A Stepping-Type Wind Speed Maximeter Using Standard Parts

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Introduction

During the latter part of the recent war, in response to an immediate need for an instrument that would indicate, record, or transmit the maximum wind travel during any one minute of a longer reporting interval (such as one hour), extensive experiments were conducted, and several workable instruments were designed and constructed. These devices, described elsewhere[1], having been built under "war rush" conditions, on a "cost immaterial" basis, are not suitable, in their original form, for ordinary station or laboratory use, because of high first cost, short service life, and excessive maintenance needs.

Further study of the problem has resulted in the development of a design for an instrument to indicate, record, or transmit "hourly one-minute wind-speed maxima", composed entirely of standard parts, to be reported here; and of an instrument for indicating, recording, or transmitting longer-term wind-speed maxima (such as monthly one-hour), to be reported separately at a later date.

Basic Principles

The stepping-type maximeter consists, in brief, of a telephone-type stepping switch, which, starting from zero at zero time, is "stepped up" one contact for each wind travel increment until reset to zero by the clock. The position of the contact arm of the switch immediately before resetting to zero at the end of the time interval corresponds to the number of wind travel increments received during that time interval.

Electrically coupled to this first stepping switch is another of identical electromechanical design, so connected to the first that, when both switches start from zero, the second switch steps up one contact each time the first switch is stepped up by a wind travel increment. However, when the first switch is reset by the clock, the second is not. In consequence, at the end of the first time interval, if the first switch stepped to its Nth contact before resetting, the second switch, after the first is reset, remains on its Nth contact. Thereafter, the second switch remains on its Nth contact until the first steps to its N+1th contact. When this occurs, the second switch steps to the N+1th contact and retains that position. As a result, the position retained by the second switch is the maximum attained by the first switch during the time interval under consideration. (Further details of the follower mechanism are given in Figure 4, and in the technical description of the followers).

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[1] Ives, R. L. *Experimental Maximeters for Wind Speed,* Bull. Amer. Met. Soc, Vol. 27, 1946, 224-229.

Arrangement of Components

Arrangement of components of this maximeter is shown in Figure 1, a block diagram in which the major operating connections are indicated. Although the decaders, followers, and interlocks are complexly interconnected, and must be placed close together, the other components are relatively simple, both electrically and mechanically, and may be placed where convenient.

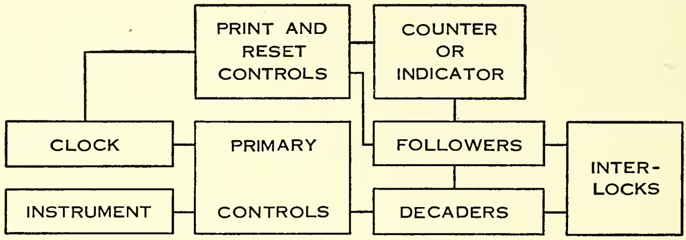

Fig. 1. Block diagram showing arrangement of components of maximeter.

Construction and Function of Components

Introduction. Each major component of this maximeter has a definite and specific function. To reduce the complexity of the circuit diagrams, each circuit is shown with its own battery. In practice, the number of batteries, or D.C. power supplies, is considerably less, and the entire device can be operated from a single power supply of sufficient capacity. Where all components work from a single supply, however, care must be taken to prevent circuit interlocks, power surges, and resultant conflicts of functions.

Instrument. The instrument for which this maximeter is designed is any contacting anemometer of conventional design, such as the Signal Corps ML-80 anemometer, which is a Robinson three-cup instrument, with one-sixtieth mile contacts.

The instrument supplies the wind travel increments (contact closures) from which the maximeter operates. By use of a modified contacting gear, contact intervals other than one-sixtieth mile are obtainable. For special purposes, an electrical submultiplier[2] may be used in conjunction with the anemometer contacts.

Clocks. The clock used with this maximeter is any convenient contacting clock, such as the Struthers-Dunn "Repeating Timer". Two contacting intervals are necessary—one for the measuring period (such as one minute) and one for the recording period (such as one hour). Where line power is available, an electric clock movement is convenient.

The clock supplies the time impulses which determine the measuring and reporting periods. These may be altered, within reasonable limits, by proper choice of gearing and contacting mechanisms.

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[2] Ives, R. L. *Submultiple Anemometer Contactors,* Bull. Amer. Met. Soc. Vol. 27, 1946, 346-347.

Primary Controls. The primary controls couple the instrument and clock to the decaders, and are designed to reduce the possibility of conflicts between instrument and clock signals.

