TECHNICAL REPORT

METEOROLOGICAL-TOWER INDUCED WIND-FIELD PERTURBATIONS (Supplement)

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1. INTRODUCTION

This report is a supplement to the Meteorological-Tower Induced Wind-Field Perturbations Studies under U.S. Army Research Grant DA-AMC-28-043-64-G-9*.

The specific objectives of this supplementary investigation are:

1. To study the mean wind pattern in the neighborhood of a meteorological tower subjected to the same mean ambient wind velocity but at different turbulence levels to determine the effect of turbulence on this mean wind velocity pattern.
2. To acquire measurements of wind speed at the anemometer position (boom mounted) for all possible wind directions.

In the original study an air stream having a low-level of turbulence was used to study the tower induced wind-field perturbations. The normal wind-tunnel turbulence of about 0.1% is considerably lower than the level of turbulence encoutered in the atmospheric surface layer most of the time. Therefore, the first phase of this

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*Hsi, G. and J. E. Cermak, Meteorological-tower induced wind-field perturbations. Fluid Mechanics Program, College of Engineering, Colorado State University, October 1965, CER65GH-JEC49.

supplementary work is an effort to determine if higher levels of turbulence intensity will have sensible effect on the wind-field perturbations. If the turbulence intensity in the oncoming air stream has negligible effect upon the tower produced perturbations, the wind-tunnel data obtained in the original study can be used to make corrections on actual field data.

By inserting grids at the test-section entrance, two different turbulence levels were obtained at the same free-stream wind velocity. The wind-speed data obtained using the original 1:4 scale model of the meteorological tower revealed that an increase of turbulence level induced only a slight increase in the wind defect. As far as the meteorological tower model was concerned, the wind defect was changed about 2% in this experiment.

The second phase of the supplementary work, suggested by Mr. Harry Maynard, was devoted to a determination of wind-field perturbations at a typical anemometer location relative to the tower. In this study, the meteorological tower was rotated through 360^0 with a wind-speed sensor mounted at the anemometer location at the end of a 10 ft. boom. The meteorological tower model was rotated 15 degrees between successive data points and made a complete revolution. The Prandtl tube which was fixed on the portable positioner was moved to the new position. In this procedure, the Prandtl tube was placed 3 in. (1 ft in prototype) directly above the boom tip and parallel to the free-stream wind direction. The most influenced wind defect sector was found to be the area behind the tower shadow, called the wake region. Little wind defect occurred in other sectors. Hence, when the boom tip was within the wake area, the field anemometer reading had to be adjusted. The procedure is described in the original report (Part I).

Both of the original study and this supplementary work were performed in the Fluid Dynamics and Diffusion Laboratory at Colorado State University.

2. EXPERIMENTAL PROGRAM AND DATA ANALYSIS

2.1. Turbulence Level and Wind-Defect Study

For higher and different turbulence levels, a turbulence grid was constructed from ten lengths of 2 x 4 in. wood boards. The wooden grid was placed 7 ft upstream from the modified meteorological tower model. The turbulence level at the model location was 1% in the original study. With the wooden grid at the same free-stream wind velocity of 30 ft/sec, the turbulence level was 6%. Table 1 gives some typical values of turbulence intensities and mean velocities with and without grids.

TABLE 1. A comparison of Results Under Two Wind-Tunnel Turbulence Levels

Station No.	Without Wood Grids		With Wood Grids	
	$\frac{\sqrt{\overline{u^2}}}{U_a}$	$\frac{U}{U_a}$	$\frac{\sqrt{\overline{u^2}}}{U_a}$	$\frac{U}{U_a}$
-1	.01	.995	.06	.97
5	.03	.90	.04	.90

In Figs. 1 and 2, detailed data for turbulence intensities and mean velocities with the grids are given. These data reveal that the higher turbulence level does not have a significant effect on the wind velocity defect in the wind tunnel. This result means that the wind-field data obtained in the original study with low levels of turbulence intensity can be used with confidence to make corrections to anemometer sensings taken in the field.

2.2. Study of Velocity Perturbations at Typical Anemometer Locations

The maximum wind defect positions were located by a vertical mean velocity profile (see Fig. 3) which was made at station 2A along the center axis of the modified tower model. One set of wind-speed measurements was made at each of the two levels of 21 in. and 35.5 in. as shown in Figs. 4 and 5 respectively. The model was set at the zero degree position and rotated 15 degrees for each successive reading. The Prandtl tube was mounted 3 in. above the boom tip and parallel to the ambient-wind direction.

