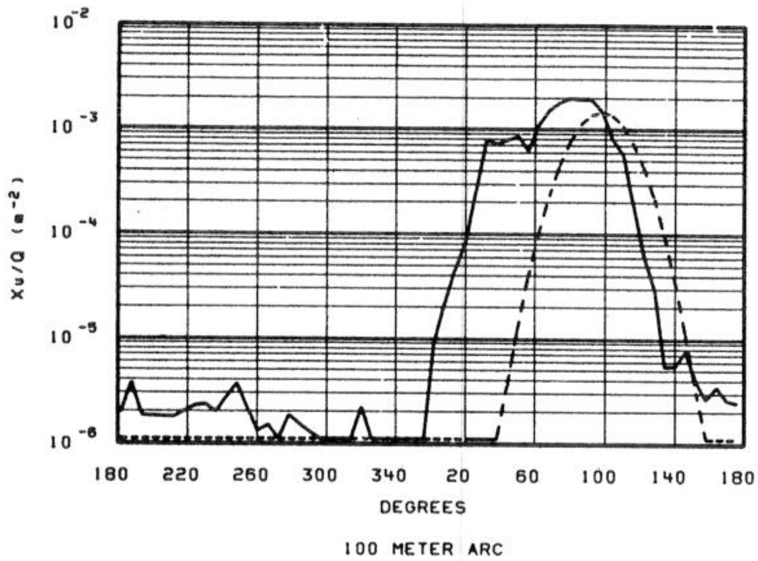
——— Measured

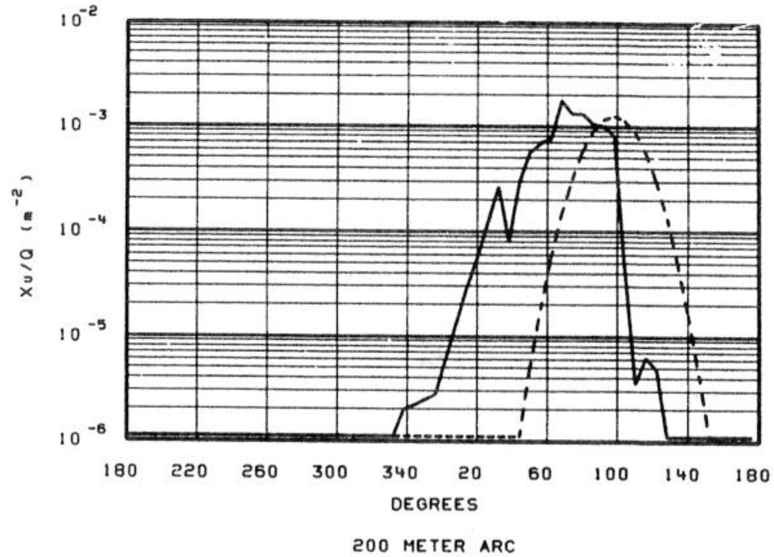
- - - - - Calculated



400 METER ARC

FIG. 38





TEST 12 SPLIT SIGMA

04:11 - 05:11 4/30/74

u = 1.1 m/sec

Q = 0.032 gm/sec

——— Measured

- - - - - Calculated

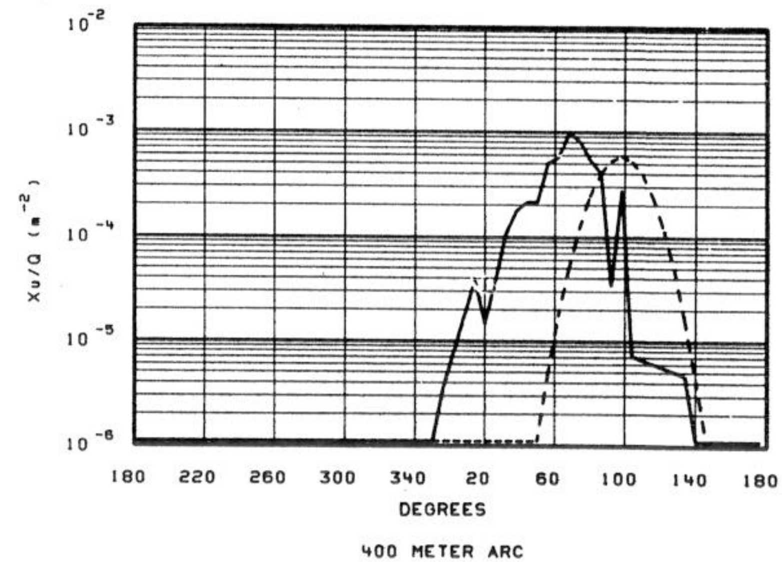
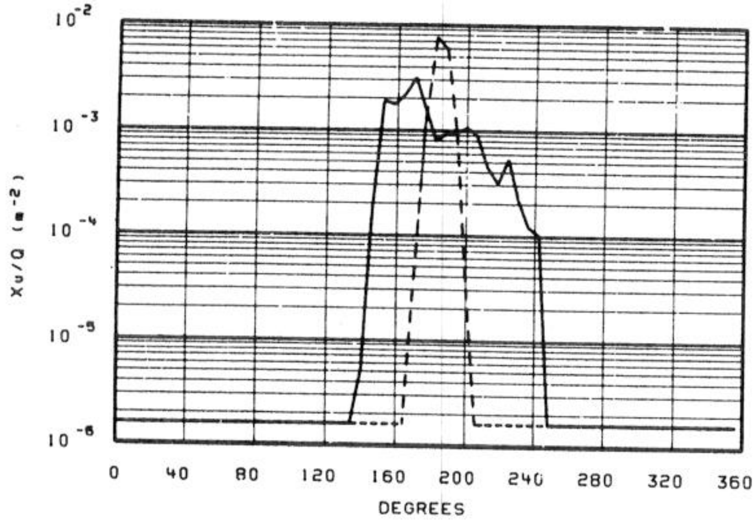
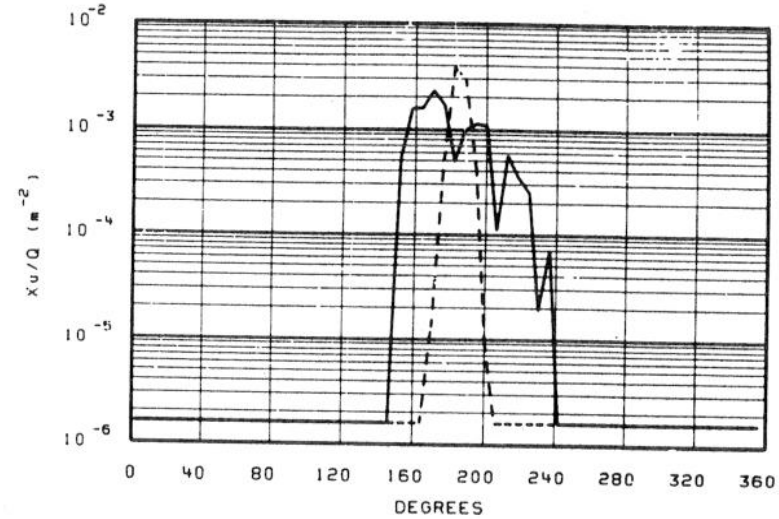


FIG. 39



100 METER ARC



200 METER ARC

TEST 13 SPLIT SIGMA

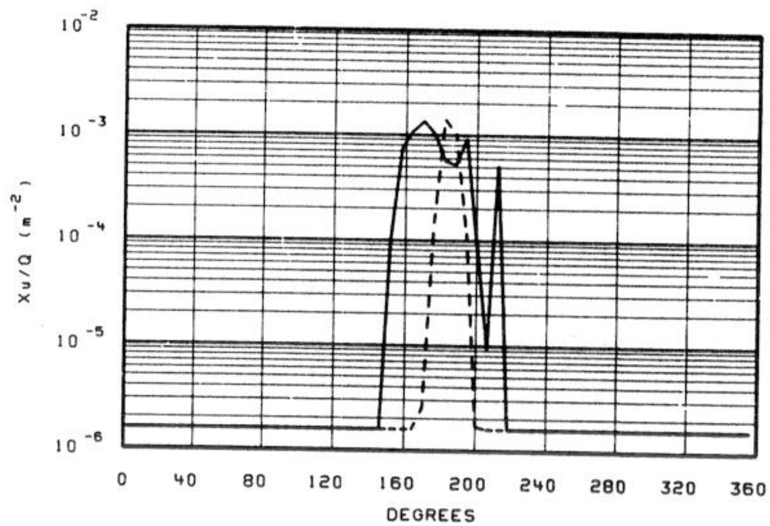
04:22 - 05:22 5/3/74

$u = 1.6$ m/sec

$Q = 0.033$ gm/sec

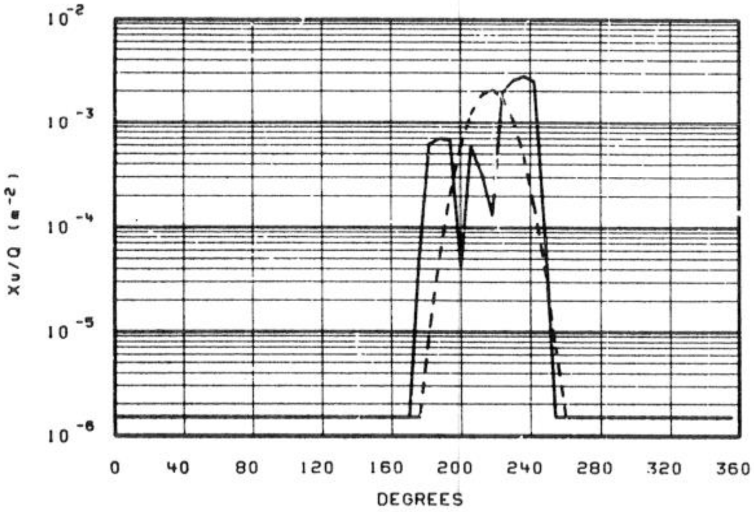
———— Measured

-------- Calculated

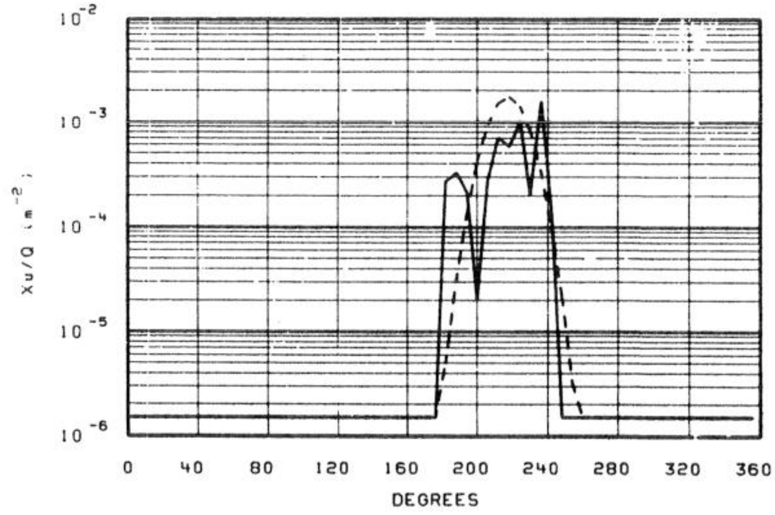


400 METER ARC

FIG. 40



100 METER ARC



200 METER ARC

TEST 14 SPLIT SIGMA

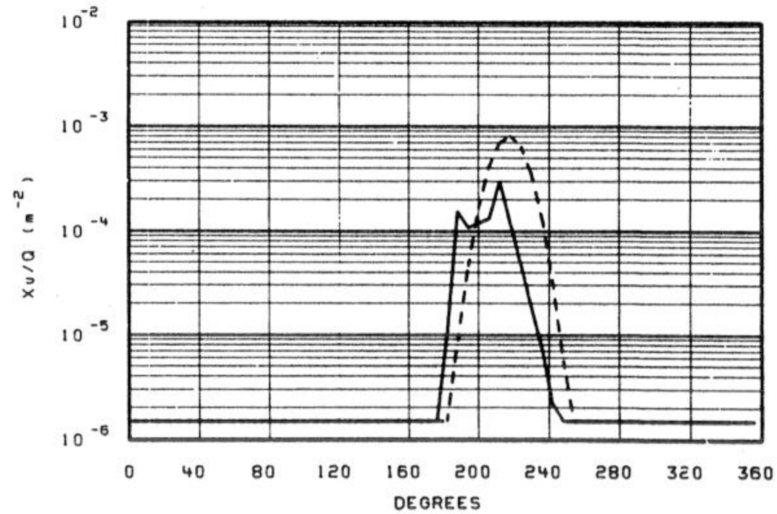
03:45 - 04:45 5/22/74

u = 1.5 m/sec

Q = 0.032 gm/sec

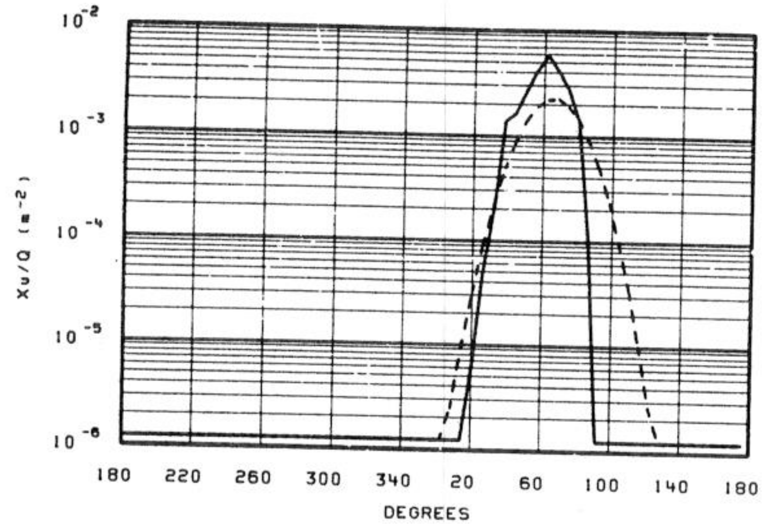
——— Measured

- - - - - - - Calculated

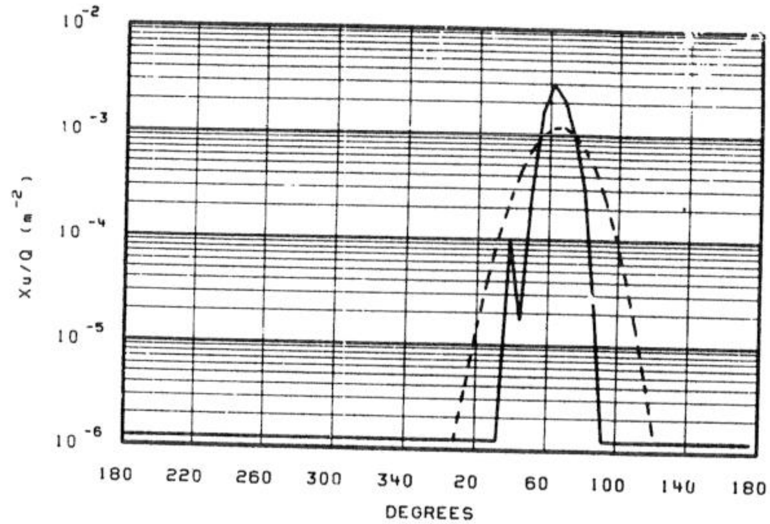


400 METER ARC

FIG. 41



100 METER ARC



200 METER ARC

TEST 4 STANDARD (INEL)

