Weston ENGINEERING NOTES

VOLUME 11 MAY 1956 NUMBER 1

In This Issue

John Parker, Editor

W. A. Graham, Technical Editor

WESTON ELECTRICAL INSTRUMENT CORP.,
A Subsidiary of Daystrom, Incorporated,
614 Frelinghuysen Avenue,
Newark 5, N. J., U. S. A.

AUTOMATIC SPEED-CHANGE SENSING SYSTEM FOR USE WITH AUTOMATION EQUIPMENT

FOR many years, electrical tachometer generators have been used to provide a signal for the indication and recording of speed. To meet the requirements of automation, several methods were developed for the use of this signal in automatic speed control. Most of the systems employing these methods do not have many of the necessary qualities. Some are too costly or require expensive maintenance, especially where vacuum tubes are involved, and many are disproportionately large. Others are so inflexible in their adaptation that they must be specifically designed for each installation. The system described in this article offers advantages which make it especially adaptable to automatic motor speed control.

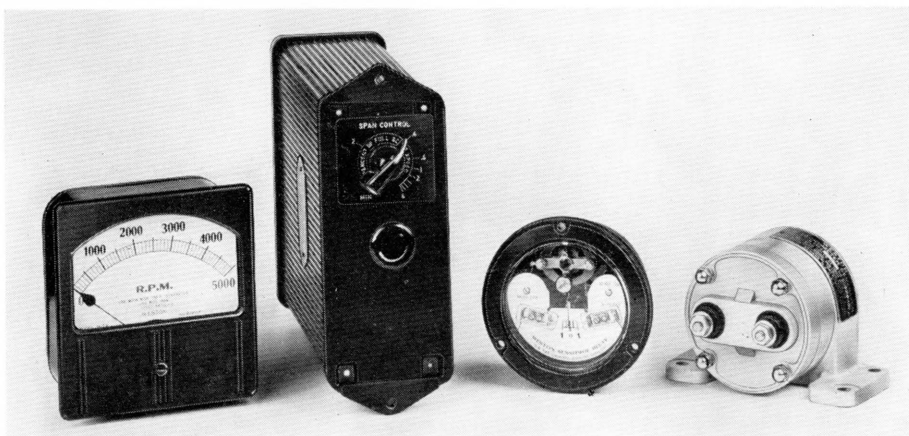


Figure 1—The Component Parts of the Automatic Speed-Change Sensing System Dismounted From Panel.

The system consists of four components; an a-c tachometer generator, a d-c indicator, a d-c relay in a differential circuit, and a frequency responsive transformer box which is the "brain" of the device. In an installation (Figure 1), these components are, left to right: a 5 ma d-c, zero left, Weston Model 741 Tachometer Indicator; a Weston Model 9906 Type 41A9R transformer box modified for this particular application; a 4.5 ua d-c, zero center, Weston Model 723 SENSITROL® Relay containing a special bridge type resistor network; and a Weston Model 758 Type ABF Tachometer Generator.

Automatic Speed-Control Units

This system has been designed for use by many speed-control manufacturers as the basis of their automatic units. When used in a control unit, it can maintain the speed of the controlled device to within ± ¼% of the maximum operating (or top) speed. In addition, visual indication of speed changes of as little as 2 rpm in 5,000 can be seen on the relay scale, and this value can be considered as the sensitivity of the arrangement.

In order to give complete flexibility of control, the system has been provided with three major adjustments. The principal adjustment is used to choose the point of operation at any desired speed between 500 rpm and the top speed which has been set by the second adjustment. This second adjustment sets the top speed of the control system equal to the top speed of the machine to be controlled, and it is continuously variable from 1,000 to 5,000 rpm. This allows the control manufacturer to derive certain advantages, which will be discussed later, by narrowing the control range of the system. It also establishes the machine speed required for full-scale deflection of the monitor speed indicator. The third adjustment is used to vary the span of control from $\pm \frac{1}{4}\%$ to $\pm 6\%$ of top speed, and is also continuously variable.

