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THE WAKE STRUCTURE AND DIFFUSION BEHIND A MODEL INDUSTRIAL COMPLEX

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1. INTRODUCTION

Building complex in a planetary boundary layer creates a wake behind the complex. The wake is generally characterized by increased turbulence intensity and decreased mean longitudinal velocity and obstacle wake of this type is known as momentum wake. Passage of a shear flow around a surface obstacle also creates longitudinal vortices in the wake of the obstacle and this type of wake is classified as a vortex wake. Diffusion of material released in the wake of an industrial complex will be strongly altered, particularly if the pollutant is released within the separation bubble. The purpose of this paper is to determine experimentally and analytically the flow characteristics and pollutant dispersion around 1:200 scale model of the EOCR reactor building and surrounding complex placed in a neutral atmospheric boundary layer wind. The diffusion experimental results are described in detail by Hatcher et al. (1977) and flow characteristics by Kothari et al. (1980). It was thought that with surrounding buildings the vortices due to the main complex will degenerate and hence the wake and diffusion structure will be discussed in light of momentum wake theory.

2. THEORETICAL METHODS

Hunt and Smith (1969) proposed a theory to calculate time mean velocity in the wake of two- and three-dimensional bluff bodies immersed in a thick turbulent boundary layer. The theory is based on the assumption that only small perturbations to the turbulent boundary layer are caused by the obstacle, that the ratio of the model height to the boundary layer height is small, that velocity defects in the wake are small compared with longitudinal velocity, and the velocity profile power-law exponent $n<<1$. The details of the formulation and final results are described by Hunt and Smith (1969), and the theory has been successfully compared by Kothari et al. (1979a) for their experimental measurements of wake characteristics for buildings placed in stably stratified turbulent boundary layer.

Kothari et al. (1979b) have proposed to calculate time mean concentration in the wake of a three-dimensional bodies in a thick turbulent boundary layer. The theory is based on the assumptions that only small perturbations in pollutant concentration are caused by the obstacle and that the velocity profile power-law exponent $n<<1$. The theory has been described in detail and the results are compared by Kothari et al. (1979b, 1980).

3. EXPERIMENTAL RESULTS AND COMPARISON WITH THE THEORIES

The wake and diffusion measurements were performed in the Industrial Aerodynamics Wind Tunnel and Meteorological Wind Tunnel, respectively, at Colorado State University. The mean velocity defect, Delta U, and turbulence excess, Delta Variance, were determined from

$$\text{Delta U} = \left(\frac{\overline{U}(z)}{\overline{U}(\delta)}\right)_1 - \left(\frac{\overline{U}(z)}{\overline{U}(\delta)}\right)_2$$

and

$$\text{Delta Var} = \left(\frac{U_{rms}(z)}{\overline{U}(z)}\right)_2^2 - \left(\frac{U_{rms}(z)}{\overline{U}(z)}\right)_1^2$$

where $\overline{U}(z)$ and $U_{rms}(z)$ are the mean and rms velocities at elevation z at a given x and y location, $\overline{U}(\delta)$ is the free stream velocity and suffix 1 and 2 corresponds to conditions without model and with model respectively. The wakes and diffusion measurements were performed with n equal to 0.12 and 0.14 respectively. Wake measurement locations are shown in Figure 1. The measurements were performed with and without building at all locations.

Figure 2 shows the vertical profiles of mean velocity defect, Delta U, and comparison with the theoretical prediction for $y/H = 0.0$. The maximum vertical extent of the velocity defect wake is about 1.5H near the complex and is about 2H in the far wake, and is of the same order as reported by Woo et al. (1976). It should be noticed that the wake extends much farther than those reported by Counihan (1971) and other researchers, but its extension agrees with that of Woo et al. (1976). The theoretical values of the velocity defect agree very well. The maximum velocity defect observed and calculated at each x/H location for various y/H positions is shown in Figure 3. The maximum Delta U measurement shows a very good comparison with the theoretical prediction

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except for y/H equal to −0.67. At y/H = −0.67, additional velocity defects are created due to silo and tank building. The maximum Delta Var occurring at each x/H is plotted in Figure 4, for various y/H with predicted theoretical slope of −2. Again the theoretical prediction of a decay rate of turbulence intensity agrees well with experiments.