06:42 - 07:42 2/7/74

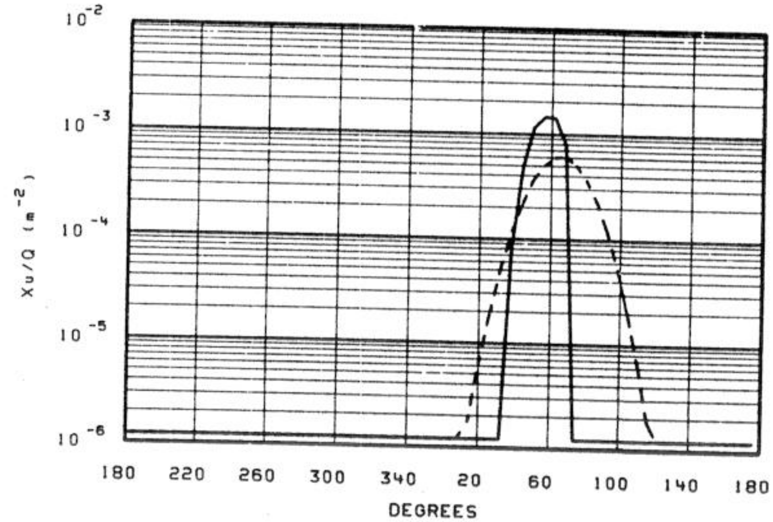
u = 1.2 m/sec

Q = 0.032 gm/sec

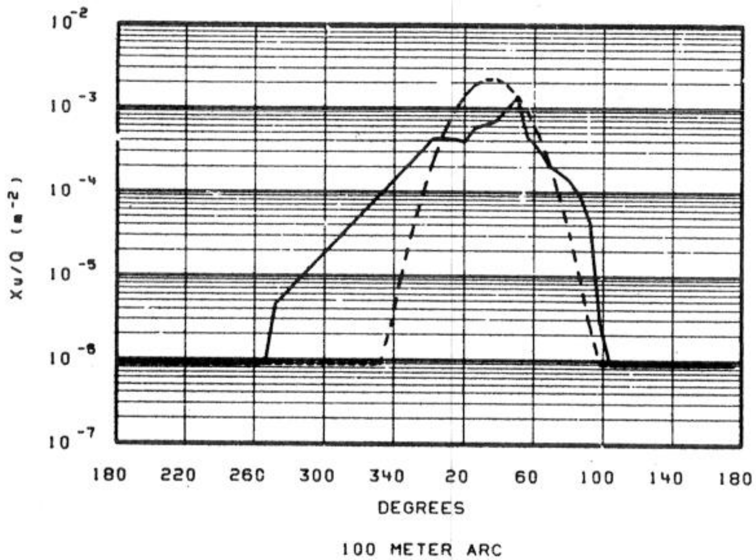
———— Measured

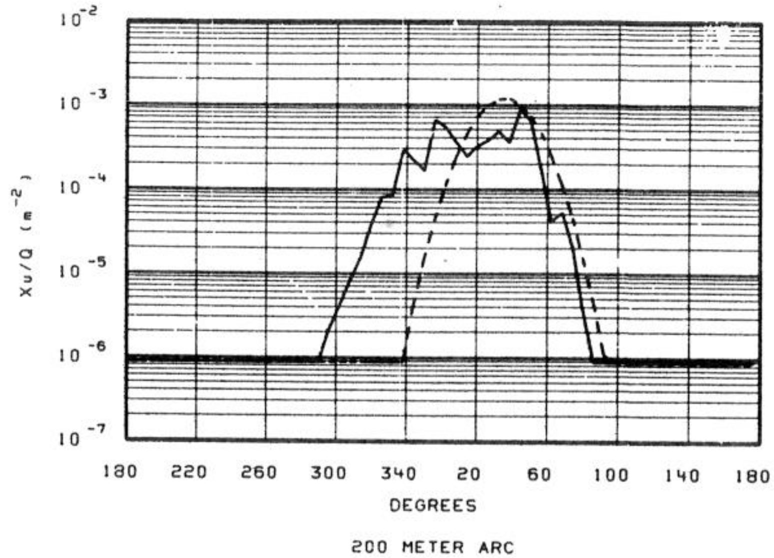
-------- Calculated

FIG. 42



400 METER ARC





TEST 5 STANDARD (INEL)

06:30 - 07:30 2/8/74

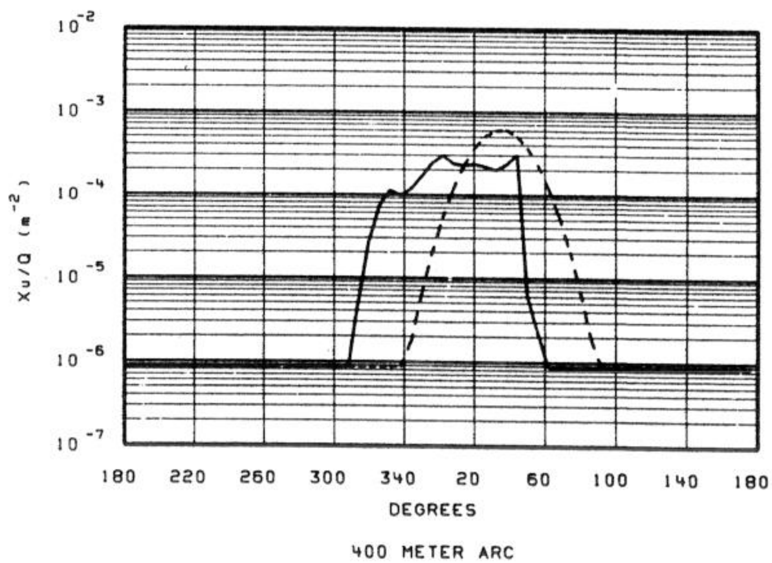
u = 0.9 m/sec

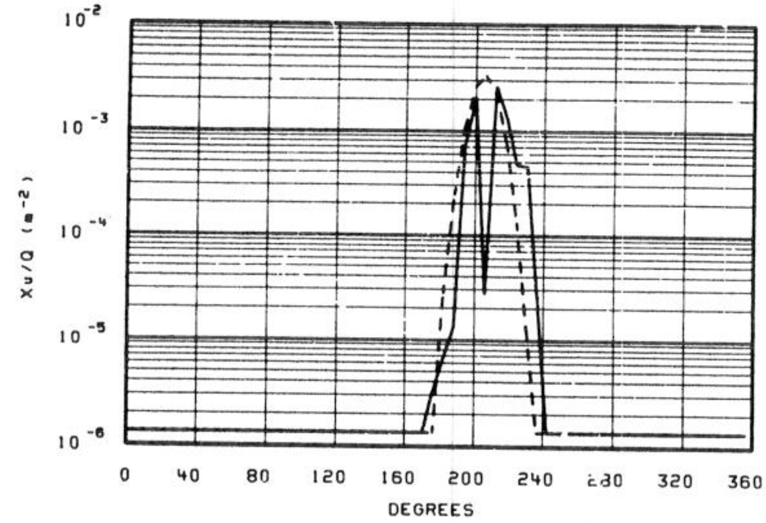
Q = 0.032 gm/sec

——— Measured

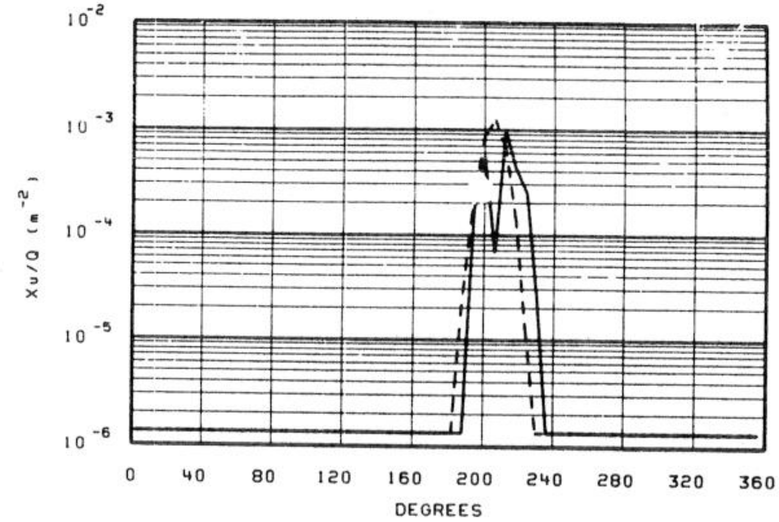
- - - - - - Calculated

FIG. 43





100 METER ARC



200 METER ARC

TEST 6 STANDARD (INEL)

06:46 - 07:46 2/9/74

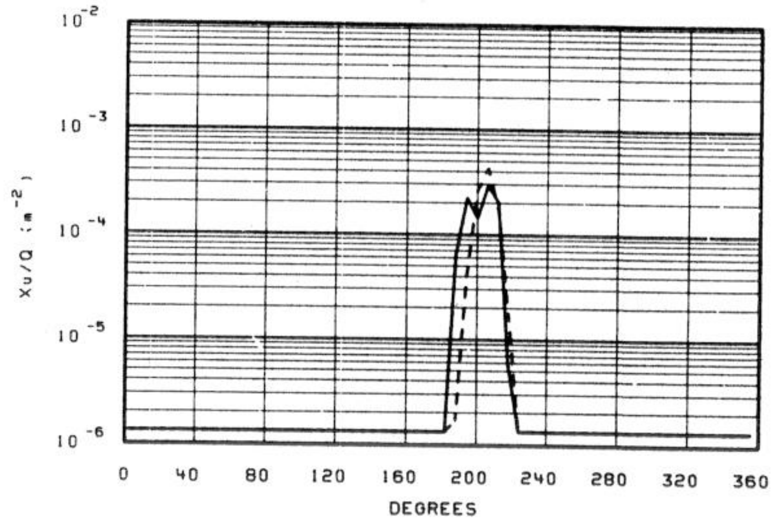
u = 1.3 m/sec

Q = 0.031 gm/sec

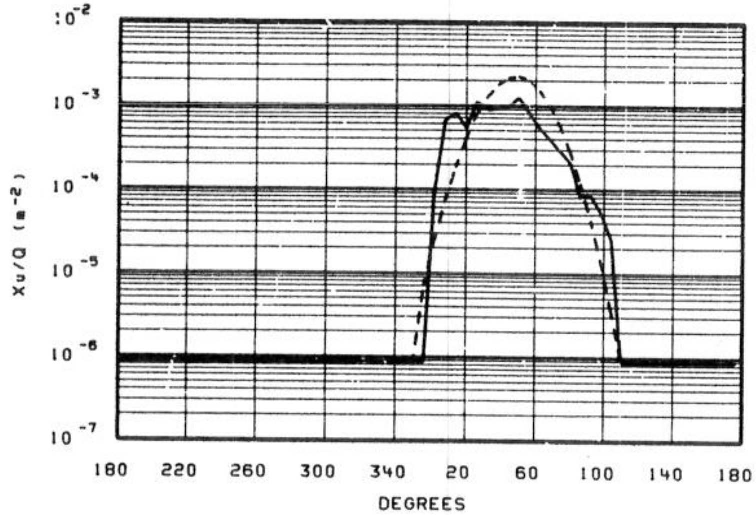
——— Measured

- - - - Calculated

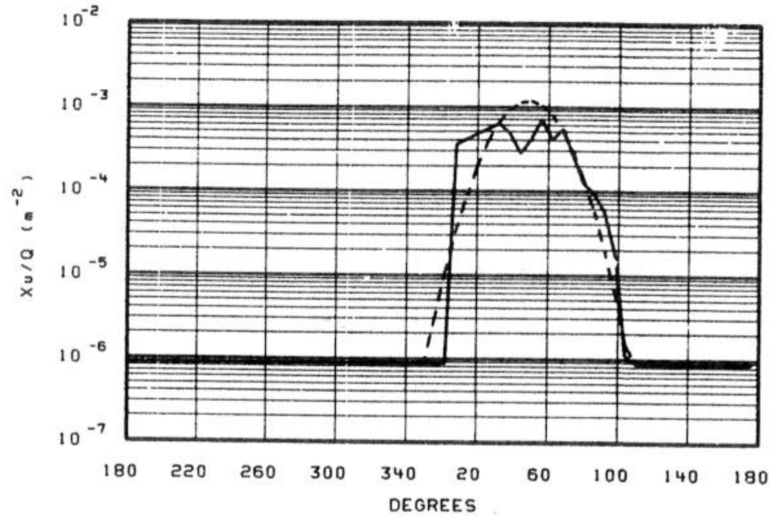
FIG. 44



400 METER ARC



100 METER ARC



200 METER ARC

TEST 7 STANDARD (INEL)

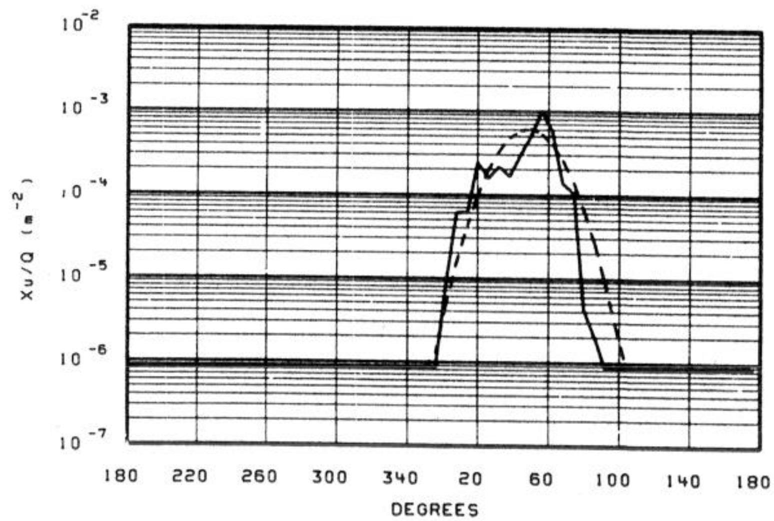
06:30 - 07:30 2/12/74

u = 0.9 m/sec

Q = 0.033 gm/sec

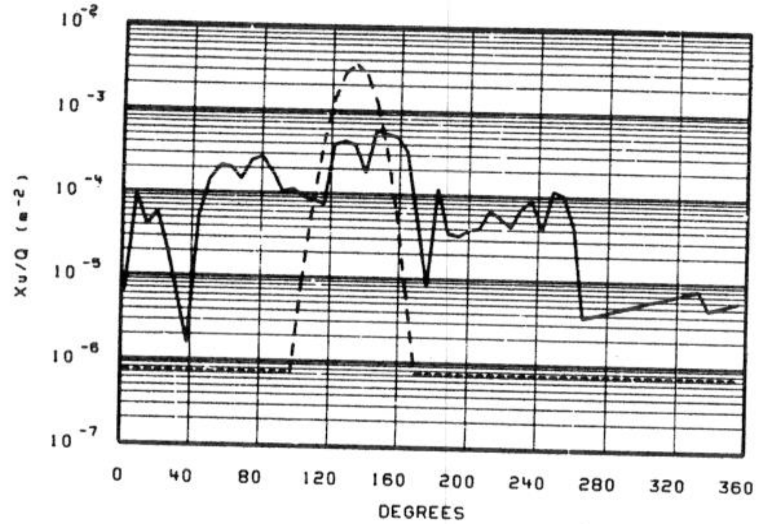
———— Measured

-------- Calculated

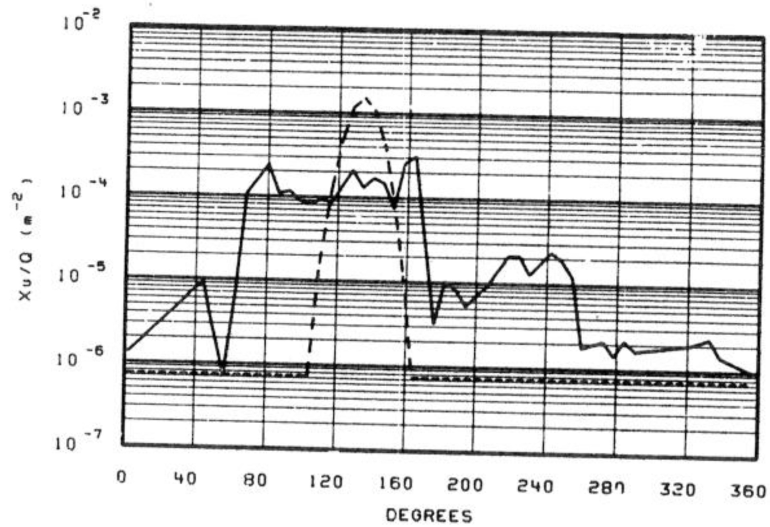


400 METER ARC

FIG. 45



100 METER ARC



200 METER ARC

TEST 8 STANDARD (INEL)