At 35 1/2 in. above the floor, the maximum dimensionless wind defect was found to be 0.57. The maximum dimensionless wind defect at 21 in. above the floor was 0.73. These large values of wind defect were noted only when the tower was set at the zero degree position in the wake region.

During the study, the wake sector remained at $30^0 \sim 35^0$. Additional measurements were taken within the wake region for the purpose of clarification.

The main portion of the mean velocity profile in this study compared to that in the original study (Fig. 12) had the same pattern excepting within the wake region. This difference is primarily due to holding the tower in the zero-degree position during the original study whereas the tower was rotated so that the entire tower moved relative to the ambient-wind direction in the supplementary study. Figs. 4 and 5 provide realistic reference for the correlation of the wind defect with the field anemometer location relative to the wind direction.

2.3. The Transverse Velocity Profile of the Wind Tunnel with Wood Grids

Figure 6 shows a reference transverse velocity profile with the wood grids at the entrance of the wind tunnel without the tower model in the wind tunnel taken at mid-height in the test section. This profile reveals a transverse velocity distribution for the study of the turbulence level and the wind defect, which is sufficiently uniform to not produce any secondary effects upon the quantities being studied.

3. CONCLUSION

This study of the turbulence effect on the wind velocity profile showed that wind-tunnel and field data should be closely correlated without considering the various characteristics of turbulence encountered in the field. The main concern then, in considering anemometer correction due to perturbations of the wind-field by a tower, is the geometric configuration of the tower-anemometer system.

