TRANSPARENT RESPONSE OF ANEMOMETERS

Synopsis

In 1954, Schubaur and Adams in USA and Yaglim in USSR, independently developed a linear transient theory for rotating anemometers and introduced a method of representing the transient characteristics by a certain length which was called as the "Distance constant" by the American workers and as a "Synchronisation length" by Yaglim. It was supposed that this length represented a minimum eddy size which the instrument could resolve. It was practically assumed by all workers that the steady state calibration curves of "standard" anemometers inside the wind tunnels are essentially valid even when the instruments are exposed to natural non-steady wind. The nonlinearity in the aerodynamic interactions of the wind and the anemometers has not been discussed before, with the consequence that it has been taken that the anemometers behave like linear sensors.

In the present thesis, a nonlinear theory for the anemometers has been developed and it is claimed that this nonlinear theory is more suitable for the real atmosphere than the linear theory. In the light of this theory, it is found that the records of currently used anemometers suffer from the following defects.

1) The current concept of "Distance constant"
of anemometers for the interpretation of transient response is not valid for the real atmospheric conditions.

ii) Currently used anemometers underestimate the amplitudes of gusts by quite large amounts, frequently by a factor of two or more.

iii) These anemometers also exaggerate the mean wind speeds, frequently to the extent of about 25%.

A new equipment based on the principle of "lead compensation" for the lag has been developed for the anemometers. The equipment is simple and economical. This equipment, when attached to the currently used electrical anemometers, is shown to provide a substantial improvement in the recording of the amplitudes of the gusts and in the reading of the mean wind speeds.

In the first chapter, the nonlinear theory is developed for the cup anemometers. It has been shown that the values of speeds of rotation for various steady state wind speeds inside the wind tunnel can be calculated from the mechanical properties of the rotor assembly, viz. the inertia, the friction and the aerodynamic forces that would act on stationary cups. The data on these latter forces published by Brevoort and Joyner (1934) have been used for calculation. It is shown that the calculated
speeds of rotation for various wind speeds agree with the published experimental values. It is further shown that the time constants of anemometers for sudden rise in wind speeds of different values calculated from the theory also agree with the published data.

The theory has been extended in the second chapter for the vane anemometers. The calibration curves for these anemometers calculated on the theoretical grounds have been shown to agree with the experimental curves. Effects of various parameters, viz. the air density, the inertia and the friction on the response of rotating anemometers have been discussed on the basis of the theoretical formulae.

The differential equation representing the rotating anemometers was solved on analogue computers for the following three cases.

1) To study the response of frictionless anemometers for wind speeds assumed to vary sinusoidally,

2) To study the response of frictionless anemometers for random wind speeds,

3) To study the response of actual anemometers with friction in natural air.

The solution represents the true response of the anemometers.
On the basis of linear theory, this response is interpreted as the wind speed. Now, the comparison between the real wind speed (input) and the indicated wind speed (output) reveals the following characteristics.

a) considerable reduction in the amplitudes of gusts, sometimes amounting to a factor of two or more, in the indicated wind when compared to the real wind;

b) considerable exaggeration of mean indicated wind speeds over the actual mean speeds, and

c) a phase lag or displacement of the instants of occurrence of the indicated fluctuations along the time axis.

The problem of evaluation of the true wind structure in natural air has been tackled in the fourth chapter. To achieve extreme precision with error within about 1.0%, the equipment would become quite complicated. However, since an accuracy within 10% is satisfactory for the measurement of instantaneous wind speed (along with an accuracy within 5% for the measurement of the mean wind speed) for the normal aviation purposes, a much simpler arrangement is possible. A simple circuit has been devised which would give, on theoretical grounds, the true structure of wind to this accuracy. The details of experimental set up are given. The equipment has been called the "wind speed evaluator" or simply the "evaluator". It is meant to be used along with the electrical anemometers.
The shapes of true gustiness structure demand new definitions for the various gust parameters. These definitions are introduced in the fifth chapter. The effects of lag of the anemometers on these parameters are discussed. Certain statistical characteristics of monsoon wind, viz. the moving averages, standard deviations, autocorrelations and the power spectral components are derived, in this chapter, from the gustiness structure recorded by the "evaluator." These are compared with those quantities derived from the direct indications of the anemometer. The comparative results are presented and discussed in this chapter.

In the sixth chapter, the response characteristics of static anemometers, viz. the Pitot's tube and the Dines anemometers have been analysed. This class of anemometers is also shown to have similar characteristics as the rotating types due to the nonlinear effects.

The seventh chapter describes a sensitive anemometer of the vane type with very low inertia and sensitivity down to about 2 cm per sec. with a range extending to 80 cm per sec. Within the range of operation of this sensor also, the transient theory is found applicable and hence the effect of its inertia is just the same as in other anemometers. In other words, it does not appear possible to get a record of true wind structure by simply
reducing the inertia and hence increasing the sensitivity of the anemometer.

The last chapter summarises the essential results of the earlier chapters.