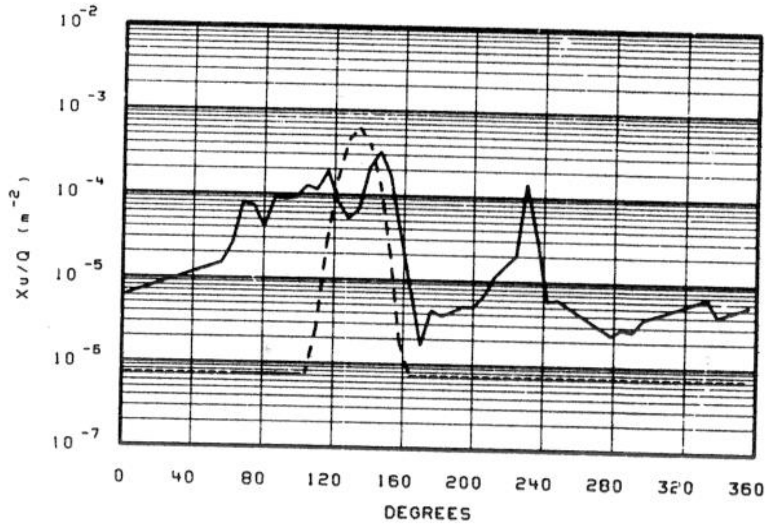
06:30 - 07:30 2/21/74

u = 0.8 m/sec

Q = 0.033 gm/sec

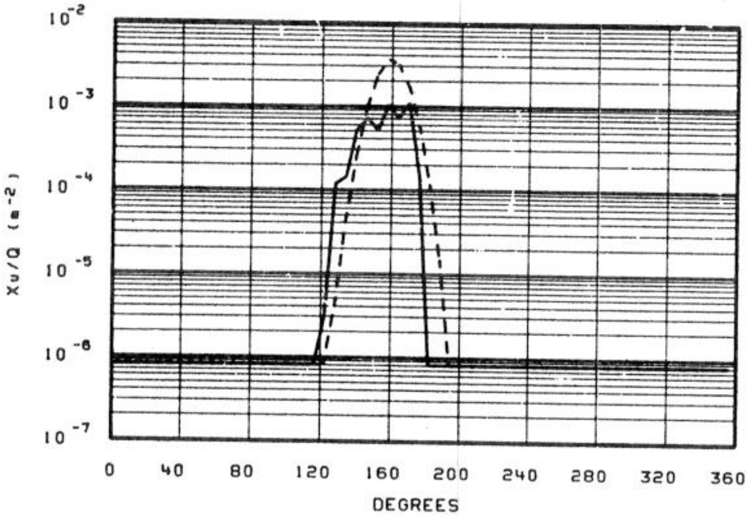
——— Measured

- - - - Calculated

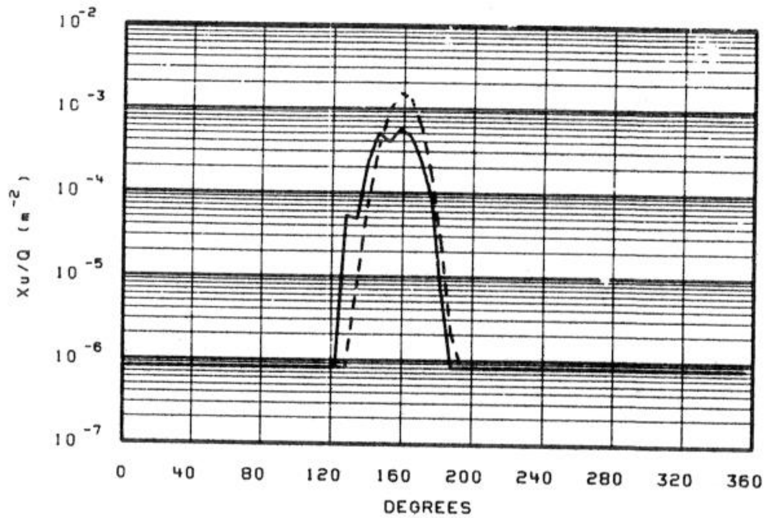


400 METER ARC

FIG. 46



100 METER ARC



200 METER ARC

TEST 9 STANDARD (INEL)

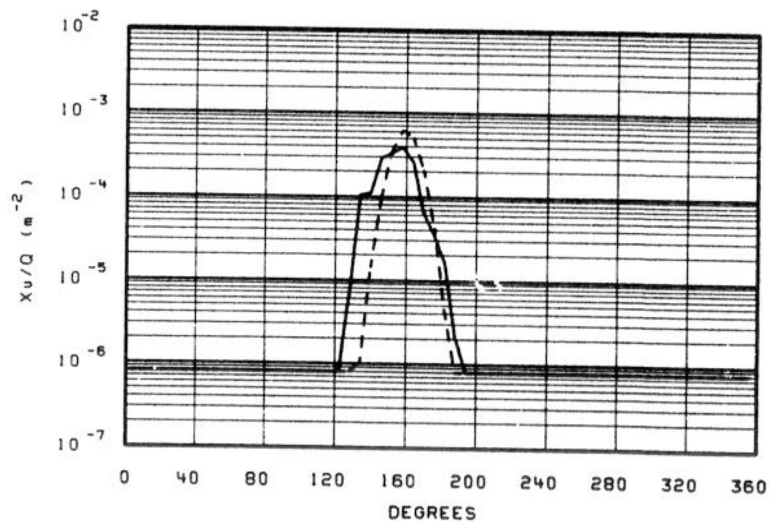
05:30 - 06:30 3/21/74

u = 0.8 m/sec

Q = 0.032 gm/sec

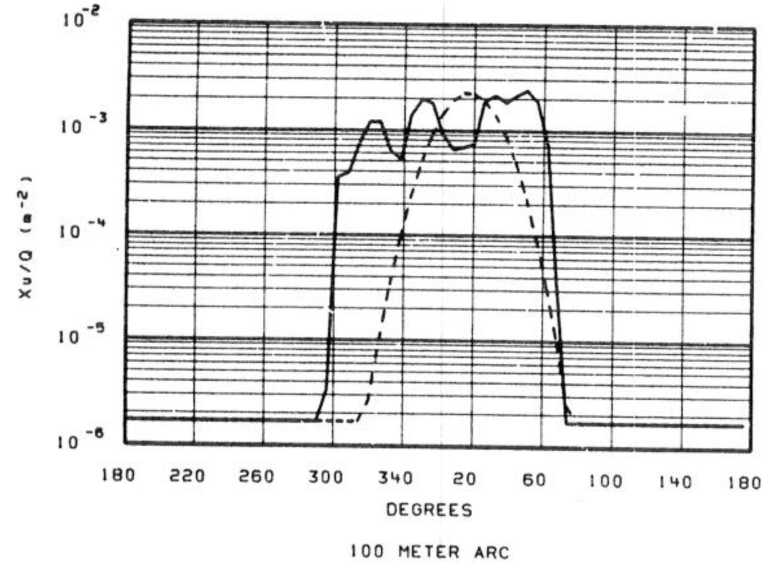
——— Measured

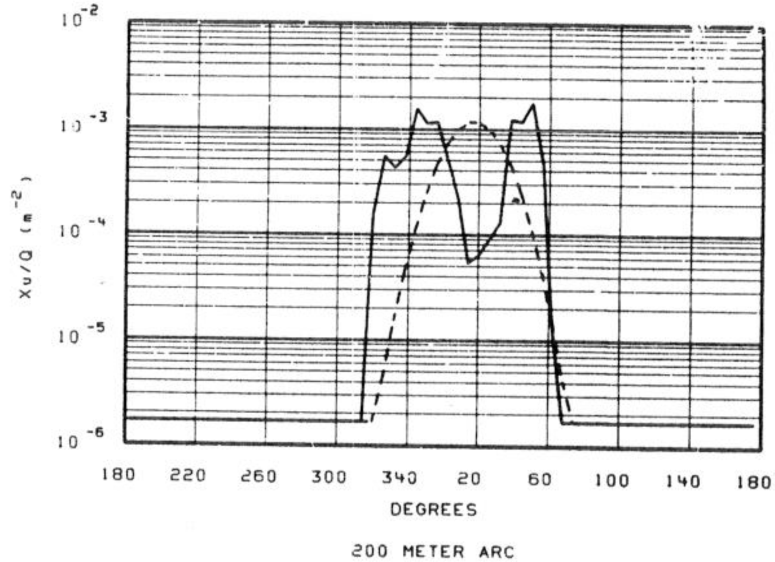
- - - - - - - Calculated



400 METER ARC

FIG. 47





TEST 10 STANDARD (INEL)

04:58 - 05:47 4/17/74

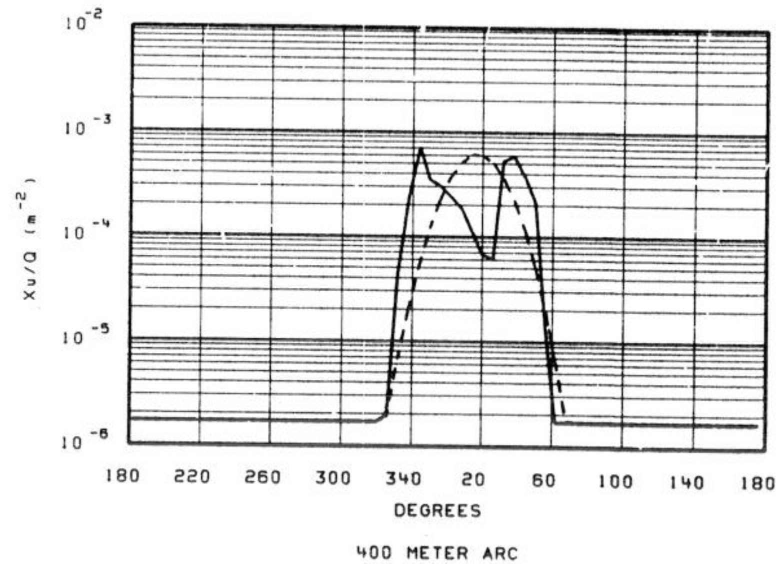
u = 1.7 m/sec

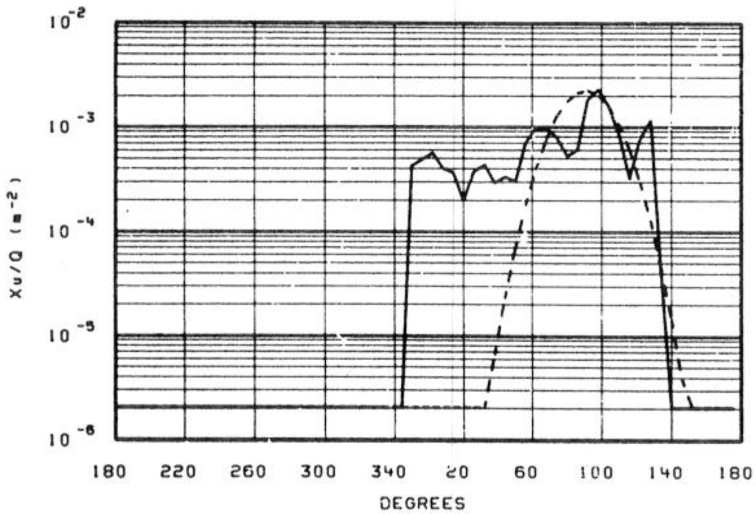
Q = 0.032 gm/sec

———— Measured

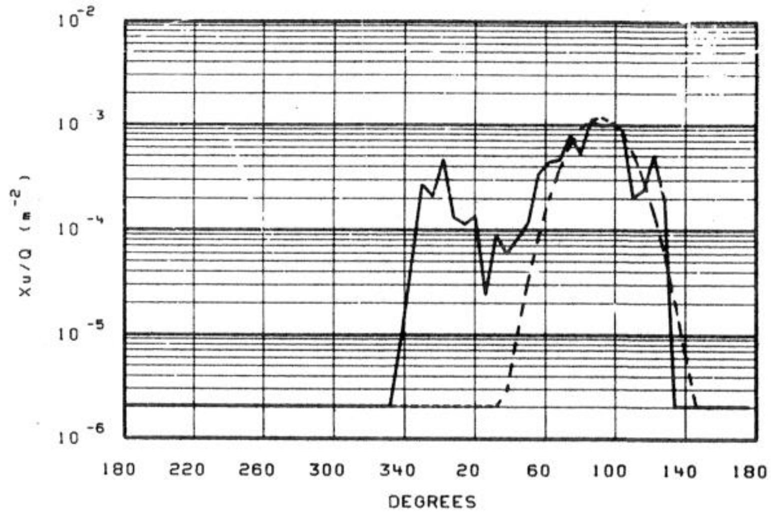
- - - - - - - - Calculated

FIG. 48





100 METER ARC



200 METER ARC

TEST 11 STANDARD (INEL)

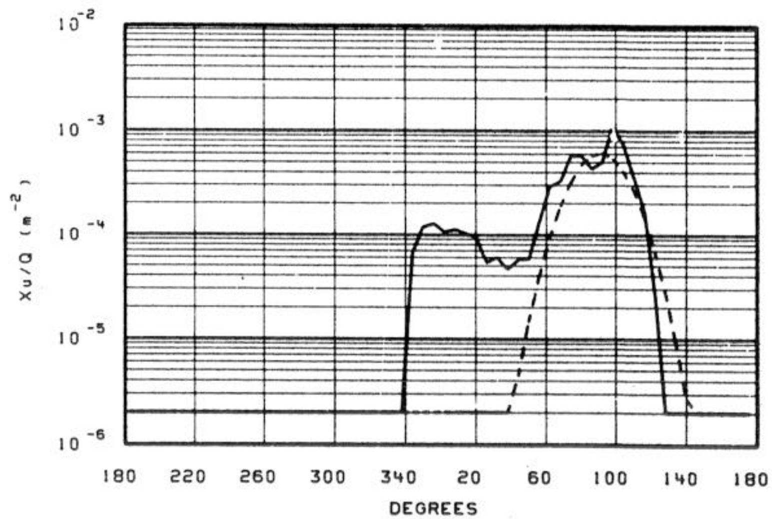
01:46 - 02:46 4/30/74

u = 1.9 m/sec

Q = 0.031 gm/sec

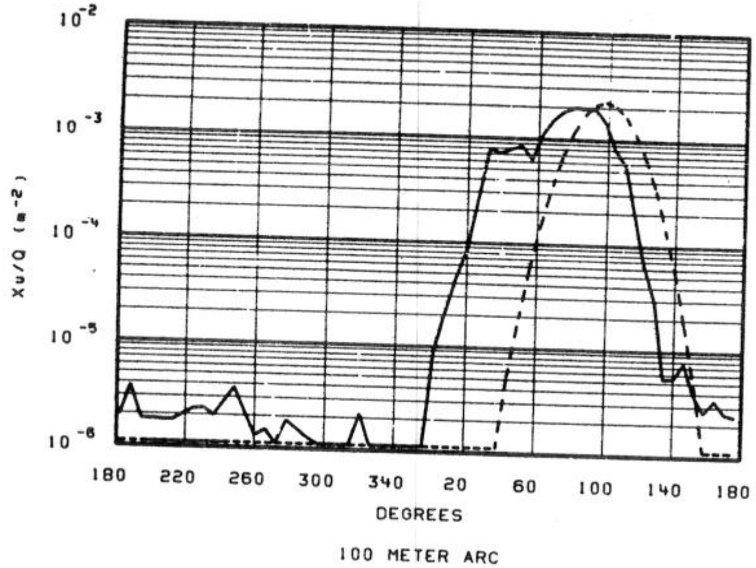
——— Measured

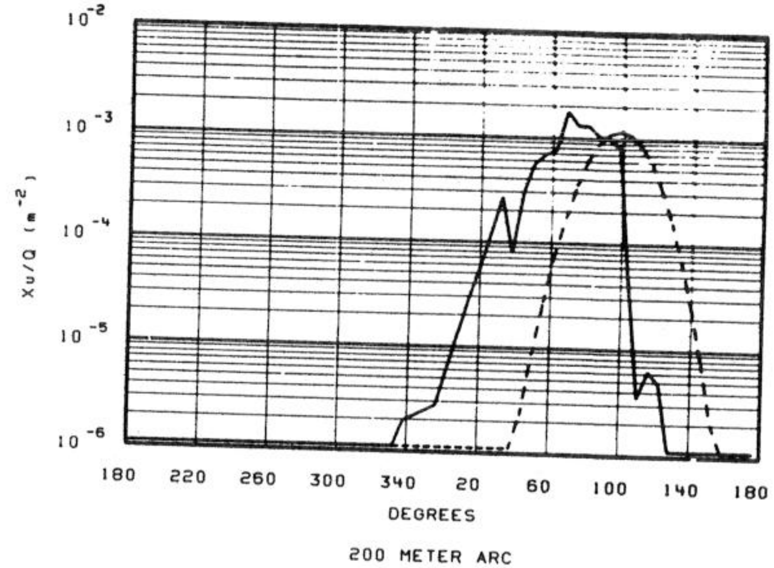
- - - - - - - - Calculated



400 METER ARC

FIG. 49





TEST 12 STANDARD (INEL)

