WIND FORCES AND MOMENTS ON A PRISMAFLOOD LIGHTING UNIT

by

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Acknowledgments

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Symbol	Definition
U	Reference mean wind velocity
D	Diameter of reflector
F_x	Force in x-direction
F_y	Force in y-direction
F_z	Force in z-direction
M_x	Moment about x axis
M_y	Moment about y axis
M_z	Moment about z axis
C_{F_x}, C_{F_y}, C_{F_z}	Nondimensional force coefficients in x, y, z direction
C_{M_x}, C_{M_y}, C_{M_z}	Nondimensional moment coefficients about x, y, z axes
α	Angle of wind approach (degrees)
β	Angle of reflector to wind direction in horizontal plane (degrees)
γ	Angle of reflector to wind direction in vertical plane (degrees)
ρ	Density of wind (slugs/ft^3)

INTRODUCTION

This study was undertaken to determine wind forces and moments on a Prismaflood* lighting unit by means of wind-tunnel testing. The lighting unit consists of a cone-shape reflector, mounting yoke, base plate and irregularly shaped ballast assembly. Figures 1 and 2 show details of the assembled lighting unit.

TEST PROCEDURES

The wind study was performed in the meteorological wind tunnel located in the Fluid Dynamics and Diffusion Laboratory at Colorado State University (Fig. 3). This is a closed circuit facility with a test section of 6 ft^2. The mean velocity can be adjusted continuously from 1 to 120 ft/s.

Models

Measurements of forces and moments were made on an actual prismaflood lighting unit made available by Holophane. A special pedestal base with the provision for 360° rotation about the vertical axis was made to mount the six-component strain-gage force and moment balance and the lighting fixture. This pedestal was placed on the centerline of the tunnel. In this position the lighting unit could be orientated in various desired configurations with respect to the wind.

Preliminary observation of the lighting unit subjected to wind revealed substantial vibrations of the system to be present. Accordingly the system was viscously damped by a long cylinder moving in a viscous fluid under atmospheric conditions (Fig. 1). The system worked

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*Trade name for lighting unit manufactured by Holophane, a division of the Johns-Manville Corporation.

very satisfactorily and did not influence the measurement of mean forces and moments. Details of the force measuring system are given in Figs. 1 and 4.

Test Configurations

Measurements were made at three, and in some cases four, different velocities (ranging from 54 to 90 ft/s) to observe any dependence of the force and moment coefficients on Reynolds number. Details of various configurations of the lighting unit and approaching flow used in this study are given in Table 1 and shown in Figs. 5, 6, and 7.

Table 1

Test Configurations

Configuration No.	α	β	γ
1	0	0	0
2	45	0	0
3	90	0	0
4	0	30	0
5	0	45	0
6	0	60	0
7	0	0	22.5
8	0	0	45
9	0	30	22.5
10	0	30	45
11	0	45	22.5
12	0	45	45
13	0	60	22.5
14	0	60	45
15	45	0	22.5
16	45	0	45

Wind velocity in the tunnel was uniform across the lighting unit with turbulence intensity of 1.5 percent. Wind velocity at the level of the unit was monitored constantly by a pitot tube and averaged for the duration of each test.

INSTRUMENTATION AND DATA ACQUISITION

Forces and moments were measured using an Inca six-component strain-gage balance. Wind forces and moments were measured in x, y, z directions in a coordinate system fixed to the reflector as shown in Figs. 5, 6, and 7. Due to the lack of maneuverability and excessive weight of the unit moments could not be measured exactly at the support bracket (see Fig. 4). The new center of rotation is close to the support bracket. The moments can be easily transformed to any other desired location.

Data Processing

Eacn strain-gage bridge of the Inca balance was monitored by a Honeywell Accudata 118 gage control/amplifier unit for signal conditioning. These units are characterized by a very stable excitation voltage and amplifier gain. Each channel signal was further reduced on line by digital integrating voltmeters for mean values. Calibration of the balance was accomplished in a test rig in which known forces and moments could be applied to the balance. From calibration results a calibration matrix was developed for reducing the mean output of the strain gages. Load and strain relationship is strictly linear for the range of loads applied in these tests.

Flow Visualization

Visualization of the flow about the model is helpful in defining the zones of separated flow and reattachment. This can also be a useful indicator for determining the projected area contributing to various forces acting on the lighting fixture.

A 200-ft motion picture was made and constitutes a part of this report. The film shows a flow characteristic about the light fixture in various approach-flow orientations. A listing of the contents of the film is given in Table 2.