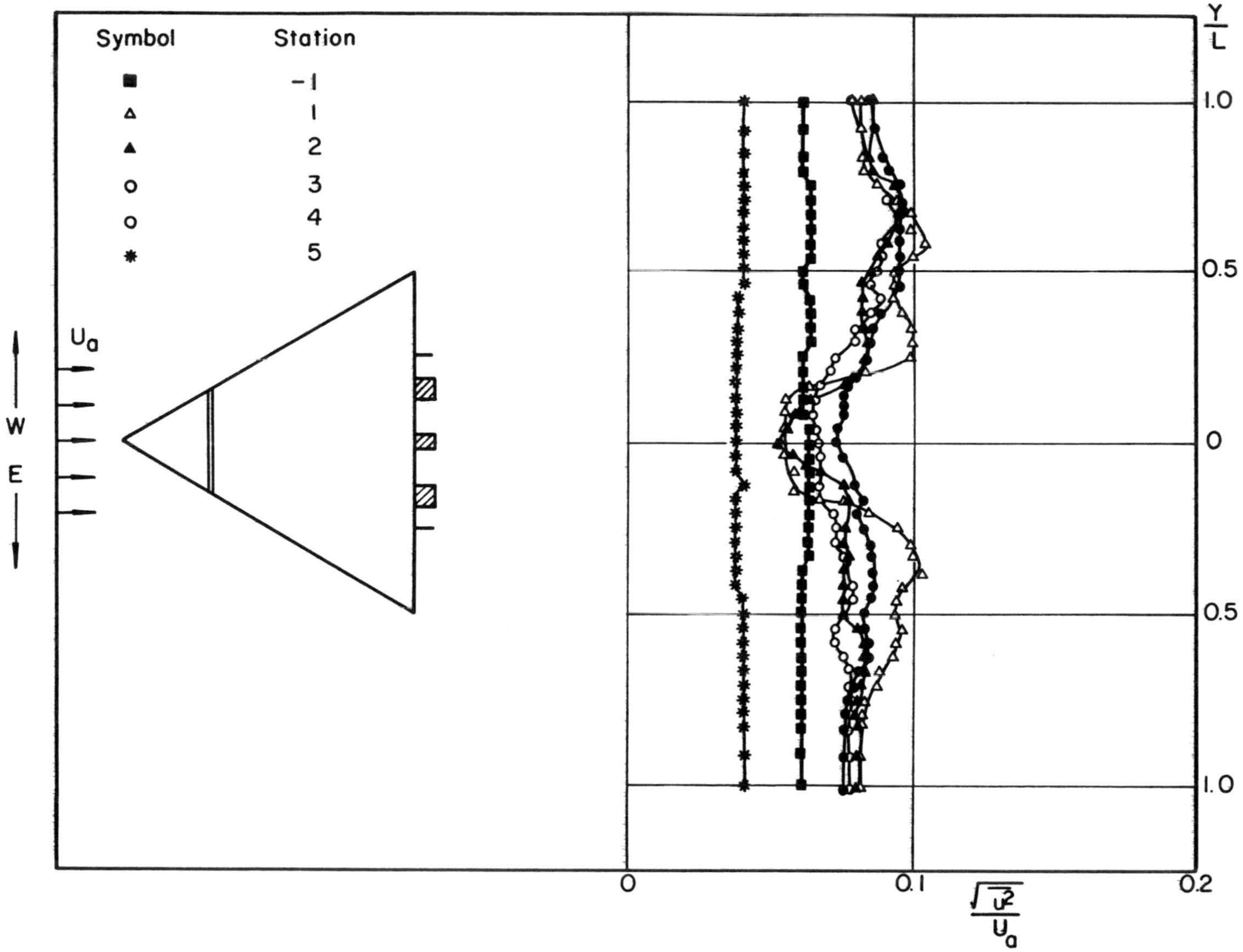

Fig. 1 Turbulence intensity profile, modified tower, with wood grids

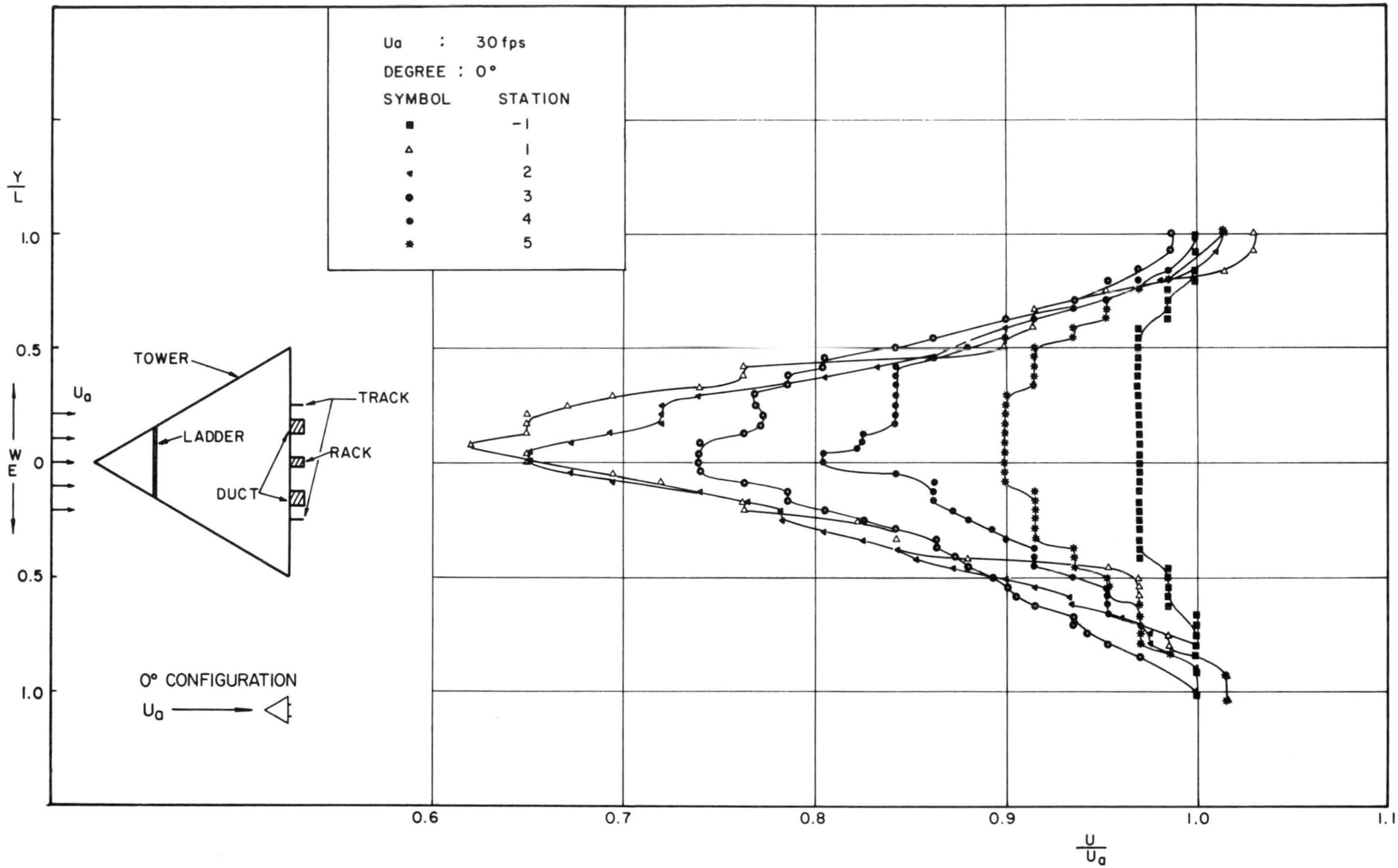

