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PEDESTRIAN WIND DATA SUPPLEMENT FOR INPATIENT
REPLACEMENT BUILDING, MASSACHUSETTS GENERAL
HOSPITAL, BOSTON

by

J. A. Peterka,* J. E. Cermak**
and W. W. Li***



**FLUID MECHANICS AND
WIND ENGINEERING PROGRAM**

COLLEGE OF ENGINEERING

**COLORADO STATE UNIVERSITY
FORT COLLINS, COLORADO**

CER85-86JAP-JEC-WWL 5a

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1. INTRODUCTION

This report provides pedestrian wind data in addition to that presented in the basic report, "Wind-Tunnel Study of Inpatient Replacement Building, Massachusetts General Hospital, Boston," Report CER85-86JAP-JEC-WWL5, Fluid Mechanics and Wind Engineering Program at Colorado State University. Data presented in this report concentrates on the eventual configuration approved by the Boston Redevelopment Authority (BRA) and on mitigation measures which can decrease wind speeds in critical areas.

Data acquisition and data reduction procedures for the tests reported herein duplicate those in the basic report and are thus not repeated here. Four configurations were tested in this supplemental effort, all in addition to data obtained in the basic report. The configurations represent the final architectural configuration approved by the BRA and three modifications intended to provide mitigating, but not necessarily architectural or functional, modifications whose intent was to demonstrate the extent of changes in geometry required to decrease wind speeds in critical areas by various amounts.

2. EXPERIMENTAL CONFIGURATION

Figures 1-3 show the four geometries for which pedestrian velocities were measured for this supplemental report. For reference, the two geometries for which velocities were measured in the basic study are reproduced in Figures 4 and 5. A brief description of these geometries follows:

Configuration F (Figure 4) -- Preconstruction geometry. Velocities were measured at the 23 locations shown and results were reported in the basic report.

Configuration C (Figure 5) -- Interim stage of construction with 258 and 192 foot structures in place and with a 48 foot lowrise. Velocities were measured at the 25 locations marked and results were reported in the basic report. Location 23 was located in a drive-through below the lowrise.

Configuration G (Figure 1) -- Final stage of construction as approved by the BRA. Velocities were measured at locations 18-25 surrounding the location 23 which was found to have high velocities in Configuration C. Results are reported herein.

Configuration I (Figure 2) -- Modification to Configuration G suggested by the project architect. Lowrise structure was extended toward Charles Street as an overhang. Locations 24 and 25 were located under the overhang entrance. Velocities were measured at locations 18 to 25 and results are reported herein.

Configuration J (Figure 3) -- Modification to Configuration I in which the lowrise was extended toward Fruit Street. The crosshatch area on the east and south sides of the extension were left open maintaining the flow-through. This addition was not made as a viable architectural option, but was inserted to determine how much decrease in wind speeds below the lowrise would result from additional lowrise extension. Velocities were measured at locations 20 and 22-24; results are reported herein.

Configuration K (Figure 3) -- Modification to Configuration J in which vertical walls were extended across the lowrise passage in the crosshatched area. The only opening permitting airflow is a small walkway. This configuration was included to show the effect of virtually blocking the passage under the lowrise, and not as

a functionally viable solution. Velocities were measured at locations 20 and 23-24; results are reported herein.

As indicated in the introduction, data acquisition and analysis were the same as in the basic report.

3. RESULTS AND DISCUSSION

Velocity data obtained at each of the pedestrian measurement locations shown in Figures 1-3 are listed in Table 1 as mean velocity U/U_{∞} , turbulence intensity U_{rms}/U_{∞} , and largest effective gust

$$U_{pk} = \frac{U + 3U_{rms}}{U_{\infty}},$$

where U is the mean velocity at a pedestrian location, U_{rms} is the root-mean-square velocity about the mean, and U_{∞} is the velocity at the reference location at 900 ft elevation. These data are plotted in polar form in Figure 6. These data plots show the approach wind directions giving the highest wind speeds at each site.

To enable a quantitative assessment of the wind environment, the wind-tunnel data were combined with wind frequency and direction information obtained at Logan International Airport as described in the basic report. Table 2 shows wind frequency by direction and magnitude obtained from summaries published by the National Weather Service. These data, obtained at an elevation of 22 ft, were converted to velocities at the reference velocity height for the wind-tunnel measurements (900 ft) and combined with the wind-tunnel data to obtain cumulative probability distributions (percent time a given velocity is exceeded) for wind velocity at each measuring location. The percentage times were summed by wind direction to obtain a percent time exceeded at each

measuring position independent of wind direction (but accounting for the fact that the wind blows from different directions with varying frequency). These results are plotted in Figure 7.

Interpretation of Figure 7 is aided by a description of the effects of wind of various magnitudes on people. The earliest quantitative description of wind effects was established by Sir Francis Beaufort in 1806 for use at sea and is still in use today. Several recent investigators have added to the knowledge of wind effects on pedestrians. These investigations along with suggested criteria for acceptance have been summarized by Penwarden and Wise (1) and Melbourne (2). The Beaufort scale (from ref. 1), based on mean velocity, is reproduced as Table 3 including qualitative descriptions of wind effects. Table 3 suggests that mean wind speeds below 12 mph are of minor concern and that mean speeds above 24 mph are definitely inconvenient. Quantitative criteria for acceptance from reference 2 are superimposed as dashed lines on Figure 7. The peak gust curves shown in Figure 7 are the percent of time during which a short gust of the stated magnitude could occur (say about one of these gusts per hour).

The overall indications of pedestrian wind comfort are best described by Figure 7, in particular the percent time exceeded plots which show the effective gust (mean plus 3*rms). The mean velocity percent time exceeded plots are useful, but may present too severe a comparison to acceptance criteria because of conservative assumptions about anticipated urban turbulence intensities which were incorporated into the acceptance criteria.

Figure 7 shows that location 20 was the windiest of the locations measured and was unacceptable for wind gusts 6 to 10 percent of the time for each of the tested configurations. Locations 23 and 24 in the

center of the drive-through exceeded the comfort criteria for walking for gusts in both Configurations G and I for 10 to 20 percent of the time.

The BRA uses for an informal guideline the effective peak velocity exceeded one percent of the time. The effective velocity is defined as the mean plus 1.5 rms. Effective peak velocities exceeded one percent of the time are shown in Table 4 for each pedestrian location measured in Configurations G, I, J and K. In addition, peak effective velocities are shown for Configurations F and C from the basic report for comparison. Location 20 is well above the informal guideline limit of 31 mph for effective gust for all configurations, including the existing configuration. All new configurations made location 20 somewhat worse. Location 23 was exposed to high wind speeds in the intermediate construction phase (Configuration C) and was improved to essentially the preconstruction wind level (which was under the informal guideline) in Configuration I. Virtually enclosing the east and south end of the drive-through substantially reduced the velocity at location 23, but may not be functionally feasible.

Location 24 did not exist in the preconstruction environment, was a relatively low 18 mph in the intermediate configuration where it was not greatly affected by the wind in the flow-through and increased to 30 mph in the BRA approved design where it became part of the flow-through. Addition of the lowrise segment in Configuration I further increased the velocity to 32 mph, one mph above the guideline. Location 25 was 29 mph in the intermediate construction phase where southeast winds exiting the flow-through impinged directly on the location and decreased to 19 mph in the BRA approved geometry.

Location 18 was reduced in velocity from 29 in the existing configuration to 22-24 in the various built configurations -- a significant improvement. Locations 19 and 21 increased in velocity from 25 mph in the preconstruction configuration to 29 and 34 mph, respectively, in the BRA approved geometry. Some benefit was obtained with the lowrise addition of Configuration I.

Where wind velocities are high, the cause is the positive to negative pressure difference from front side to back side of a building. This type of wind velocity is difficult to decrease except by eliminating the pressure difference or blocking the passage. Extension of the lowrise or complete blockage of the passage under the lowrise will decrease winds -- however, architectural and functional limitations may prevent this.

One mitigation measure not tried is to roughen the ceiling of the soffit in the flow-through. If large roughness elements (6 in. to 12 in.) were used in a relatively dense packing -- say 15 to 20 percent of the soffit area covered with roughness elements, then a small decrease in wind speeds within the flow-through might result.

REFERENCES

1. Penwarden, A. D. and Wise, A. F. E., "Wind Environment Around Buildings," Building Research Establishment Report, HMSO, 1975.
2. Melbourne, W. H., "Criteria for Environmental Wind Conditions," J1. Industrial Aerodynamics, Vol. 3, pp. 241-247, 1978.

FIGURES

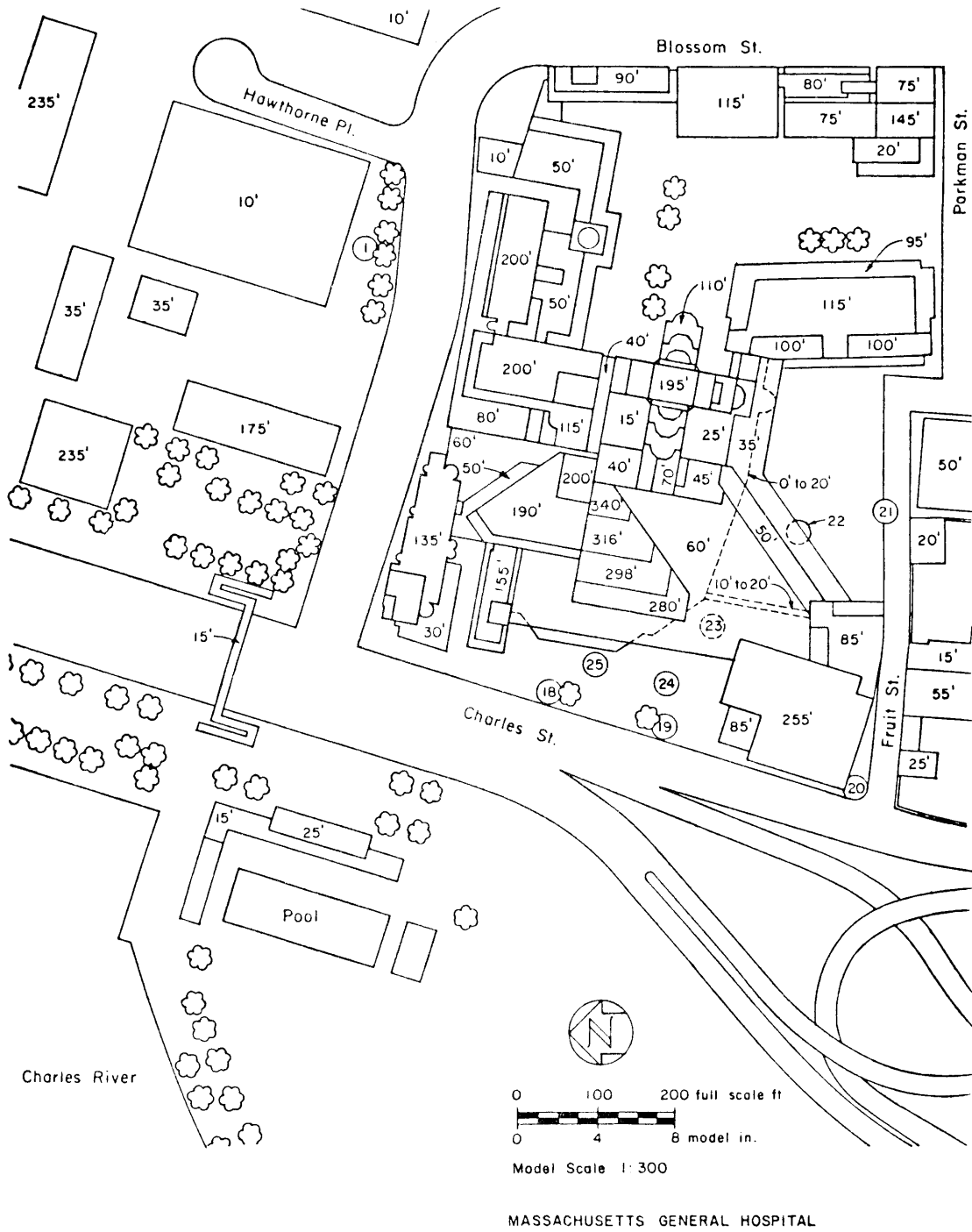
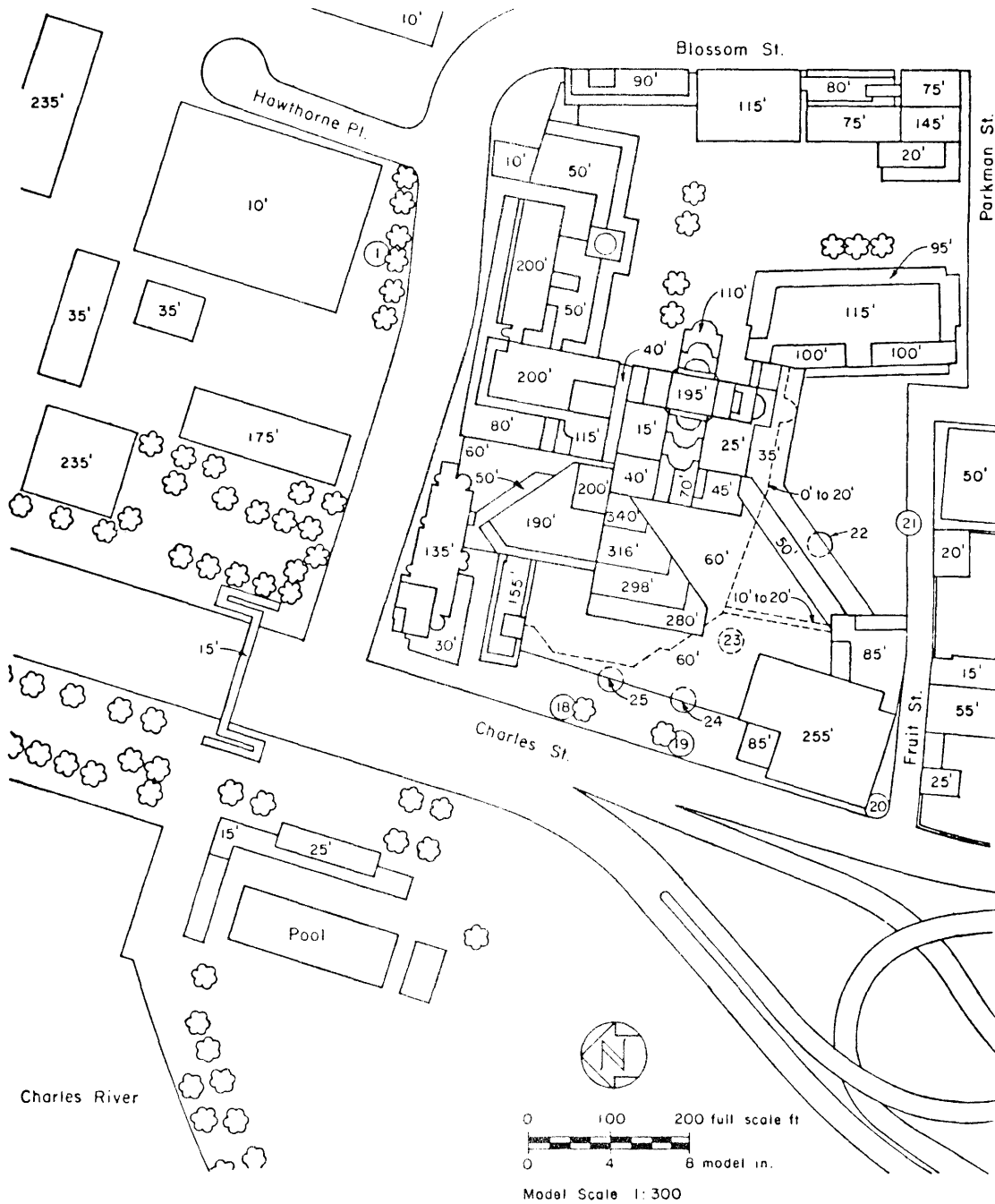


Figure 1. Building Location and Pedestrian Wind Velocity Measuring Positions for Configuration G



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Figure 2. Building Location and Pedestrian Wind Velocity Measuring Positions for Configuration I

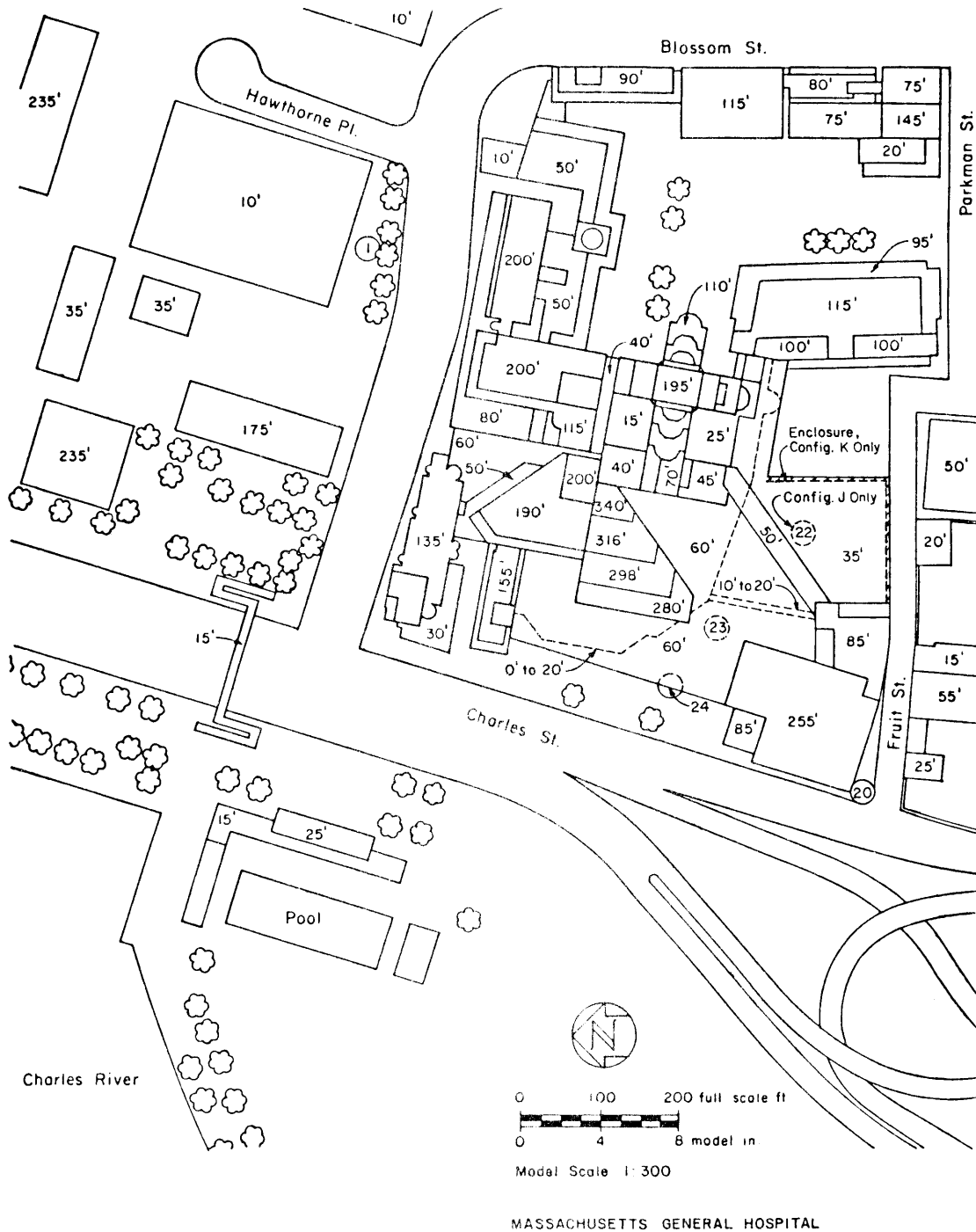


Figure 3. Building Location and Pedestrian Wind Velocity Measuring Positions for Configurations J and K