Table 2

Motion-Picture Scene Guide

Scene	Wind Velocity ft/s	Configuration	Location of Smoke Source
1	10	1	upstream of the fixture
2	10	8	upstream of the fixture
3	10	5	upstream of the fixture
4	10	1	surface of the reflector
5	10	8	surface of the reflector

TEST RESULTS

Force measurements at different velocities showed no significant dependence on Reynolds numbers. Selection of dynamic pressure $(1/2)\ \rho U^2$ should be made by the designer based on the annual extreme fastest-mile wind speed 30 ft above the ground having a mean recurrence interval of 50 years.*

* Refer to American National Standard Building Code Requirements for Minimum Design Loads in Buildings and Other Structures, ANSI A58.1, American National Standards Institute, Inc., 1430 Broadway, New York, N.Y. 10018.

The forces and moments are given in terms of nondimensional coefficients C_F and C_M, respectively. These are defined as follows:

$$C_{F_x} = \frac{F_x}{(\rho U^2/2)(\pi\ D^2/4)}$$

$$C_{F_y} = \frac{F_y}{(\rho U^2/2)(\pi\ D^2/4)}$$

$$C_{F_z} = \frac{F_z}{(\rho U^2/2)(\pi\ D^2/4)}$$

$$C_{M_x} = \frac{M_x}{(\rho U^2/2)(\pi\ D^3/8)}$$

$$C_{M_y} = \frac{M_y}{(\rho U^2/2)(\pi\ D^3/8)}$$

$$C_{M_z} = \frac{M_z}{(\rho U^2/2)(\pi\ D^3/8)}$$

Results of the study are given in Table 3 for each configuration.

The use of these coefficients for calculation of forces and moments on the lighting unit caused by wind is illustrated in Appendices I and II.

Table 3: Test Results

Coef.	Configuration Number															
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
C_{F_x}	1.02	1.03	0.21	1.26	0.91	0.51	1.07	0.82	1.08	0.96	0.98	0.84	0.56	0.47	1.05	0.85
C_{F_y}	0.07	0.59	0.71	0.26	0.52	0.55	0.22	0.24	0.19	0.20	0.46	0.54	0.62	0.69	0.55	0.69
C_{F_z}	0.45	0.97	0.15	1.38	0.13	1.01	1.55	1.32	1.84	1.43	0.97	1.08	0.69	0.65	1.18	1.41
C_{M_x}	0.11	0.35	0.31	1.91	0.81	0.39	0.04	0.23	1.18	1.24	0.73	0.92	0.62	0.64	0.68	0.50
C_{M_y}	-4.61	-1.06	-0.39	-2.08	-1.47	-0.35	4.68	5.82	3.13	2.37	1.19	1.01	1.05	1.11	0.68	0.69
C_{M_z}	0.05	3.58	4.70	4.14	2.41	0.26	0.59	0.81	2.81	1.98	1.88	1.70	2.72	3.46	2.28	1.98