Fig. 2 Transverse velocity profile, modified tower, with wood grids

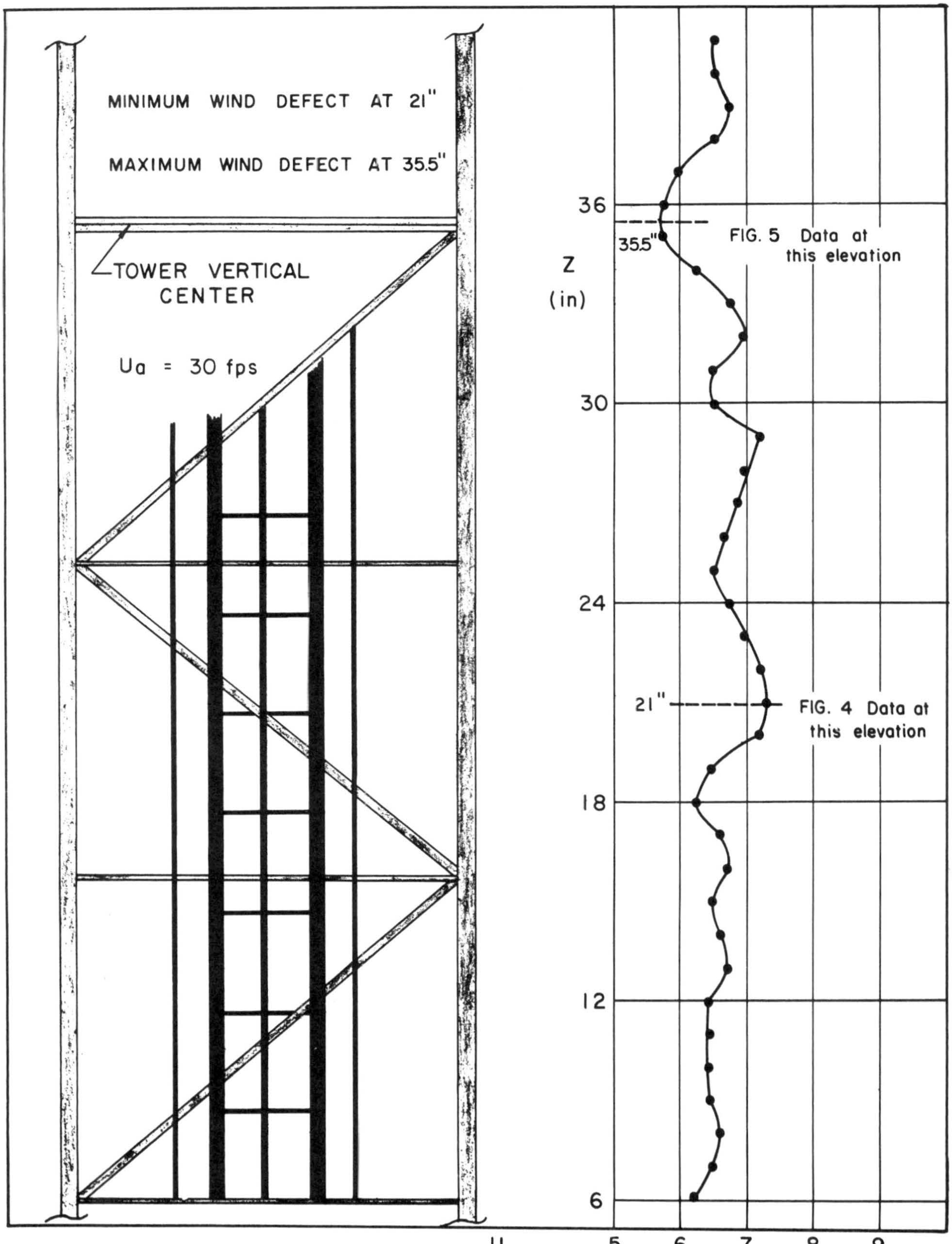

Fig. 3 Vertical velocity profile, modified tower