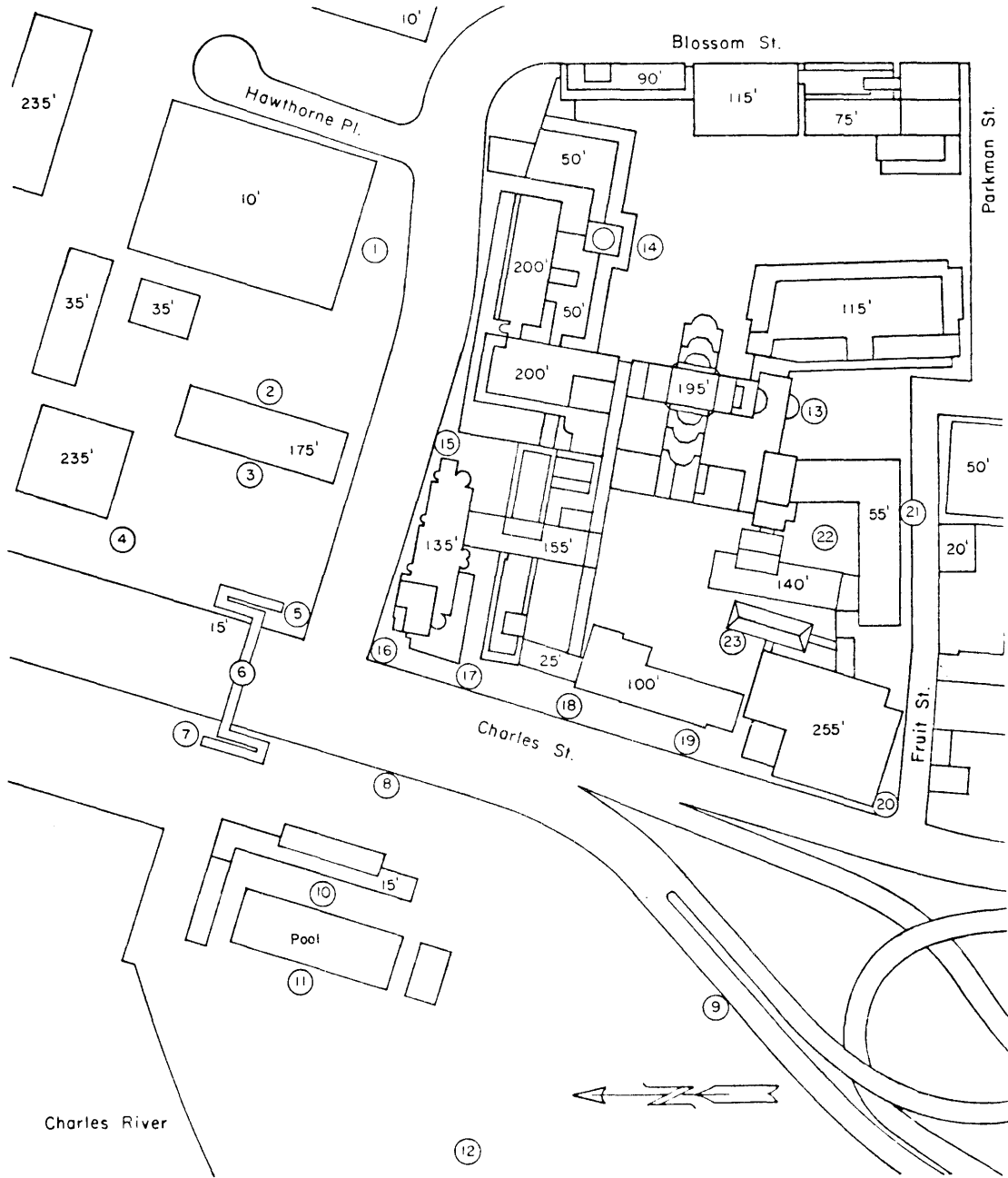


Figure 4. Building Location and Pedestrian Wind Velocity Measuring Positions for Configuration F

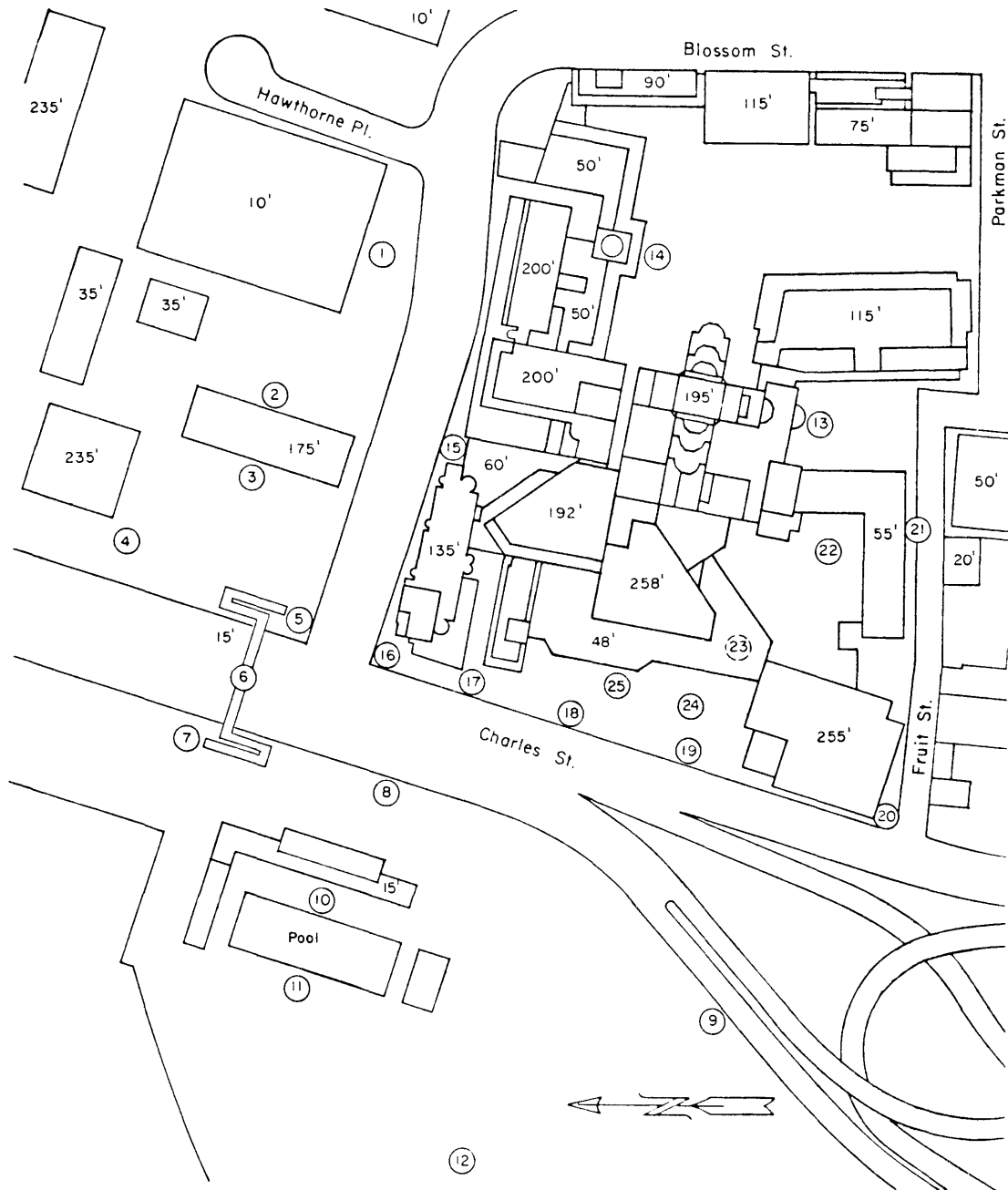


Figure 5. Building Location and Pedestrian Wind Velocity Measuring Positions for Configuration C

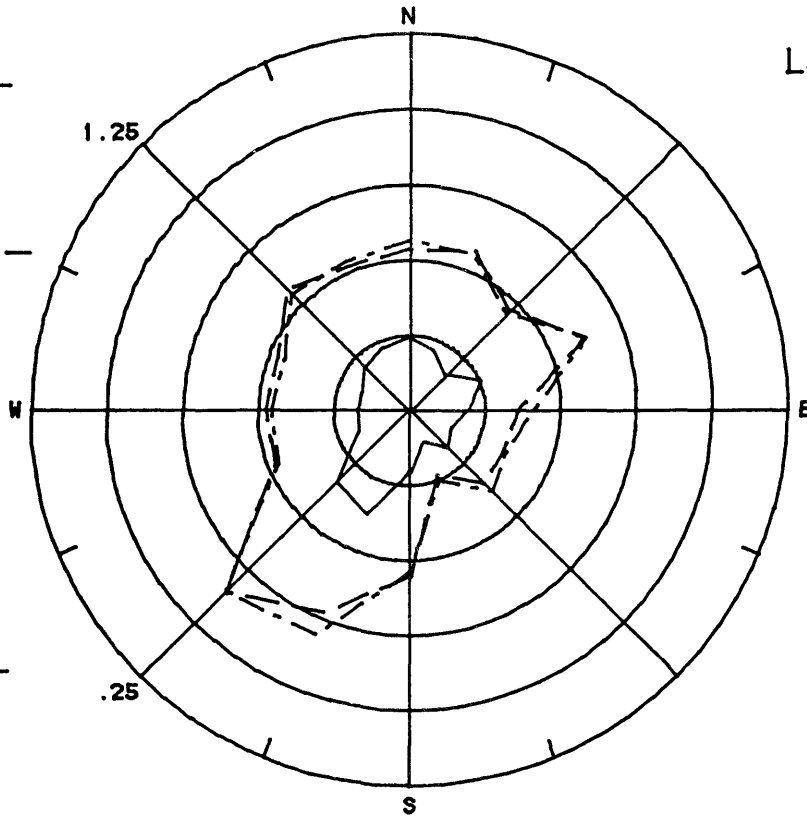
CONFIGURATION G

$\frac{U_{mean}}{U_{inf}}$ ———
 U_{inf}

Location 18

$\frac{U_{mean} + 3.0 * U_{rms}}{U_{inf}}$ - - - -
 U_{inf}

.25/Div



$\frac{U_{rms}}{U_{inf}}$ - - - -
 U_{inf}

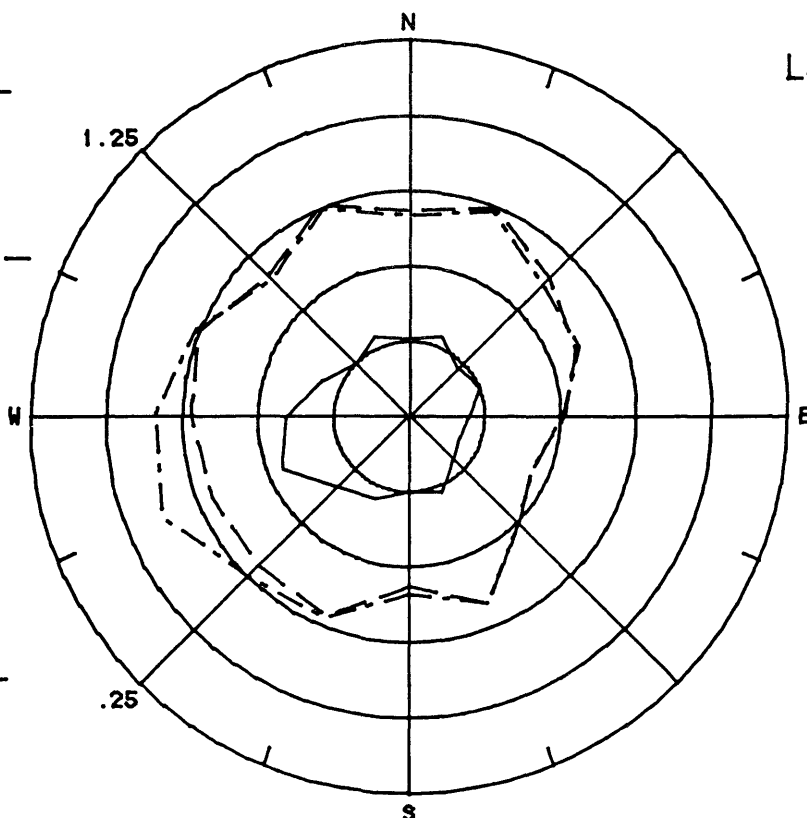
.05/Div

$\frac{U_{mean}}{U_{inf}}$ ———
 U_{inf}

Location 19

$\frac{U_{mean} + 3.0 * U_{rms}}{U_{inf}}$ - - - -
 U_{inf}

.25/Div



$\frac{U_{rms}}{U_{inf}}$ - - - -
 U_{inf}

.05/Div

Figure 6a. Mean Velocities and Turbulence Intensities at Pedestrian Locations 18 and 19

CONFIGURATION G

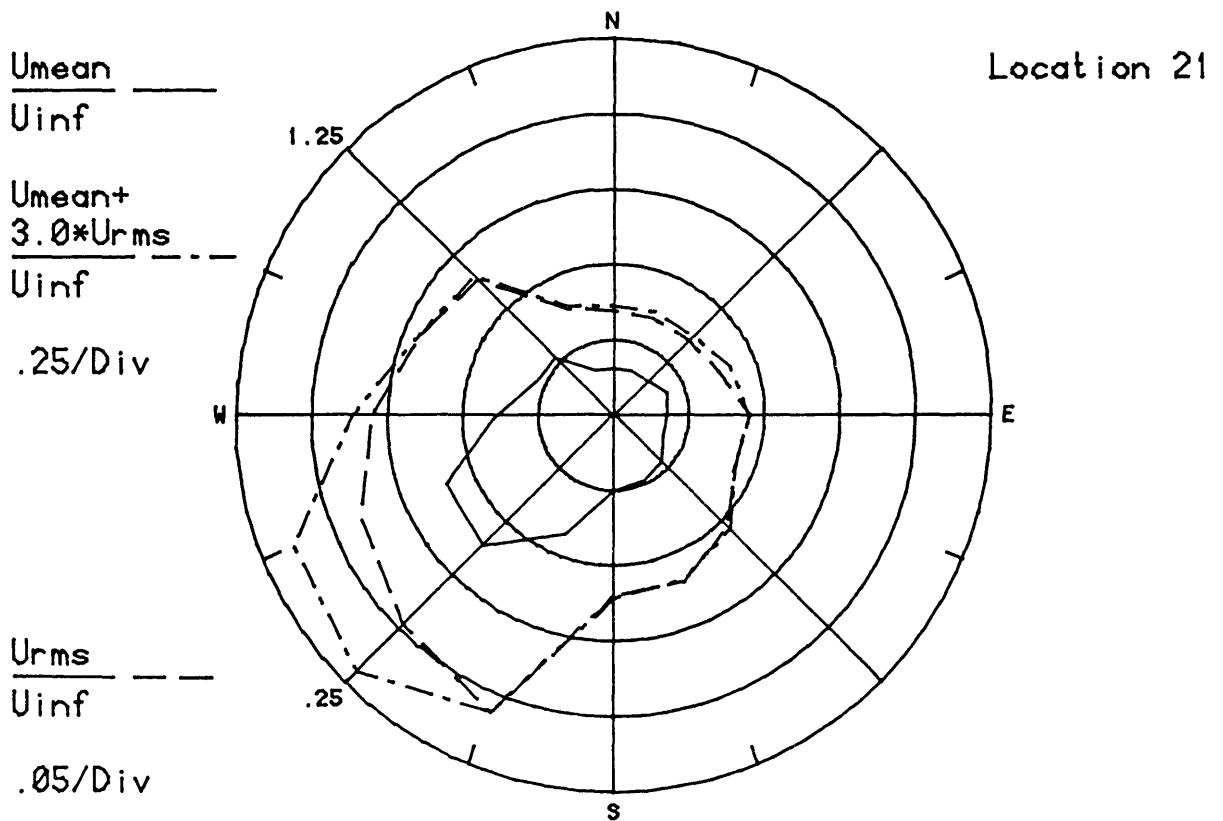
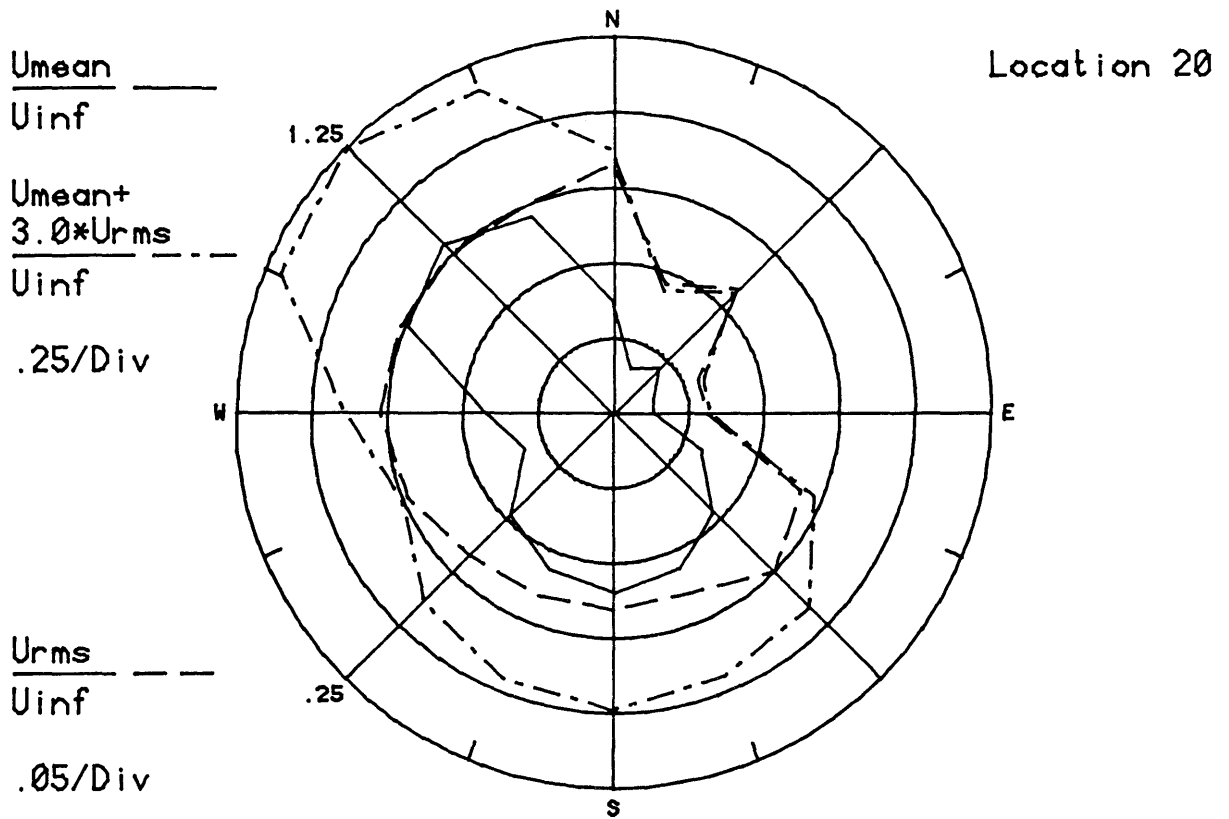


Figure 6b. Mean Velocities and Turbulence Intensities at Pedestrian Locations 20 and 21