04:11 - 05:11 4/30/74

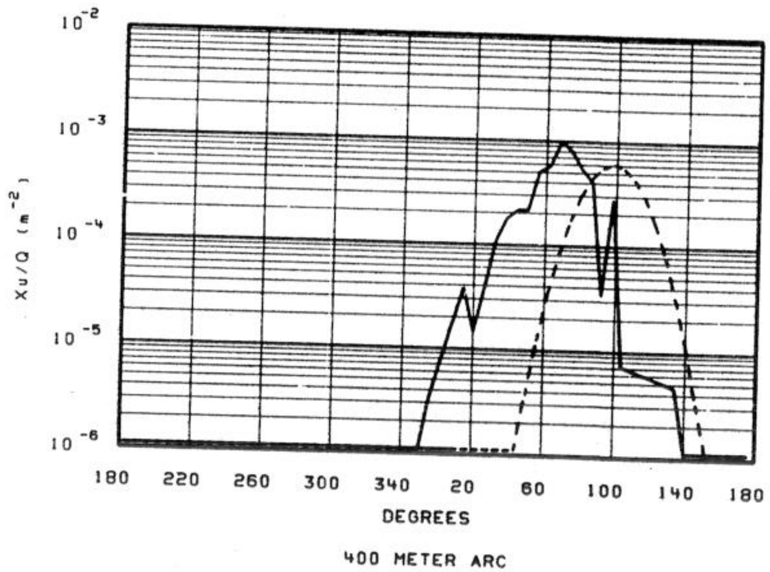
u = 1.1 m/sec

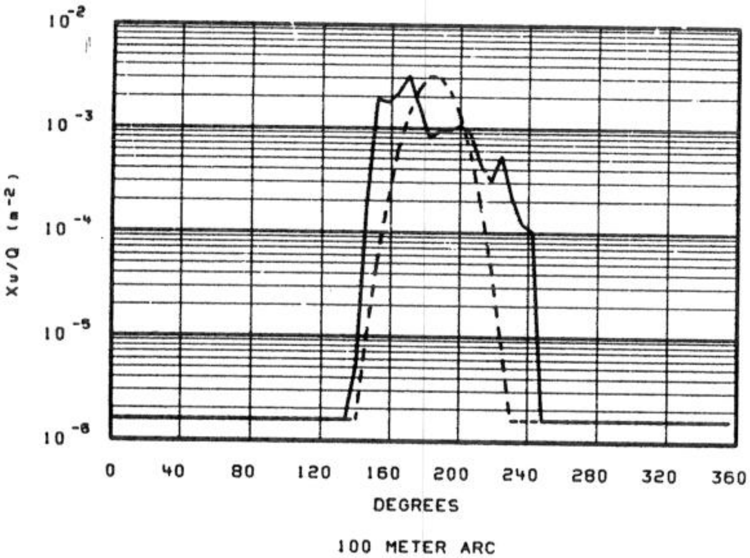
Q = 0.032 gm/sec

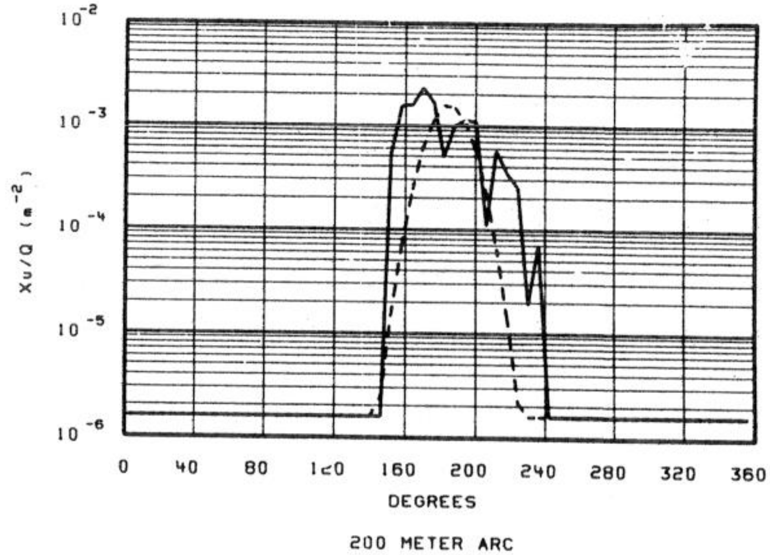
——— Measured

- - - - - - - - Calculated

FIG. 50







TEST 13 STANDARD (INEL)

04:22 - 05:22 5/3/74

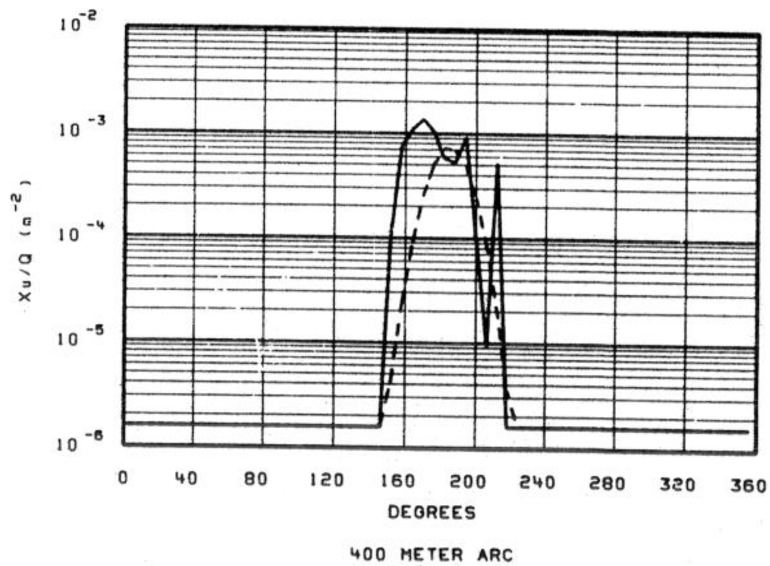
u = 1.6 m/sec

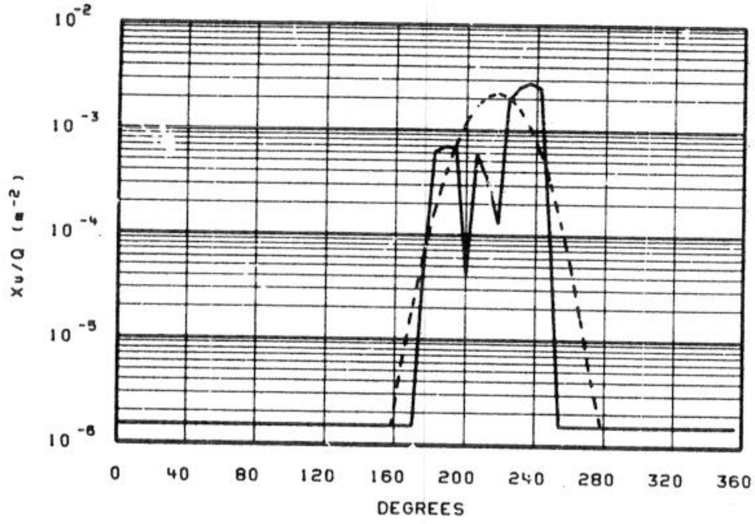
Q = 0.033 gm/sec

——————— Measured

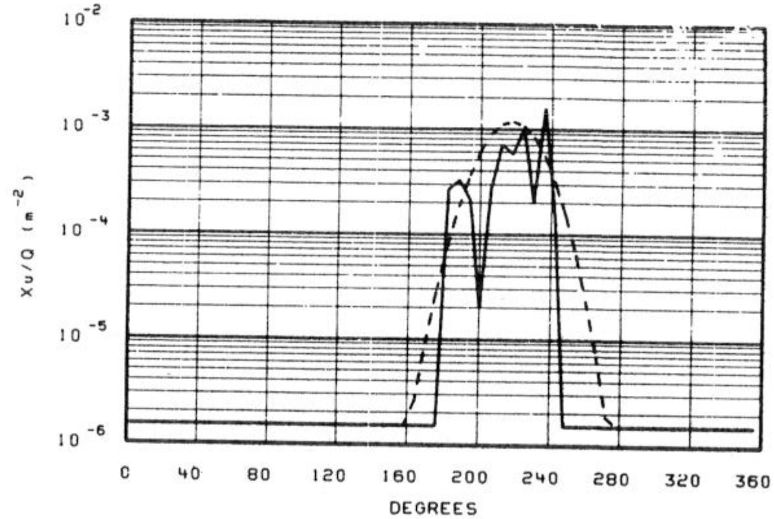
- - - - - - - - Calculated

FIG. 51





100 METER ARC



200 METER ARC

TEST 14 STANDARD (INEL)

