ENGINEERING RESEARCH INSTITUTE
THE UNIVERSITY OF MICHIGAN
ANN ARBOR

First Quarterly Progress Report

RESEARCH STUDY PERTAINING TO LOW-LEVEL WIND STRUCTURE

May 1, 1955 to July 31, 1955

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Project 2377

LABORATORY PROCUREMENT OFFICE, SIGNAL CORPS SUPPLY AGENCY
CONTRACT NO. DA-36-039, SC-64676

September, 1955

OBJECTIVE

The object of the research is to analyze low-level wind structure as it pertains to dynamic wind loading.

ABSTRACT

During the first quarter, a number of conferences with scientists have been held and the problem considered from a number of points of view, including those of statistical design and instrument analysis.

A survey of the literature on wind loading of structures has been conducted and its pertinence for the present investigation considered. Probably the earlier study by Professor R. H. Sherlock and associates is the most significant of these, and it is planned to evaluate it in greater detail in connection with the present project. References to some of the publications examined are listed.

In the analysis of instruments for delineating low-level wind structure, the following types have been subjected to preliminary assessment: kite balloons, sonic gustometers, and differential microbarographs.

PURPOSE

The purpose of the research is to analyze, using the resources of mathematical physics, meteorology, aerodynamics, and statistics, the problem of the determination of the structure of wind in the lower layers of the atmosphere as it pertains to dynamic wind loading of objects.

The research may be considered as consisting of four tasks, as follows:

Task A: To produce one or more statistical designs for field experiments which will reveal the wind-flow features which are significant for dynamic-loading problems.

Task B: To evaluate existing or possible wind-measuring instruments, such as anemometers, gustometers, and bivanes, to determine their suitability for field use in measuring the three-dimensional large-scale eddy structure of the atmosphere.

Task C: To recommend one or more systems for reduction to usable form of the data obtained by the sensing elements of the instruments.

Task D: To assess the suitability of the wind tunnel as a device for simulating eddy structure over specified terrain features.

PUBLICATIONS, LECTURES, REPORTS, AND CONFERENCES

There have been no publications or lectures during the reporting period.

Two Monthly Reports have been submitted.

Conferences held may be mentioned in three groups:

1. On May 2, 1955, a conference was held at Princeton University. The main discussions were held between Dr. John W. Tukey, Professor of Mathematics at Princeton University, and the writer, but a number of other scientists also participated during the day. It was concluded that two important objectives of the overall program are as follows:

a. To understand the four dimensional structure of the lower atmosphere, not just the spectra of turbulence.

b. To obtain the integrated gust loading on a moving object whose path is to be specified in terms of an x-, y-, z-, and t-system of coordinates.

Among the apparatus discussed were the following: kites, kite balloons, integrating anemometers, sonic gustometers, and differential microbarographs. It was concluded that a primary purpose of instruments mounted in a multi-tower array is to answer the following question: "Do eddies propagate downwind, and if so, how?"

2. Numerous conferences have been held throughout the reporting period with staff members of The University of Michigan. Among these may be mentioned:

Professor E. F. Barker, Physics
Professor A. H. Copeland, Statistics
Professor C. C. Craig, Statistics
Dr. A. N. Dingle, Meteorology
Professor B. G. Johnston, Civil Engineering
Professor A. M. Kuethe, Aerodynamics
Dr. V.-C. Liu, Aerodynamics
Professor R. H. Sherlock, Civil Engineering
Professor R. M. Thrall, Statistics
Dr. M. S. Uberoi, Aerodynamics

3. On July 22, 1955, a conference was held at Evans Signal Laboratory, Belmar, N. J. Among those present were Messrs. D. A. Deisinger, H. J. aufm Kampe, L. P. Panak, A. Arnold, and the writer. The future program of research was discussed in detail, and tentative plans for the future were made.

FACTUAL DATA

TASK A: STATISTICAL DESIGNS

A survey of the literature to determine the relevance of earlier studies of low-level wind structure as it pertains to dynamic wind loading has been conducted. Perhaps the most significant of the earlier studies are those made by R. H. Sherlock and associates (References 1 through 6) in which the gust structure of portions of several winter storms was examined in detail. Many of the data available have not been published. For example, there are on IBM cards 60,000 wind velocities, each representing an average for 1/4, 1/2, 1, 2, 5, or 10 seconds; the measurements were made at heights of 25, 50, 75, 100, 125, 150, 200, and 250 feet, and horizontally at points 60 feet apart and 50 feet high extending for a total length of 660 feet. A considerable amount of statistical analysis of the measured values has been carried out earlier. This includes averages, standard deviations, coefficients of skewness, and coefficients of variation, calculated for 5-minute intervals. In addition, correlations between values at a given station and those at each of the other stations have been computed. These correlations were also done with various time lags.