CONFIGURATION G

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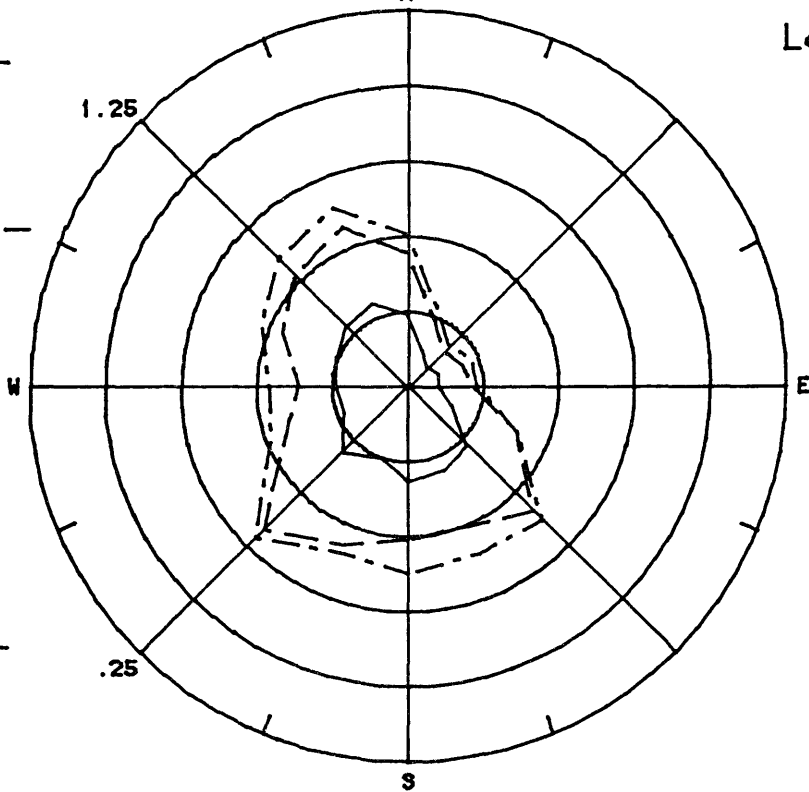
U_{inf}

1.25

$\frac{U_{mean} + 3.0 * U_{rms}}{U_{inf}}$ - - -

U_{inf}

.25/Div



Location 22

$\frac{U_{rms}}{U_{inf}}$ - - -

U_{inf}

.05/Div

$\frac{U_{mean}}{U_{inf}}$ ———

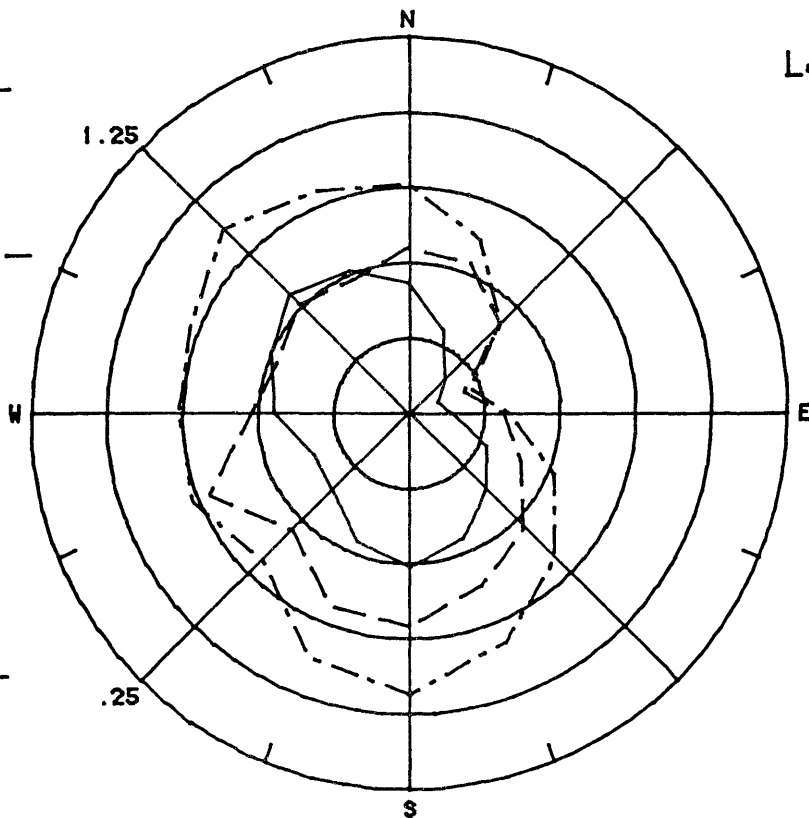
U_{inf}

1.25

$\frac{U_{mean} + 3.0 * U_{rms}}{U_{inf}}$ - - -

U_{inf}

.25/Div



Location 23

$\frac{U_{rms}}{U_{inf}}$ - - -

U_{inf}

.05/Div

Figure 6c. Mean Velocities and Turbulence Intensities at Pedestrian Locations 22 and 23

CONFIGURATION G

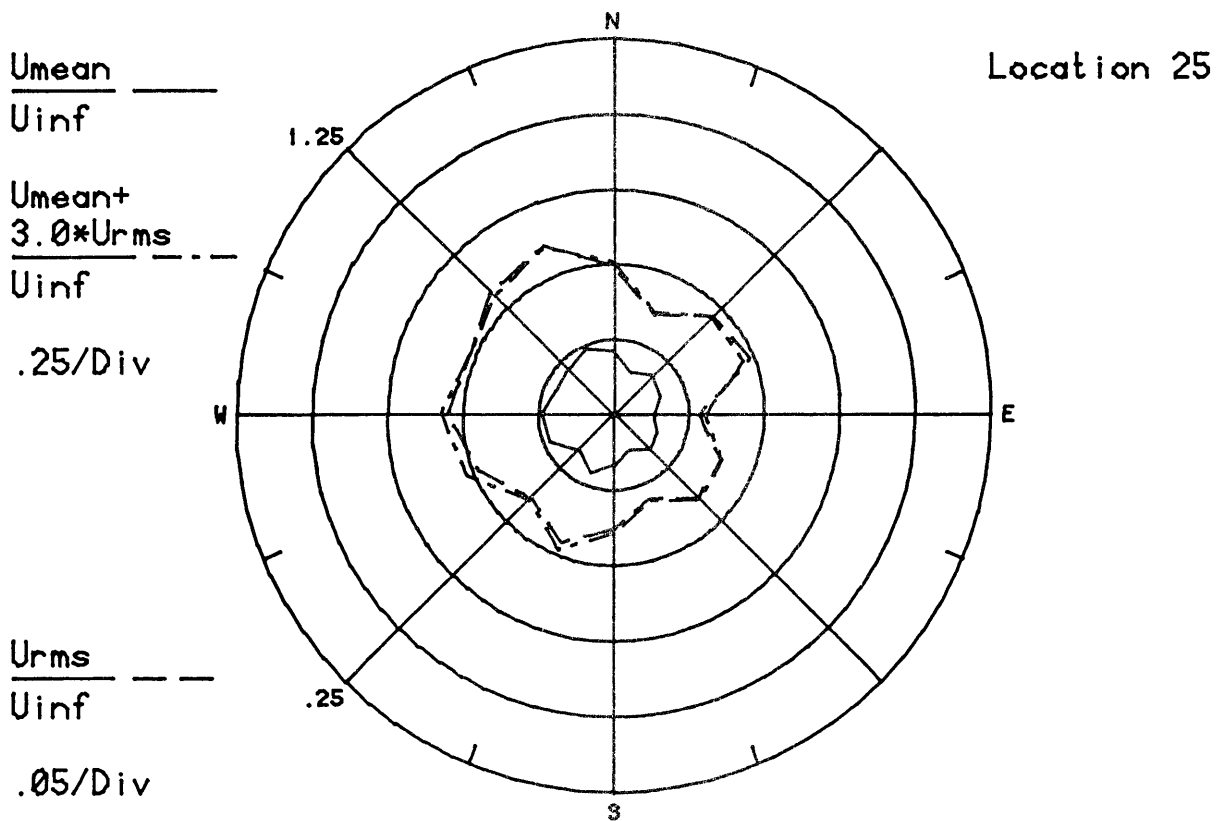
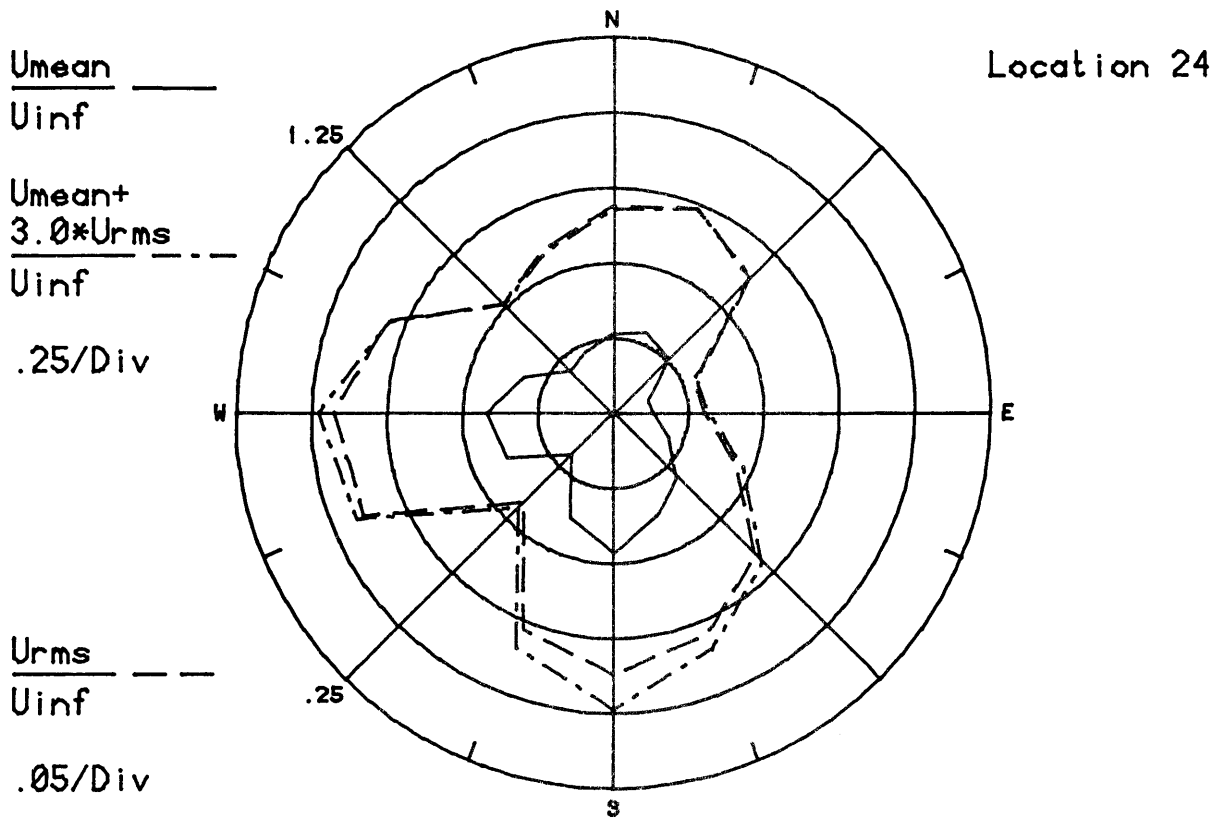


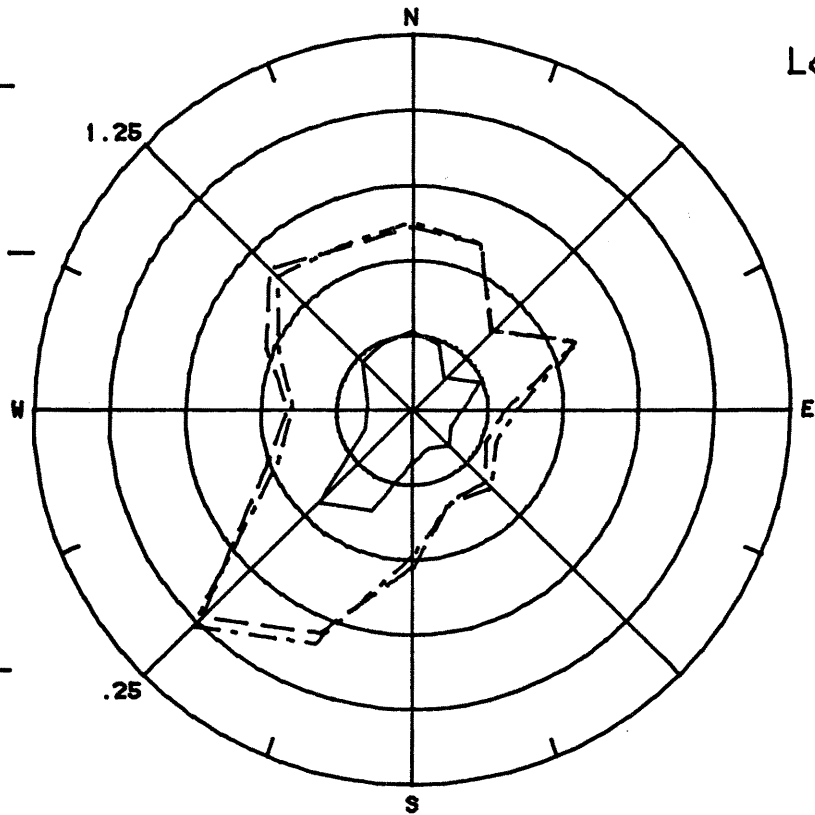
Figure 6d. Mean Velocities and Turbulence Intensities at Pedestrian Locations 24 and 25

CONFIGURATION I

$\frac{U_{mean}}{U_{inf}}$ ———

$\frac{U_{mean} + 3.0 \times U_{rms}}{U_{inf}}$ - - -

Location 18



$\frac{U_{rms}}{U_{inf}}$ - - -

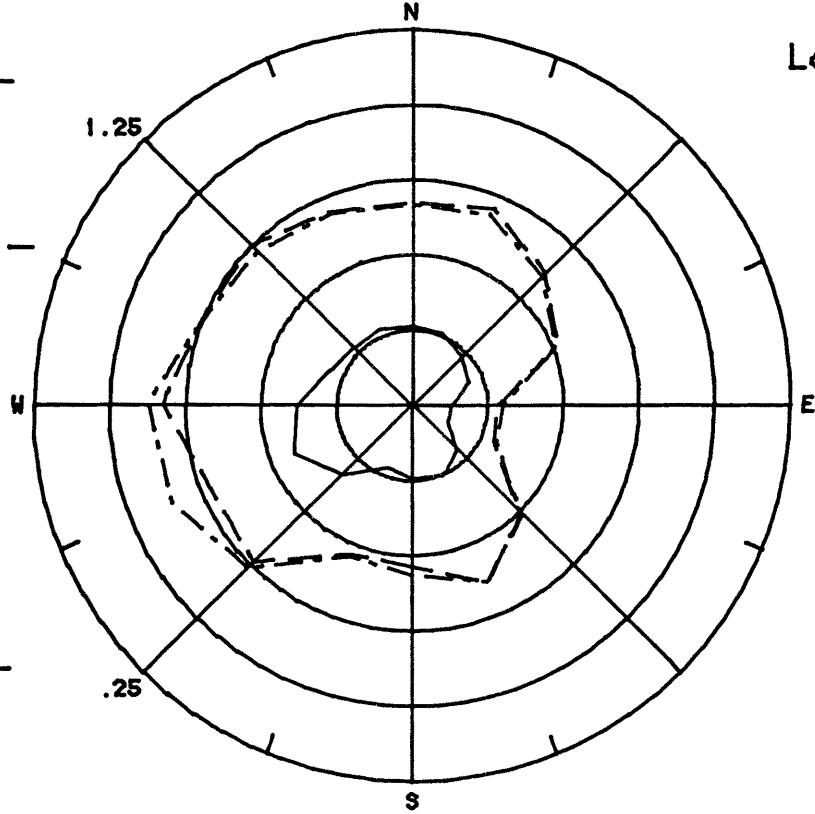
.25/Div

.05/Div

$\frac{U_{mean}}{U_{inf}}$ ———

$\frac{U_{mean} + 3.0 \times U_{rms}}{U_{inf}}$ - - -

Location 19



$\frac{U_{rms}}{U_{inf}}$ - - -

.25/Div

.05/Div

Figure 6e. Mean Velocities and Turbulence Intensities at Pedestrian Locations 18 and 19