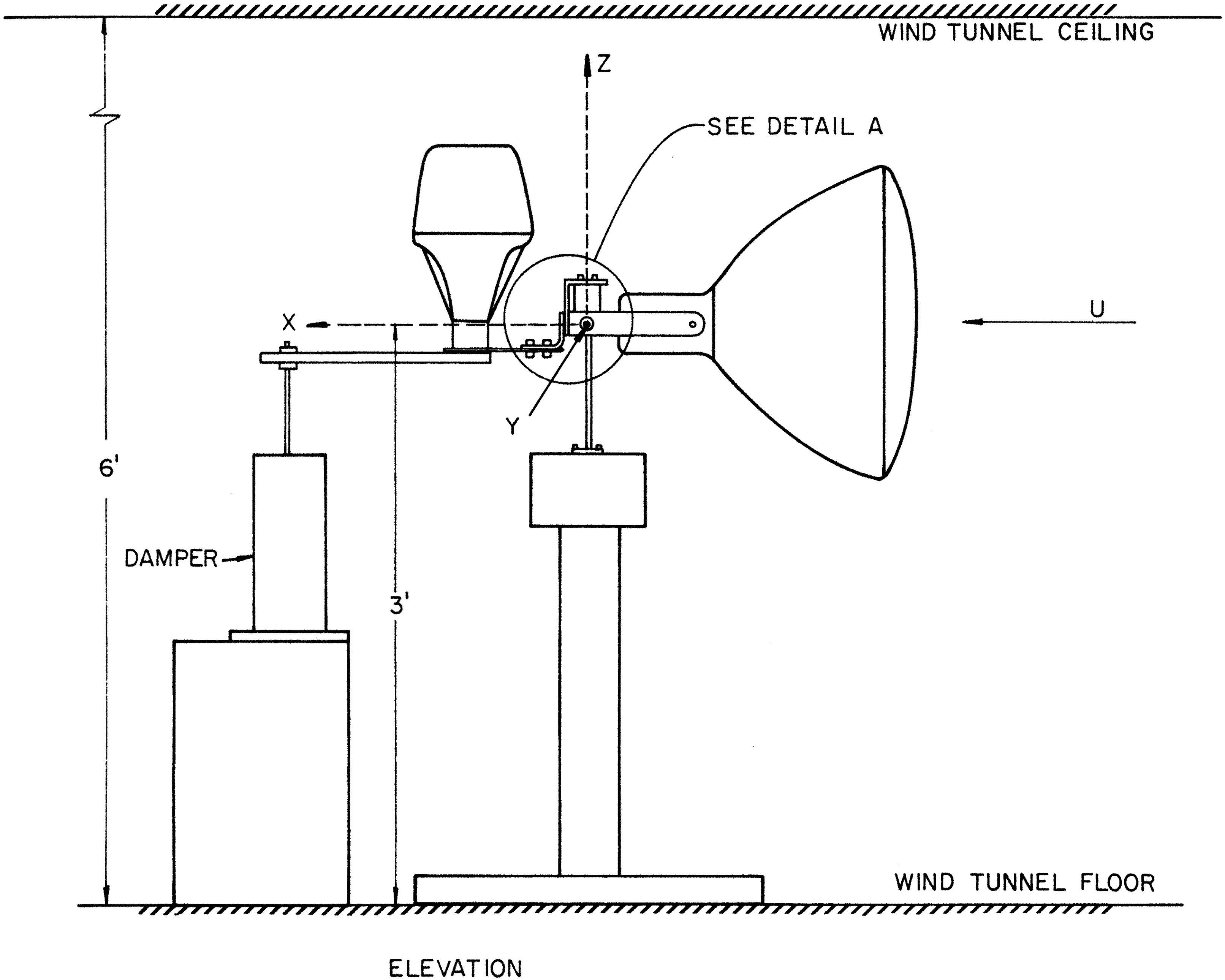


Figure 1 Schematic of the lighting unit and measurement system

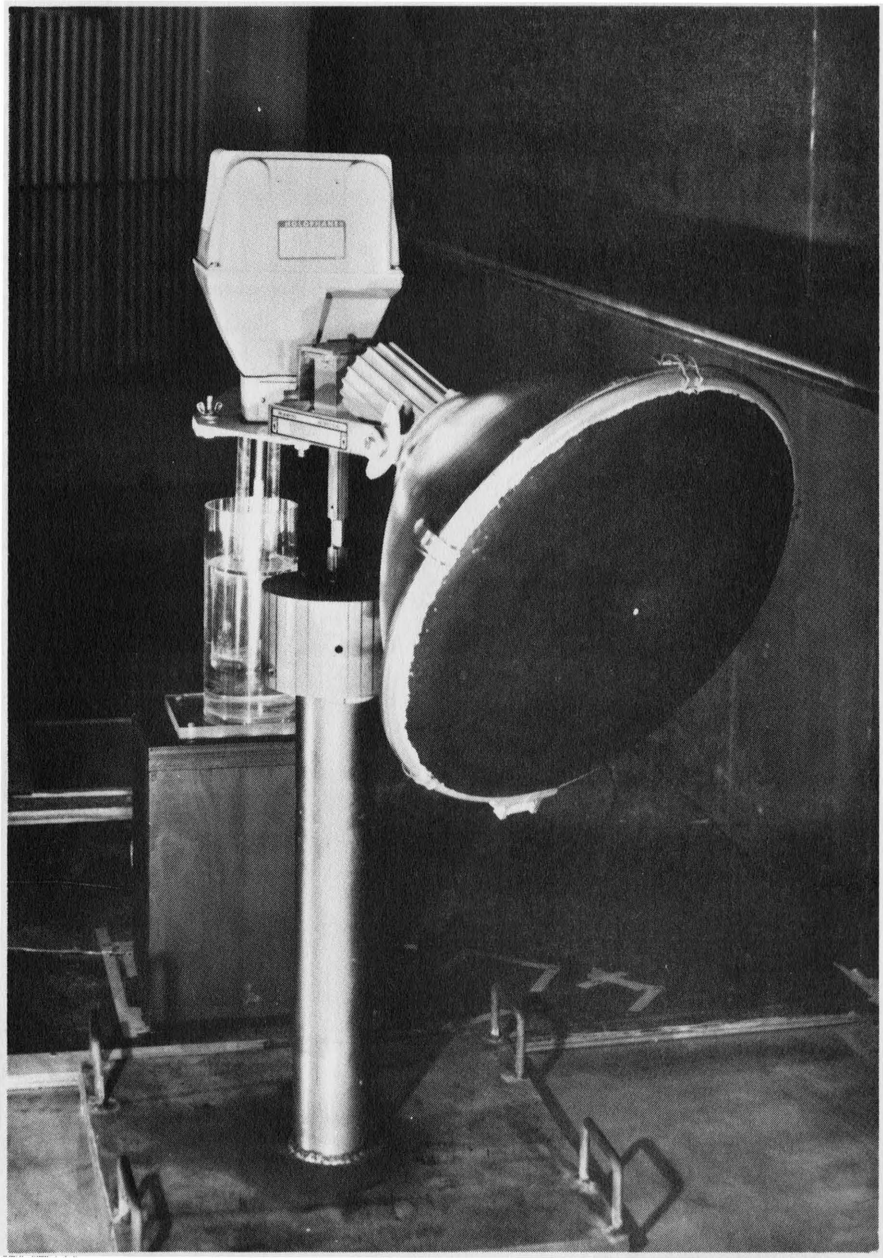


Figure 2 Photograph of the lighting unit and measurement system in the Meteorological Wind Tunnel (configuration 9)