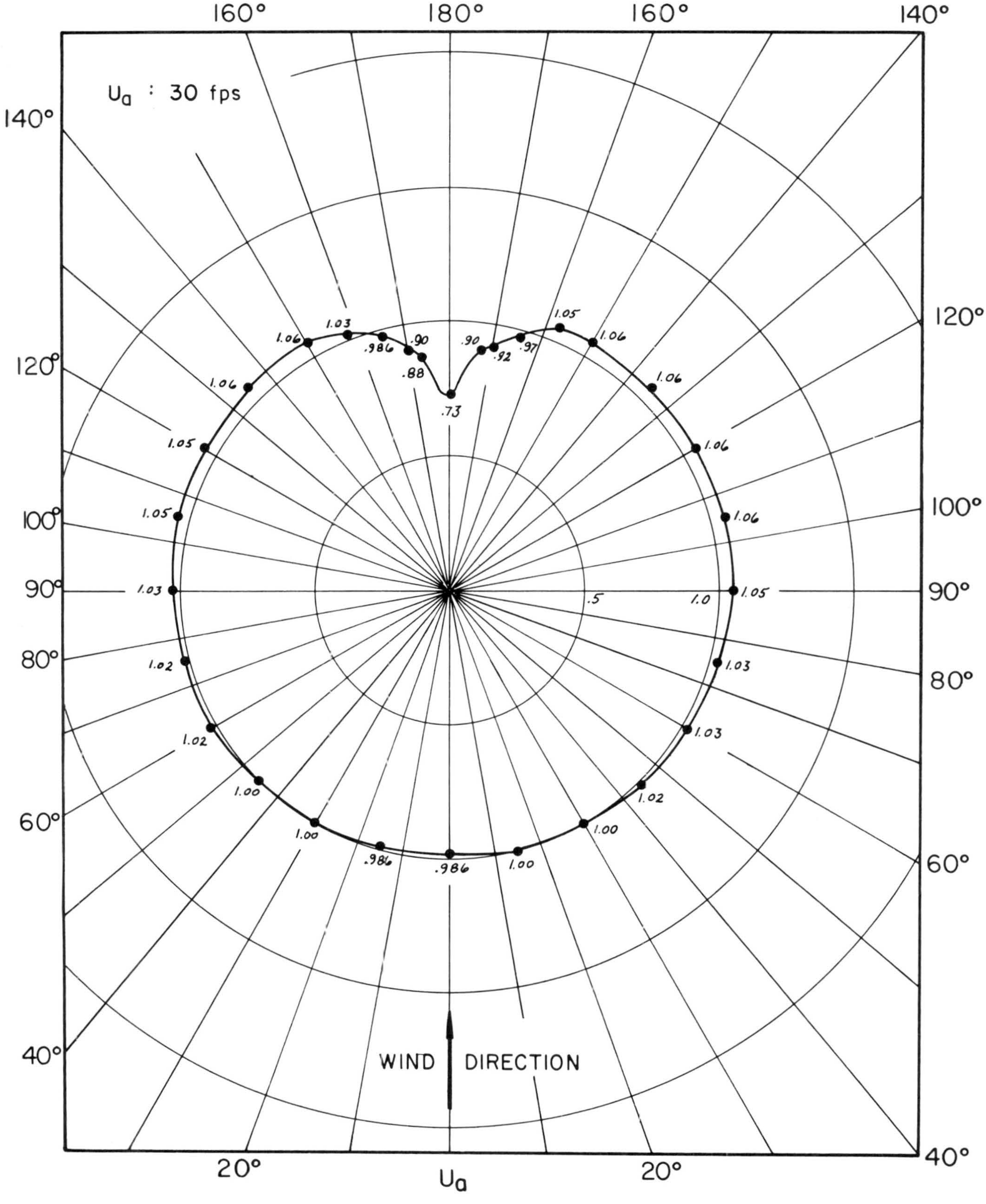

Fig. 4 Mean velocity profile around modified tower, 35 inche radius circle, data taken 21 inches above the floor of test section