CONFIGURATION I

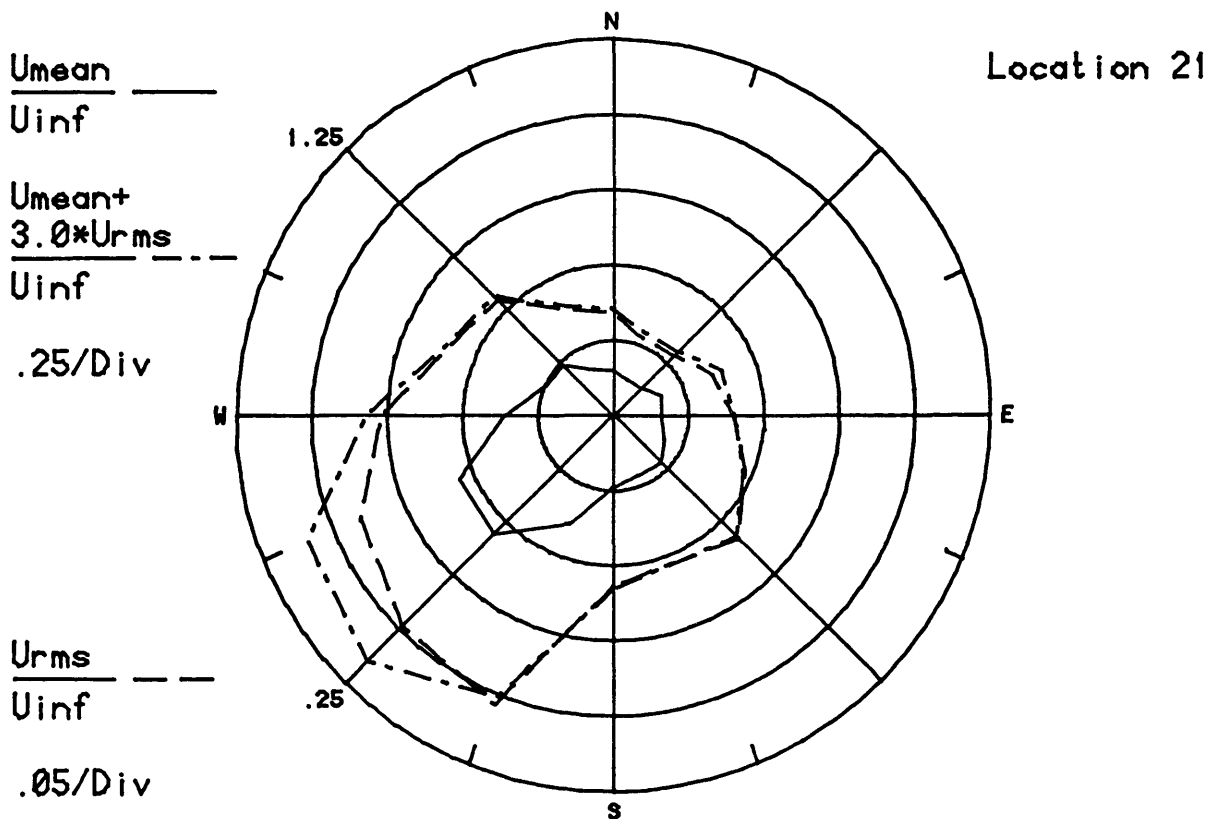
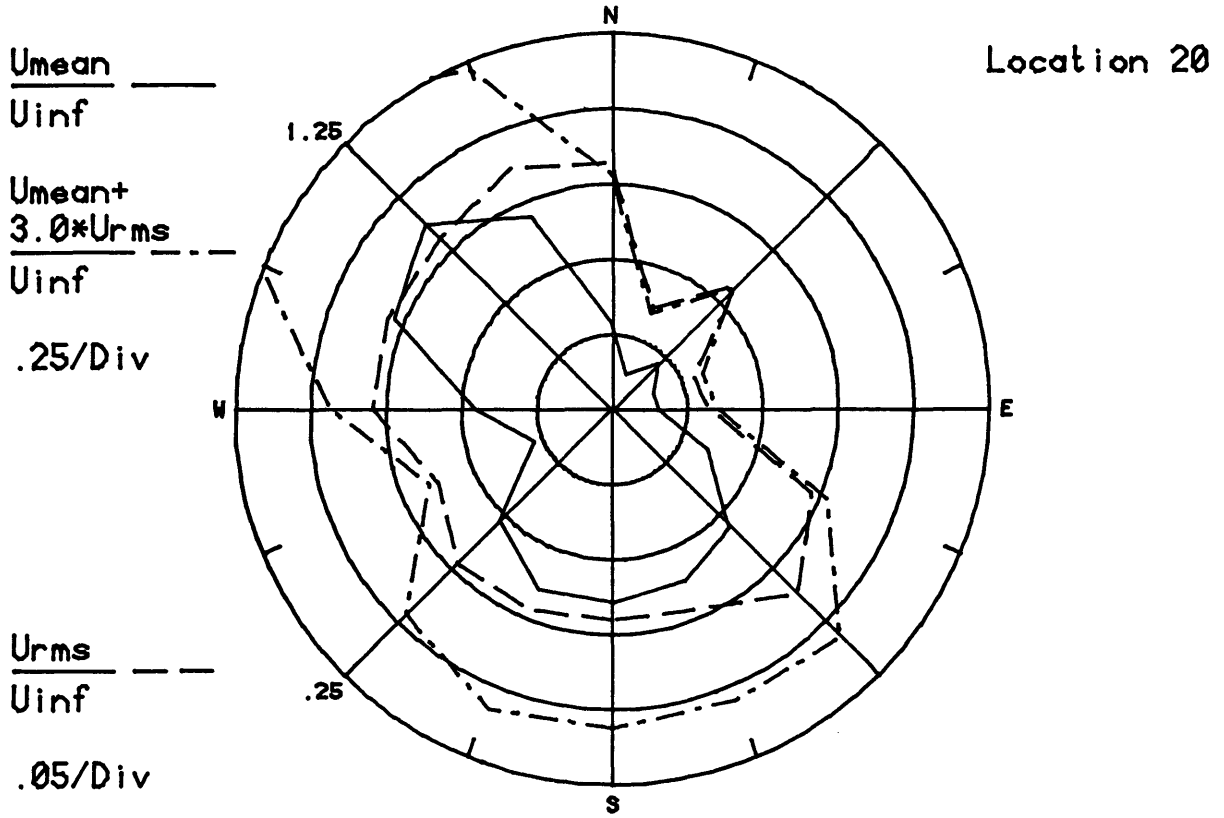


Figure 6f. Mean Velocities and Turbulence Intensities at Pedestrian Locations 20 and 21

CONFIGURATION I

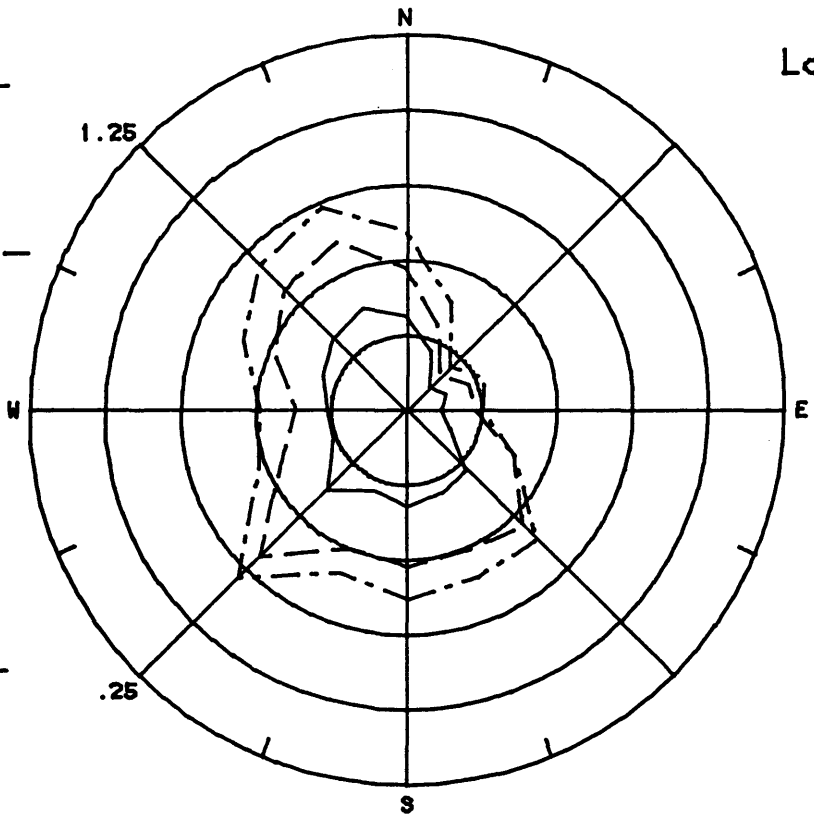
$\frac{U_{mean}}{U_{inf}}$ ———

U_{inf}

$\frac{U_{mean} + 3.0 * U_{rms}}{U_{inf}}$ - - -

U_{inf}

.25/Div



Location 22

$\frac{U_{rms}}{U_{inf}}$ - - -

U_{inf}

.05/Div

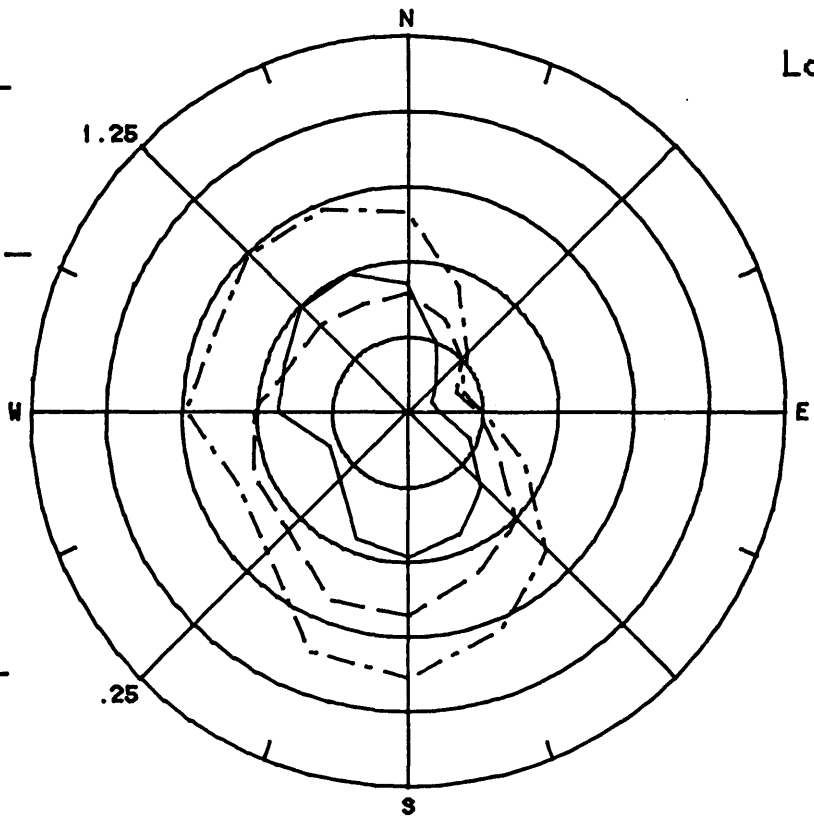
$\frac{U_{mean}}{U_{inf}}$ ———

U_{inf}

$\frac{U_{mean} + 3.0 * U_{rms}}{U_{inf}}$ - - -

U_{inf}

.25/Div



Location 23

$\frac{U_{rms}}{U_{inf}}$ - - -

U_{inf}

.05/Div

Figure 6g. Mean Velocities and Turbulence Intensities at Pedestrian Locations 22 and 23

CONFIGURATION I

$\frac{U_{mean}}{U_{inf}}$ ———

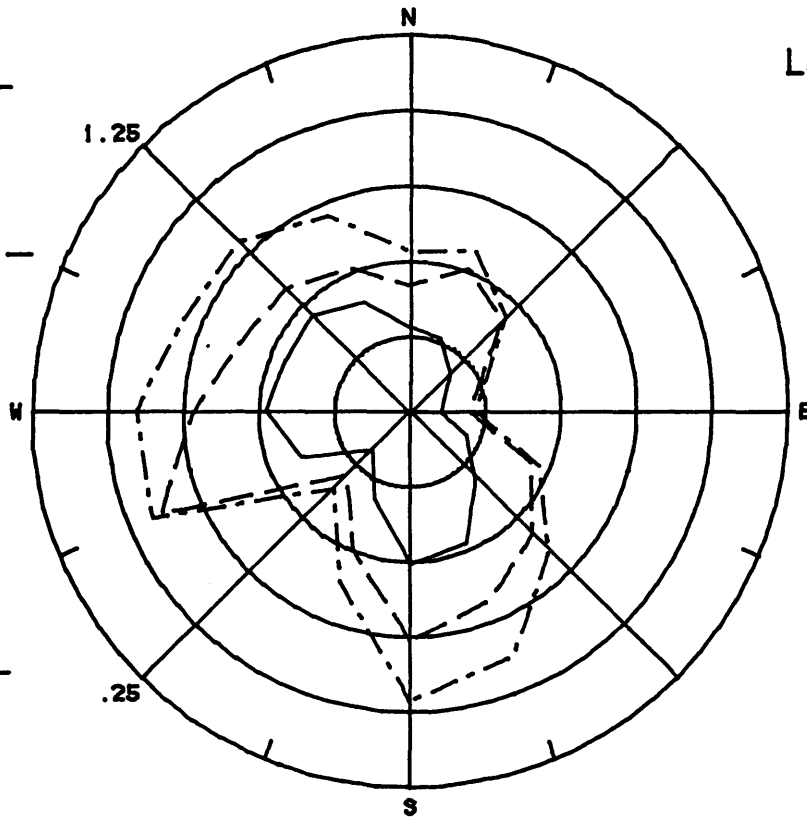
$\frac{U_{mean} + 3.0 * U_{rms}}{U_{inf}}$ - - -

$\frac{U_{rms}}{U_{inf}}$ - - -

.25/Div

.05/Div

Location 24



$\frac{U_{mean}}{U_{inf}}$ ———

$\frac{U_{mean} + 3.0 * U_{rms}}{U_{inf}}$ - - -

$\frac{U_{rms}}{U_{inf}}$ - - -

.25/Div

.05/Div

Location 25

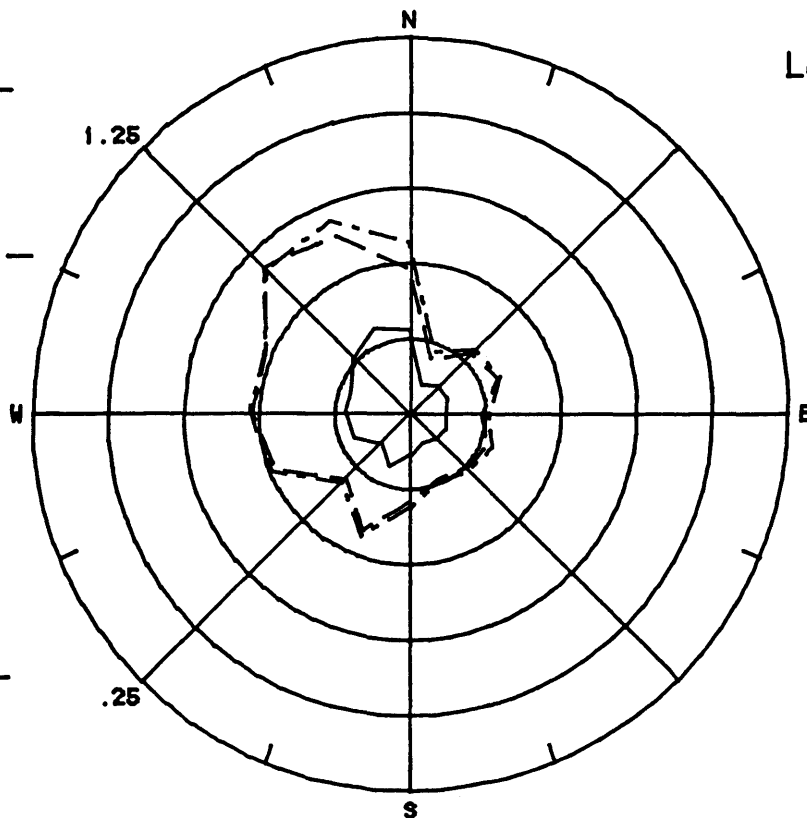


Figure 6h. Mean Velocities and Turbulence Intensities at Pedestrian Locations 24 and 25

CONFIGURATION J

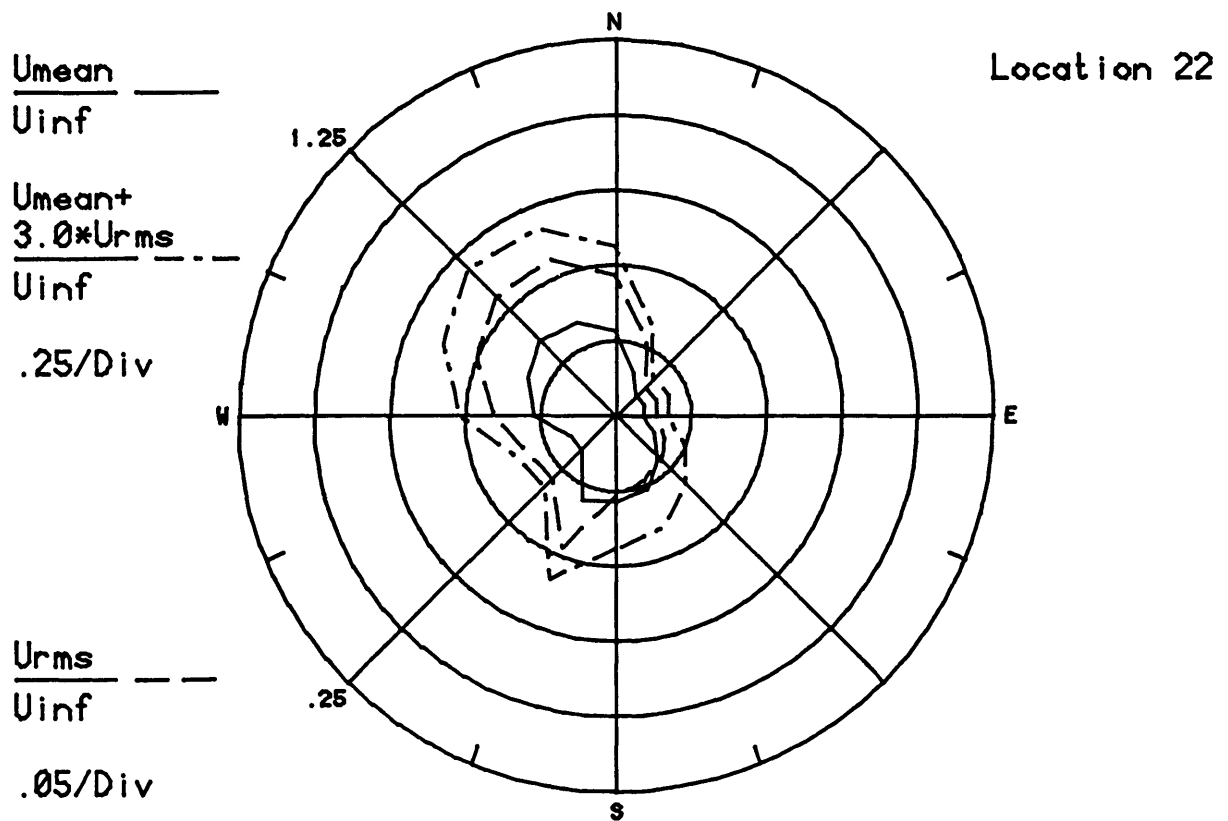
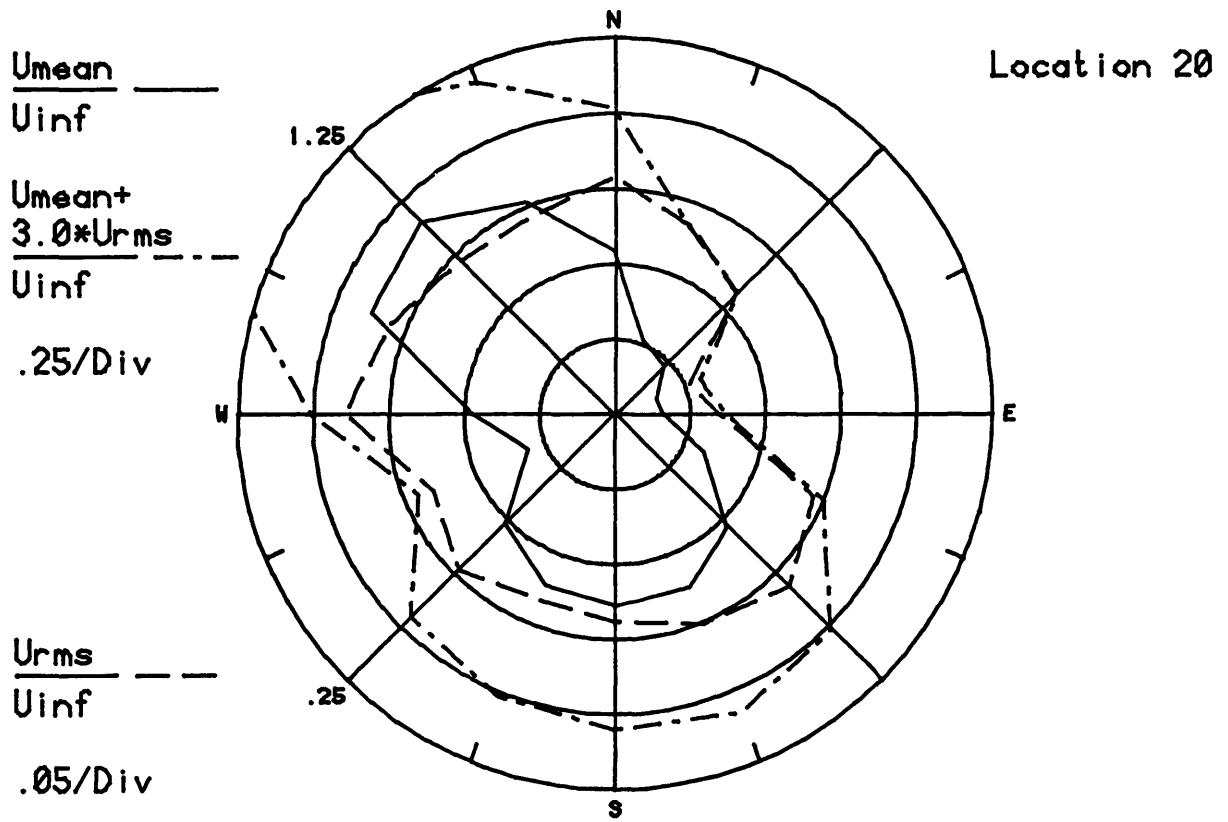


