Acoustic Anemometer-Anemoscope

Instantaneous visual presentation of wind direction and velocity on a cathode-ray tube screen. Sixty-cycle pulses from an acoustic transmitter are received at four transducers equally spaced from the transmitter at cardinal points. Doppler effect of wind velocity actuates a discriminator and indicator

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ELECTRONIC instrumentation involving acoustic effects has invaded many fields in the measurement of physical phenomena. Currently, investigation is being conducted to extend this invasion into the measurement of wind velocity and determination of wind direction.

The acoustic anemometer-anemoscope to be described is based on a Doppler phenomenon effectively relating wind velocity with the difference between upwind and downwind acoustic velocity. The components of the instrument, shown in Fig. 1, include a pulse generator which drives a sound head creating acoustic pulses, four electromechanical-transducer listening stations that are oriented at the cardinal points of the compass around the sound head, an amplifier, a discriminator to sort the information coming from the listening stations and an indicator for presenting the information in convenient form.

Operating Principle

The sound head is placed in a convenient location exposed to the free flow of the wind, and the listening stations are arranged as shown at a known distance s from the head. The orientation of the listening stations with compass directions is necessary for determining the direction of the wind.

The sound head, driven by a 60-cycle pulse generator, emits acoustic pulses with nearly vertical wave fronts. The pulses propagate at the speed of sound in all directions and arrive at all the listening stations at the same instant under quiescent conditions, that is, when there is no wind.

Consider a wind as shown in Fig. 2A with the velocity vectors involved in a pulse reaching the listening stations for the east-west component, V_e. Because of the greater acoustic velocity downwind, there will be a time differential between the arrivals of the acoustic pulses at the listening stations.

$$\Delta t = \frac{2sV_e}{v^2 - V^2} \cong \frac{2sV_e}{v^2} \qquad (1)$$

when v is speed of sound, V is wind speed and t is time. The approximate expression is in only slight error amounting to less than