Connections of instrument, clock, and primary controls are shown in Figure 2. The anemometer circuit, consisting of battery A and relay

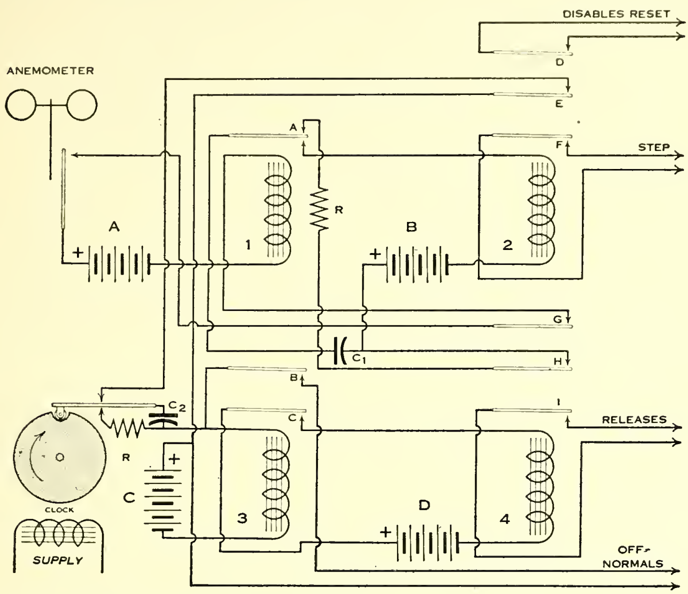

Fig. 2. Circuit of primary controls.

1 may include a long line (up to several miles) from the anemometer tower to the instrument location. Battery voltage, obviously, must be sufficient to compensate for line drop. If desired, an A.C. relay may be used in this circuit, with an alternating current line supply.

Controlled by the anemometer circuit is a limiter circuit, consisting of battery B, relay 2, and condenser C_1. When the anemometer contacts close, the armature of relay 1 pulls down, connecting relay 2, battery B, and condenser C_1 in series. Relay 2 now closes, but remains closed only as long as the charging current of C_1 exceeds the drop out current of the relay. When the current falls below this critical value, relay 2 opens, and remains open, no matter how long the anemometer contacts remain closed[3]. This protects the stepping circuit of the decader, controlled by contacts F of relay 2, from overheating should the anemometer "stall" with its contacts closed, a not infrequent occurrence.

[3] Details and constants of the relay—condenser limiter are fully described in Ives, R. L. *The Relay Oscillator and Related Devices,* Jour. Franklin Institute, Vol. 242, 1946, 243-279; and in Army Report (classified) DPGSR 63, 1946, OC-CWS 5063-63.

When the anemometer contacts open, relay 1 is deenergised, its armature rises, and condenser C_1 is discharged through protective resistor R.

The contact closures which determine the measuring period are produced by the clock, through a limiter circuit consisting of relay 3, battery C, and condenser C_2. Incorporated in this limiter circuit is a "lock in" circuit (contacts B, relay 3), so arranged that the release circuit of the decader is continually energised until all off-normal contacts (in the decader) have opened, but no longer, regardless of the duration of the clock contact closure. This prevents conflict or duplication of release functions, and makes unnecessary a critical adjustment of the clock contacts.

Controlled by the clock limiter (relay 3) is a power relay (4), which energises the release circuits in the decader. One contact on this relay is required for each stepping switch in the decader, and these contacts must be of ample capacity for the relatively large currents drawn. If desired, the local circuit, consisting of relay 4, battery D, and contacts C of relay 3, can be modified for alternating current operation at any desired voltage (within reason).

To prevent overlapping of the control impulses from the clock and anemometer requires protective equipment of impracticable complexity. The number of such overlaps and conflicts, however, can be reduced to a negligible value (such as one per 1,000,000 operations) by use of relatively simple interlock circuits.

Whenever the release circuit (contacts I, relay 4, Fig. 2) is closed, the stepping circuit is disabled by opening of contacts G (relay 4). To prevent a dual stepping impulse when a clock contact closure occurs soon after an anemometer contact closure, discharge of C_1, during a reset period, is prevented by opening of contacts H (relay 4). Conflict of release and anemometer functions is still further reduced by disablement of the clock limiter, during stepping intervals, by opening of contacts E (relay 2). The printer is also kept out of operation during stepping intervals by a disabler (contacts D, relay 2).

A number of alternative interlock circuits are possible. Use of more complicated protective devices is entirely possible, but a condition of "overinsurance", in which more records are lost by failure of the protective devices than would be lost were the protective devices simpler or absent, must be guarded against.