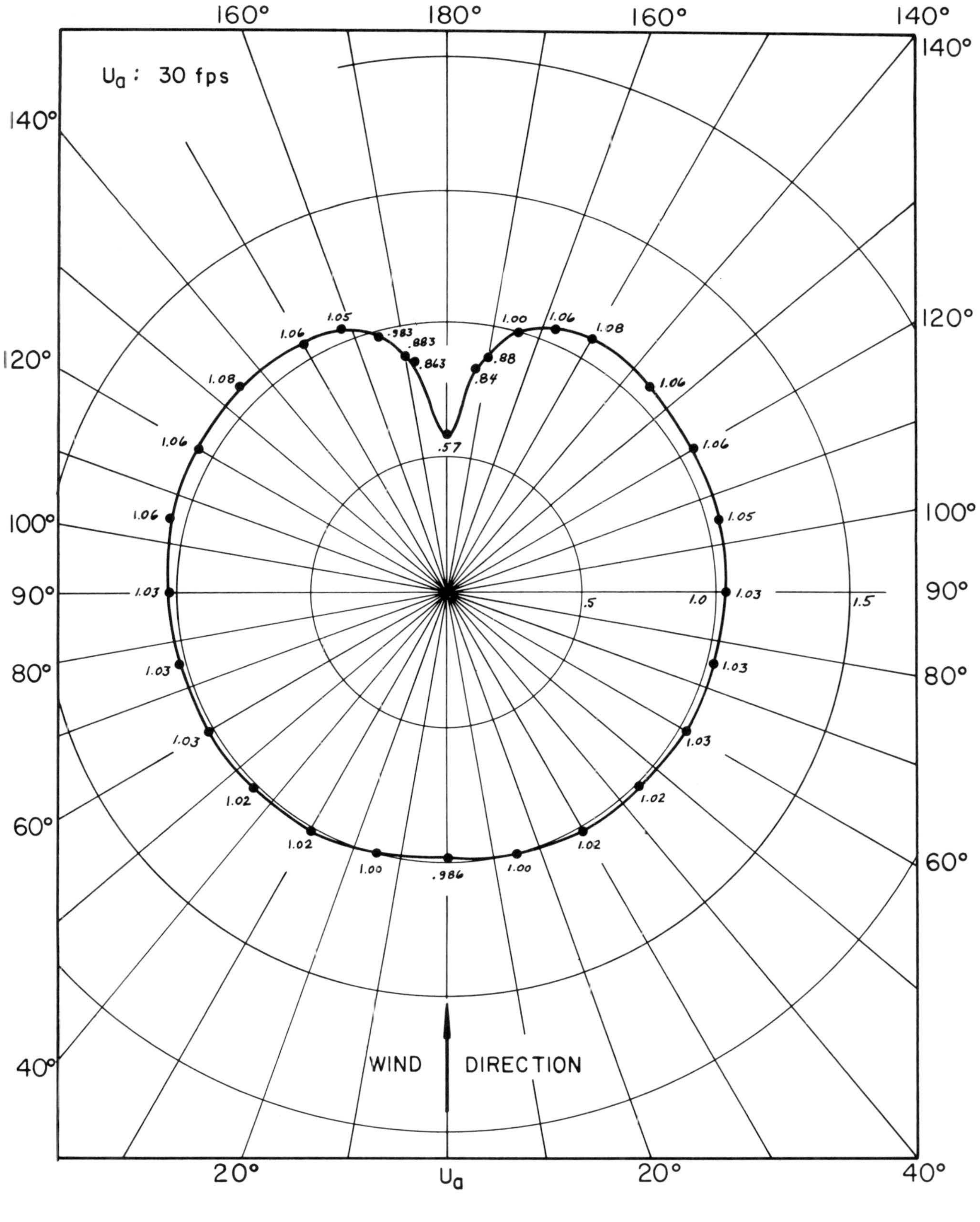

Fig. 5 Mean velocity profile around modified tower, 35 inch radius circle, data taken 35.5 inches above the floor of test section