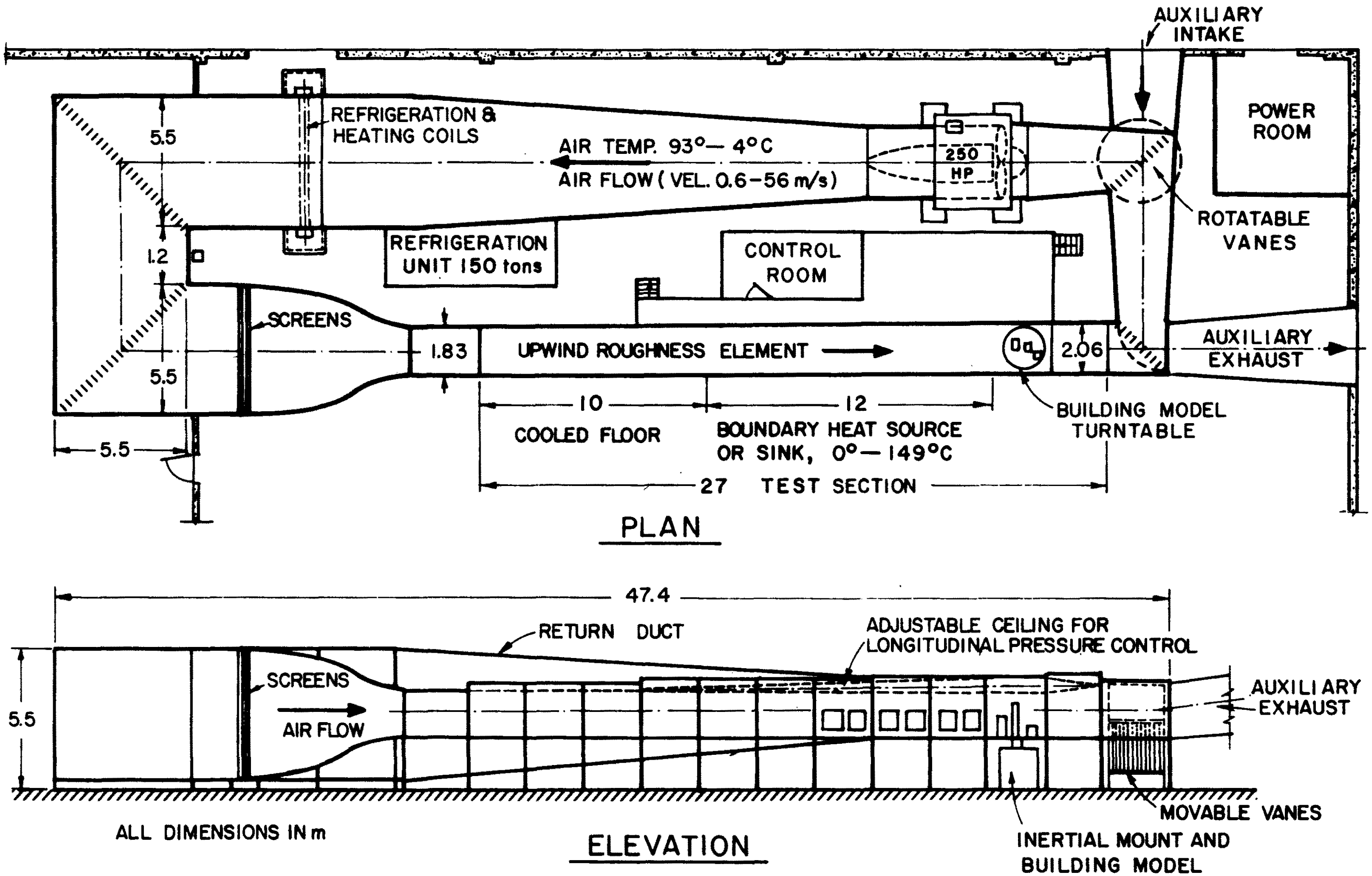


Figure 3 Meteorological Wind Tunnel
Fluid Dynamics & Diffusion Laboratory
Colorado State University