Figure 61. Mean Velocities and Turbulence Intensities at Pedestrian Locations 20 and 22

CONFIGURATION J

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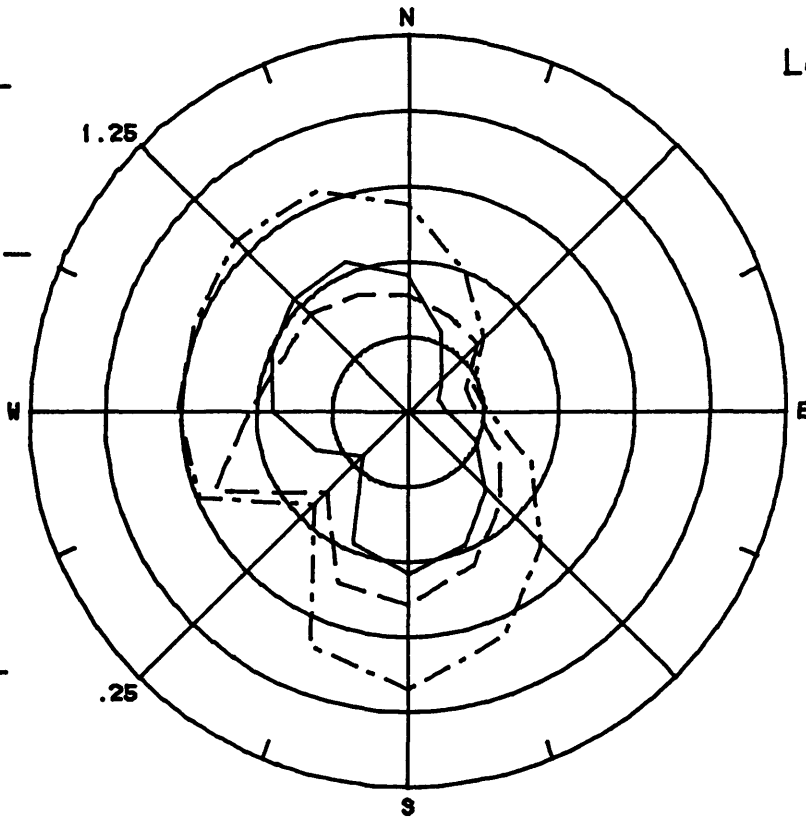
U_{inf}

1.25

$\frac{U_{mean} + 3.0 * U_{rms}}{U_{inf}}$ - - - -

U_{inf}

.25/Div



Location 23

$\frac{U_{rms}}{U_{inf}}$ - - - -

U_{inf}

.25

.05/Div

S

$\frac{U_{mean}}{U_{inf}}$ ———

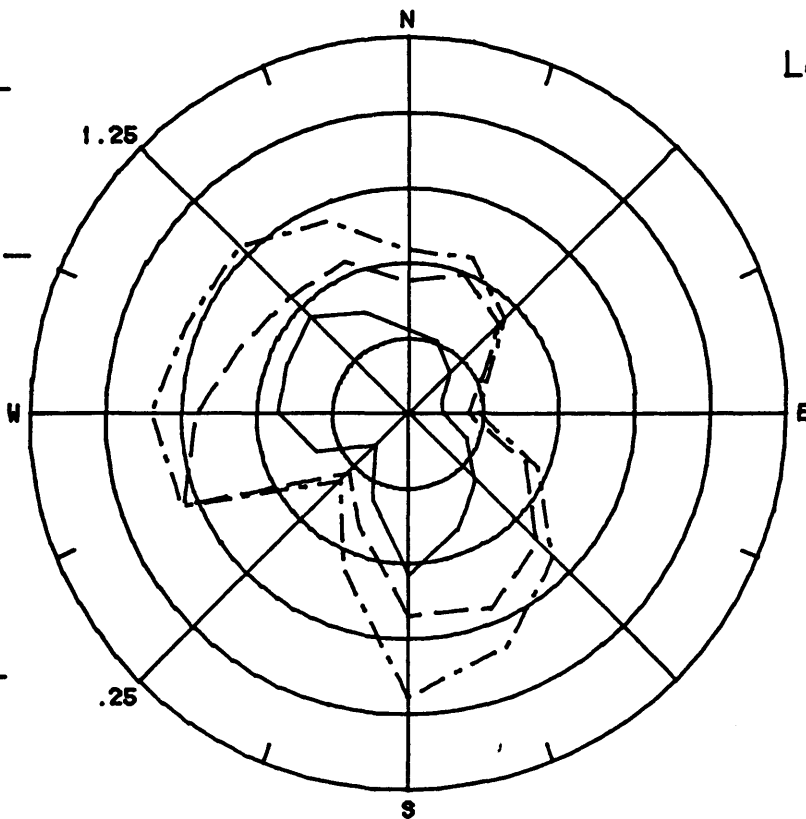
U_{inf}

1.25

$\frac{U_{mean} + 3.0 * U_{rms}}{U_{inf}}$ - - - -

U_{inf}

.25/Div



Location 24

$\frac{U_{rms}}{U_{inf}}$ - - - -

U_{inf}

.25

.05/Div

S

Figure 6j. Mean Velocities and Turbulence Intensities at Pedestrian Locations 23 and 24

CONFIGURATION K

$\frac{U_{mean}}{U_{inf}}$ ———

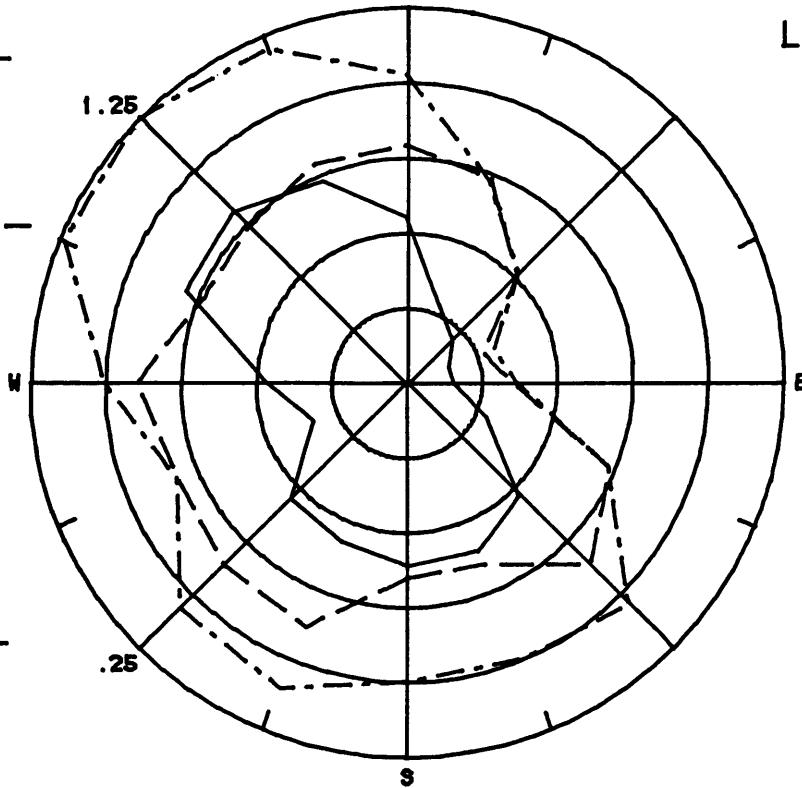
Location 20

U_{inf}

$\frac{U_{mean} + 3.0 \cdot U_{rms}}{U_{inf}}$ - - -

U_{inf}

.25/Div



$\frac{U_{rms}}{U_{inf}}$ - - -

U_{inf}

.05/Div

S

$\frac{U_{mean}}{U_{inf}}$ ———

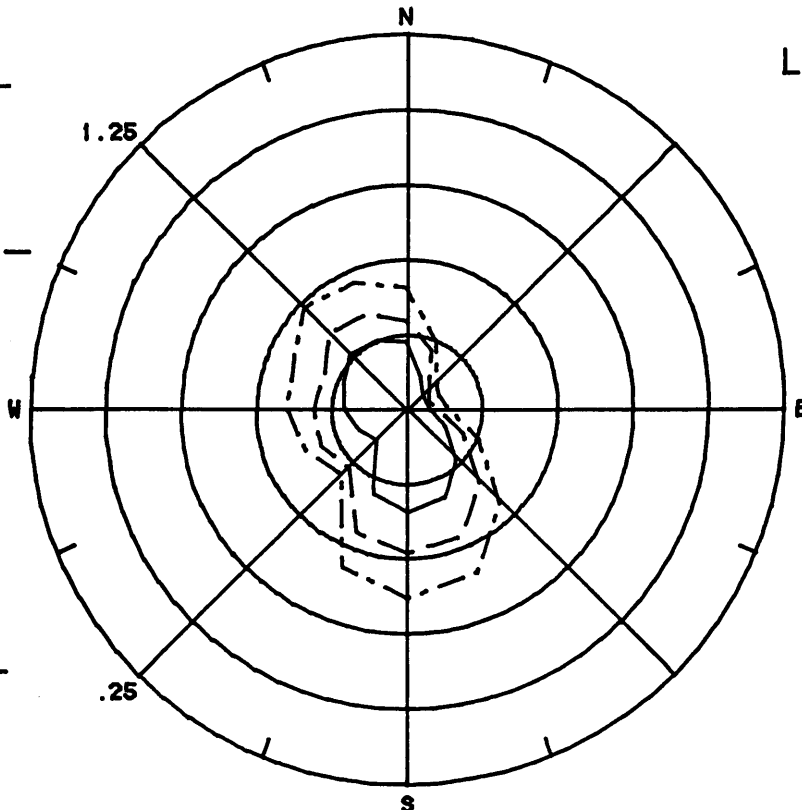
Location 23

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U_{inf}

.25/Div



$\frac{U_{rms}}{U_{inf}}$ - - -

U_{inf}

.05/Div

S

Figure 6k. Mean Velocities and Turbulence Intensities at Pedestrian Locations 20 and 23

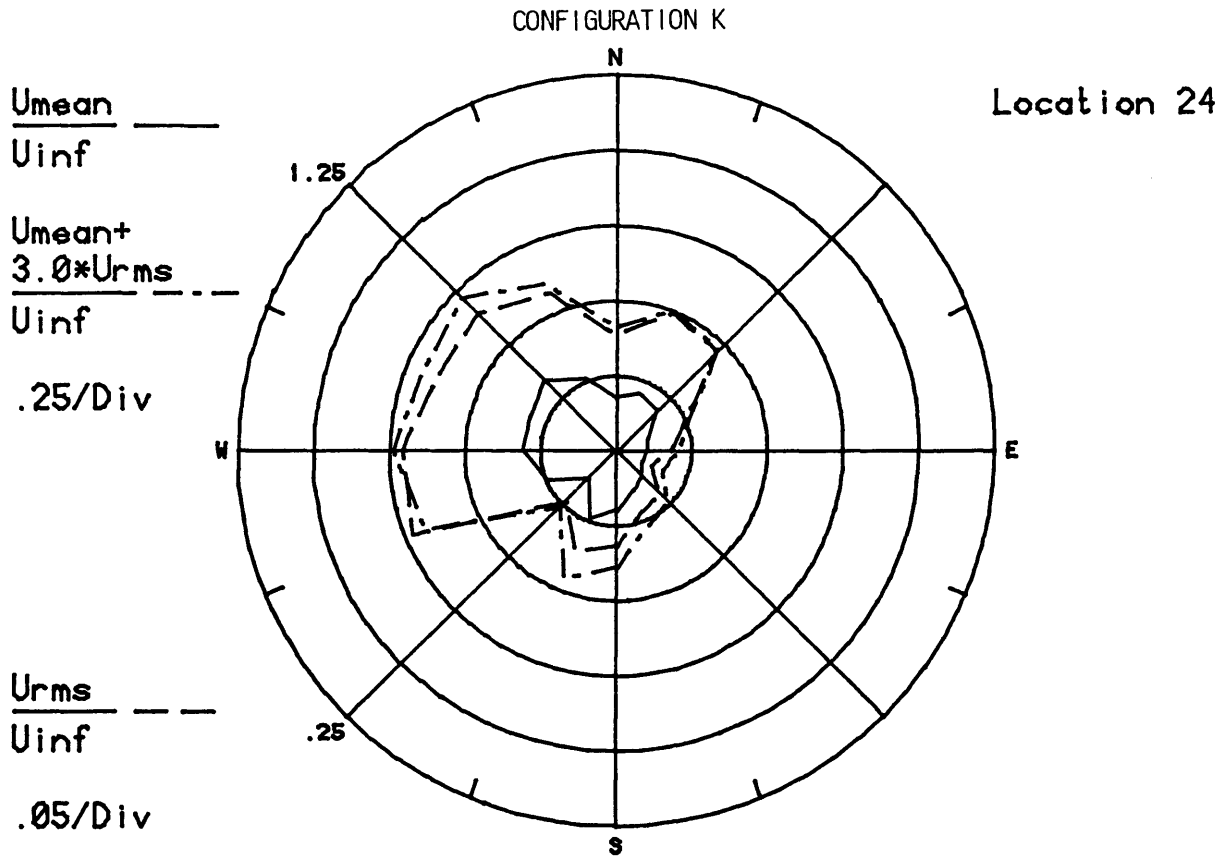


Figure 61. Mean Velocities and Turbulence Intensities at Pedestrian Location 24

CONFIGURATION G

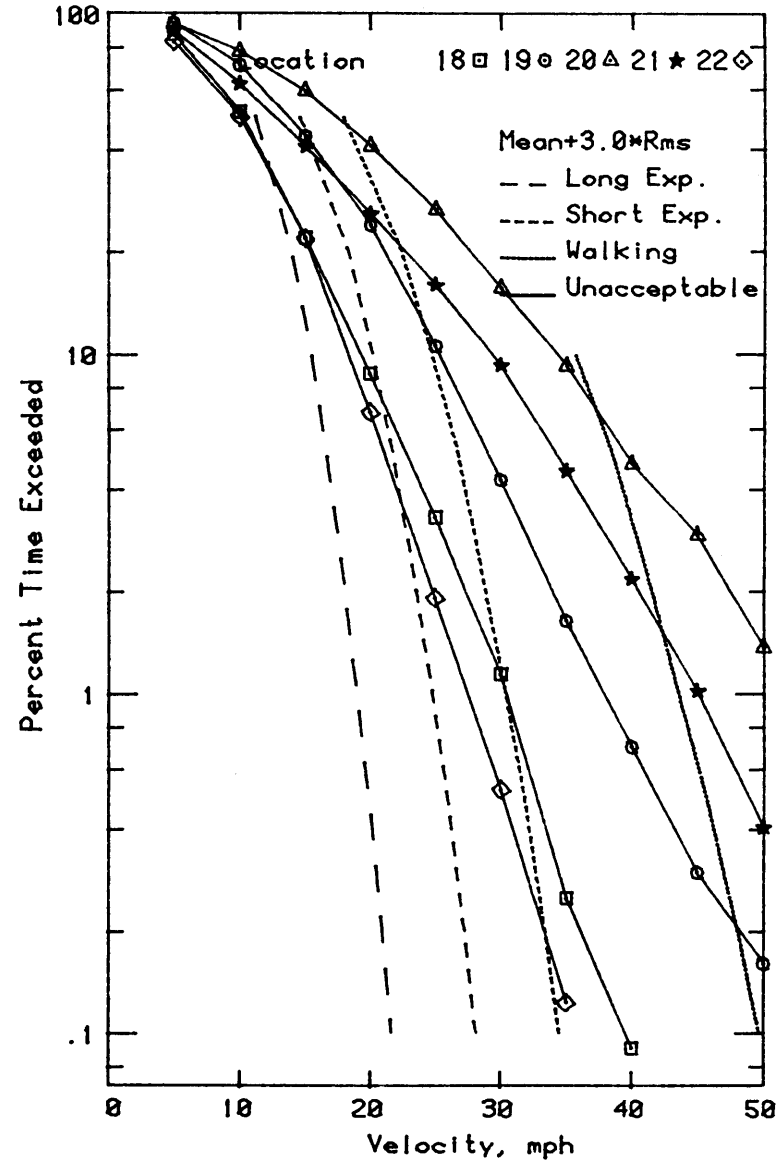
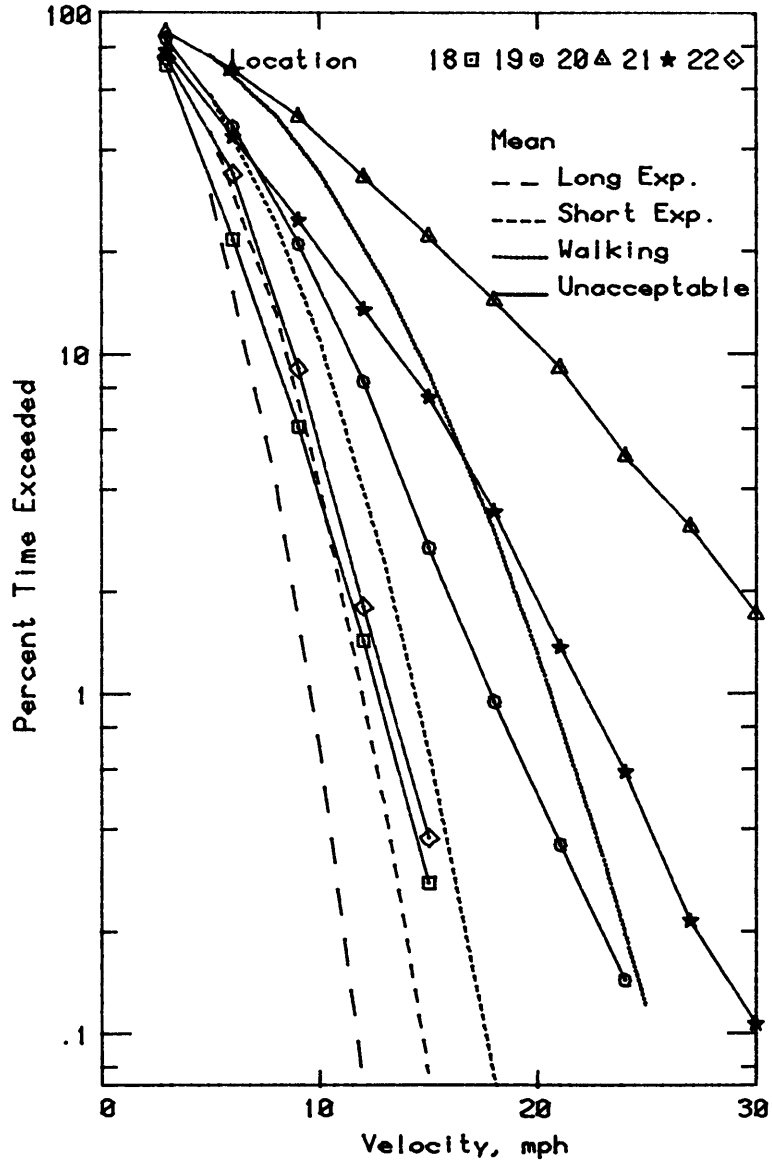