Schematic Circuit Diagram

The circuit of this system is shown schematically in Figure 2. The generator provides a signal at a voltage and frequency which are proportional to its speed. This signal is applied to the primary of T_1 (a saturable core transformer). A 110 vac, 60 cps signal from any source is stepped down by T_3 and applied to the primary of T_2. This frequency need not be 60 cps (e.g., it could be 50 cps or 400 cps), but it must be maintained within $\frac{1}{2}\%$ of its nominal value. Since the transformer cores saturate early with respect to the applied voltages, the output of both transformers is a series of a-c pulses (pips). Each train of pulses is of constant amplitude; therefore, the average value of the currents caused to flow in the secondaries of T_1 and T_2 will depend only on the frequency of these pulses, higher frequency corresponding to higher average current. Voltage variations in either source will not disturb the frequency response by more than a negligible fraction of the practical precision of which the system is capable. Finally, both currents are rectified and applied to opposite sides of the relay bridge circuit. Note that full wave, half bridge, rectifiers are used. This is done both to protect the rectifier elements from any current surge which would result if one of the signal sources were disconnected, and to reduce temperature effects. The main bridge circuit consists of three precision resistors and the relay moving coil. Since the function of this bridge requires that the resistance relationships of its arms remain unaffected by variations in temperature, all elements are physically located within the relay. The relay makes contact when the current to one side of the bridge exceeds that to the other by an amount established by the setting of R_2.

M_1 is the moveable coil of the speed indicator and requires the passage of 5 ma d-c for full-scale deflection. The setting of R_1 determines at which actual tachometer generator speed this current will flow. R_2 is a ganged potentiometer with one section connected in series with the moveable coil of the relay and the other shunting it. Varying this control changes the amount of current required in this arm of the bridge to cause actuation of the relay. R_3 is the "Zero" control. Once the operating speed has been chosen, R_3 is adjusted until the current to its side of the bridge matches that being supplied to the generator side. At this point, no current will flow in the moveable coil arm of the bridge and the relay contact arm will be centered so that both control contacts are open. Any deviation from the speed thus established will cause the current from the generator side to be either greater or less than that from the 60-cycle source side. When this condition exists, current will flow through the arm of the bridge containing the relay moveable coil, causing deflection of the relay contact arm, so that one or the other control contact will close.

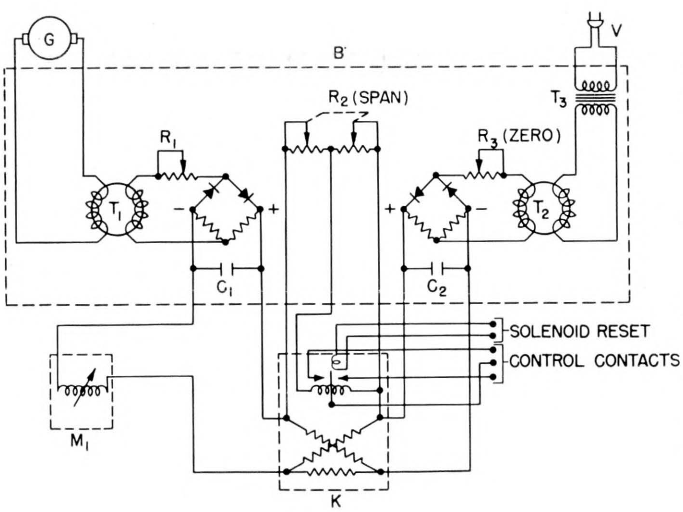


Figure 2—Schematic Circuit Diagram of Speed Sensing System.

G—Model 758 Type ABF Tachometer Generator.

B—Model 9906 Type 41A9R Modified Transformer Box.

M_1—Model 741 Tachometer Indicator.