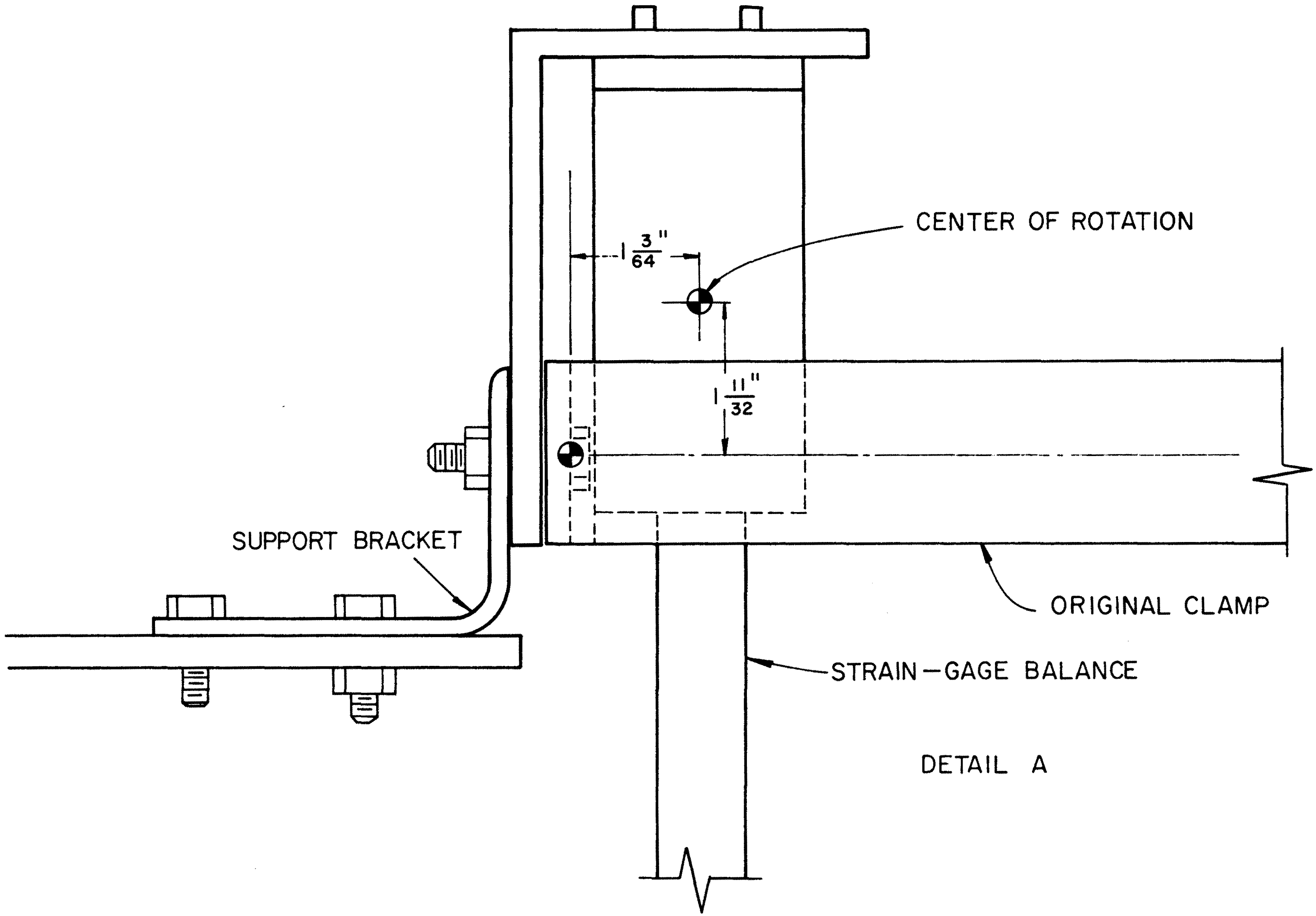