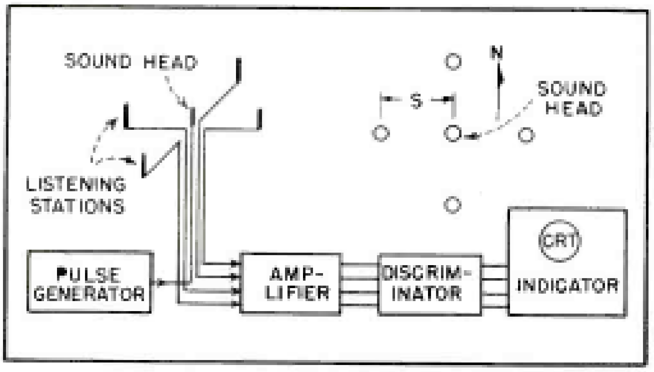


FIG. 1—Block diagram of the acoustic wind direction and velocity indicator

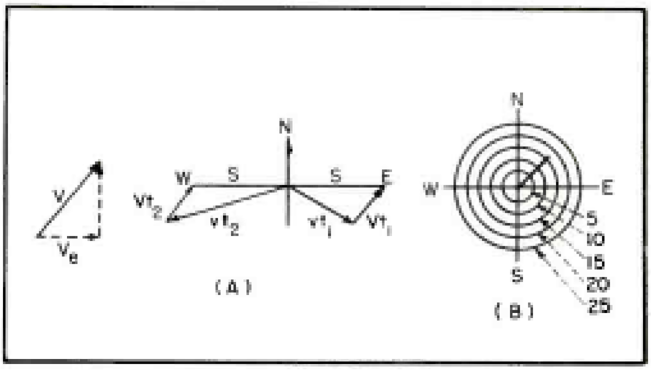
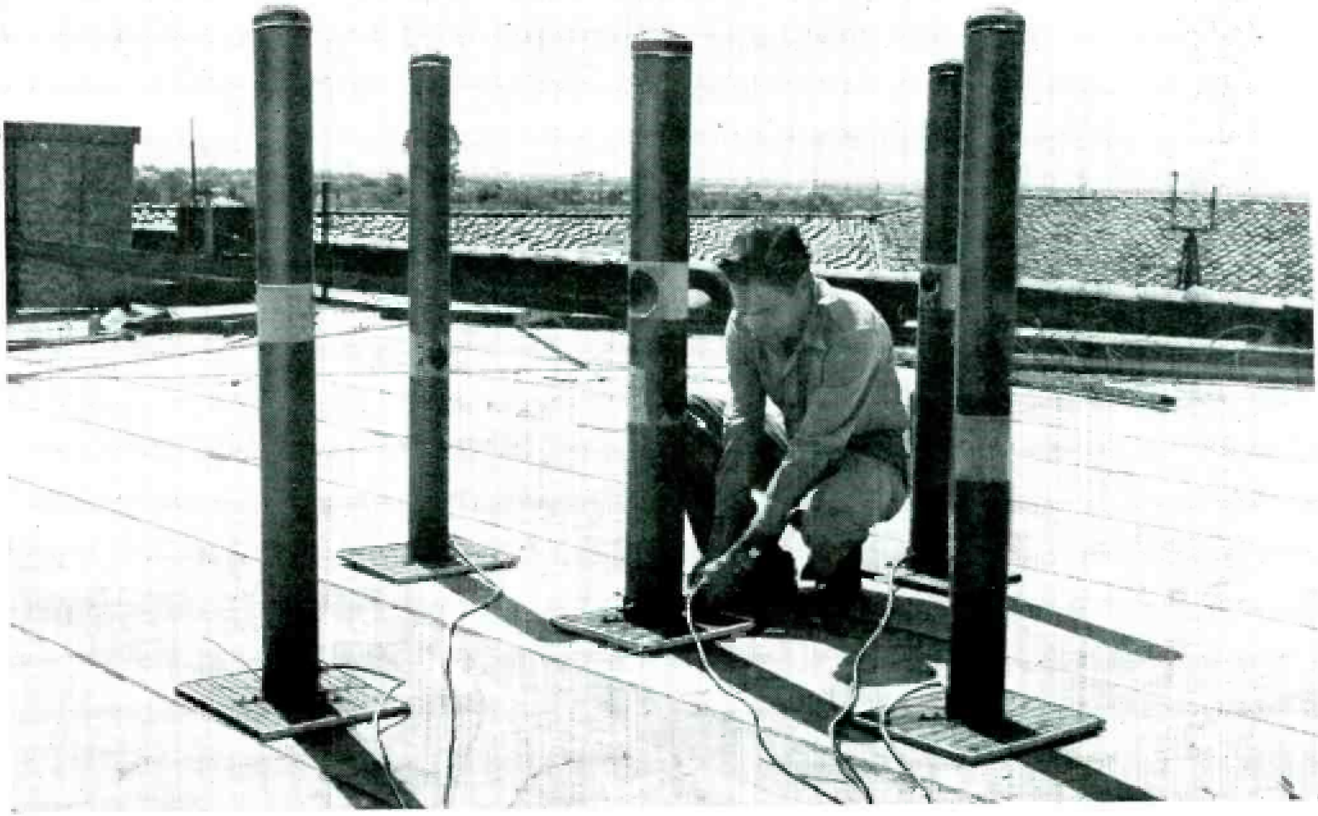


FIG. 2—Vector relationships for a wind from a southwesterly direction (A) and crt presentation (B)



The sound generator is connected to the center-pillar transducer or sound head. Simultaneous transmission to four directions is picked up by the four surrounding receiver transducers. Wind retards or accelerates the normal velocity of sound