Decaders. In the original maximeter design, the stepping equipment consisted of two 100-point stepping switches in cascade, so that, when the first had stepped upward to its limit (100 points), the second was connected in circuit, and recorded all incoming impulses from 101 to 200. This system, which also required sixteen auxiliary relays, suffered from high first cost, high maintenance cost, and required a major overhaul every few thousand miles (of wind).

Equipment performing the same electrical functions, but consisting of three ten-point stepping switches and only two auxiliary relays, is shown in Figure 3. With this arrangement, the DECADER of Figure 1, the first stepping switch (UNITS, Fig. 3) is advanced one contact for each incoming anemometer contact closure, these closures being of very short duration, because of the action of the limiter (in PRIMARY CONTROLS, Fig. 2).

When the first stepping switch reaches the tenth position, relay 1 (Fig. 3) is energised through the switch arm and contact 10, and closes. This locks in place, through contacts A, and energises both the release

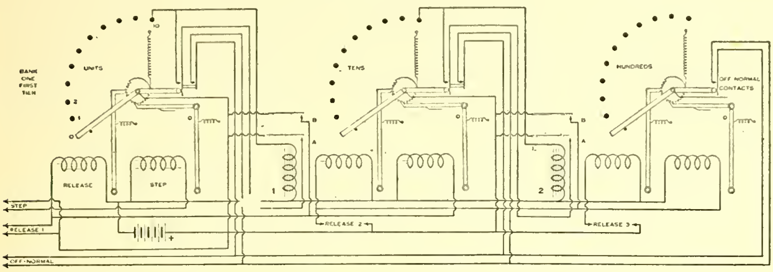

Fig. 3. Wiring diagram of decader.

coil of the Units stepping switch, and the step coil of the Tens stepping switch. This steps the Tens switch from zero position to contact 1, and releases the Units switch, permitting its arm to return to zero position. When this occurs, the off-normal contacts, controlled by the switch arm, open, relay 1 is released by the opening of its lock-in circuit (contacts A), and the Units switch is ready for the 11th impulse, which advances the arm from zero position to contact 1.

An identical sequence of events takes place when the Tens switch arm reaches the tenth contact. The Tens switch is reset to zero, and the hundreds switch is advanced from zero to contact 1. This system can be extended to accommodate any number of incoming impulses, one stepping switch and one relay being required for each power of ten concerned.

At the end of the measuring interval (one minute in this case), the clock, through the limiter circuit in the PRIMARY CONTROLS, closes all the release circuits (Release 1, Release 2, etc., Fig. 3) so that the release coil of each stepping switch is energised from the battery (Fig. 3). The ratchet of each stepping switch is thus released, and each switch arm, actuated by its own return spring, returns to zero position.

As each switch arm reaches zero position, the off-normal contacts controlled by it are opened. The off-normal contacts of all three switches are connected in parallel, and to the "Off Normal" line, which is in series with the lock-in circuit (Fig. 2). When all three off-normal contacts are open, and only then, the lock-in circuit is opened, and the release circuits are deenergised. The decader is then ready for further incoming impulses. The releasing sequence takes place in 0.05 sec. or less, depending upon the tension of the return springs in the stepping switches and related factors.

Immediately prior to reset, the positions of the arms of the decader stepping switches indicate the total number of wind travel impulses during the previous measuring period (minute).

Followers. To retain a record of the maximum count attained during any single measuring period (minute) until the end of a recording period (hour), each stepping switch in the decader is connected to a similar switch wired as a follower. Electrical operation is accomplished by wiring each contact of the second bank in the decader switches to the N-1th contact in the first bank of the corresponding follower switch. Electrical details of these connections are shown for one pair of switches in Figure 4. A relay shunted across the release coil of the follower

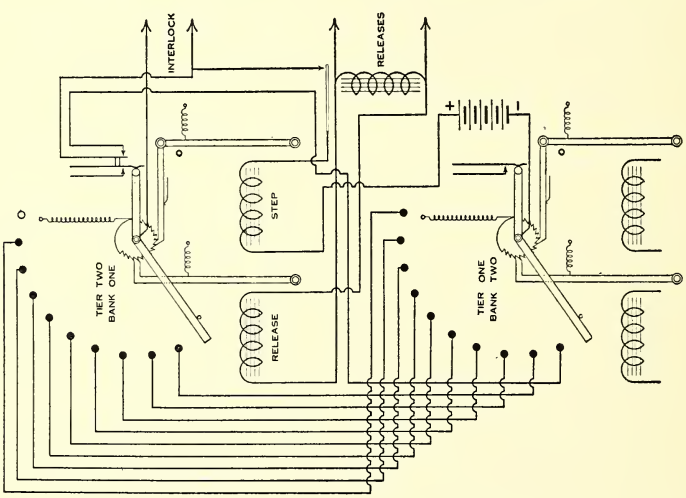

Fig. 4. Electrical connections of follower mechanism.

disables the stepping coil during the time that the switch is resetting to zero, thereby preventing circuit conflicts, with resultant "grabbing" and stripping of the stepping ratchet. The release coil of the units switch in the follower is connected across the step coil of the tens switch in the follower through an interlock (Fig. 5). An identical interconnection of the tens and hundreds followers is made. In practice, both interlocks can be controlled by the same relay, which may be a component of the print and reset unit, also performing other switching functions.