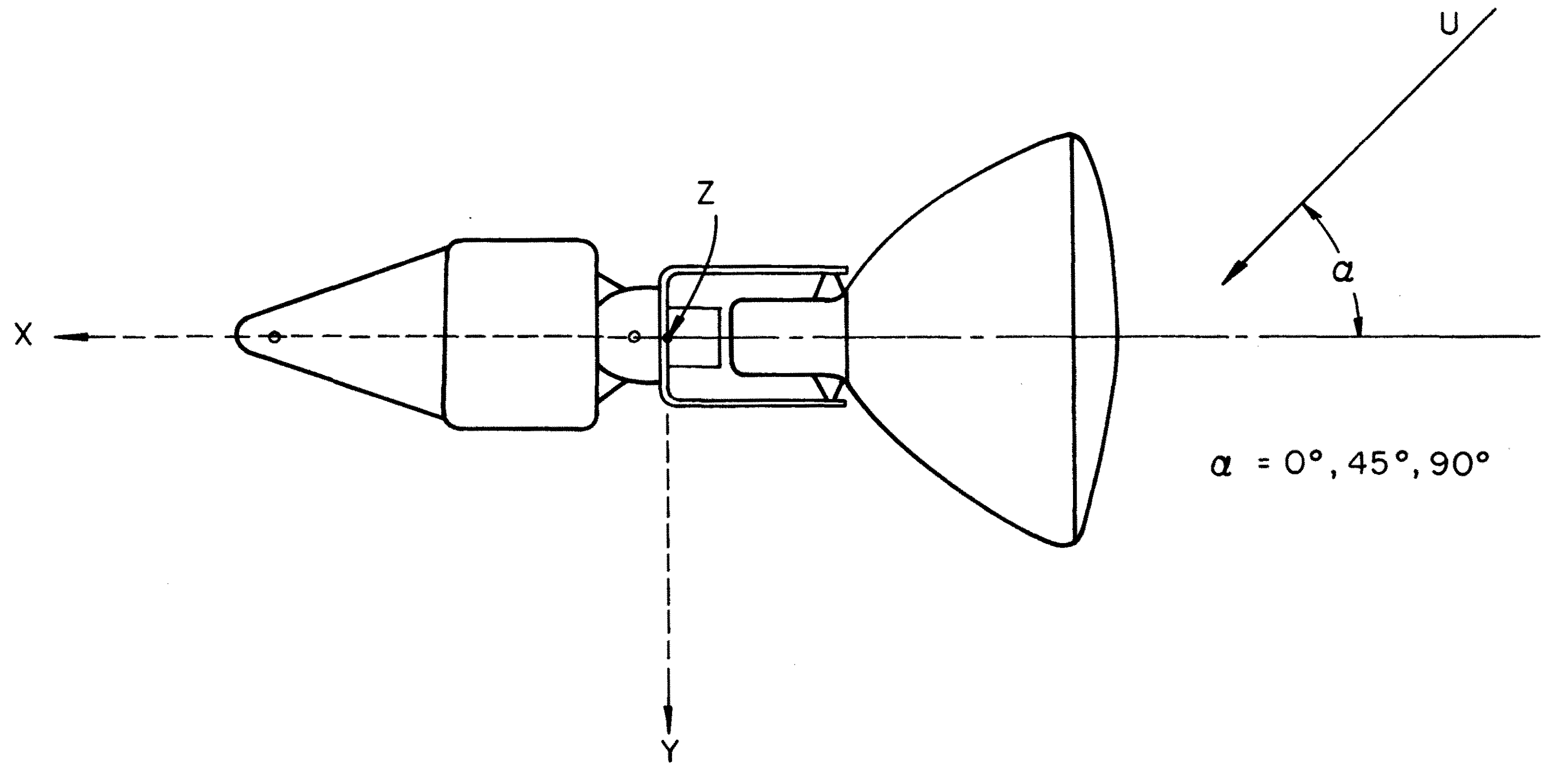