K—Model 723 D-C Relay in differential circuit.

V—110 Volt A-C 60 Cycle.

System Operating Tables

The tables in Figure 3 help to explain the operating parameters of the system. Since the system is sensitive to frequency, it is easily seen that a change in the frequency of the 60-cycle source can cause a deflection of the relay moveable contact similar to that caused by a change in speed. The higher the speed at the control point, the lower will be the percentage change in frequency necessary to actuate the relay, and consequently the greater effect such a change of line frequency will have. Let us assume that the frequency of the 60-cycle source could vary as much as 0.3 cps. (The short-term frequency variations involved are usually less than 0.25 cps and the long-term changes usually less than 0.1 cps.) Table A demonstrates that, at 5,000 rpm for top speed, minimum span, and 5,000 rpm operating speed, the maximum percentage change in line frequency is twice that required to actuate the relay. At 2,500 rpm operating speed and with the same top speed and span conditions, the maximum line change is equal to the required percentage change. Below this speed, line frequency changes become essentially ineffectual. Table B shows the same conditions, except that the span has been set at four times the minimum. Under these conditions, line frequency variation is never more than half the required percentage change and can be disregarded.

Note that the minimum span in C is 7.5 rpm, whereas in A it was 12.5 rpm. It is the nature of this system that, as top speed is reduced, minimum span is reduced proportionately. At 1,000 rpm, which is the lowest point to which the top speed can be set, the minimum span is ± 2.5 rpm.

Table E shows the conditions of a system with a top speed of 3,000 rpm, but with a span equal to that in A. The percentage change required in both cases is equal. It can be seen that the percentage shift in speed required for actuation is dependent directly upon the span. However, the lowest possible span is dependent upon the top speed, and therefore the top speed indirectly affects the percentage deviation required for actuation of the relay.

Complete Interchangeability

Basically, all components are completely interchangeable with others similarly constructed. For given speeds, the frequency of the generator output is dependent upon the number of its poles. The average value of the current from the secondary of the saturable core transformer is dependent upon the frequency of the generator. Therefore, generators with the same nominal voltage output and number of poles can be interchanged with no loss in accuracy. The transformer box is completely adjustable, thus does not introduce inaccuracies when interchanged. The relay contains the balanced bridge. So long as a replacing relay contains an identical circuit, no inaccuracies will be caused by replacement. If, however, the resistance of the moveable coil of the replacing relay is not substantially equal to that of the original, there may be a slight change in bridge balance, causing an error in the indication of the speed indicator. This error will be small by comparison to the 1½% over-all accuracy of the indicator and can usually be disregarded. Any 5 ma d-c instrument can be substituted at M_1 (Figure 2). Once installed and properly adjusted, its accuracy will be that of the instrument proper plus ½% of top mark to allow for possible temperature and aging influences on the rectifier bridge. It must be remembered, though, that the absolute accuracy of the indications of this instrument will depend upon the accuracy of the adjustment of R_1. This adjustment should be made against a reliable tachometer standard or with the generator driven by a synchronous motor of known speed.

Because of the complete interchangeability and adjustability of all components of the system, it is possible for the speed control system manufacturer to stock a quantity of identical relays, transformer boxes and generators plus a quantity of speed indicators calibrated to various top marks, e.g., 0—1,000, 0—2,000, 0—3,000 etc., and still be able to supply each of his customer's individual requirements. If an accuracy of ± 2½% on the speed indicator is satisfactory, this program can be broadened by stocking a quantity of identical speed indicators together with a quantity of variously calibrated scale plates instead of the variety of indicators previously mentioned. The reductions in cost and increased speed of delivery obtained by this approach are readily apparent. From the manufacturer's viewpoint, such a program permits a certain degree of quantity production with advantage to himself and the customer in reduced costs and improved deliveries.