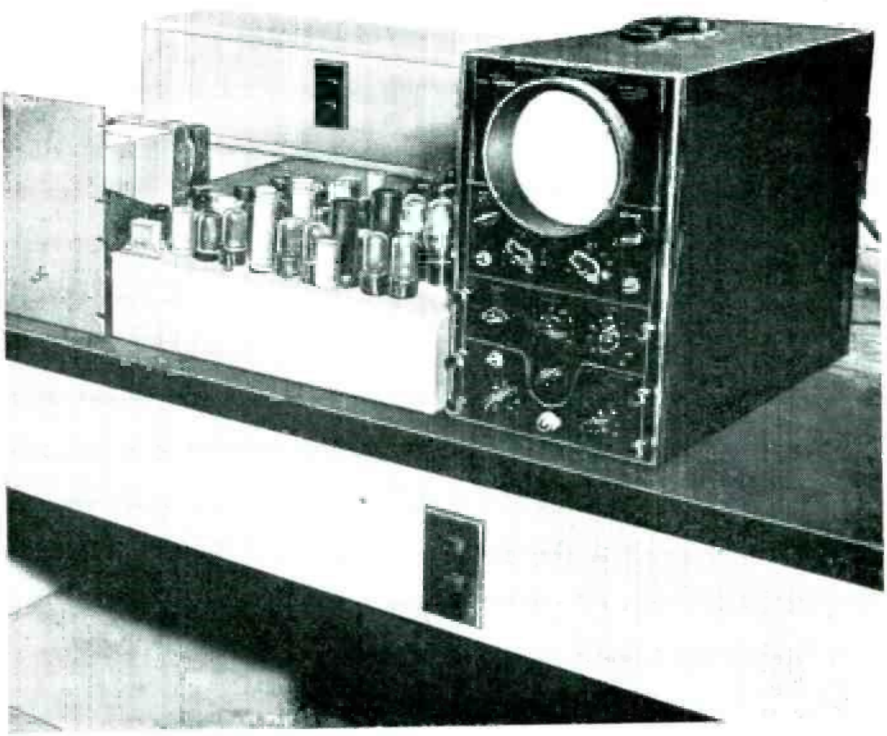
0.5 percent at a wind velocity of 50 miles per hour.

It is evident that a given pulse will arrive at the east station before reaching the west station and that the time differential is proportional to the speed of the wind as indicated in Eq. 1. By approximation, assuming that s equals 5 feet, it can be found that Δt is in the order of 15 microseconds per mile per hour.

Winds coming in from other than cardinal-point directions are divided into east-west and north-south components automatically by virtue of the placement of the listening stations. These components, as determined by the discriminator, are recombined in quadrature by the indicating unit to yield the wind velocity, as shown in Fig. 2B.

The Apparatus

The electronic apparatus, in general, is conventional. The discriminator, however, performs an inter-



Laboratory setup of the electronic elements of the wind instrument comprises power supply, chassis with twice the equipment shown in Fig. 3 and cro