The experimental measurements and predicted ground level concentration using the theory of Kothari et al. (1979b) in the EOCR wake are shown in Figure 5. The comparison between the measurements and analytical prediction is very good between x/H equal to 5 to 35.

4. CONCLUSIONS

The theoretical predictions of velocity and diffusion in the wake of buildings compared favorably with experimental measurements.

5. REFERENCES

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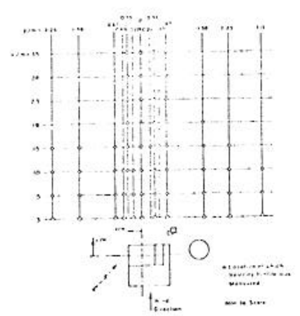

Fig. 1 Vertical Profiles Measurement Locations and EOCR Configuration

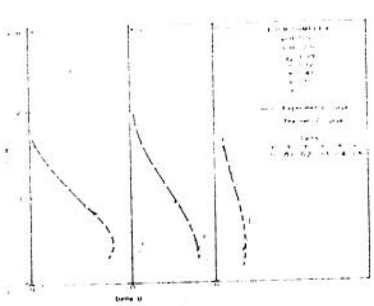

Fig. 2a Comparison of Experimental Measurement and the Theoretical Prediction of Velocity Defect in the Wake of EOCR Complex

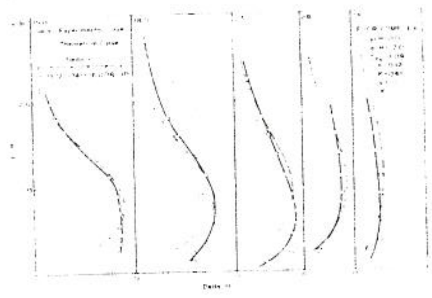

Fig. 2b Comparison of Experimental Measurement and the Theoretical Prediction of Velocity Defect in the Wake of EOCR Complex

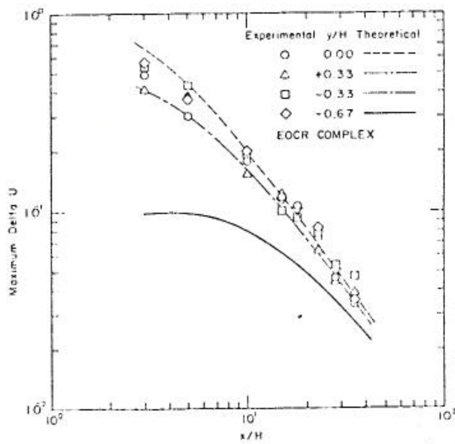

Fig. 3 Comparison of Decay Rates of Maximum Velocity Defect in the Wake of EOCR Complex With the Theory

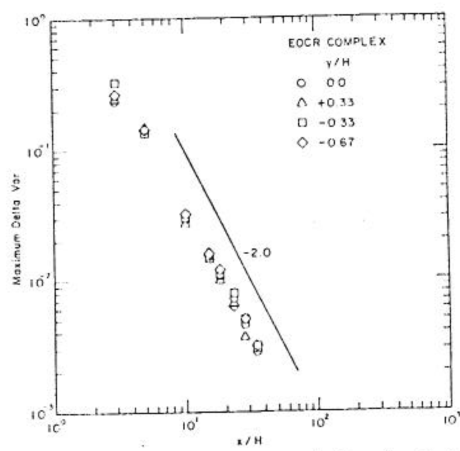

Fig. 4 Comparison of Decay Rates of Maximum Excess Turbulence Intensity Variance in the Wake of EOCR Complex With the Theory

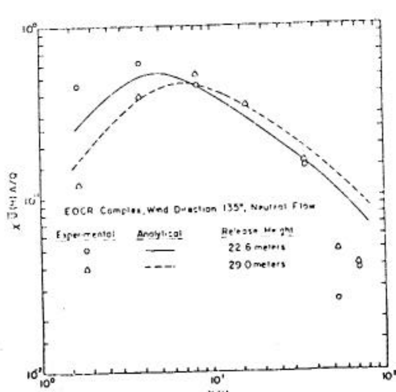

Fig. 5 Comparison of Turbulent Diffusion in the Wake of EOCR Complex With the Theory