Since generator voltage errors do not affect the operation of the speed sensing system, it is possible to use bearingless tachometer generators such as the Weston Model 758 Type XF. Through the use of this type generator, the top speed at which the system can be operated can be extended up to 80,000 rpm.

In the present design of the unit, R_1 and R_3 (Figure 2) are 10-turn rheostats with resistance values of 6,000 and 2,000 ohms, respectively. This type of control must be used in order to obtain the resolution re-

Operating Speed, rpm	Generator Speed, cps	Span, rpm	Change in Gen. Frequency to Operate Relay, %	Max. Line Frequency Var., %
TABLE A — Full Scale—5,000 RPM				
5,000	333.3	12.5	0.25	½
2,500	166.7	12.5	0.50	½
500	33.3	12.5	2.50	½
TABLE B — Full Scale—5,000 RPM				
5,000	333.3	50	1.00	½
2,500	166.7	50	2.00	½
500	33.3	50	10.00	½
TABLE C — Full Scale—3,000 RPM				
3,000	200.0	7.5	0.25	½
1,500	100.0	7.5	0.50	½
500	33.3	7.5	1.50	½
TABLE D — Full Scale—3,000 RPM				
3,000	200.0	30	1.00	½
1,500	100.0	30	2.00	½
500	33.3	30	6.00	½
TABLE E — Full Scale—3,000 RPM				
3,000	200.0	12.5	0.42	½
2,500	166.7	12.5	0.50	½
500	33.3	12.5	2.50	½

Figure 3—Typical Operating Parameters.

quired in a system of such high accuracy. R_2 has been designed so that control span variations leave the total resistance of this bridge arm unchanged. Condensers C_1 and C_2 reduce the d-c ripple component of the rectified current. The germanium rectifiers in the rectifier bridges are especially selected for their low temperature coefficients and exceptional linearity. The relay is of the Weston SENSITROL® type in which the contacts, once made, are held closed magnetically. The inclusion of a reset solenoid in the relay permits remote or automatic resetting. The latter is useful when the system is used for speed regulation and serves to center the relay contact arm once the correct speed has been re-attained.

Typical Installation

Figure 4 illustrates a typical installation using this equipment. To adjust this system, the person installing the speed control runs the generator at a speed equal to that required for full-scale deflection of the speed indicator. He then adjusts R_1 (Figure 2) until the pointer of the indicator is at top mark. The

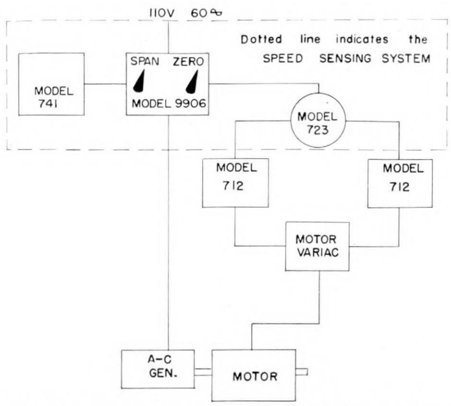


Figure 4—Block Diagram of a Typical Application.

unit is then ready for installation. When in use, the operator runs the machine at the speed required for a particular operation and, maintaining this speed, adjusts R_3, marked "Zero," until the relay indicates zero. He then sets R_2, "Span," to the required limits of control.

The system will now attempt to maintain the motor at this preset speed within the established limits. Any change from this speed greater than the span setting will cause the Model 723 Relay to make contact. This in turn actuates one of the Model 712 Power Relays. These relays are designed to perform a dual function. One set of contacts resets the Model 723 Sensing Relay as soon as the latter is actuated by a change in speed. Since the power relay contacts are self-releasing, they will therefore be closed only momentarily. The other set of contacts supplies a pulse of a-c current to the motor variac, changing its position, thus changing the voltage to the motor being controlled. This process will repeat until the correct speed is regained by the controlled motor. Under proper conditions, regulation can be achieved without hunting.