03:45 - 04:45 5/22/74

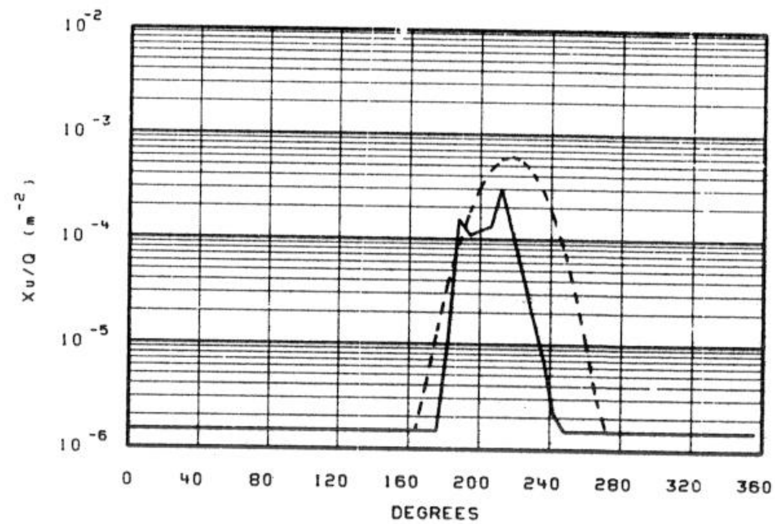
$u = 1.5$ m/sec

$Q = 0.032$ gm/sec

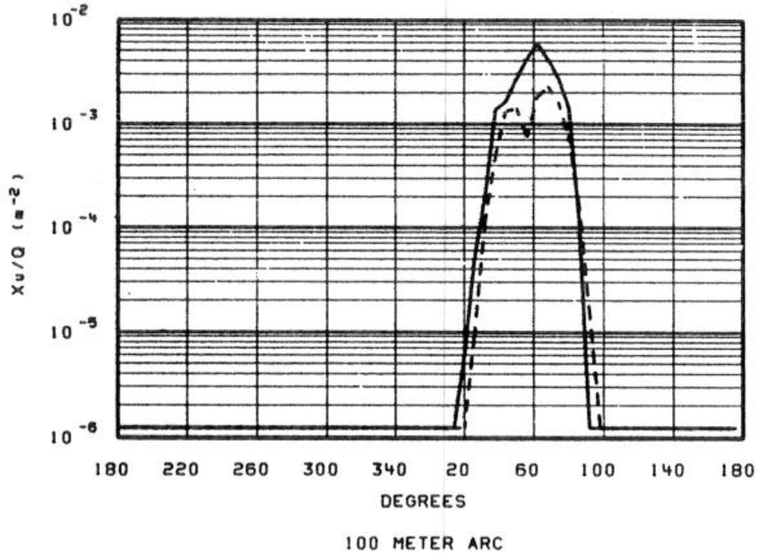
——— Measured

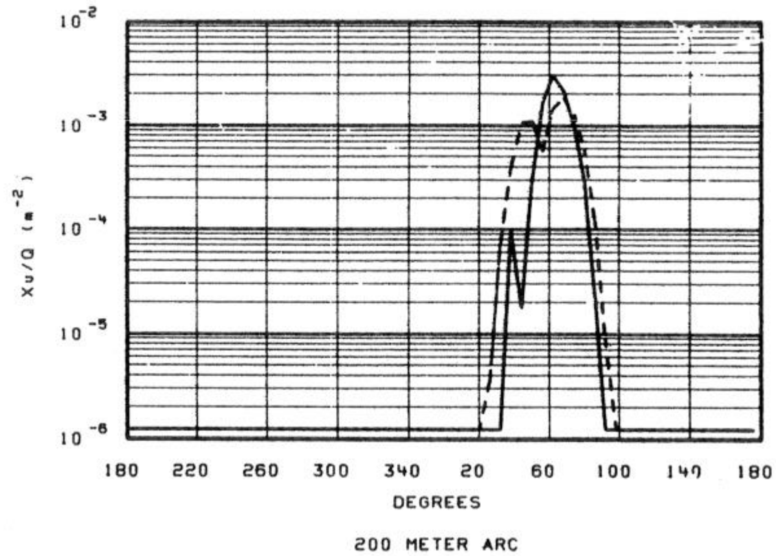
- - - - - - - Calculated

FIG. 52



400 METER ARC





TEST 4 SEGMENTED PLUME

06:42 - 07:42 2/7/74

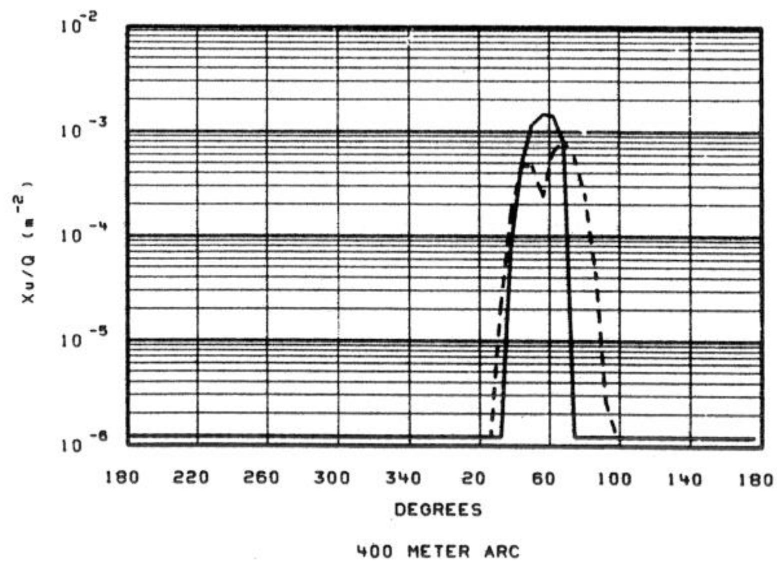
u = 1.2 m/sec

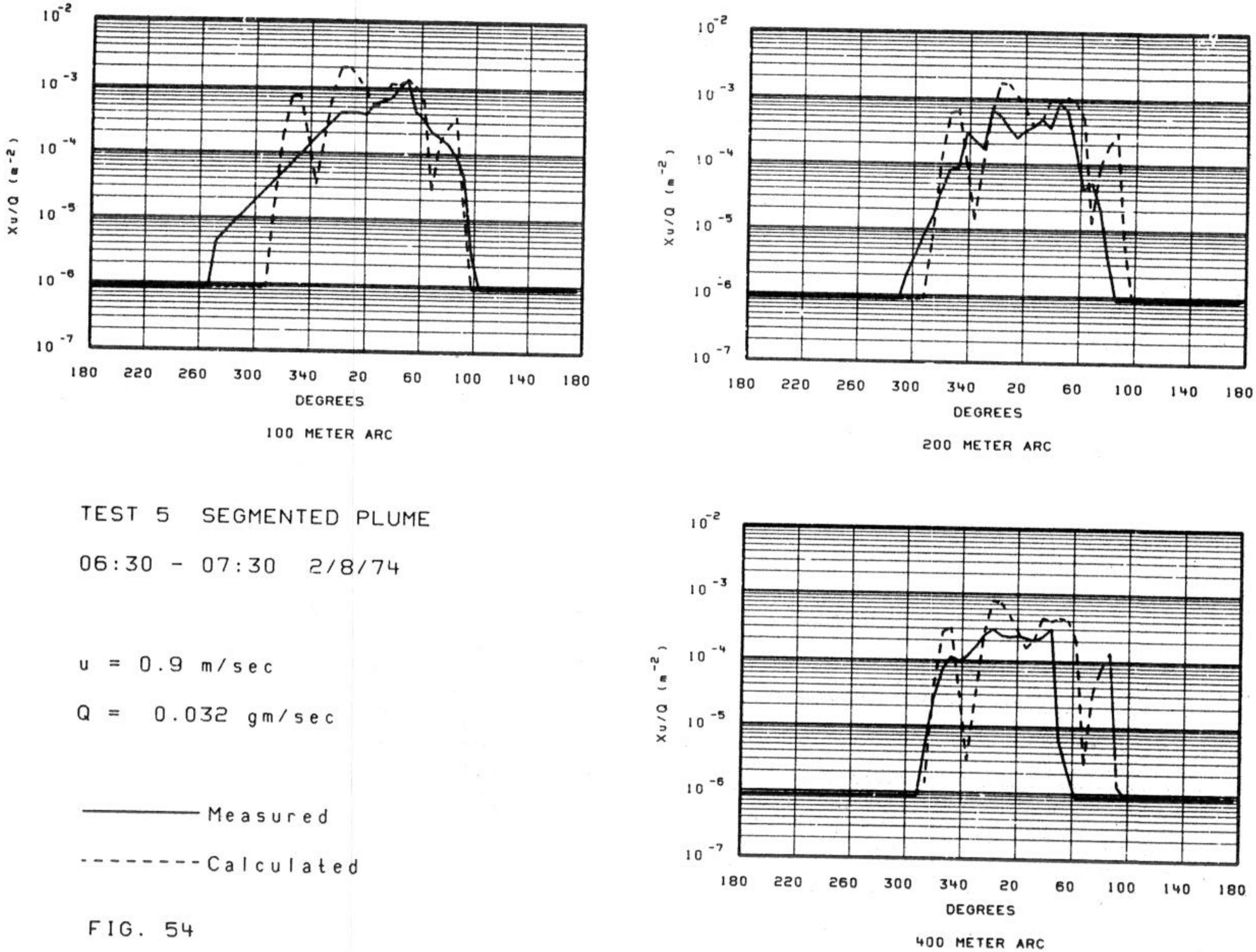
Q = 0.032 gm/sec

——————— Measured

- - - - - - - - Calculated

FIG. 53





TEST 5 SEGMENTED PLUME

06:30 - 07:30 2/8/74

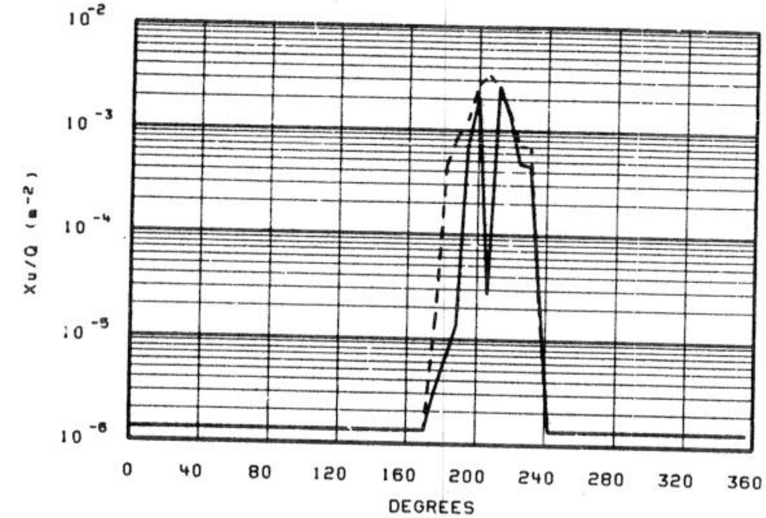
u = 0.9 m/sec

Q = 0.032 gm/sec

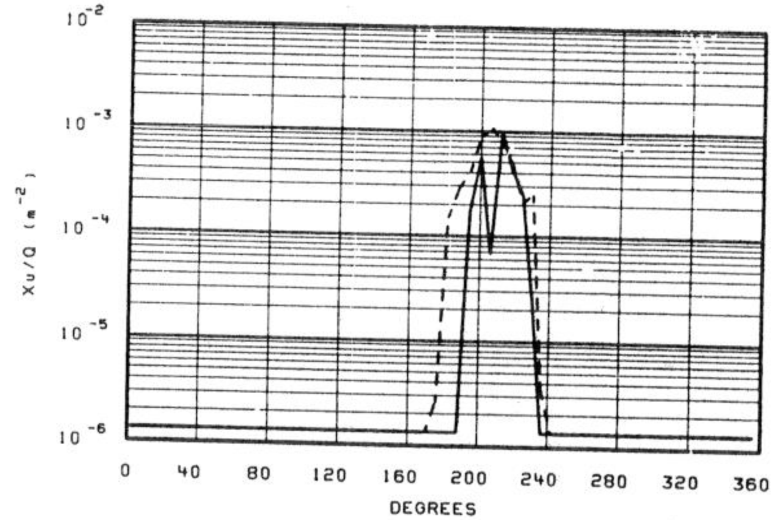
——— Measured

- - - - - - - - Calculated

FIG. 54



100 METER ARC



200 METER ARC

TEST 6 SEGMENTED PLUME

06:46 - 07:46 2/9/74

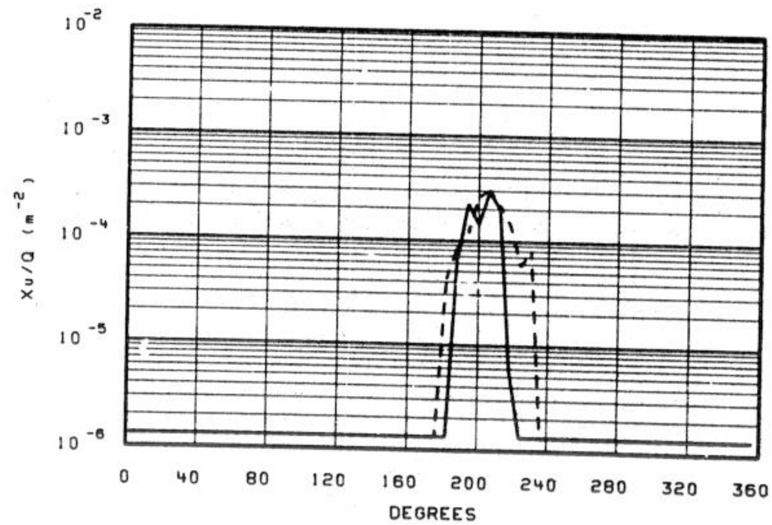
u = 1.3 m/sec

Q = 0.031 gm/sec

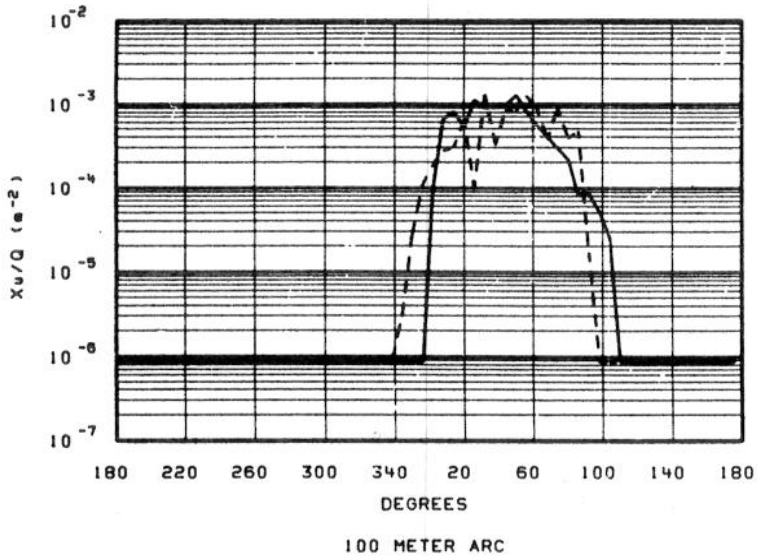
——————— Measured

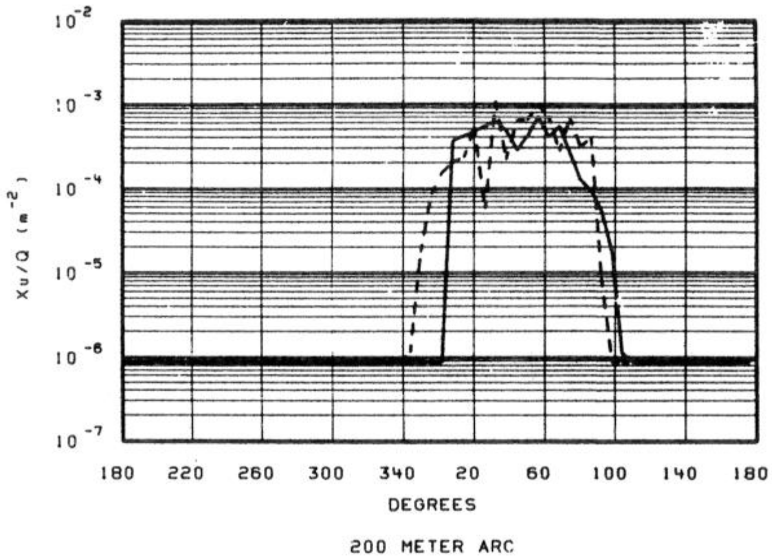
- - - - - - - - Calculated

FIG. 55



400 METER ARC





TEST 7 SEGMENTED PLUME

06:30 - 07:30 2/12/74

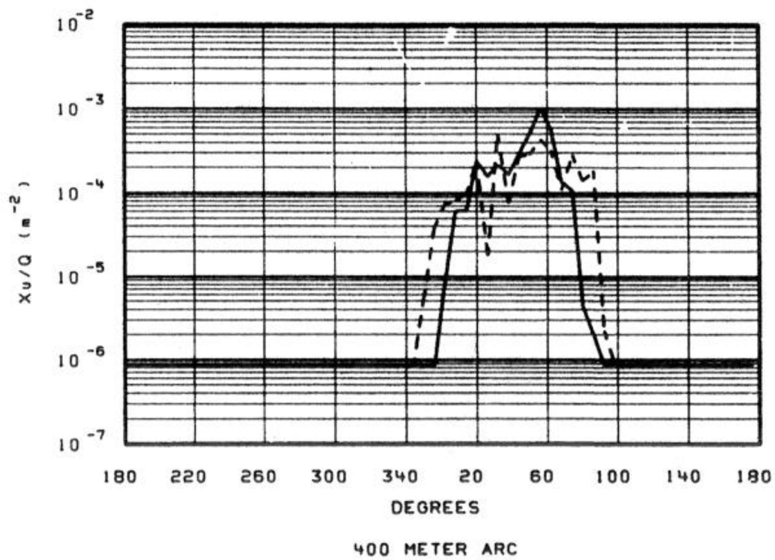
u = 0.9 m/sec

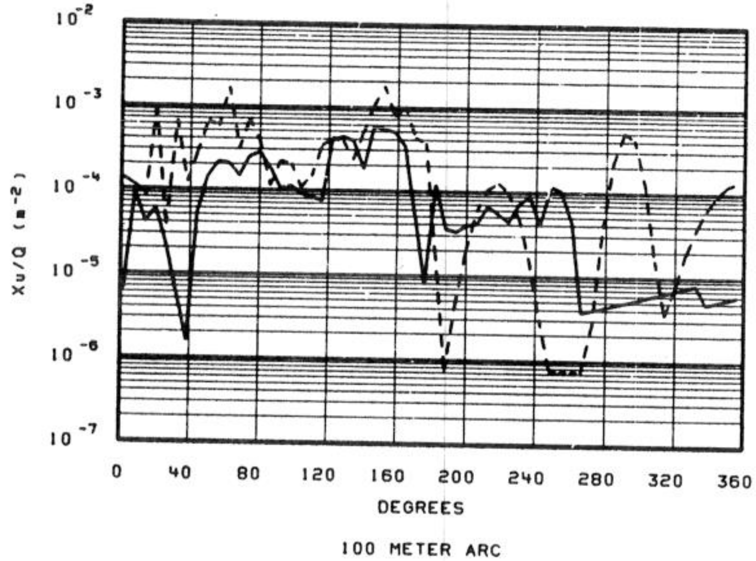
Q = 0.033 gm/sec

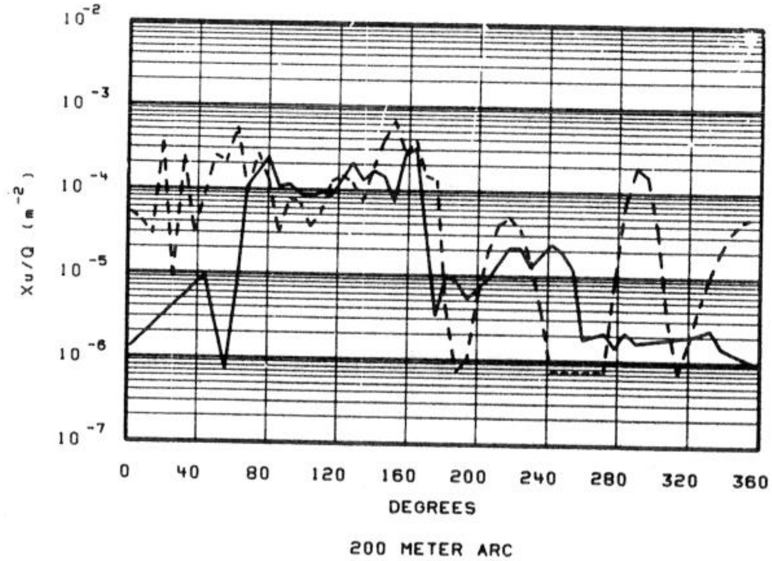
———— Measured

-------- Calculated

FIG. 56







TEST 8 SEGMENTED PLUME

06:30 - 07:30 2/21/74

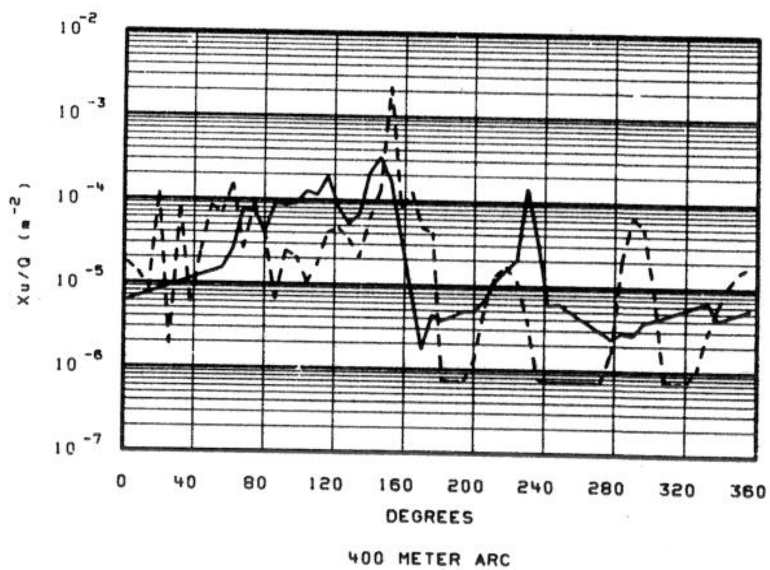
u = 0.8 m/sec

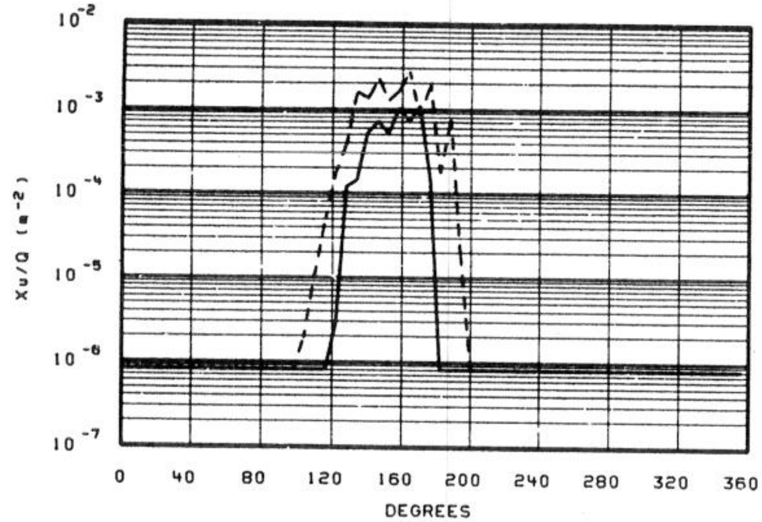
Q = 0.033 gm/sec

———— Measured

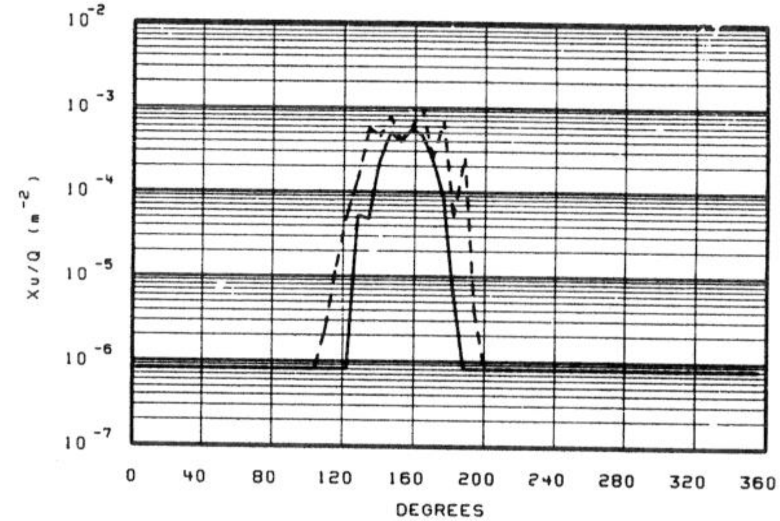
- - - - - - - Calculated

FIG. 57





100 METER ARC



200 METER ARC

TEST 9 SEGMENTED PLUME

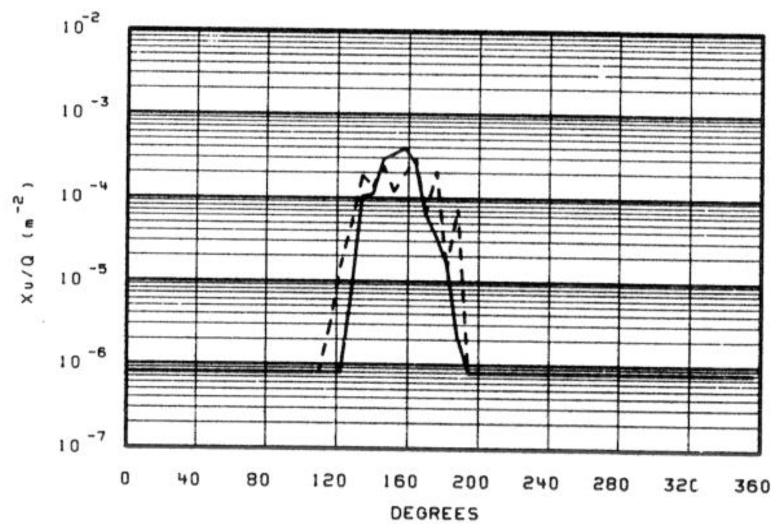
05:30 - 06:30 3/21/74

$u = 0.8$ m/sec

$Q = 0.032$ gm/sec

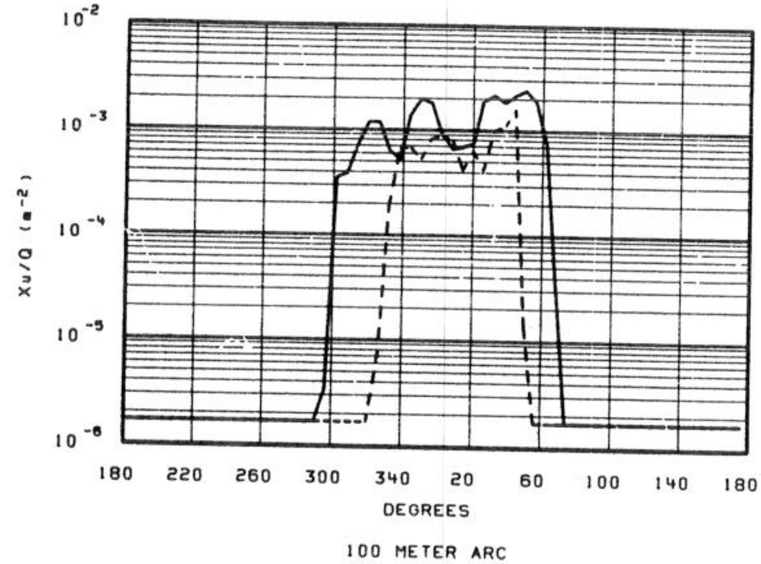
——————— Measured

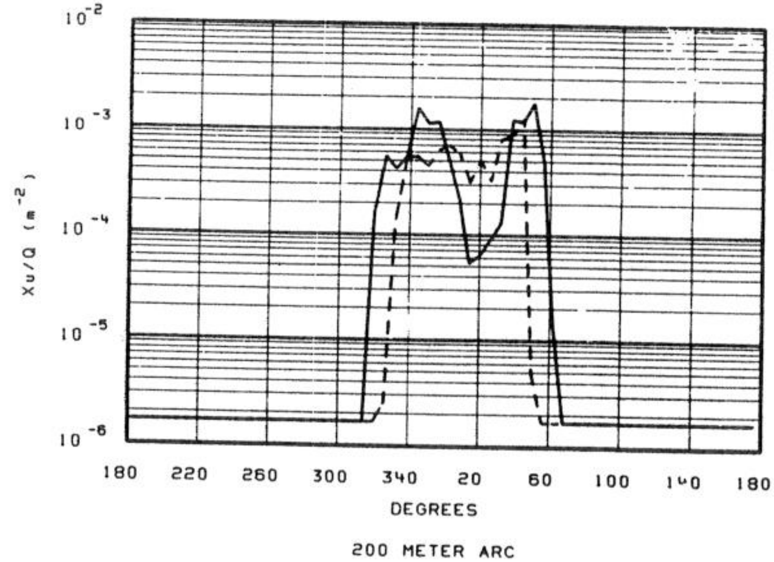
- - - - - - - - Calculated



400 METER ARC

FIG. 58





TEST 10 SEGMENTED PLUME

04:58 - 05:47 4/17/74

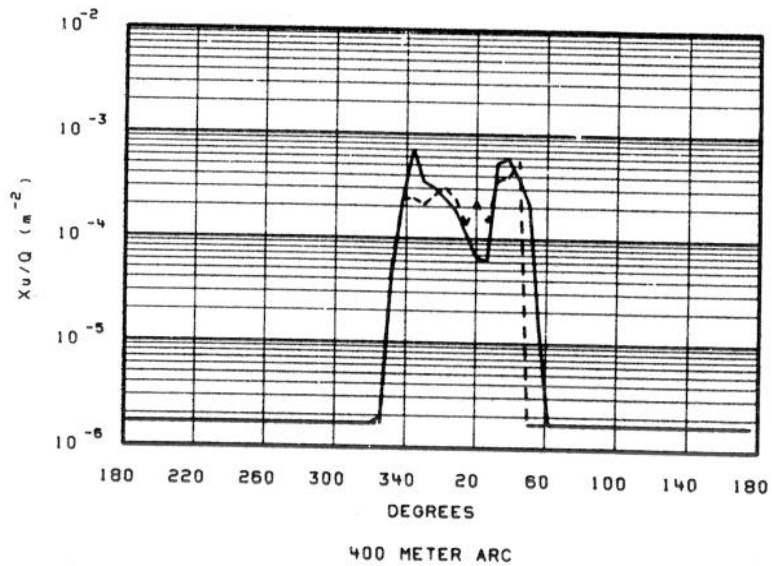
u = 1.7 m/sec

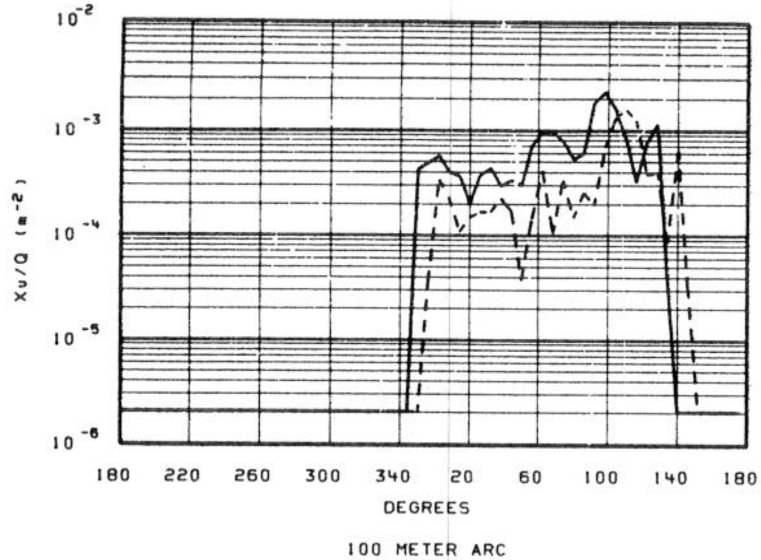
Q = 0.032 gm/sec

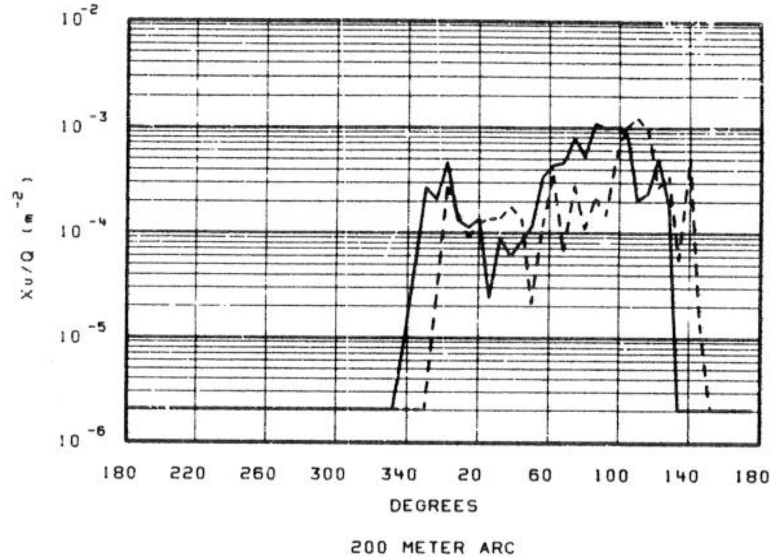
——— Measured

- - - - - - - - Calculated

FIG. 59







TEST 11 SEGMENTED PLUME

01:46 - 02:46 4/30/74

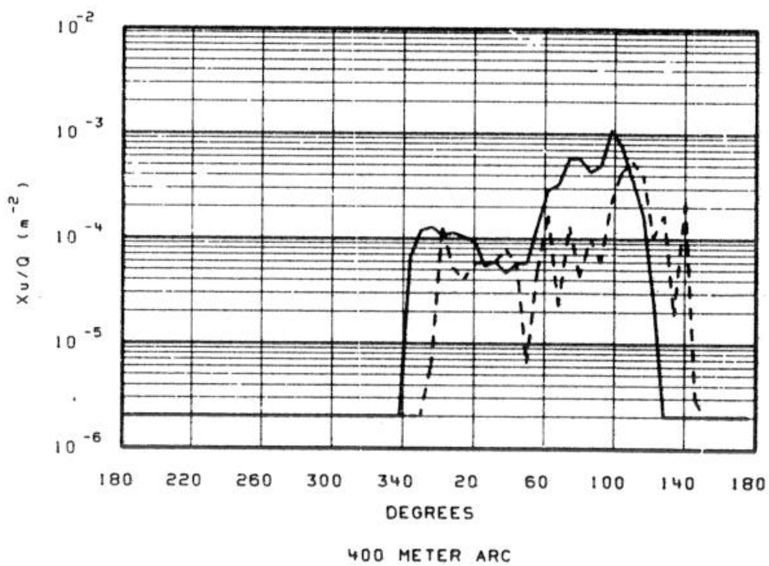
u = 1.9 m/sec

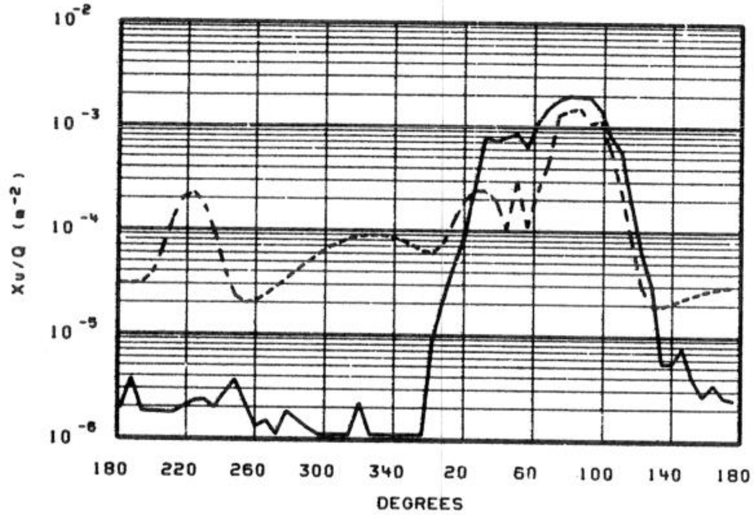
Q = 0.031 gm/sec

——— Measured

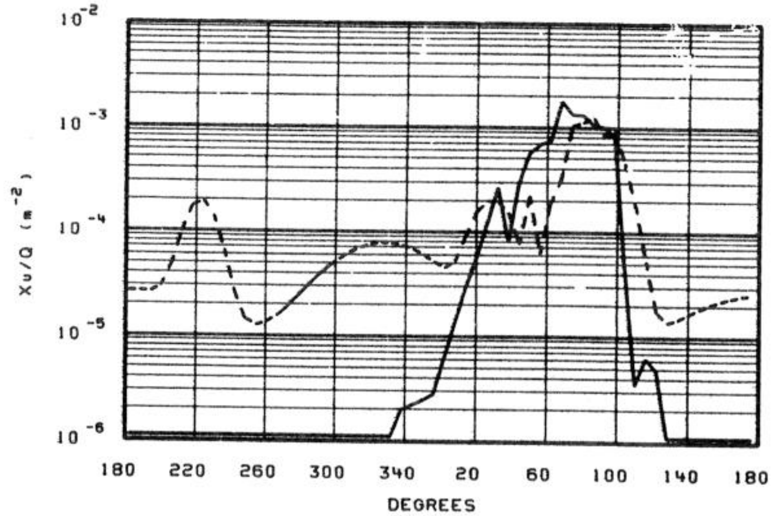
- - - - Calculated

FIG. 60





100 METER ARC



200 METER ARC

TEST 12 SEGMENTED PLUME

04:11 - 05:11 4/30/74

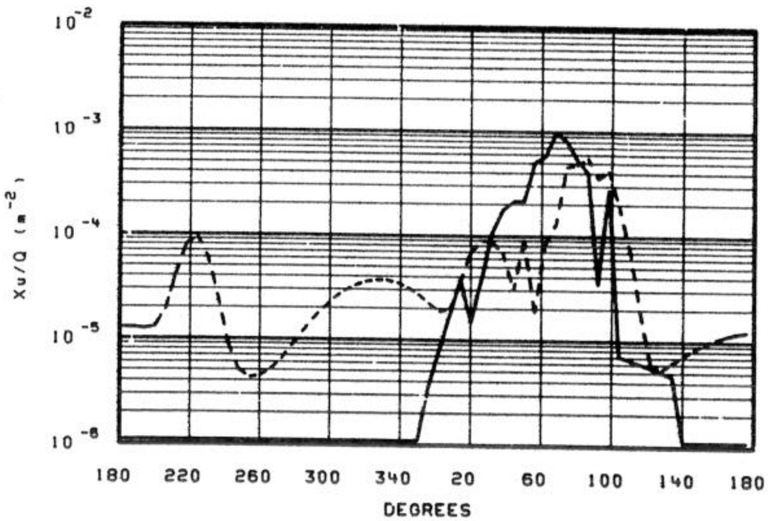
u = 1.1 m/sec

Q = 0.032 gm/sec

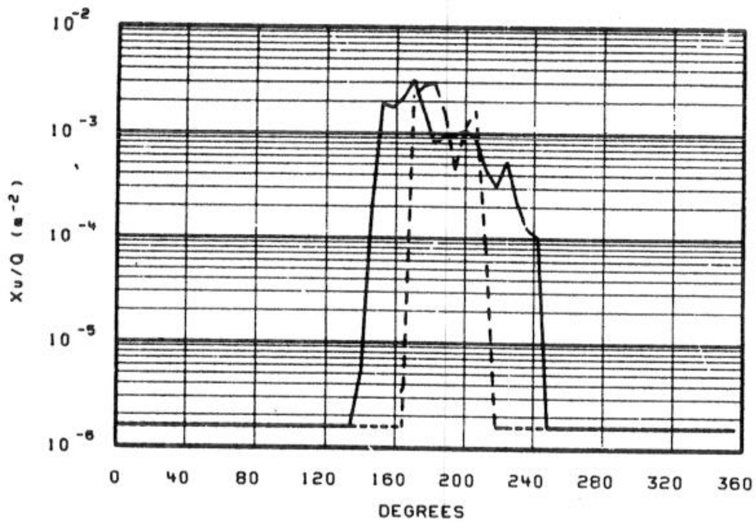
——— Measured

- - - - - - - Calculated

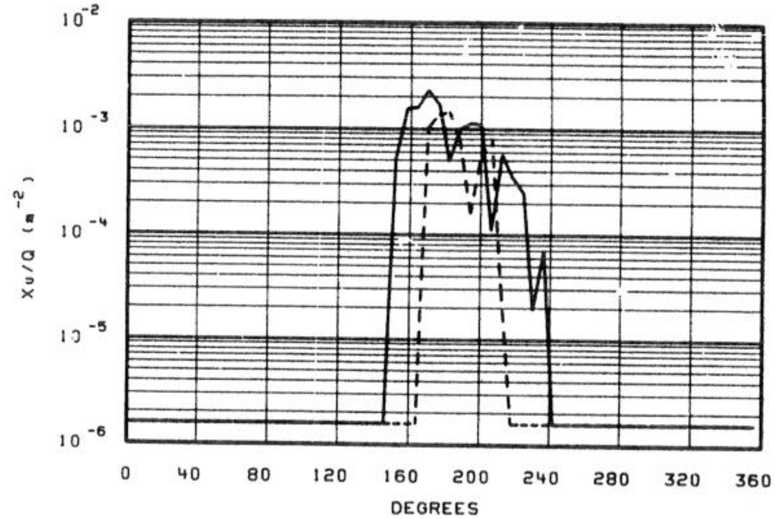
FIG. 61



400 METER ARC



100 METER ARC



200 METER ARC

TEST 13 SEGMENTED PLUME

04:22 - 05:22 5/3/74

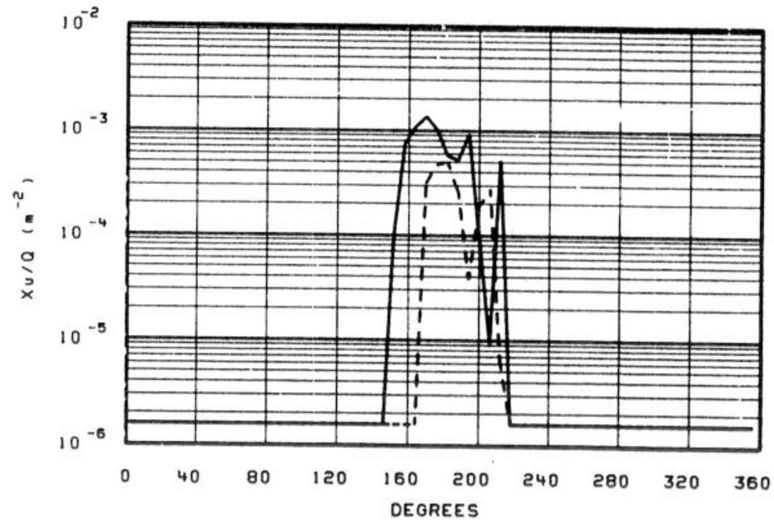
u = 1.6 m/sec

Q = 0.033 gm/sec

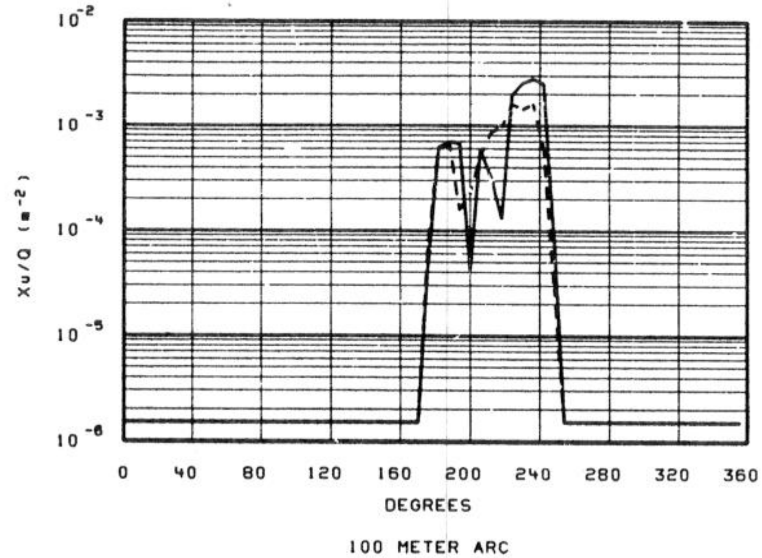
——— Measured

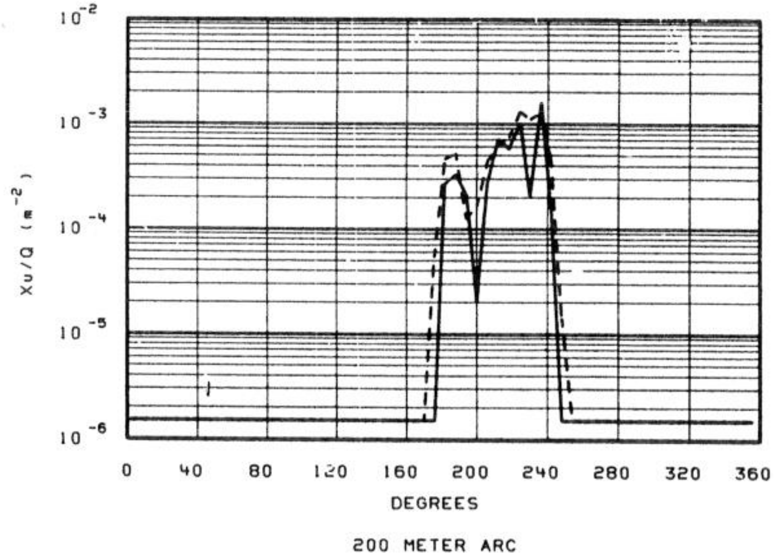
- - - - - - - - Calculated

FIG. 62



400 METER ARC





TEST 14 SEGMENTED PLUME

03:45 - 04:45 5/22/74

u = 1.5 m/sec

Q = 0.032 gm/sec

——— Measured

- - - - - - - - Calculated

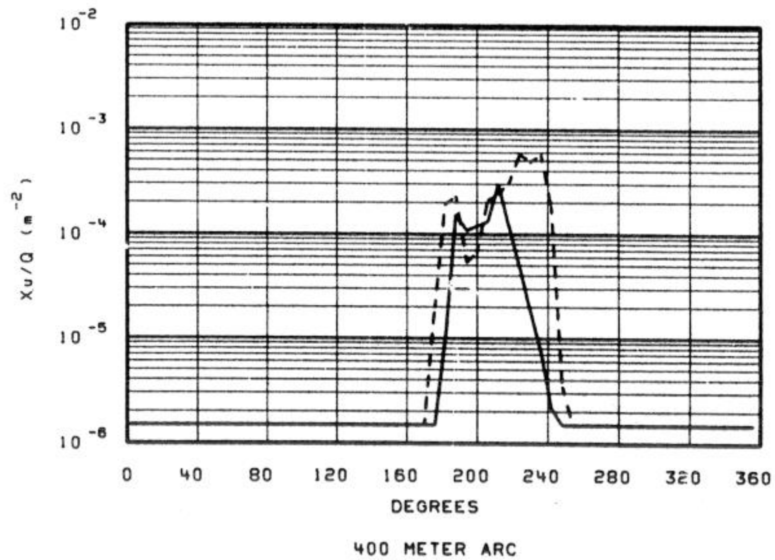


FIG. 63

6. SUMMARY AND CONCLUSIONS