Figure 7a. Wind Velocity Probabilities for Pedestrian Locations

CONFIGURATION G

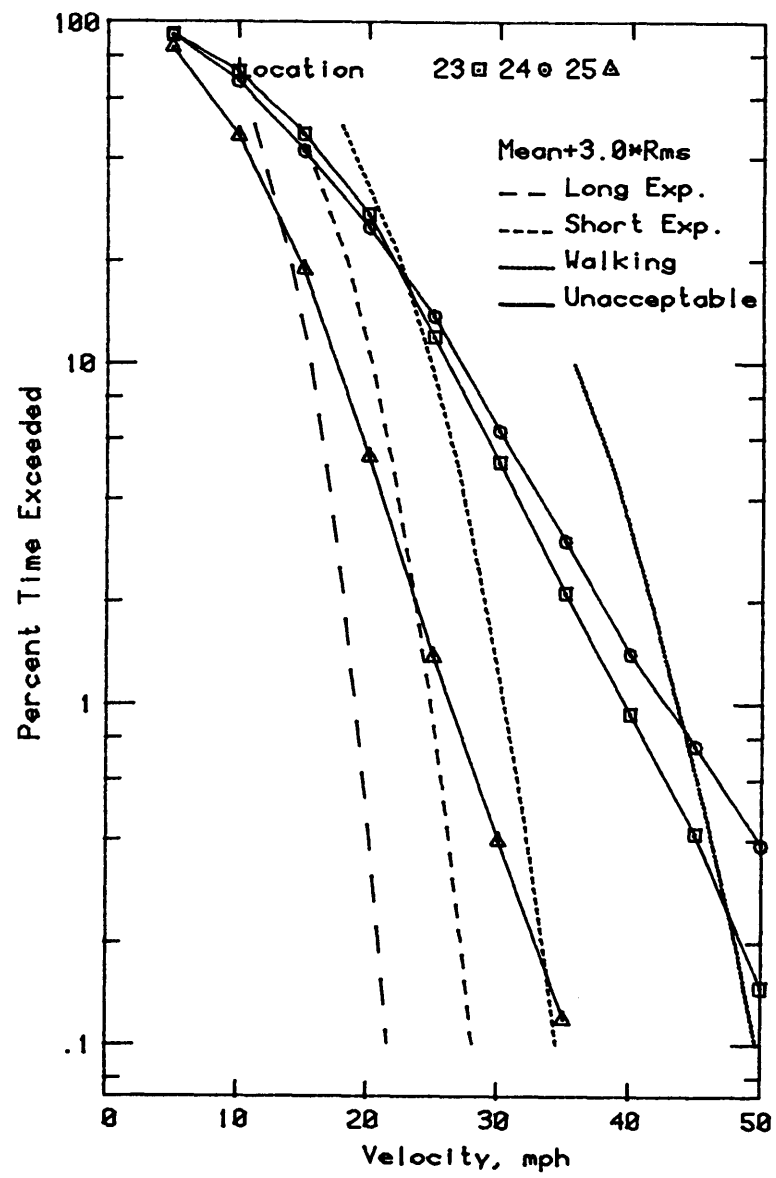
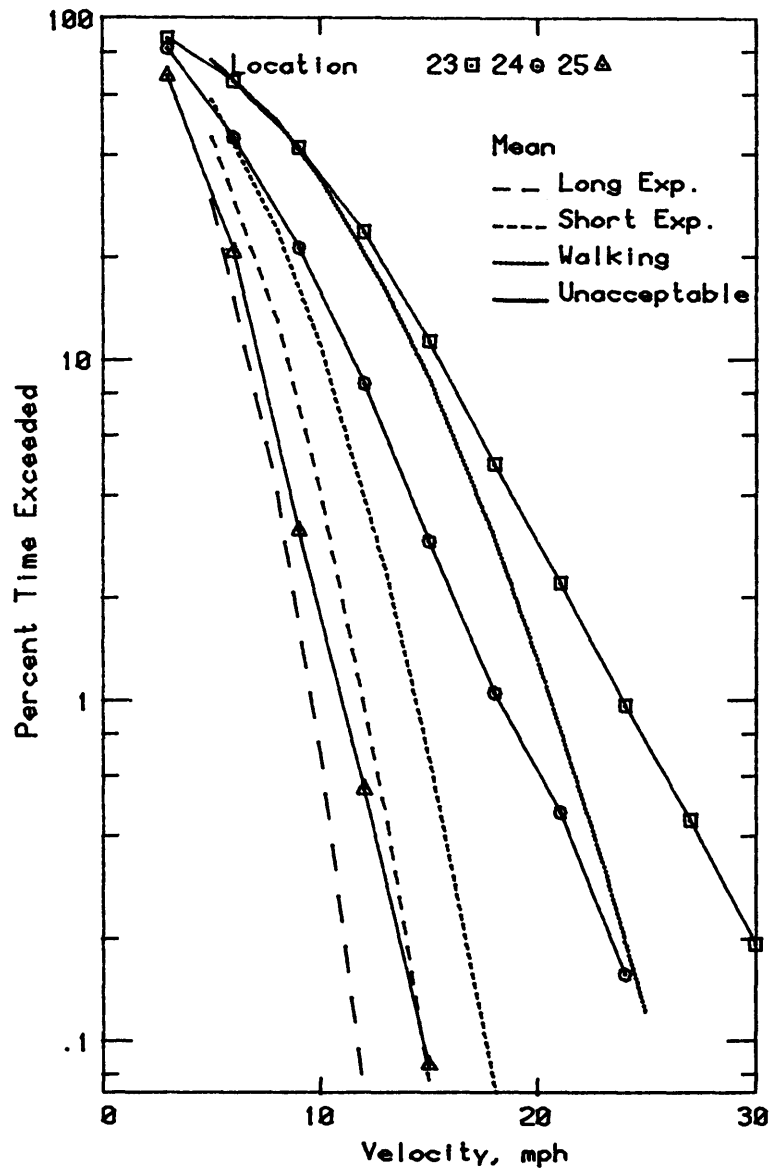


Figure 7b. Wind Velocity Probabilities for Pedestrian Locations

CONFIGURATION I

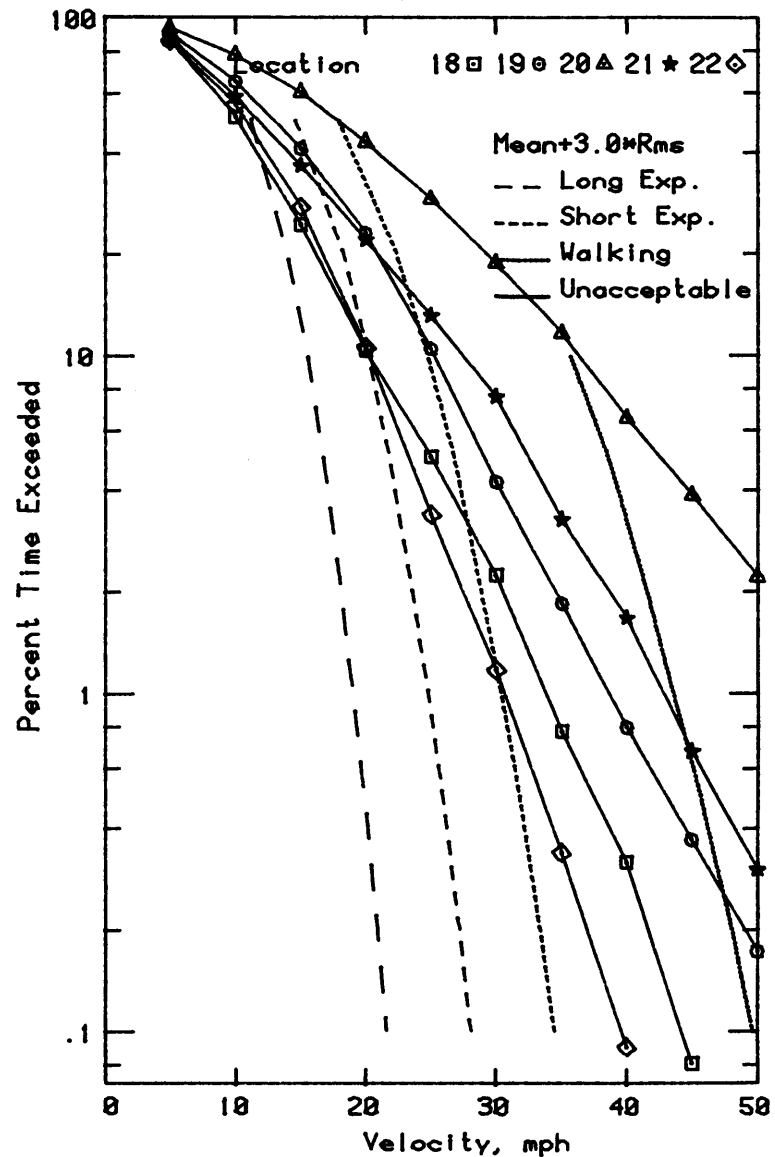
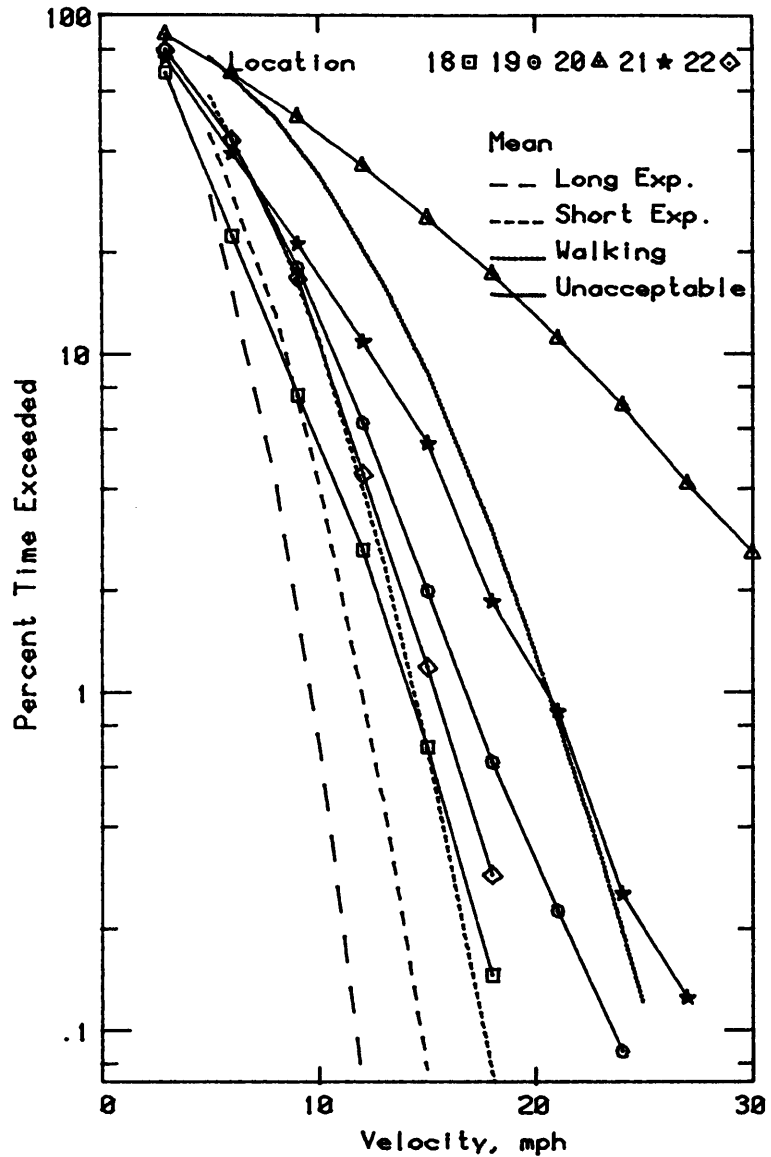


Figure 7c. Wind Velocity Probabilities for Pedestrian Locations

CONFIGURATION 1

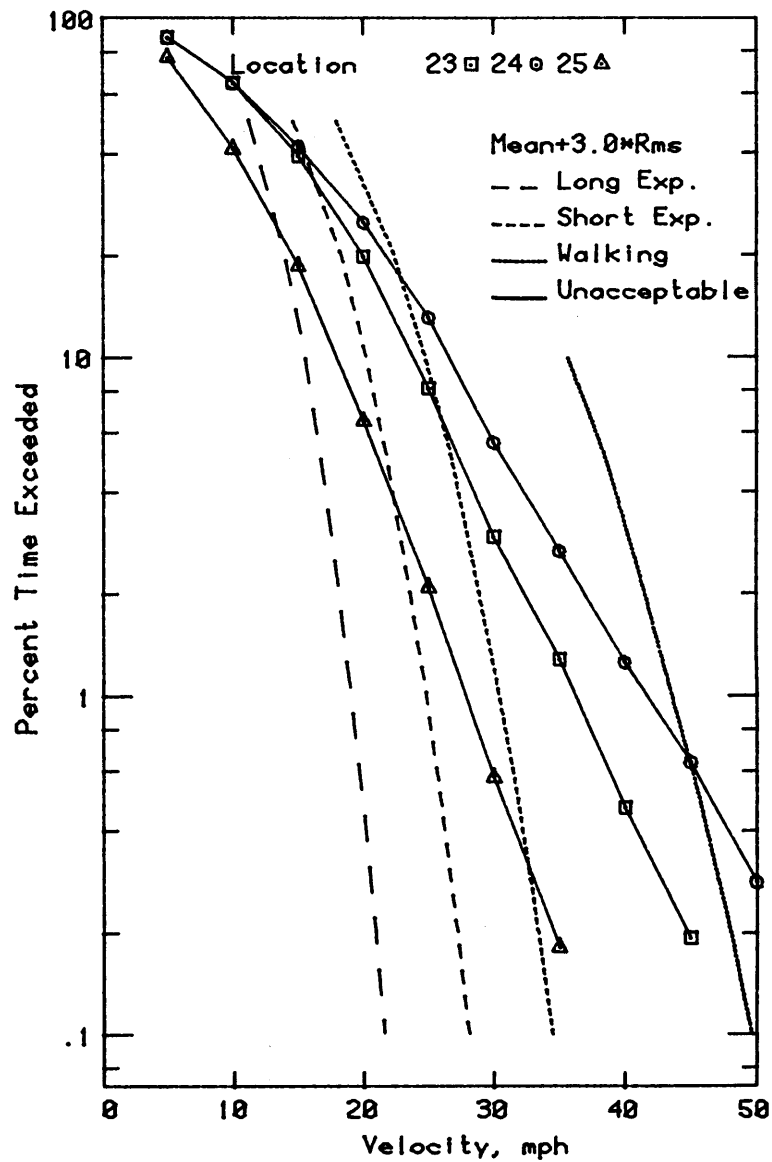
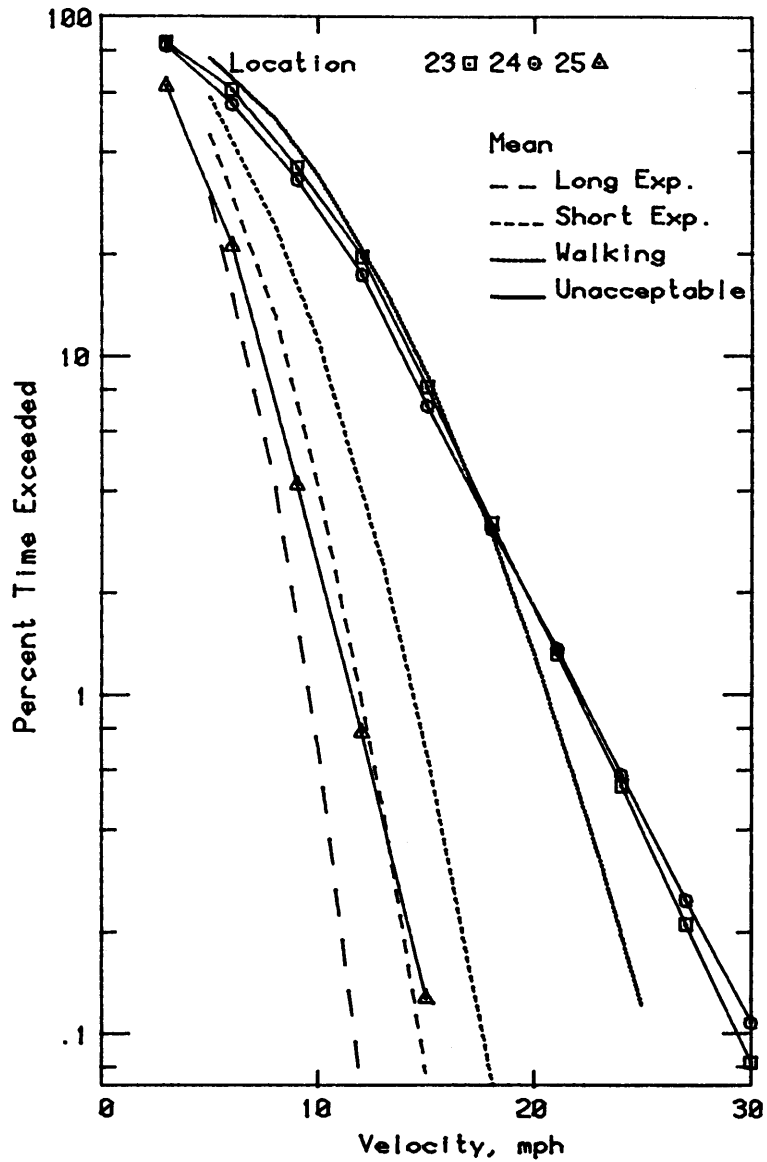