From the above discussion, it can be seen that the equipment embodies the qualities considered desirable for a system of this nature, namely, accuracy, flexibility in use, economy both in initial and maintenance costs, complete interchangeability of components, ruggedness, long life and compact design. The Weston Speed-Change Sensing System should be of considerable value in meeting many of the problems faced in the field of automatic control.

E. N.—No. 113

—*R. E. Weber* and *P. A. Panfile.*

DIFFERENTIAL SPEED INDICATOR

EDITOR'S NOTE: This article is a reprint of a paper presented by Mr. A. H. Wolferz, Division Chief, A-C Development, of Weston Electrical Instrument Corporation, on February 1, 1956, in New York City, before a session on Instruments and Measurements of the Winter General Meeting of the American Institute of Electrical Engineers. Applications of this system are in use in a number of industrial plants.

ALONG with the measurement of speed, the measurement of speed difference is finding an important place in industry.

In the manufacture of paper, for example, the successive rolls are required to rotate at slightly different and very definite peripheral speeds so as to provide the proper take-up and to avoid undue tension, and the same holds true in the rolling of metals. Some processes require the speeds to be kept equal, the difference, therefore, being zero. It is also desirable, on occasion, to use this difference of speeds as a means of control.

Among the methods employed, the differential gear systems have been successfully used, but are limited to the speed range of the gears and the proximity of the members whose speed difference is to be considered.

For a more flexible system, d-c generators may be driven by the sources under consideration. These generators produce a voltage proportional to speed and, when connected in opposition, a current indicator in series will give a measure of the difference in these speeds. This method, however, is dependent upon the voltage stability of the generators. Voltmeters are usually connected to the generators to show the actual speeds, and the readings of these indicators will be affected by the difference current between the generators. The speed range of these generators would also limit their usefulness. If one generator should fail, the indication of speed by the voltmeter connected to the other generator would be in considerable error.

A-c generators in opposition would allow a wide range of speed, but cannot be used directly because of phase relation. If the outputs were rectified and compared, any nonlinearity of the rectifiers and the stability of the generator voltages would also influence the measurement.

Requirements for Satisfactory Differential Speed Indicator

We may consider, at this point, the several requirements for a satisfactory differential speed indicator:

1. Responsive to the speed, but not influenced by the voltage change of the transducers.
2. A wide range of speed.
3. Good resolution.
4. Readings concurrent with the speed.
5. Measurement of each speed should not be influenced by the difference.
6. Speed indications should be independent.
7. Not affected by phase relation of generators.
8. Not affected by ambient temperature.

Basic Circuit

A system which conforms to these requirements is shown by the schematic circuit diagram, Figure 1, the

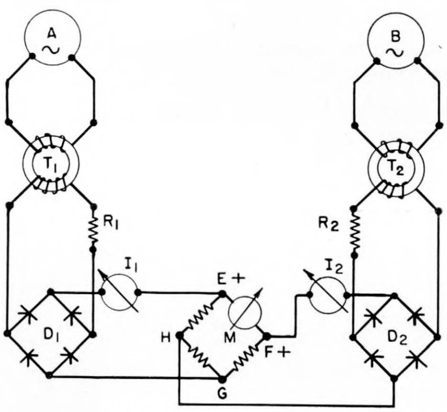


Figure 1—Schematic of Differential Speed Tachometer System.

components of which system are described as follows:

Generators A and B may be considered transducers of motion, whether angular or linear, into electrical energy. They are of the rotating permanent magnet a-c type, and preferably produce a good sine wave. They should be of low impedance.

Saturable core transformers T_1, T_2 are of the oriented nickel iron ribbon type having a rectangular hysteresis loop.

Resistors R_1 and R_2 are non-inductive adjusting resistors.

Rectifier bridges D_1 and D_2 are composed of germanium diodes or equivalent.

Speed indicators I_1 and I_2 are direct current milliammeters of the permanent magnet movable coil type.