This test series was designed to examine diffusion under inversion conditions with light winds. It has long been recognized that vertical diffusion is suppressed by a stable atmosphere. The light winds that often accompany temperature inversions are also generally assumed to restrict diffusion. Wind direction under light winds, however, is very often unsteady. The variability of wind direction, which has been referred to as meander, enhances horizontal diffusion. In this test series the restricted vertical diffusion resulted in the enhanced horizontal diffusion with the result that the standard method of calculating ground-level concentrations resulted in overpredicting the measured concentrations by an average factor of about 8.

The oil fog plumes in these tests were observed to tilt in the manner of an Ekman spiral so that the lifted side was elevated about 5 or 6 m above the surface. Since the plumes were partially elevated, this tilt effect also resulted in reduced ground level concentrations. An attempt to account for the plume tilt was made by assuming an average effective plume height of 3 m for all calculations.

On some occasions, in these near-calm conditions, plume segments became stationary puddles lying in some areas of the grid. Prolonged episodes of "puddling" could result in localized areas of higher concentrations. There were some tests where higher peak concentrations were measured at 400 m than at 200 m and this might be due to puddling.

These studies took place in a rather flat plain with semidesert characteristics. The results may therefore not be applicable to other areas with differing types of terrain and climate. A similar test series has been conducted in a wooded, hilly area in eastern Tennessee and these results will soon be available for further comparisons.

7. REFERENCES

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DATA APPENDIX

Tower Samples $x\bar{U}/Q \times 10^{-5}$ (m^{-2})

	Tower	.76-m*	2-m	4.5-m	6-m	9-m
Test #10	1	119.6	188.5	-	-	3.6
	2	0.0	0.5	1.6	0.5	-
Test #11	1	8.4	12.5	12.0	22.5	9.9
	2	46.5	96.5	-	14.4	4.0
	3	109.0	123.1	200.4	0.7	1.4
	4	88.8	-	190.0	168.8	-
	5	19.1	85.8	80.6	32.7	8.1
Test #12	1	30.9	47.4	65.1	126.2	11.5
	2	177.4	113.6	119.1	-	11.5
	3	105.4	126.0	67.6	-	15.6
	4	4.7	-	57.7	52.3	-
	5	0.0	9.0	23.8	16.4	6.1
	6	0.0	9.2	-	5.7	6.0
	7	0.0	-	16.0	-	8.2
	8	0.0	-	-	25.8	6.7
Test #13	7	159.9	-	181.9	-	0.7
	8	100.5	162.3	131.2	66.1	0.9
Test #14	8	33.4	49.2	30.6	61.6	45.1

* The .76-m value is obtained from the nearest ground sampler

- Indicates a missing value

LOW WIND SPEED TEST # 4 2/7/74 07:42 - 08:42 MDT

NORMALIZED CONCENTRATIONS (CHI*U/Q)

U = 1.212 M/SEC Q = 0.032 GRAMS/SEC

DEGREES	100 METERS	200 METERS	400 METERS
2	-	-	-
8	-	-	-
14	-	-	-
20	5.931E-06	-	-
26	4.958E-05	-	-
32	1.991E-04	-	-
38	1.391E-03	9.481E-05	8.539E-05
44	1.671E-03	1.770E-05	5.015E-04
50	2.678E-03	2.818E-04	1.174E-03
56	4.221E-03	1.669E-03	1.468E-03
62	5.809E-03	2.993E-03	1.422E-03
68	4.150E-03	2.152E-03	8.094E-04
74	2.788E-03	~~9.900E-04~~	-
80	1.442E-03	3.078E-04	-
86	1.273E-04	2.310E-05	-
92	-	-	-
98	-	-	-
104	-	-	-
110	-	-	-
116	-	-	-
122	-	-	-
128	-	-	-
134	-	-	-
140	-	-	-
146	-	-	-
152	-	-	-
158	-	-	-
164	-	-	-
170	-	-	-
176	-	-	-
182	-	-	-
188	-	-	-
194	-	-	-
200	-	-	-
206	-	-	-
212	-	-	-
218	-	-	-
224	-	-	-
230	-	-	-
236	-	-	-
242	-	-	-
248	-	-	-
254	-	-	-
260	-	-	-
266	-	-	-
272	-	-	-
278	-	-	-
284	-	-	-
290	-	-	-
296	-	-	-
302	-	-	-
308	-	-	-
314	-	-	-
320	-	-	-
326	-	-	-
332	-	-	-
338	-	-	-
344	-	-	-
350	-	-	-
356	-	-	-
PEAK VALUES	5.809E-03	2.993E-03	1.468E-03

LOW WIND SPEED TEST # 5 2/8/74 07:30 - 08:30 MDT

NORMALIZED CONCENTRATIONS (CHI*U/Q)

U = 0.875 M/SEC Q = 0.032 GRAMS/SEC

DEGREES	100 METERS	200 METERS	400 METERS
2	4.264E-04	5.364E-04	3.002E-04