When the interlock terminals in Fig. 4 are shorted, the follower will immediately step up, in response to an increment in the count of the units switch in the decader, to any position; but when it reaches the tenth contact, it remains there, while the decader units switch returns to zero. The follower units switch is returned to zero only when the decader tens switch steps up one position.

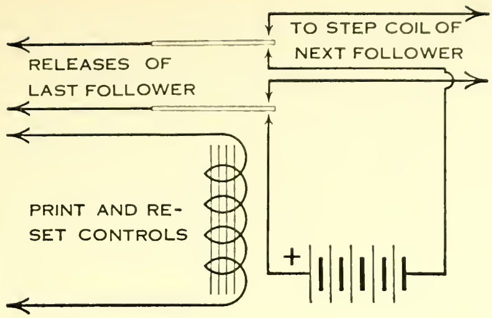

Fig. 5. Follower release interlock circuit.

An electrically and mechanically identical arrangement of switches coupled to the tens and hundreds switches of the decader enables the follower to attain and retain any position reached by the contact arms of the decader switches.

Interlocks. The purpose of the major interlocks between the decaders and the followers (Fig. 1, 3, 4 and 6) is to keep the two systems in phase. Without the interlocks, the units follower, if on position 5 (for example) would step to position 6, in response to an increment in the units switch of the decader, regardless of the positions of the tens and hundreds followers with respect to their respective decaders. By interconnecting the decaders and followers of the tens and hundreds components, so that the units follower will not step in response to a units decader increment unless the increment is an actual increase over the previously-recorded maximum, the total count of the followers becomes a true maximum.

Interlock connections for the units follower are shown in Fig. 6. It will be noted that the units follower interlock circuit is closed only when the tens decader and follower are on like-numbered contacts; and when the hundreds decader and follower are likewise on like-numbered contacts.

Analogous connections are made in the hundreds circuit, using bank three of both decader and follower, to keep the tens circuits in phase with each other. There being no decades beyond the hundreds, the interlock connections (Fig. 4) of the hundreds decader and follower are short-circuited. It should be noted that one bank of contacts, on each switch, is needed for each power of ten concerned in a decaded system, unless subsidiary interlock relays are employed.

Counter or Indicator Connections. A counter or other indicator may be connected to the follower system in many ways, most of them obvious. Simplest connection is to shunt the counter across the units follower stepping coil. This will then indicate the maximum wind travel (per measuring period) since the system (counter and followers) was last reset.

Where counter operating voltage is not compatible with that of the units follower, the counter may be controlled by a relay shunted across the units follower stepping coil.

A slightly different arrangement, permitting close regulation of the counter timing cycle (desirable with high-speed and printing counters)

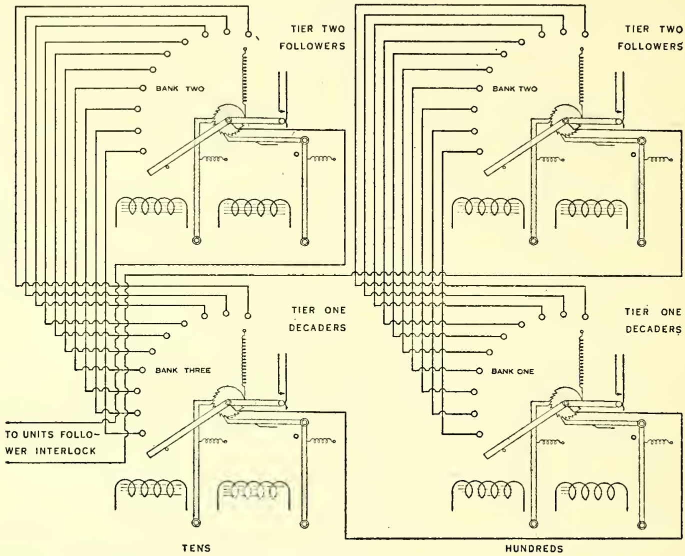

Fig. 6. Interlock circuit for units follower.