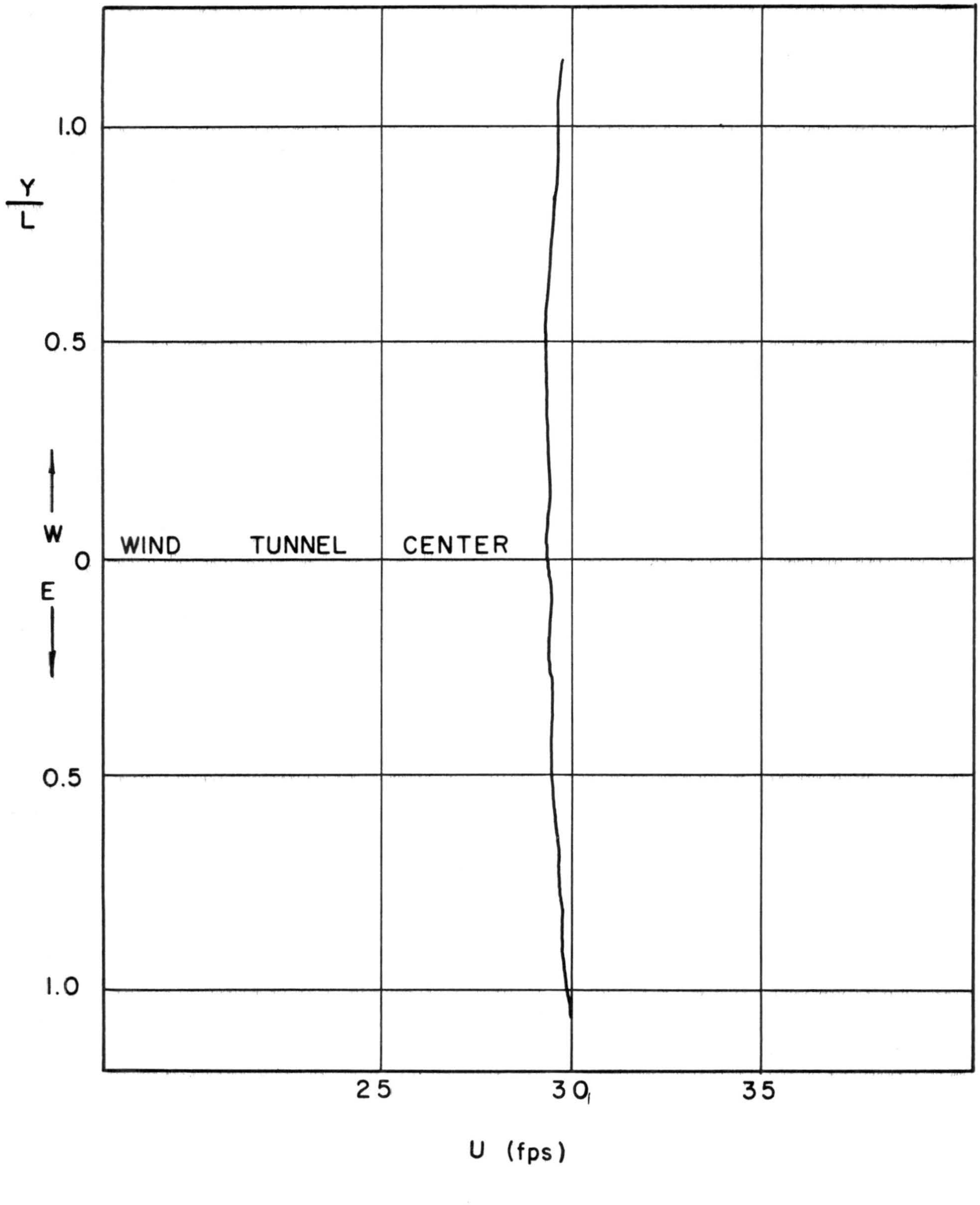

Fig. 6 Transverse velocity profile with wood grids, without tower, at station (-1)