8	4.261E-04	3.576E-04	2.409E-04
14	4.173E-04	2.461E-04	2.302E-04
20	3.912E-04	3.222E-04	2.386E-04
26	5.730E-04	3.799E-04	2.215E-04
32	6.346E-04	4.831E-04	2.028E-04
38	7.027E-04	3.597E-04	2.356E-04
44	9.765E-04	8.670E-04	3.035E-04
50	1.357E-03	6.575E-04	6.103E-06
56	4.424E-04	1.765E-04	2.169E-06
62	3.338E-04	4.163E-05	-
68	2.107E-04	5.317E-05	-
74	1.750E-04	2.073E-05	-
80	1.400E-04	3.667E-06	-
86	9.355E-05	-	-
92	4.405E-05	-	-
98	2.703E-06	-	-
104	-	-	-
110	-	-	-
116	-	-	-
122	-	-	-
128	-	-	-
134	-	-	-
140	-	-	-
146	-	-	-
152	-	-	-
158	-	-	-
164	-	-	-
170	-	-	-
176	-	-	-
182	-	-	-
188	-	-	-
194	-	-	-
200	-	-	-
206	-	-	-
212	-	-	-
218	-	-	-
224	-	-	-
230	-	-	-
236	-	-	-
242	-	-	-
248	-	-	-
254	-	-	-
260	-	-	-
266	-	-	-
272	4.562E-06	-	-
278	6.173E-06	-	-
284	8.354E-06	-	-
290	1.131E-05	-	-
296	1.530E-05	2.197E-06	-
302	2.070E-05	4.265E-06	-
308	2.802E-05	8.425E-06	-
314	3.792E-05	1.552E-05	5.397E-06
320	5.131E-05	3.821E-05	2.780E-05
326	6.943E-05	8.234E-05	7.465E-05
332	9.396E-05	8.457E-05	1.144E-04
338	1.272E-04	2.936E-04	9.958E-05
344	1.721E-04	2.219E-04	1.196E-04
350	2.329E-04	1.692E-04	1.653E-04
356	3.151E-04	6.608E-04	2.426E-04
PEAK VALUES	1.357E-03	8.670E-04	3.035E-04

LOW WIND SPEED TEST # 6 2/9/74 07:46 - 08:46 MDT

NORMALIZED CONCENTRATIONS (CHI*U/Q)

U = 1.294 M/SEC Q = 0.031 GRAMS/SEC

DEGREES	100 METERS	200 METERS	400 METERS
2	-	-	-
8	-	-	-
14	-	-	-
20	-	-	-
26	-	-	-
32	-	-	-
38	-	-	-
44	-	-	-
50	-	-	-
56	-	-	-
62	-	-	-
68	-	-	-
74	-	-	-
80	-	-	-
86	-	-	-
92	-	-	-
98	-	-	-
104	-	-	-
110	-	-	-
116	-	-	-
122	-	-	-
128	-	-	-
134	-	-	-
140	-	-	-
146	-	-	-
152	-	-	-
158	-	-	-
164	-	-	-
170	-	-	-
176	3.261E-06	-	-
182	6.594E-06	-	-
188	1.333E-05	-	6.789E-05
194	7.221E-04	1.786E-04	2.255E-04
200	2.061E-03	5.570E-04	1.438E-04
206	2.793E-05	6.884E-05	2.934E-04
212	2.612E-03	9.722E-04	2.060E-04
218	1.350E-03	4.290E-04	5.636E-06
224	4.752E-04	2.513E-04	-
230	4.531E-04	2.763E-05	-
236	2.703E-05	-	-
242	-	-	-
248	-	-	-
254	-	-	-
260	-	-	-
266	-	-	-
272	-	-	-
278	-	-	-
284	-	-	-
290	-	-	-
296	-	-	-
302	-	-	-
308	-	-	-
314	-	-	-
320	-	-	-
326	-	-	-
332	-	-	-
338	-	-	-
344	-	-	-
350	-	-	-
356	-	-	-
PEAK VALUES	2.612E-03	9.722E-04	2.934E-04

LOW WIND SPEED TEST # 7 2/12/74 07:30 - 08:30 MDT

NORMALIZED CONCENTRATIONS (CHI*U/Q)

U = 0.897 M/SEC Q = 0.033 GRAMS/SEC

DEGREES	100 METERS	200 METERS	400 METERS
2	9.875E-05	-	8.645E-06
8	6.671E-04	3.680E-04	6.168E-05
14	8.147E-04	4.213E-04	6.231E-05
20	5.357E-04	4.822E-04	2.425E-04
26	1.099E-03	5.520E-04	1.577E-04
32	9.071E-04	6.318E-04	2.166E-04
38	9.362E-04	4.776E-04	1.673E-04
44	9.756E-04	2.874E-04	3.025E-04
50	1.263E-03	4.152E-04	5.030E-04
56	8.313E-04	7.090E-04	1.009E-03
62	5.470E-04	4.118E-04	5.920E-04
68	4.015E-04	5.440E-04	1.364E-04
74	2.947E-04	2.620E-04	1.071E-04
80	2.164E-04	1.261E-04	4.307E-06
86	8.276E-05	9.424E-05	1.978E-06
92	8.574E-05	5.559E-05	-
98	5.247E-05	1.742E-05	-
104	2.593E-05	1.113E-06	-
110	-	-	-
116	-	-	-
122	-	-	-
128	-	-	-
134	-	-	-
140	-	-	-
146	-	-	-
152	-	-	-
158	-	-	-
164	-	-	-
170	-	-	-
176	-	-	-
182	-	-	-
188	-	-	-
194	-	-	-
200	-	-	-
206	-	-	-
212	-	-	-
218	-	-	-
224	-	-	-
230	-	-	-
236	-	-	-
242	-	-	-
248	-	-	-
254	-	-	-
260	-	-	-
266	-	-	-
272	-	-	-
278	-	-	-
284	-	-	-
290	-	-	-
296	-	-	-
302	-	-	-
308	-	-	-
314	-	-	-
320	-	-	-
326	-	-	-
332	-	-	-
338	-	-	-
344	-	-	-
350	-	-	-
356	-	-	-
PEAK VALUES	1.263E-03	7.090E-04	1.009E-03

LOW WIND SPEED TEST # 8 2/21/74 07:30 - 08:30 MDT

NORMALIZED CONCENTRATIONS (CHI*U/Q)