Figure 7d. Wind Velocity Probabilities for Pedestrian Locations

CONFIGURATION J

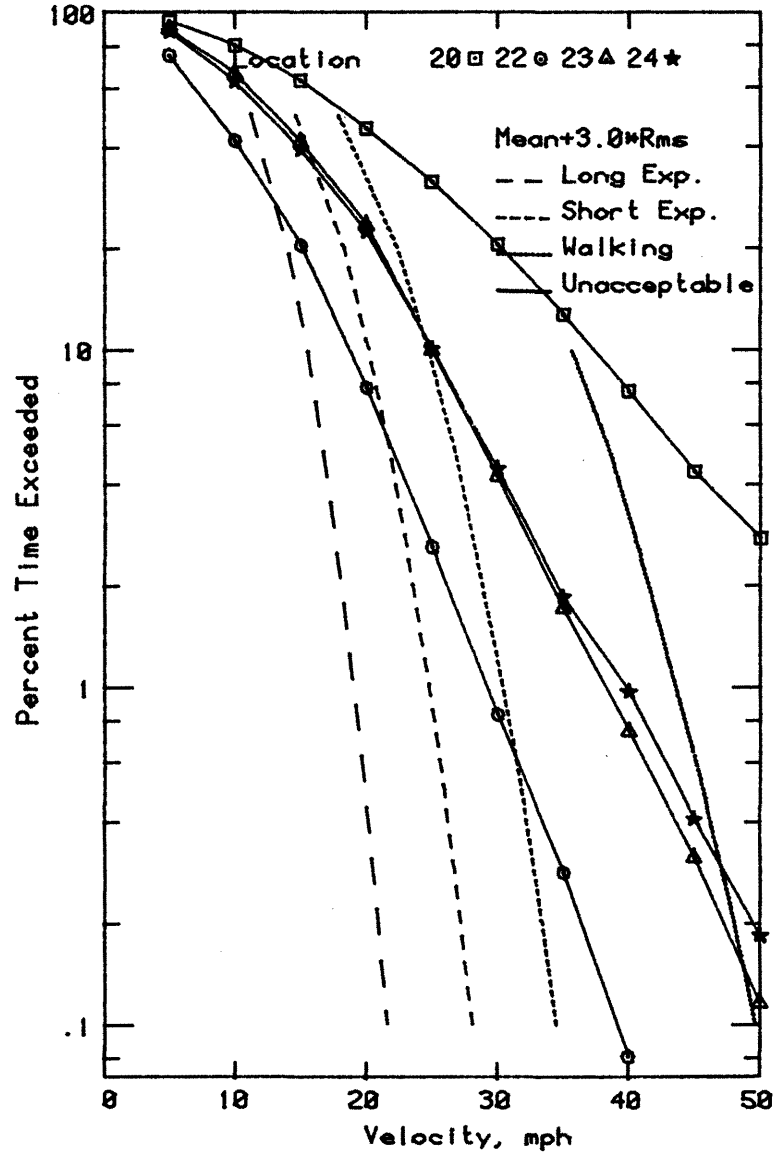
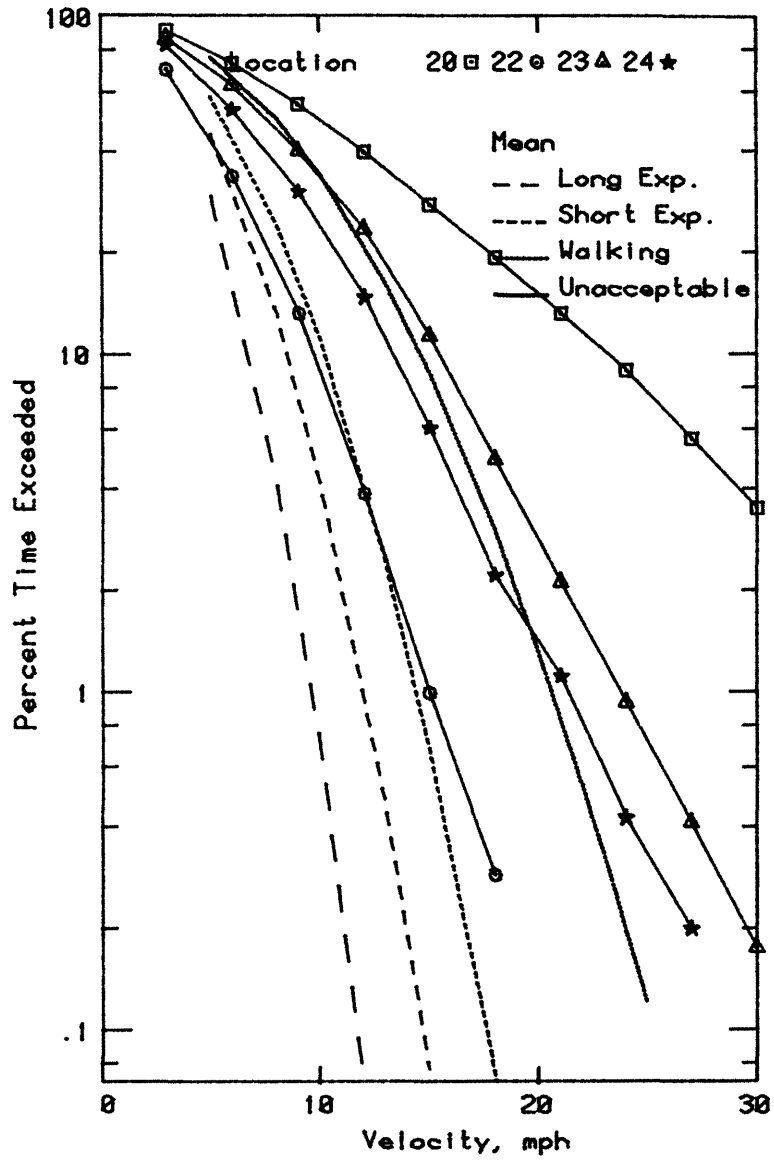


Figure 7e. Wind Velocity Probabilities for Pedestrian Locations

CONFIGURATION K

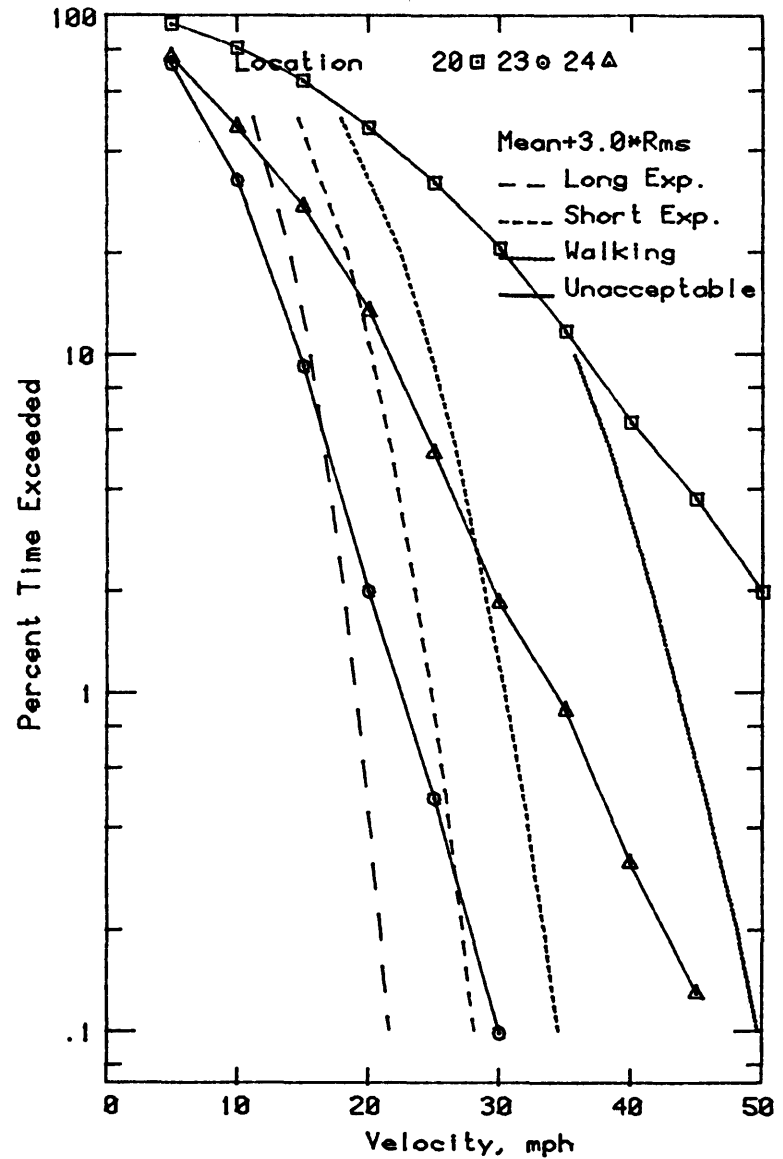
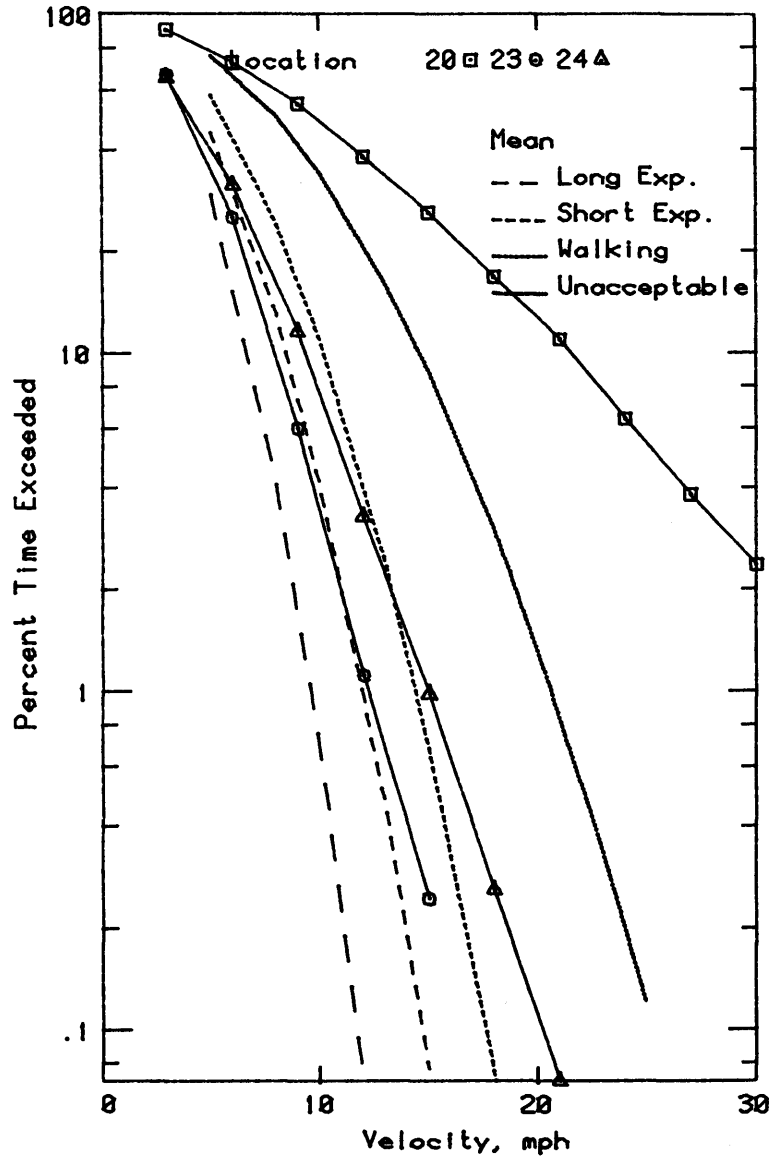


Figure 7f. Wind Velocity Probabilities for Pedestrian Locations

TABLES

TABLE 1 -- PEDESTRIAN WIND VELOCITIES AND TURBULENCE INTENSITIES
CONFIGURATION 6

LOCATION 18

WIND AZIMUTH	U/UR (PERCENT)	URMS/UR (PERCENT)	U+3.0*URMS/UR (PERCENT)
0.00	24.3	10.7	55.3
22.50	21.7	11.4	56.0
45.00	17.1	9.4	49.3
67.50	25.8	12.5	63.3
90.00	19.0	7.1	40.4
112.50	14.5	6.7	34.4
135.00	17.4	6.9	34.0
157.50	11.2	4.6	25.9
180.00	20.5	11.0	54.5
202.50	37.1	14.5	80.7
225.00	34.3	17.1	80.7
247.50	18.0	9.4	46.6
270.00	17.1	9.4	46.6
292.50	16.5	9.3	44.4
315.00	20.6	11.3	54.6
337.50	22.4	10.4	52.5

LOCATION 19

WIND AZIMUTH	U/UR (PERCENT)	URMS/UR (PERCENT)	U+3.0*URMS/UR (PERCENT)
0.00	25.6	13.6	66.5
22.50	28.7	14.9	72.5
45.00	23.1	13.1	62.3
67.50	25.1	11.9	60.9
90.00	19.4	10.2	50.1
112.50	17.8	8.7	44.0
135.00	20.1	10.1	50.3
157.50	22.7	12.4	67.3
180.00	25.1	11.3	59.1
202.50	39.4	14.3	72.4
225.00	33.0	14.0	73.1
247.50	45.6	14.1	80.8
270.00	40.6	14.4	83.8
292.50	30.9	14.9	75.6
315.00	24.7	13.1	63.9
337.50	28.8	15.1	74.2

LOCATION 20

WIND AZIMUTH	U/UR (PERCENT)	URMS/UR (PERCENT)	U+3.0*URMS/UR (PERCENT)
0.00	37.6	16.5	87.2
22.50	16.0	9.3	43.8
45.00	21.5	11.6	56.3
67.50	14.0	6.0	32.1
90.00	13.5	6.2	32.1
112.50	31.5	13.4	71.8
135.00	44.6	14.9	91.4
157.50	55.9	13.0	94.8
180.00	59.7	13.1	99.9
202.50	56.3	13.1	99.9
225.00	48.5	13.5	88.8
247.50	31.6	14.8	76.0
270.00	42.6	15.4	88.9
292.50	74.0	15.2	119.5
315.00	79.0	15.0	123.9
337.50	70.7	15.0	115.6

LOCATION 21

WIND AZIMUTH	U/UR (PERCENT)	URMS/UR (PERCENT)	U+3.0*URMS/UR (PERCENT)
0.00	15.5	6.9	36.1
22.50	15.9	7.0	36.7
45.00	16.1	7.0	37.2
67.50	19.3	7.6	42.0
90.00	17.8	9.0	44.9
112.50	17.5	8.6	43.3
135.00	22.3	10.8	53.8
157.50	24.6	12.0	59.5
180.00	24.9	12.0	61.0
202.50	42.6	21.3	106.5
225.00	61.1	19.7	120.1
247.50	60.1	18.1	114.4
270.00	38.2	15.9	85.9
292.50	28.0	14.7	69.2
315.00	26.9	13.0	64.6
337.50	16.2	7.6	36.9

TABLE 1 -- PEDESTRIAN WIND VELOCITIES AND TURBULENCE INTENSITIES
CONFIGURATION G

LOCATION 22

WIND AZIMUTH	U/UR (PERCENT)	URMS/UR (PERCENT)	U+3.0*RMS/UR (PERCENT)
0.00	24.1	8.9	50.7
22.50	13.0	4.7	27.2
45.00	9.4	3.4	19.5
67.50	11.3	3.9	23.0
90.00	10.2	4.3	23.1
112.50	15.8	7.8	39.3
135.00	27.5	11.7	62.6
157.50	30.0	10.1	60.3
180.00	31.6	10.2	62.2
202.50	25.4	11.4	59.6
225.00	30.8	13.5	71.3
247.50	22.7	8.7	48.8
270.00	24.3	7.2	45.8
292.50	25.5	9.0	52.5
315.00	28.6	10.5	60.0
337.50	29.8	11.4	64.1

LOCATION 23

WIND AZIMUTH	U/UR (PERCENT)	URMS/UR (PERCENT)	U+3.0*RMS/UR (PERCENT)
0.00	43.2	10.9	76.1
22.50	30.0	10.7	62.2
45.00	17.6	8.5	43.2
67.50	10.0	3.8	21.5
90.00	14.5	6.3	33.4
112.50	27.6	8.0	51.6
135.00	35.5	10.7	67.6
157.50	45.0	12.4	82.1
180.00	51.0	14.2	93.4
202.50	45.8	13.9	87.4
225.00	36.0	11.0	68.9
247.50	34.5	14.3	77.3
270.00	45.0	10.4	76.1
292.50	49.7	9.3	77.6
315.00	55.7	10.2	86.2
337.50	51.1	9.5	79.7

LOCATION 24

WIND AZIMUTH	U/UR (PERCENT)	URMS/UR (PERCENT)	U+3.0*RMS/UR (PERCENT)
0.00	24.6	13.8	67.8
22.50	29.2	14.7	73.3
45.00	26.2	12.7	64.4
67.50	12.4	5.7	29.6
90.00	13.7	6.1	32.1
112.50	20.2	8.9	46.8
135.00	29.9	13.3	69.8
157.50	37.0	15.9	84.7
180.00	46.3	17.4	98.5
202.50	37.7	15.6	84.6
225.00	19.3	8.4	44.5
247.50	38.4	17.9	92.1
270.00	42.2	18.5	97.7
292.50	31.5	16.0	79.6
315.00	20.1	10.3	50.8
337.50	22.4	11.8	57.8

LOCATION 25

WIND AZIMUTH	U/UR (PERCENT)	URMS/UR (PERCENT)	U+3.0*RMS/UR (PERCENT)
0.00	21.0	9.9	50.6
22.50	15.0	7.0	36.6
45.00	18.2	9.2	45.9
67.50	17.0	9.8	46.4
90.00	13.2	5.6	30.1
112.50	15.7	7.7	38.8
135.00	16.4	7.8	39.7
157.50	12.7	6.0	30.9
180.00	16.6	7.6	39.3
202.50	20.8	9.1	48.3
225.00	16.5	7.8	39.9
247.50	23.5	9.7	52.5
270.00	24.2	11.0	57.2
292.50	20.5	10.3	51.3
315.00	21.3	11.5	55.7
337.50	23.5	12.1	59.8

TABLE 1 -- PEDESTRIAN WIND VELOCITIES AND TURBULENCE INTENSITIES
CONFIGURATION G

** GREATEST VALUES **

U _{MEAN} /U _{INF} (PERCENT)					U _{RMS} /U _{INF} (PERCENT)					U _{MEAN+3.0*RMS} /U _{INF} (PERCENT)				
LOC	AZ	MEAN	RMS	M+3.0RMS	LOC	AZ	MEAN	RMS	M+3.0RMS	LOC	AZ	MEAN	RMS	M+3.0RMS
20	315.0	79.0	15.0	123.9	21	202.5	42.6	21.3	106.5	20	315.0	79.0	15.0	123.9
20	292.5	74.0	15.2	119.5	21	225.0	61.1	19.7	120.1	21	225.0	61.1	19.7	120.1
20	337.5	70.7	15.0	115.6	24	270.0	42.2	18.5	97.7	20	292.5	74.0	15.2	119.5
21	225.0	61.1	19.7	120.1	21	247.5	60.1	18.1	114.4	20	337.5	70.7	15.0	115.6
21	247.5	60.1	18.1	114.4	24	247.5	38.4	17.9	92.1	21	247.5	60.1	18.1	114.4
20	180.0	59.7	13.1	98.9	24	180.0	46.3	17.4	98.5	21	202.5	42.6	21.3	106.5
20	202.5	56.3	13.1	95.8	18	225.0	34.3	17.1	85.7	20	180.0	59.7	13.1	98.9
20	157.5	55.9	13.0	94.8	20	0.0	37.6	16.5	87.2	24	180.0	46.3	17.4	98.5
23	315.0	55.7	10.2	86.2	24	292.5	31.5	16.0	79.6	24	270.0	42.2	18.5	97.7
23	337.5	51.1	9.5	79.7	24	157.5	37.0	15.9	84.7	20	202.5	56.3	13.1	95.8

TABLE 1 -- PEDESTRIAN WIND VELOCITIES AND TURBULENCE INTENSITIES
CONFIGURATION I

LOCATION 18

WIND AZIMUTH	U/UR (PERCENT)	URMS/UR (PERCENT)	U+3.0*RMS/UR (PERCENT)
0.00	26.1	12.2	62.8
22.50	24.0	11.9	59.7
45.00	15.3	7.4	37.5
67.50	24.2	11.7	59.7
90.00	16.1	6.1	34.4
112.50	13.6	5.3	27.4
135.00	16.4	6.8	36.2
157.50	13.7	6.5	33.3
180.00	17.2	10.5	48.6
202.50	36.2	16.1	84.4
225.00	43.4	19.6	102.1
247.50	16.6	10.5	48.1
270.00	14.6	8.2	39.2
292.50	16.6	10.4	47.6
315.00	23.1	13.3	63.0
337.50	24.2	11.7	59.3

LOCATION 19

WIND AZIMUTH	U/UR (PERCENT)	URMS/UR (PERCENT)	U+3.0*RMS/UR (PERCENT)
0.00	26.2	13.4	66.5
22.50	24.7	14.1	68.0
45.00	12.3	12.5	60.8
67.50	24.3	10.5	51.7
90.00	16.7	5.6	29.5
112.50	13.4	5.8	29.8
135.00	13.9	10.1	51.3
157.50	12.2	12.8	63.5
180.00	14.4	10.7	56.7
202.50	12.2	10.7	54.4
225.00	14.4	14.8	76.8
247.50	14.4	14.4	85.6
270.00	14.9	16.5	87.3
292.50	16.6	14.9	74.4
315.00	23.0	15.0	71.9
337.50	27.2	13.9	68.9