There have been other studies of the gust loading of various structures, such as that of Cedric Marsh (Reference 7) of a 100-foot aluminum tower used to carry lighting projectors for the illumination of a marshalling yard at Bienne, Switzerland. A second example is the study by Baird (Reference 8) of wind-induced vibrations of a pipeline suspension bridge spanning the Colorado River near Blythe, California.

The wind structure over mountainous terrain has been discussed by W. Watters Pagon (Reference 9) and a comprehensive review of wind loading on structures which emphasizes the earlier British studies of F. J. Scrase, M. A. Giblett, and others has been presented by M. R. Horne (Reference 10).

Studies of the gust loading and response of moving objects seem to be of rare occurrence. A notable example of such a study is that on wind effects on automobile stability by W. E. Lay and P. W. Lett, Jr. (Reference 11).

The all-weather bivane and aerovane mounted on the tower at Brookhaven National Laboratory have been used to analyze the larger-scale features of atmospheric turbulence; analyses of the spectra, cospectra, and quadrature spectra have been presented by I. Van der Hoven and H. A. Panofsky (Reference 12) and by H. A. Panofsky and R. A. McCormick (Reference 13). Gust loading on aircraft has been studied by H. Press and J. C. Houbolt (Reference 14).

TASK B: WIND INSTRUMENTS

Only general consideration has as yet been given to the question of the most suitable wind instruments for measuring the large-scale eddy structure of the atmosphere. Among the possibilites canvassed are the following: kite balloons, sonic gustometers, and differential microbarographs.

TASKS C AND D:

Activation of these tasks will take place after Tasks A and B are further developed.

CONCLUSIONS

Past research on low-level wind structure offers relatively little guidance in establishing a suitable design for an experimental program. The problem must be viewed from its fundamental aspects and a fresh approach developed.

PROGRAM FOR NEXT INTERVAL

The study of statistical designs will continue during the next quarter. The examination of detailed designs will commence, and their features will be assessed. It is proposed to start this phase of the program by making a detailed survey of the wind data obtained by Professor R. H. Sherlock and associates and of the various statistical operations which have already been performed on these data. It may be found that this information will be useful in the analysis of the problem.

Increased emphasis will be placed on the evaluation of wind-measuring instruments during the next quarter. Mr. G. C. Gill joined the staff of The University of Michigan near the end of the reporting period and will study this phase of the problem during the next quarter.

IDENTIFICATION OF PERSONNEL

The following personnel have been employed: Professor E. Wendell Hewson, 234 man-hours; for consultation, Professor John W. Tukey of Princeton University, 8 man-hours.

REFERENCES

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5. Sherlock, R. H., "Gust Factors in the Design of Buildings," International Association for Bridge and Structural Engineering. Vol. 8, 207-236, 1947.

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8. Baird, R. C., "Wind Induced Pipe Line Bridge Vibration and Its Cure," Pipe Line News, Vol. 27, No. 1, 34-41, 1955.

9. Pagon, W. Watters, "Wind Velocity in Relation to Height above Ground," Engineering News-Record, Vol. 114, 742-745, 1935.

10. Horne, M. R., "Wind Loads on Structures," J. Institution Civil Engrs., Vol. 33, No. 3, 155-178, 1949-50.

11. Lay, W. E., and P. W. Lett, Jr., "Wind Effects on Car Stability," Transactions Soc. Automotive Engrs., Vol. 61, 608-622, 1953.

12. Van der Hoven, I., and H. A. Panofsky, "Statistical Properties of the Vertical Flux and Kinetic Energy at 100 Meters," Final Report to Air Force Cambridge Research Center under Contract No. AF19(604)-166, June 1954.

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14. Press, H., and J. C. Houbolt, "Some Applications of Generalized Harmonic Analysis to Gust Loads on Airplanes," J. Aeronautical Sciences, Vol. 22, No. 1, 17-26, 1955.