is shown in Figure 7. Here, a relay-condenser time limit circuit is operated by the second bank of contacts on the units follower stepping switch. When the switch arm moves from zero position to point 1, the condenser, battery, and counter control relay are connected in series. The

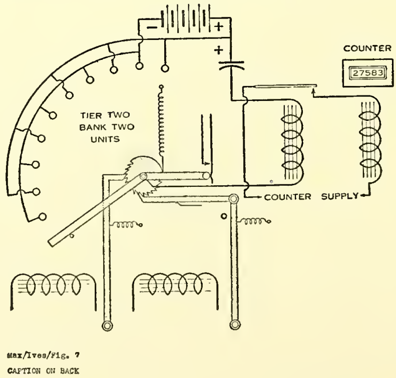

Fig. 7. Time-cycle control circuit for counter, operated by units follower.

relay closes immediately, but remains closed only so long as the charging current of the condenser exceeds the drop-out current of the relay. When this occurs, the relay opens, and will not close again, with this connection, until the condenser is discharged.

When the switch arm travels from point one to point two, the charged condenser is connected across the relay, which closes and remains closed until the discharging current falls below the drop-out value for the relay, which then opens and remains open. The condenser, however, continues to discharge through the relay coil, until its charge declines to substantially zero (see reference 3 for constants and details of operation).

Print and Reset Controls. When a printing counter is used, as is desirable in unattended or busy stations, it is operated, at the end of each reporting period, by a clock control, similar, except for contacting interval, to the clock shown in Fig. 2. Immediately after printing, the counter and the followers are reset to zero (this can be done automatically), and a new recording cycle begins. Exact circuit arrangement depends upon the construction and constants of the printing counter used, and is, in most instances, simple and obvious.

Operation

Operation of a maximeter of this type is entirely automatic, except for periodic replenishment of the recorder ink and paper, and systematic checking and maintenance.

Each anemometer contact closure causes a one-step increment in the count of the decader. When the units decade reaches top mark (10), the units switch automatically resets to zero, and in so doing steps the tens decade switch up one point. When the tens reaches top mark, it returns to zero, and steps the hundreds decade up one point.

The followers, acting in response to circuit completions in the decaders, increase their total count whenever the count of the decader exceeds the previous total count of the followers.

The decader is reset to zero at the end of each measuring period, but the followers are not. In consequence, the follower total is the maximum count attained since the last resetting by the decader. At the end of each recording period, the follower count, as recorded on a printing counter (or otherwise) is printed on a record tape, and the entire system is reset to zero.

If the measuring period is one minute, and the recording period is set at one hour, the resultant record consists of the one-minute wind speed maxima attained each hour. A wide variety of other measuring and recording intervals are possible, and relatively minor instrumental modifications make possible measurement of other maxima. If the decader alone is used, it is a convenient totalizing device for various data indicated by contact closures of irregular or random temporal arrangement (such as static or cosmic-ray "bursts").

Maintenance

Electro-mechanical equipment, in general, is fairly rugged, and will continue to function for a considerable time even under conditions of total neglect. Electro-mechanical recording equipment, such as the maximeter here described, in which a number of functions are interdependent, will not retain its accuracy, even though it may appear to be working, unless skilfully and systematically maintained. Where standard telephone components are used, weekly cleaning of contacts, oiling of bearings, and testing of all functions, is indicated. Maintenance may be facilitated if the components are mounted so that all adjustments are easily accessible to the maintainer. Adjustments that can only be made by use of a bronchoscope are usually neglected.

Experience with pilot models of this type of maximeter indicates that testing is greatly facilitated if a jack is placed in each stepping circuit, so that each switch may be tested by plugging in a standard telephone dial. This permits checking of the switches individually, and of any part of the assembly, in a matter of minutes.

Conclusions

Redesign of this maximeter, so that standard telephone parts are used in place of expensive "made to order" components, has reduced first cost from slightly more than $800.00 exclusive of the counter, to about $220.00 (1947 prices). Sixteen fewer relays are needed in this newer design, and the number of replacement parts which should be kept in stock has been halved. Maintenance costs are markedly lower, as is the difficulty of maintenance work. It is probable that component life has been increased, although, because of the ending of hostilities, no maximeter of this specific design was used long enough to wear out.

Additional minor modifications, using nonstandard assemblies of standard components, suggest slight reductions in the number of fallible parts and contacts, but give no promise of marked reduction in either costs or maintenance needs.

Where it is necessary to record hourly one-minute wind speed maxima, or similar conditions, the design here outlined is superior in all respects to the original (reference 1). Minor modifications of this instrument, or of its major components, will be found useful in various recording, computing, and discriminating instruments for use in environments where either mechanical or vacuum tube devices are not suitable.