Differential indicator M is a permanent magnet movable coil microammeter, as a part of the differential bridge. Each arm of this bridge is adjusted to an impedance equal to that of the microammeter movable coil at its mid-scale position. These bridge arms should be contained in the instrument.

Principle of Operation

Consider the system as divided into three parts: speed circuit for generator A, speed circuit for generator B, and the differential circuit M.

In speed circuit for generator A, the rotor of the generator is driven by one of the sources of speed under consideration. The voltage generated will be nearly proportional to the speed at a frequency exactly proportional.

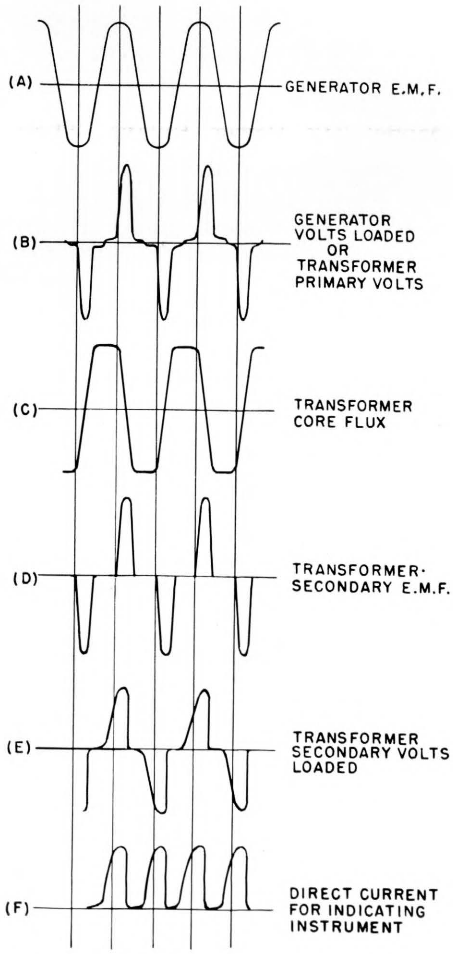


Figure 2—Graphic Analysis of Saturable Transformer Operation.

From this output, the core of transformer T_1 is saturated. In this state, as shown by the waveform analysis, Figure 2, a secondary voltage is generated when the core flux swings from one maximum to the other, and is zero during these maximum periods. The average value of this secondary voltage is proportional to the frequency and only slightly affected by changes in the primary voltage.

This voltage is applied to the remainder of the circuit, consisting of rectifier D_1, speed indicator milliammeter I_1 and the differential indicator bridge, resulting in a pulsating direct current whose magnitude is controlled by the resistor R_1 and whose average value is proportional to the frequency.

The speed indicator milliammeter I_1 being of the permanent magnet,

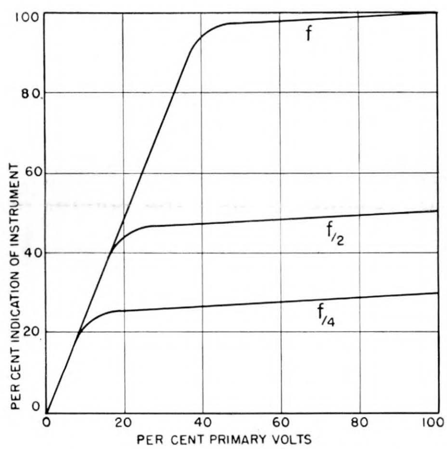


Figure 3—Per Cent Indication of Instrument vs. Per Cent Primary Volts for Frequency Responsive Tachometer.

movable coil type, will indicate in response to this average value and, thus, to the frequency of the generator A voltage. This same action occurs in speed circuit for generator B.