Figure 4 Detail A for the center of rotation



PLAN VIEW

Figure 5 Orientation of angle α with axes of reference

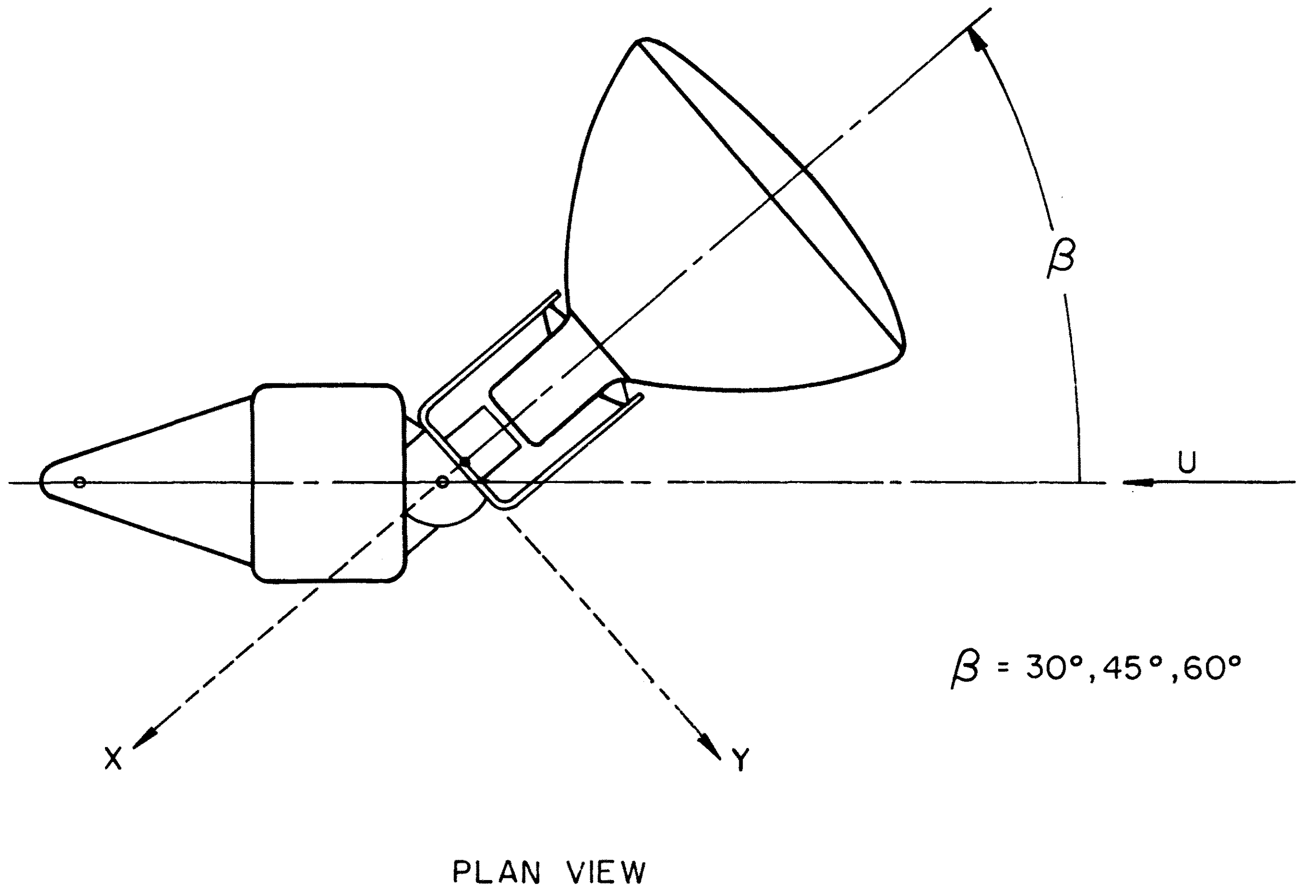
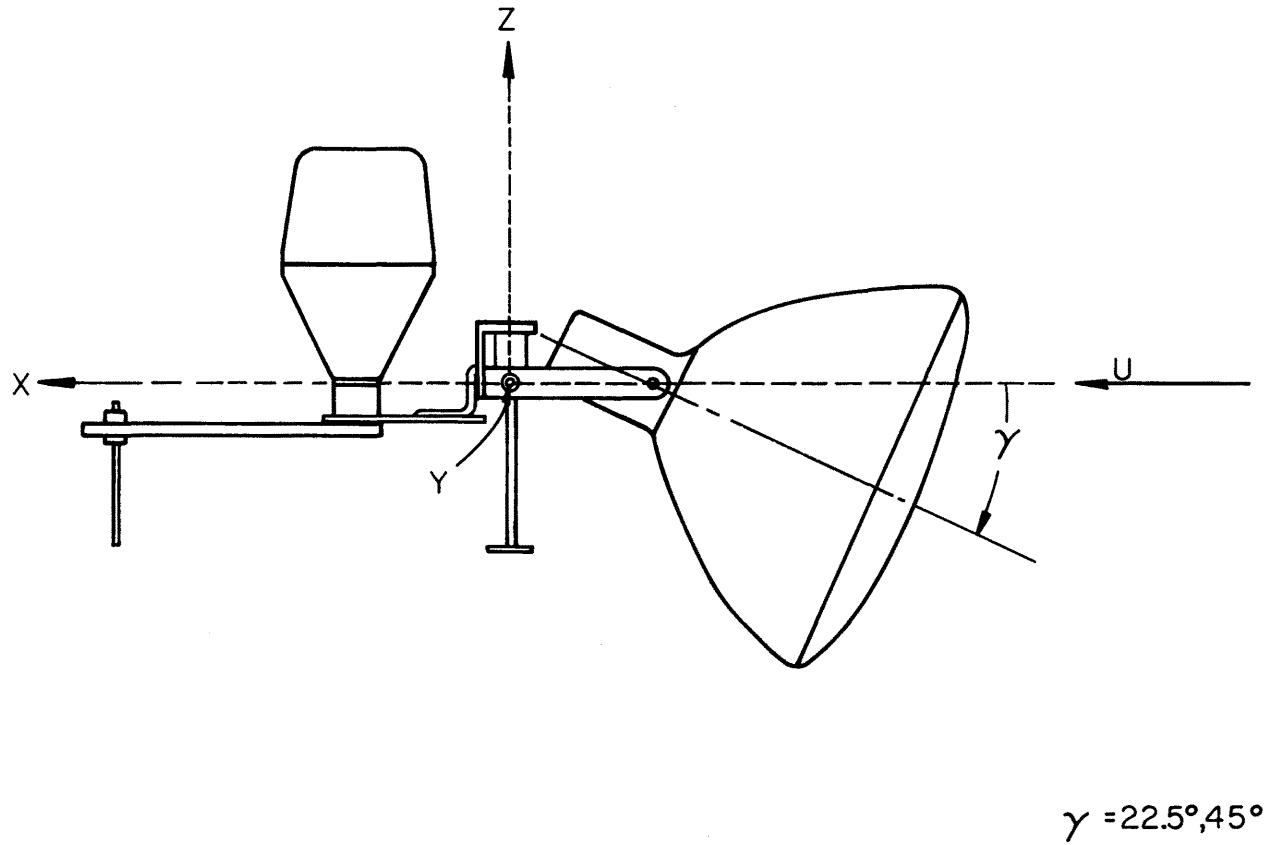