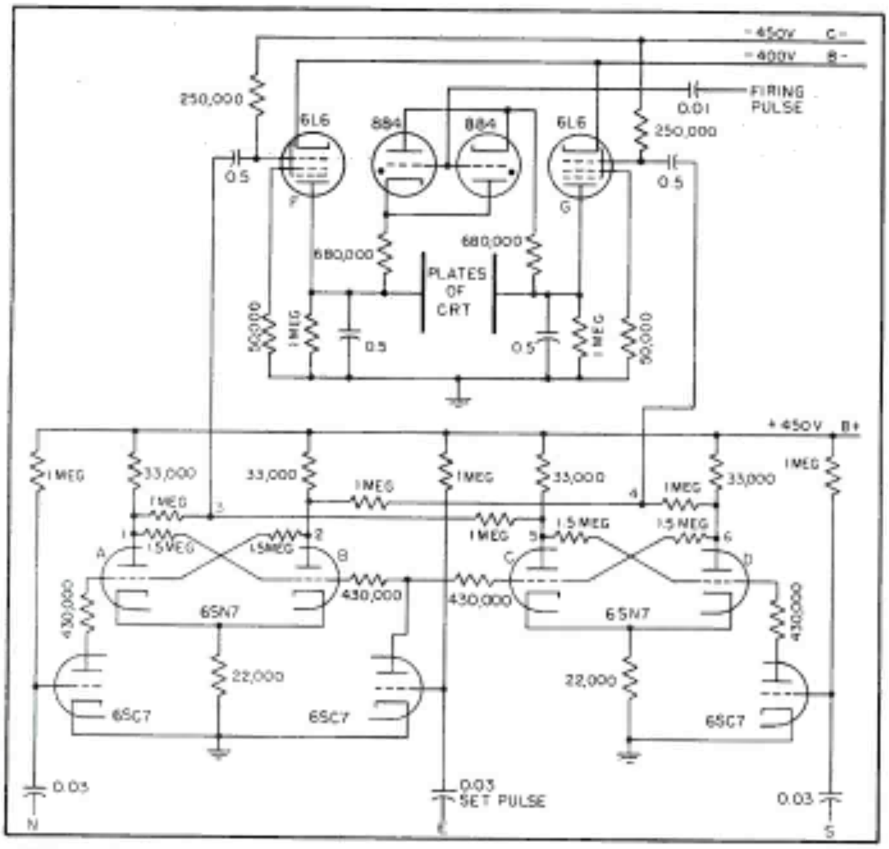


FIG. 3—Circuit of discriminator and indicator for one component of a cross wind

esting function and will be discussed considering the north-south component only.

The purpose of the discriminator is twofold: To determine whether the pulse from the north or the south listening station is received first (which must be known in determining wind direction), and to produce a square-wave pulse with its width proportional to the time differential noted above in determining wind velocity.

The discriminator shown in Fig. 3 is identical for each of the components and consists of an Eccles-Jordan trigger circuit, using a 6SN7, and a 6L6 output tube for each listening station. The 6SC7's shown are used as keying tubes to improve the stability of the trigger-circuit operation. The trigger circuits are set by a negative pulse at *E*, so that tubes *B* and *C* are conducting and *A* and *D* are cut off. In this situation points *1* and *6* are at a higher potential than *2* and *5*. Because of the voltage-dividing network, points *3* and *4* are at an intermediate potential. Points *3* and *4* are of particular interest since they control the type 6L6 output tubes which are biased only slightly below cutoff.

Under quiescent conditions the pulses from the north and south listening stations arrive simultaneously at *N* and *S;* both trigger circuits flip at the same time and the voltages at *3* and *4* remain at the same value. However, if a wind is blowing from the south, a pulse will arrive at *N* a few microseconds before a corresponding pulse reaches *S*. This causes a negative pulse to appear at *3* and a positive pulse to appear at *4*. Consequently, tube *G* puts out a pulse with its width proportional to wind velocity. If the wind blows from the north the situation reverses and tube *F* puts out the pulse. In this manner the circuits discriminate between a north and south wind and produce pulses with widths proportional to the wind velocity.

Circuit Details

The heart of the indicating unit is an electrostatic cathode-ray tube with deflection plates oriented vertically and horizontally. The wind velocity scale in miles per hour consists of concentric circles with zero at the center. The east-west component is applied to the horizontal plates and the north-south component is applied to the vertical plates so that the cardinal points of the compass are in their conventional locations.

The output of the 6L6 tubes consists of a 60-cycle series of square-wave pulses with widths depending on wind velocity. By filtering this output with an r-c filter, a d-c voltage appears across the load resistor that is proportional to the width of the pulses and therefore also proportional to wind velocity. It is this d-c voltage that is applied to the crt.

When there is no wind, a spot appears at the center of the concentric circles. When there is a wind, say from the northeast, the spot moves out the proper distance from the center in the first quadrant (as shown in Fig. 2) and indicates the direction and the speed of the wind. In order to have the indicator draw a vector the 884 thyratron tubes are fired by a 60-cycle pulse so that the plates of the crt are essentially shorted 60 times each second and the spot is returned to the center. This action causes the spot to trace the desired vector. Since the wind velocity is sampled 60 times per second (determined by the repetition rate of the pulse generator), the indicator is capable of following rapid changes of the wind. The deflection sensitivity of the indicator can be varied as desired because oscilloscope deflections of one-eighth to one-half inch per mile per hour are easily obtained.

The acoustic anemometer described is capable of reliable continuous operation and presents the information in a form easily assimilated. It can be sent over transmission lines to the indicating unit in any desired location.

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