LOCATION 20

WIND AZIMUTH	U/UR (PERCENT)	URMS/UR (PERCENT)	U+3.0*RMS/UR (PERCENT)
0.00	29.0	16.4	78.1
22.50	12.8	7.3	34.7
45.00	21.6	11.6	56.3
67.50	14.8	5.8	32.3
90.00	15.6	6.5	35.1
112.50	34.3	14.3	77.3
135.00	55.1	17.3	107.0
157.50	61.6	14.4	104.9
180.00	64.1	14.0	106.1
202.50	64.6	14.4	107.8
225.00	53.0	14.6	96.7
247.50	27.7	12.6	65.4
270.00	45.6	15.9	93.3
292.50	78.3	16.0	126.1
315.00	86.9	16.0	135.1
337.50	69.3	17.3	121.4

LOCATION 21

WIND AZIMUTH	U/UR (PERCENT)	URMS/UR (PERCENT)	U+3.0*RMS/UR (PERCENT)
0.00	14.9	6.8	35.2
22.50	13.0	5.5	29.5
45.00	13.0	10.7	30.2
67.50	17.4	7.1	39.0
90.00	16.3	8.0	40.3
112.50	18.2	9.5	46.6
135.00	22.1	11.6	56.9
157.50	23.3	10.5	52.9
180.00	31.3	11.4	57.7
202.50	38.8	20.7	101.0
225.00	38.8	19.8	115.2
247.50	35.4	18.1	109.7
270.00	34.7	15.3	81.5
292.50	41.7	11.7	60.0
315.00	33.3	10.8	55.7
337.50	16.4	7.6	39.2

TABLE 1 -- PEDESTRIAN WIND VELOCITIES AND TURBULENCE INTENSITIES
CONFIGURATION I

LOCATION 22

WIND AZIMUTH	U/UR (PERCENT)	URMS/UR (PERCENT)	U+3.0*URMS/UR (PERCENT)
0.00	31.3	9.5	59.7
22.50	21.5	5.9	39.1
45.00	10.7	3.2	20.4
67.50	14.4	4.5	28.0
90.00	11.3	4.6	25.2
112.50	15.8	7.7	38.9
135.00	28.1	10.9	60.9
157.50	29.9	10.1	60.3
180.00	31.8	10.4	63.1
202.50	28.8	10.0	58.8
225.00	37.6	13.8	79.0
247.50	26.2	9.0	53.1
270.00	26.5	7.3	48.4
292.50	30.3	9.5	58.8
315.00	34.0	11.4	68.2
337.50	36.7	12.1	73.0

LOCATION 23

WIND AZIMUTH	U/UR (PERCENT)	URMS/UR (PERCENT)	U+3.0*URMS/UR (PERCENT)
0.00	42.8	7.9	66.4
22.50	25.1	6.6	45.0
45.00	13.0	5.1	28.3
67.50	8.6	3.4	18.9
90.00	10.7	4.7	24.9
112.50	22.4	6.5	41.8
135.00	34.3	10.1	64.7
157.50	43.8	11.7	78.9
180.00	48.0	13.5	88.6
202.50	45.5	13.6	86.2
225.00	32.2	11.2	65.8
247.50	28.3	11.0	61.4
270.00	43.0	10.1	73.4
292.50	43.8	8.3	68.8
315.00	49.5	8.1	73.9
337.50	49.6	7.7	72.7

LOCATION 24

WIND AZIMUTH	U/UR (PERCENT)	URMS/UR (PERCENT)	U+3.0*URMS/UR (PERCENT)
0.00	28.2	8.4	53.3
22.50	26.8	10.2	57.4
45.00	19.0	8.6	44.8
67.50	11.9	4.9	26.5
90.00	9.9	3.9	21.6
112.50	20.3	8.7	46.4
135.00	30.8	11.5	65.2
157.50	47.3	13.6	88.1
180.00	50.5	15.2	96.1
202.50	31.3	10.1	61.5
225.00	18.1	6.0	36.0
247.50	39.2	17.8	92.6
270.00	47.7	14.3	90.5
292.50	44.5	12.1	80.7
315.00	45.2	11.5	79.8
337.50	39.4	10.3	70.2

LOCATION 25

WIND AZIMUTH	U/UR (PERCENT)	URMS/UR (PERCENT)	U+3.0*URMS/UR (PERCENT)
0.00	28.0	9.5	56.6
22.50	10.3	3.9	22.0
45.00	13.2	5.7	30.4
67.50	13.4	6.3	32.2
90.00	11.7	4.7	25.9
112.50	12.8	5.5	29.3
135.00	11.5	5.1	26.8
157.50	10.4	4.7	24.4
180.00	13.4	5.8	30.8
202.50	18.7	8.3	43.8
225.00	13.9	6.1	33.2
247.50	20.7	9.7	49.7
270.00	21.7	10.5	53.1
292.50	21.1	10.2	51.8
315.00	26.1	13.7	67.2
337.50	30.8	12.7	68.9

TABLE 1 -- PEDESTRIAN WIND VELOCITIES AND TURBULENCE INTENSITIES
CONFIGURATION I

** GREATEST VALUES **

UMEAN/UINF (PERCENT)					URMS/UINF (PERCENT)					UMEAN+3.0*RMS/UINF (PERCENT)				
LOC	AZ	MEAN	RMS	M+3.0RMS	LOC	AZ	MEAN	RMS	M+3.0RMS	LOC	AZ	MEAN	RMS	M+3.0RMS
20	315.0	86.9	16.0	135.1	21	202.5	38.8	20.7	101.0	20	315.0	86.9	16.0	135.1
20	292.5	78.3	16.0	126.1	21	225.0	55.9	19.8	115.2	20	292.5	78.3	16.0	126.1
20	337.5	69.3	17.3	121.4	18	225.0	43.4	19.6	102.1	20	337.5	69.3	17.3	121.4
20	202.5	64.6	14.4	107.8	21	247.5	55.4	18.1	109.7	21	225.0	55.9	19.8	115.2
20	180.0	64.1	14.0	106.1	24	247.5	39.2	17.8	92.6	21	247.5	55.4	18.1	109.7
20	157.5	61.6	14.4	104.9	20	337.5	69.3	17.3	121.4	20	202.5	64.6	14.4	107.8
21	225.0	55.9	19.8	115.2	20	135.0	55.1	17.3	107.0	20	135.0	55.1	17.3	107.0
21	247.5	55.4	18.1	109.7	19	270.0	37.9	16.5	87.3	20	180.0	64.1	14.0	106.1
20	135.0	55.1	17.3	107.0	20	0.0	29.0	16.4	78.1	20	157.5	61.6	14.4	104.9
20	225.0	53.0	14.6	96.7	18	202.5	36.2	16.1	84.4	18	225.0	43.4	19.6	102.1

TABLE 1 -- PEDESTRIAN WIND VELOCITIES AND TURBULENCE INTENSITIES
CONFIGURATION J

LOCATION 20

WIND AZIMUTH	U/UR (PERCENT)	URMS/UR (PERCENT)	U+3.0*RMS/UR (PERCENT)
0.00	54.3	15.7	101.6
22.50	26.2	13.5	66.6
45.00	23.4	11.4	57.7
67.50	14.5	5.3	30.4
90.00	16.2	7.0	37.2
112.50	32.2	14.2	74.8
135.00	52.5	16.2	101.3
157.50	62.4	15.1	107.7
180.00	63.6	13.8	105.0
202.50	61.6	13.3	101.6
225.00	51.6	14.7	95.6
247.50	30.8	13.1	70.2
270.00	47.2	17.9	100.8
292.50	87.3	15.9	135.0
315.00	90.2	14.4	133.2
337.50	76.3	14.2	118.9

LOCATION 22

WIND AZIMUTH	U/UR (PERCENT)	URMS/UR (PERCENT)	U+3.0*RMS/UR (PERCENT)
0.00	28.2	9.3	56.0
22.50	15.9	5.5	32.4
45.00	9.7	2.7	17.8
67.50	10.3	2.9	19.0
90.00	9.0	2.7	17.1
112.50	14.0	3.5	24.6
135.00	19.7	4.2	32.4
157.50	26.1	4.6	40.0
180.00	28.2	5.3	44.1
202.50	30.2	4.4	58.5
225.00	15.8	5.9	33.6
247.50	16.5	6.4	35.6
270.00	27.5	8.1	51.8
292.50	31.8	10.0	61.8
315.00	35.2	11.1	68.6
337.50	33.6	11.2	67.1

LOCATION 23

WIND AZIMUTH	U/UR (PERCENT)	URMS/UR (PERCENT)	U+3.0*RMS/UR (PERCENT)
0.00	45.5	7.8	68.9
22.50	29.2	6.9	50.1
45.00	16.1	6.4	35.4
67.50	10.8	4.1	23.0
90.00	13.3	4.6	27.0
112.50	24.3	6.6	44.3
135.00	36.4	8.6	62.2
157.50	48.1	11.1	81.4
180.00	53.8	12.8	92.3
202.50	47.5	12.3	84.4
225.00	20.7	7.6	43.5
247.50	33.3	13.8	74.7
270.00	44.8	10.4	76.0
292.50	49.1	9.0	76.0
315.00	53.0	9.1	80.4
337.50	53.9	8.4	79.1

LOCATION 24

WIND AZIMUTH	U/UR (PERCENT)	URMS/UR (PERCENT)	U+3.0*RMS/UR (PERCENT)
0.00	27.8	8.8	54.1
22.50	26.0	9.9	55.7
45.00	19.7	8.5	45.2
67.50	12.1	5.1	27.4
90.00	11.5	3.9	23.3
112.50	21.3	8.4	46.4
135.00	31.4	12.1	67.6
157.50	42.0	14.0	84.0
180.00	53.7	15.5	94.1
202.50	31.1	8.3	56.1
225.00	14.8	5.6	31.6
247.50	33.0	16.0	81.0
270.00	42.9	13.9	84.6
292.50	43.0	11.8	78.5
315.00	45.4	10.9	78.2
337.50	36.4	10.9	68.9

TABLE 1 -- PEDESTRIAN WIND VELOCITIES AND TURBULENCE INTENSITIES
CONFIGURATION J

** GREATEST VALUES **

UMEAN/UINF (PERCENT)					URMS/UINF (PERCENT)					UMEAN+3.0*RMS/UINF (PERCENT)				
LOC	AZ	MEAN	RMS	M+3.0RMS	LOC	AZ	MEAN	RMS	M+3.0RMS	LOC	AZ	MEAN	RMS	M+3.0RMS
20	315.0	90.2	14.4	133.2	20	270.0	47.2	17.9	100.8	20	292.5	87.3	15.9	135.0
20	292.5	87.3	15.9	135.0	20	135.0	52.5	16.2	101.3	20	315.0	90.2	14.4	133.2
20	337.5	76.3	14.2	118.9	24	247.5	33.0	16.0	81.0	20	337.5	76.3	14.2	118.9
20	180.0	63.6	13.8	105.0	20	292.5	87.3	15.9	135.0	20	157.5	62.4	15.1	107.7
20	157.5	62.4	15.1	107.7	20	0.0	54.3	15.7	101.6	20	180.0	63.6	13.8	105.0
20	202.5	61.6	13.3	101.6	20	157.5	62.4	15.1	107.7	20	202.5	61.6	13.3	101.6
20	0.0	54.3	15.7	101.6	20	225.0	51.6	14.7	95.6	20	0.0	54.3	15.7	101.6
23	337.5	53.9	8.4	79.1	20	315.0	90.2	14.4	133.2	20	135.0	52.5	16.2	101.3
23	180.0	53.8	12.8	92.3	20	112.5	32.2	14.2	74.8	20	270.0	47.2	17.9	100.8
24	180.0	53.7	13.5	94.1	20	337.5	76.3	14.2	118.9	20	225.0	51.6	14.7	95.6

TABLE 1 -- PEDESTRIAN WIND VELOCITIES AND TURBULENCE INTENSITIES
CONFIGURATION K

LOCATION 20

WIND AZIMUTH	U/UR (PERCENT)	URMS/UR (PERCENT)	U+3.0*RMS/UR (PERCENT)
0.00	55.3	15.8	102.8
22.50	28.4	14.7	72.5
45.00	21.4	10.3	52.4
67.50	14.7	5.4	30.8
90.00	15.5	7.1	36.9
112.50	28.6	14.6	72.3
135.00	52.7	17.1	104.1
157.50	60.3	13.1	99.6
180.00	60.7	13.0	99.8
202.50	57.3	17.6	110.2
225.00	54.9	17.2	106.5
247.50	33.3	16.5	82.8
270.00	46.8	17.9	100.5
292.50	79.4	14.6	123.3
315.00	80.7	14.7	124.9
337.50	72.7	15.8	120.1

LOCATION 23

WIND AZIMUTH	U/UR (PERCENT)	URMS/UR (PERCENT)	U+3.0*RMS/UR (PERCENT)
0.00	22.8	5.9	40.6
22.50	12.1	4.3	25.1
45.00	7.9	2.0	13.9
67.50	7.2	1.5	11.8
90.00	7.8	2.1	14.1
112.50	13.7	4.0	25.7
135.00	22.9	6.8	43.3
157.50	31.7	9.2	59.3
180.00	34.3	9.6	63.2
202.50	30.3	8.9	57.0
225.00	14.1	5.5	30.6
247.50	17.5	6.3	36.4
270.00	21.3	6.2	39.9
292.50	22.9	5.9	40.5
315.00	26.2	7.2	47.9
337.50	25.1	6.9	45.7

LOCATION 24

WIND AZIMUTH	U/UR (PERCENT)	URMS/UR (PERCENT)	U+3.0*RMS/UR (PERCENT)
0.00	18.0	7.7	41.1
22.50	20.7	9.9	50.4
45.00	19.3	9.4	47.6
67.50	10.9	4.8	25.3
90.00	9.8	3.6	20.6
112.50	18.9	2.5	16.4
135.00	12.0	4.1	24.4
157.50	14.0	4.3	27.0
180.00	19.7	6.3	38.7
202.50	24.0	7.3	45.8
225.00	12.3	4.8	26.6
247.50	25.0	14.6	68.7
270.00	31.1	14.2	73.5
292.50	30.3	12.7	68.5
315.00	33.2	12.8	71.7
337.50	25.9	11.4	60.0

TABLE 1 -- PEDESTRIAN WIND VELOCITIES AND TURBULENCE INTENSITIES
CONFIGURATION K

** GREATEST VALUES **

UMEAN/UINF (PERCENT)					URMS/UINF (PERCENT)					UMEAN+3.0*RMS/UINF (PERCENT)				
LOC	AZ	MEAN	RMS	M+3.0RMS	LOC	AZ	MEAN	RMS	M+3.0RMS	LOC	AZ	MEAN	RMS	M+3.0RMS
20	315.0	80.7	14.7	124.9	20	270.0	46.8	17.9	100.5	20	315.0	80.7	14.7	124.9
20	292.5	79.4	14.6	123.3	20	202.5	57.3	17.6	110.2	20	292.5	79.4	14.6	123.3
20	337.5	72.7	15.8	120.1	20	225.0	54.9	17.2	106.5	20	337.5	72.7	15.8	120.1
20	180.0	60.7	13.0	99.8	20	135.0	52.7	17.1	104.1	20	202.5	57.3	17.6	110.2
20	157.5	60.3	13.1	99.6	20	247.5	33.3	16.5	82.8	20	225.0	54.9	17.2	106.5
20	202.5	57.3	17.6	110.2	20	0.0	55.3	15.8	102.8	20	135.0	52.7	17.1	104.1
20	0.0	55.3	15.8	102.8	20	337.5	72.7	15.8	120.1	20	0.0	55.3	15.8	102.8
20	225.0	54.9	17.2	106.5	20	315.0	80.7	14.7	124.9	20	270.0	46.8	17.9	100.5
20	135.0	52.7	17.1	104.1	20	22.5	28.4	14.7	72.5	20	180.0	60.7	13.0	99.8
20	270.0	46.8	17.9	100.5	20	292.5	79.4	14.6	123.3	20	157.5	60.3	13.1	99.6

TABLE 2

PERCENTAGE FREQUENCIES OF WIND DIRECTION AND SPEED

GENERAL LOGAN INTERNATIONAL AIRPORT

(1965-1974)

SEASON: ANNUAL

NO. OF OBS. = 29206

HT. OF MEAS. = 22 FT

VELOCITY LEVELS IN MPH

DIRECTION	0-4	5-7	8-12	13-19	20-24	25-31	32-38	39-45	46 +	TOTAL
N	.30	1.40	3.00	2.20	.40	.10	.04	0.00	0.00	7.44
NNE	.20	.80	.90	.70	.20	.10	0.00	0.00	0.00	2.90
NE	.20	.50	1.10	1.00	.30	.20	0.00	0.00	0.00	3.30
ENE	.10	.70	1.20	1.10	.30	.10	0.00	0.00	0.00	3.50
E	.30	1.00	2.40	2.30	.30	.10	.02	0.00	0.00	6.42
ESE	.30	.90	1.90	1.90	.30	0.00	.02	0.00	0.00	5.32
SE	.20	1.00	1.60	.60	0.00	0.00	0.00	0.00	0.00	3.40
SSE	.20	.80	1.10	.40	0.00	0.00	0.00	0.00	0.00	2.50
S	.30	1.60	3.00	1.80	.20	.10	.02	0.00	0.00	7.02
SSW	.10	.70	2.00	2.40	.60	.10	0.00	0.00	0.00	5.90
SW	.10	.80	1.90	2.70	.60	.10	0.00	0.00	0.00	6.20
WSW	.10	1.10	3.30	3.90	.70	.10	.04	0.00	0.00	9.24
W	.20	.90	2.70	5.00	1.50	.50	.10	.05	0.00	10.95
WNW	.10	.70	2.70	4.70	1.60	.50	.10	.05	0.00	10.45
NW	.10	.80	3.10	4.10	1.10	.30	.06	0.00	0.00	9.56
NNW	.10	.70	2.20	2.20	.40	0.00	0.00	0.00	0.00	5.60
CALM	.30	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	.30
TOTAL	3.30	14.30	34.20	36.90	8.50	2.30	.40	.10	0.00	100.00

TABLE 3
SUMMARY OF WIND EFFECTS ON PEOPLE

	<u>Beaufort number</u>	<u>Speed (mph)</u>	<u>Effects</u>
Calm, light air	0,1	0-3	Calm, no noticeable wind
Light breeze	2	4-7	Wind felt on face
Gentle breeze	3	8-12	Wind extends light flag Hair is disurbed Clothing flaps
Moderate breeze	4	13-18	Raises dust, dry soil and loose paper Hair disarranged
Fresh breeze	5	19-24	Force of wind felt on body Drifting snow becomes airborne Limit of agreeable wind on land
Strong breeze	6	25-31	Umbrellas used with difficulty Hair blown straight Difficult to walk steadily Wind noise on ears unpleasant Windborne snow above head height (blizzard)
Near gale	7	32-38	Inconvenience felt when walking
Gale	8	39-46	Generally impedes progress Great difficulty with balance in gusts
Strong gale	9	47-54	People blown over by gusts

Note: Table from Reference 4, p. 40.

TABLE 4

VELOCITIES EXCEEDED ONE PERCENT OF THE TIME

Effective Gust (Mean + 1.5 RMS), MPH
Exceeded 1% of the Time

LOCATION	<u>Configuration F</u> existing	<u>Configuration C</u> intermediate construction	<u>Configuration G</u> BRA approved geomtry	<u>Configuration I</u> added lowrise on Charles	<u>Configuration J</u> added lowrise on Fruit	<u>Configuration K</u> vertical walls added to J
18	29	23	22	24	--	--
19	25	33	29	29	--	--
20	40	43	43	46	49	45
21	25	26	34	32	--	--
22	18	24	21	24	23	--
23	28	42	32	29	32	19
24	*	18	30	32	31	25
25	*	29	19	20	--	--

* Locations do not exist in the existing configuration.