Figure 6 Orientation of angle β with axes of reference



ELEVATION

Figure 7 Orientation of angle γ with axes of reference

Appendix I

AIR DENSITY

The density of air is dependent on the barometric pressure and temperature. It can be evaluated by the following relation:

$$\text{Density} = \frac{\text{(Barometric pressure in inches)}}{\text{(Absolute temperature)} \times 24.296968} \quad [\text{slugs/ft}^3]$$

(Absolute temperature = temperature in $^\circ$F + 459.69) .

Appendix II

FORCE AND MOMENT CALCULATIONS

The following example is used to explain the procedure of calculating the forces and moments on the lighting unit. Assume the following conditions at the site:

Temperature	= 80°F
Barometric pressure	= 26.20 in.
Wind speed	= 100 ft/s
Density	= 26.20/(539.69 x 24.25) = 0.0020 slugs/ft^3
Diameter of reflector	= 22 in.

<u>Typical Force</u>

$$C_{F_x} = \frac{F_x}{(\rho U^2/2)(\pi D^2/4)}$$

$$F_x = (\rho U^2/2)(\pi D^2/4)\ C_{F_x}$$

$$= (26.47)(C_{F_x})$$

For configuration No. 1 ($\alpha = \beta = \gamma = 0$) Table 3 gives $C_{F_x} = 1.02$; therefore,

$$F_x = 26.93 \text{ lbs} .$$

<u>Typical Moment</u>

$$M_x = (\rho U^2/2)(\pi D^3/8)\ C_{M_x}$$

$$= (24.27)\ (C_{M_x})$$

For configuration No. 1 Table 3 gives $C_{M_x} = 0.11$; therefore,

$$M_x = 2.66 \text{ lb-ft} .$$

The force and moment calculated above are aerodynamic loads that do not include contributions from the dead weight of the system.