U = 0.753 M/SEC Q = 0.033 GRAMS/SEC

DEGREES	100 METERS	200 METERS	400 METERS
2	6.504E-06	1.319E-06	6.265E-06
8	9.099E-05	1.749E-06	6.919E-06
14	4.058E-05	2.319E-06	7.642E-06
20	5.892E-05	3.076E-06	8.440E-06
26	2.124E-05	4.079E-06	9.321E-06
32	5.836E-06	5.410E-06	1.029E-05
38	1.604E-06	7.175E-06	1.137E-05
44	5.425E-05	9.516E-06	1.256E-05
50	1.467E-04	2.566E-06	1.387E-05
56	2.156E-04	-	1.532E-05
62	2.063E-04	6.458E-06	2.555E-05
68	1.475E-04	1.085E-04	7.892E-05
74	2.489E-04	1.614E-04	7.306E-05
80	2.810E-04	2.400E-04	4.116E-05
86	1.831E-04	1.098E-04	9.181E-05
92	1.066E-04	1.161E-04	8.803E-05
98	1.141E-04	9.030E-05	9.267E-05
104	9.190E-05	8.203E-05	1.280E-04
110	8.408E-05	9.376E-05	1.163E-04
116	7.694E-05	8.666E-05	1.916E-04
122	3.945E-04	1.345E-04	8.201E-05
128	4.326E-04	2.087E-04	5.314E-05
134	3.878E-04	1.322E-04	6.875E-05
140	1.847E-04	1.710E-04	2.178E-04
146	5.855E-04	1.476E-04	3.283E-04
152	5.396E-04	7.709E-05	1.753E-04
158	4.974E-04	2.643E-04	3.623E-05
164	3.422E-04	3.154E-04	7.710E-06
170	5.287E-05	3.253E-05	1.753E-06
176	8.171E-06	3.360E-06	4.450E-06
182	1.190E-04	1.030E-05	3.815E-06
188	3.592E-05	8.409E-06	4.368E-06
194	3.323E-05	5.408E-06	5.001E-06
200	3.974E-05	7.118E-06	4.967E-06
206	4.148E-05	9.410E-06	6.908E-06
212	6.803E-05	1.421E-05	1.160E-05
218	5.459E-05	2.146E-05	1.538E-05
224	4.381E-05	2.152E-05	2.038E-05
230	7.357E-05	1.298E-05	1.468E-04
236	9.070E-05	1.770E-05	3.328E-05
242	4.059E-05	2.412E-05	5.976E-06
248	1.176E-04	1.912E-05	6.239E-06
254	1.035E-04	1.214E-05	5.156E-06
260	4.521E-05	1.788E-06	4.261E-06
266	3.758E-06	1.990E-06	3.522E-06
272	4.034E-06	2.175E-06	2.911E-06
278	4.331E-06	1.452E-06	2.406E-06
284	4.650E-06	2.226E-06	2.871E-06
290	4.992E-06	1.674E-06	2.711E-06
296	5.360E-06	1.735E-06	3.782E-06
302	5.754E-06	1.798E-06	4.177E-06
308	6.178E-06	1.864E-06	4.613E-06
314	6.633E-06	1.932E-06	5.095E-06
320	7.121E-06	2.003E-06	5.627E-06
326	7.645E-06	2.206E-06	6.215E-06
332	8.208E-06	2.431E-06	6.864E-06
338	4.895E-06	1.488E-06	4.211E-06
344	5.256E-06	1.301E-06	4.651E-06
350	5.643E-06	1.137E-06	5.137E-06
356	6.058E-06	9.943E-07	5.673E-06
PEAK VALUES	5.855E-04	3.154E-04	3.283E-04

LOW WIND SPEED TEST # 9 3/21/74 06:30 - 07:30 MDT

NORMALIZED CONCENTRATIONS (CHI*U/Q)

U = 0.802 M/SEC Q = 0.032 GRAMS/SEC

DEGREES	100 METERS	200 METERS	400 METERS
2	-	-	-
8	-	-	-
14	-	-	-
20	-	-	-
26	-	-	-
32	-	-	-
38	-	-	-
44	-	-	-
50	-	-	-
56	-	-	-
62	-	-	-
68	-	-	-
74	-	-	-
80	-	-	-
86	-	-	-
92	-	-	-
98	-	-	-
104	-	-	-
110	-	-	-
116	-	-	-
122	2.784E-06	-	-
128	1.212E-04	5.379E-05	6.838E-06
134	1.461E-04	4.890E-05	1.062E-04
140	5.378E-04	2.295E-04	1.129E-04
146	7.198E-04	5.066E-04	2.936E-04
152	5.185E-04	3.984E-04	3.394E-04
158	1.033E-03	5.681E-04	3.924E-04
164	7.201E-04	4.708E-04	2.595E-04
170	1.093E-03	2.388E-04	6.391E-05
176	1.488E-04	9.084E-05	3.459E-05
182	-	6.510E-06	1.633E-05
188	-	-	2.108E-06
194	-	-	-
200	-	-	-
206	-	-	-
212	-	-	-
218	-	-	-
224	-	-	-
230	-	-	-
236	-	-	-
242	-	-	-
248	-	-	-
254	-	-	-
260	-	-	-
266	-	-	-
272	-	-	-
278	-	-	-
284	-	-	-
290	-	-	-
296	-	-	-
302	-	-	-
308	-	-	-
314	-	-	-
320	-	-	-
326	-	-	-
332	-	-	-
338	-	-	-
344	-	-	-
350	-	-	-
356	-	-	-
PEAK VALUES	1.093E-03	5.681E-04	3.924E-04

LOW WIND SPEED TEST #10 4/17/74 05:48 - 06:47 MDT

NORMALIZED CONCENTRATIONS (CHI*U/Q)

U = 1.660 M/SEC Q = 0.032 GRAMS/SEC

DEGREES	100 METERS	200 METERS	400 METERS
2	9.233E-04	5.176E-04	2.414E-04
8	6.600E-04	2.287E-04	1.888E-04
14	6.881E-04	5.434E-05	1.122E-04
20	7.429E-04	6.393E-05	6.671E-05
26	1.899E-03	9.053E-05	6.205E-05
32	2.171E-03	1.282E-04	5.374E-04
38	1.847E-03	1.245E-03	5.890E-04
44	2.169E-03	1.196E-03	3.767E-04
50	2.406E-03	1.801E-03	2.153E-04
56	1.888E-03	4.940E-04	1.288E-05
62	7.428E-04	1.336E-05	-
68	2.877E-05	-	-
74	-	-	-
80	-	-	-
86	-	-	-
92	-	-	-
98	-	-	-
104	-	-	-
110	-	-	-
116	-	-	-
122	-	-	-
128	-	-	-
134	-	-	-
140	-	-	-
146	-	-	-
152	-	-	-
158	-	-	-
164	-	-	-
170	-	-	-
176	-	-	-
182	-	-	-
188	-	-	-
194	-	-	-
200	-	-	-
206	-	-	-
212	-	-	-
218	-	-	-
224	-	-	-
230	-	-	-
236	-	-	-
242	-	-	-
248	-	-	-
254	-	-	-
260	-	-	-
266	-	-	-
272	-	-	-
278	-	-	-
284	-	-	-
290	-	-	-
296	3.318E-06	-	-
302	3.538E-04	-	-
308	3.914E-04	-	-
314	7.215E-04	-	-
320	1.198E-03	1.636E-04	-
326	1.181E-03	5.491E-04	1.970E-06
332	6.333E-04	4.289E-04	4.641E-05
338	5.196E-04	5.512E-04	2.439E-04
344	1.407E-03	1.571E-03	7.078E-04
350	1.976E-03	1.155E-03	3.513E-04
356	1.807E-03	1.171E-03	3.057E-04
PEAK VALUES	2.406E-03	1.801E-03	7.078E-04

LOW WIND SPEED TEST #11   4/30/74   02:46 - 03:46 MDT

NORMALIZED CONCENTRATIONS (CHI*U/Q)

U = 1.925 M/SEC   Q = 0.031 GRAMS/SEC

DEGREES	100 METERS	200 METERS	400 METERS
2	5.692E-04	4.671E-04	1.075E-04
8	4.023E-04	1.314E-04	1.137E-04
14	3.679E-04	1.129E-04	1.039E-04
20	2.007E-04	1.354E-04	9.494E-05
26	3.761E-04	2.462E-05	5.478E-05
32	4.395E-04	8.851E-05	6.037E-05
38	2.975E-04	6.007E-05	4.691E-05
44	3.395E-04	8.350E-05	5.842E-05
50	3.044E-04	1.161E-04	5.880E-05
56	7.129E-04	3.432E-04	1.372E-04
62	9.683E-04	4.465E-04	2.936E-04
68	9.715E-04	4.650E-04	3.359E-04
74	7.823E-04	7.808E-04	5.874E-04
80	5.340E-04	5.279E-04	5.868E-04
86	6.021E-04	1.090E-03	4.383E-04
92	1.867E-03	9.795E-04	5.004E-04
98	2.323E-03	1.022E-03	1.096E-03
104	1.605E-03	8.881E-04	7.686E-04
110	8.205E-04	2.081E-04	3.622E-04
116	3.261E-04	2.407E-04	1.707E-04
122	7.745E-04	5.098E-04	2.861E-05
128	1.151E-03	1.911E-04	-
134	4.124E-05	-	-
140	-	-	-
146	-	-	-
152	-	-	-
158	-	-	-
164	-	-	-
170	-	-	-
176	-	-	-
182	-	-	-
188	-	-	-
194	-	-	-
200	-	-	-
206	-	-	-
212	-	-	-
218	-	-	-
224	-	-	-
230	-	-	-
236	-	-	-
242	-	-	-
248	-	-	-
254	-	-	-
260	-	-	-
266	-	-	-
272	-	-	-
278	-	-	-
284	-	-	-
290	-	-	-
296	-	-	-
302	-	-	-
308	-	-	-
314	-	-	-
320	-	-	-
326	-	-	-
332	-	-	-
338	-	8.738E-06	-
344	-	4.864E-05	6.775E-05
350	4.324E-04	2.708E-04	1.202E-04
356	4.961E-04	2.126E-04	1.287E-04
PEAK VALUES	2.323E-03	1.090E-03	1.096E-03

LOW WIND SPEED TEST #12 4/30/74 05:11 - 06:11 MDT

NORMALIZED CONCENTRATIONS (CHI*U/Q)

U = 1.080 M/SEC Q = 0.032 GRAMS/SEC

DEGREES	100 METERS	200 METERS	400 METERS
2	9.108E-06	6.106E-06	7.786E-06
8	2.165E-05	1.346E-05	1.717E-05
14	4.560E-05	2.965E-05	3.787E-05
20	8.486E-05	5.681E-05	1.495E-05
26	2.546E-04	1.229E-04	3.882E-05
32	7.842E-04	2.658E-04	1.093E-04
38	7.260E-04	8.153E-05	1.792E-04
44	7.878E-04	3.085E-04	2.167E-04
50	8.550E-04	5.662E-04	2.183E-04
56	6.343E-04	6.998E-04	5.168E-04
62	1.104E-03	7.561E-04	5.793E-04
68	1.542E-03	1.774E-03	9.941E-04
74	1.832E-03	1.328E-03	8.127E-04
80	2.001E-03	1.322E-03	5.511E-04
86	1.936E-03	1.054E-03	4.102E-04
92	1.935E-03	1.011E-03	3.488E-05
98	1.465E-03	8.151E-04	2.792E-04
104	8.088E-04	4.715E-05	7.254E-06
110	5.847E-04	3.582E-06	6.647E-06
116	1.924E-04	6.280E-06	6.090E-06
122	6.256E-05	4.891E-06	5.579E-06
128	3.027E-05	-	5.112E-06
134	5.529E-06	-	4.683E-06
140	5.538E-06	-	-
146	7.654E-06	-	-
152	3.922E-06	-	-
158	2.663E-06	-	-
164	3.479E-06	-	-
170	2.594E-06	-	-
176	2.449E-06	-	-
182	1.944E-06	-	-
188	3.697E-06	-	-
194	1.830E-06	-	-
200	1.810E-06	-	-
206	→1.791E-06	-	-
212	1.772E-06	-	-
218	2.012E-06	-	-
224	2.285E-06	-	-
230	2.335E-06	-	-
236	1.993E-06	-	-
242	2.704E-06	-	-
248	3.669E-06	-	-
254	2.199E-06	-	-
260	1.318E-06	-	-
266	1.495E-06	-	-
272	-	-	-
278	1.835E-06	-	-
284	1.536E-06	-	-
290	1.286E-06	-	-
296	-	-	-
302	-	-	-
308	-	-	-
314	-	-	-
320	2.188E-06	-	-
326	-	-	-
332	-	-	-
338	-	1.989E-06	-
344	-	2.221E-06	-
350	-	2.481E-06	-
356	-	2.771E-06	3.531E-06
PEAK VALUES	2.001E-03	1.774E-03	9.941E-04

LOW WIND SPEED TEST #13   5/3/74   05:22 - 06:22 MDT

NORMALIZED CONCENTRATIONS (CHI*U/Q)

U = 1.608 M/SEC   Q = 0.033 GRAMS/SEC

DEGREES	100 METERS	200 METERS	400 METERS
2	-	-	-
8	-	-	-
14	-	-	-
20	-	-	-
26	-	-	-
32	-	-	-
38	-	-	-
44	-	-	-
50	-	-	-
56	-	-	-
62	-	-	-
68	-	-	-
74	-	-	-
80	-	-	-
86	-	-	-
92	-	-	-
98	-	-	-
104	-	-	-
110	-	-	-
116	-	-	-
122	-	-	-
128	-	-	-
134	-	-	-
140	5.198E-06	-	-
146	2.033E-04	-	-
152	1.885E-03	5.397E-04	1.062E-04
158	1.763E-03	1.558E-03	7.566E-04
164	2.194E-03	1.599E-03	1.111E-03
170	3.157E-03	2.303E-03	1.367E-03
176	1.592E-03	1.701E-03	1.041E-03
182	8.029E-04	4.982E-04	5.795E-04
188	9.447E-04	1.005E-03	5.291E-04
194	9.632E-04	1.141E-03	9.233E-04
200	1.064E-03	1.090E-03	9.418E-05
206	8.872E-04	1.121E-04	9.606E-06
212	4.443E-04	5.671E-04	5.218E-04
218	3.138E-04	3.500E-04	-
224	5.380E-04	2.545E-04	-
230	2.163E-04	1.958E-05	-
236	1.215E-04	7.059E-05	-
242	1.024E-04	-	-
248	-	-	-
254	-	-	-
260	-	-	-
266	-	-	-
272	-	-	-
278	-	-	-
284	-	-	-
290	-	-	-
296	-	-	-
302	-	-	-
308	-	-	-
314	-	-	-
320	-	-	-
326	-	-	-
332	-	-	-
338	-	-	-
344	-	-	-
350	-	-	-
356	-	-	-
PEAK VALUES	3.157E-03	2.303E-03	1.367E-03

LOW WIND SPEED TEST # 14   5/22/74   04:45 - 05:45 MDT

NORMALIZED CONCENTRATIONS (CHI*U/Q)

U = 1.470 M/SEC   Q = 0.032 GRAMS/SEC

DEGREES	100 METERS	200 METERS	400 METERS
2	-	-	-
8	-	-	-
14	-	-	-
20	-	-	-
26	-	-	-
32	-	-	-
38	-	-	-
44	-	-	-
50	-	-	-
56	-	-	-
62	-	-	-
68	-	-	-
74	-	-	-
80	-	-	-
86	-	-	-
92	-	-	-
98	-	-	-
104	-	-	-
110	-	-	-
116	-	-	-
122	-	-	-
128	-	-	-
134	-	-	-
140	-	-	-
146	-	-	-
152	-	-	-
158	-	-	-
164	-	-	-
170	-	-	-
176	5.151E-05	-	-
182	6.179E-04	2.724E-04	1.015E-05
188	6.975E-04	3.340E-04	1.540E-04
194	6.639E-04	2.166E-04	1.099E-04
200	4.289E-05	2.036E-05	1.213E-04
206	5.800E-04	2.894E-04	1.338E-04
212	3.292E-04	7.128E-04	3.017E-04
218	1.305E-04	5.789E-04	1.191E-04
224	1.963E-03	1.016E-03	4.701E-05
230	2.581E-03	2.074E-04	1.855E-05
236	2.814E-03	1.587E-03	7.324E-06
242	2.532E-03	1.574E-04	2.193E-06
248	8.257E-05	-	-
254	-	-	-
260	-	-	-
266	-	-	-
272	-	-	-
278	-	-	-
284	-	-	-
290	-	-	-
296	-	-	-
302	-	-	-
308	-	-	-
314	-	-	-
320	-	-	-
326	-	-	-
332	-	-	-
338	-	-	-
344	-	-	-
350	-	-	-
356	-	-	-
PEAK VALUES	2.814E-03	1.587E-03	3.017E-04

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