These pulsating direct currents will be present in the differential bridge M where circuit A is connected at E and G. Since the bridge, including the movable coil of the instrument, is balanced, the points F and H, with respect to this current, will have no potential difference and, therefore, any circuit may be connected at these points and will not affect this current. Similarly, with circuit for generator B connected at F and H, the points E and G will have no potential difference and any circuit connected here will not affect this current.

When the direct currents of these speed circuits have the same average value, no difference of potential will exist between E and F. The movable coil of the differential microammeter connected between these points will receive no current and will therefore indicate zero. This is the condition when the speeds of generators A and B are equal.

This same condition will also appear in the arm between H and G. When the speeds are not equal, the currents through the milliammeters I_1 and I_2 are not equal, and the difference will appear in bridge arms E, F and H, G, causing the differential indicator to indicate in response to this difference. Since these direct currents are pulsating, all values referred to are average values.

By these means, the currents for the speed indicators are independent of each other, are responsive to the speeds of their transducers, and are not influenced by the difference current.

Accuracy of Indication

Ambient temperatures will have very slight effect, if any, on the differential indicator because of the bridge composition, and the fact that these resistors are placed inside the instrument. Because of the rectifiers, the indications of the speed indicators I_1 and I_2 will be affected approximately 1 percent for 40° C change.

The phase relation between generator voltages has negligible effect because the indications of the differential indicator are proportional to the average value of the d-c pulses to the differential indicator bridge.

While the waveform of the generators is of no serious concern, any change in the waveform over the speed range from that at which the adjustment is made would be reflected in the indications. It is, therefore, most desirable that the waveform of the generator output be nearly sinusoidal and remain fixed over its entire speed range.

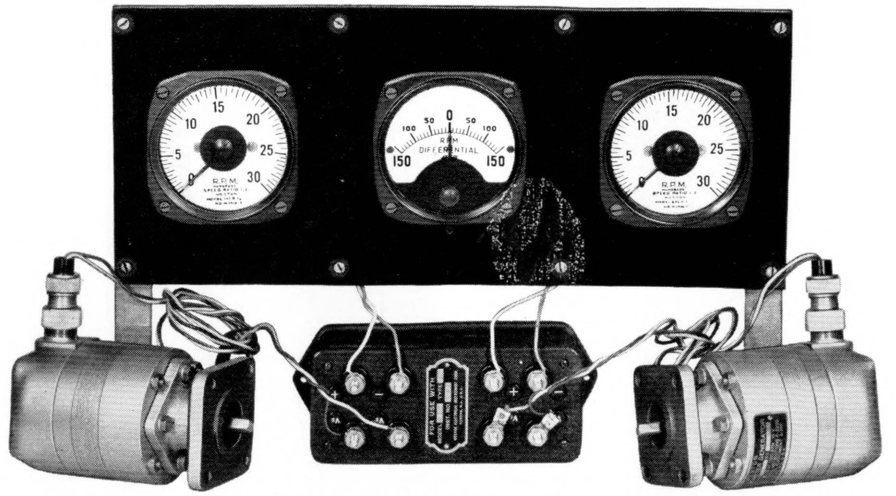


Figure 4—Typical Instruments Used for Development of Differential Speed Tachometer.

The speed indicators I_1 or I_2 may show a slight effect if their corresponding generator voltage should change as shown in Figure 3. This amounts to approximately 1 percent of full-scale value for a generator voltage change of 20 percent. These curves also show that less voltage is required to saturate the transformer as the frequency, speed of generator, becomes less. This generator, whose voltage is nearly proportional to speed, is ideally suited for this purpose. These curves also show that when the transformer is saturated at the highest speed of the range, it will remain saturated for all speeds below.

Changes in impedance of the movable coil of the differential microammeter alter the balance of the differential bridge to such a small amount that they may be considered negligible with respect to the over-all requirements.

Conclusion

Returning to the original specification, this system very closely meets the requirements.

1. It is responsive to speeds and very slightly affected by the voltages of the generator transducers.

2. A wide range of speeds may be covered. Speeds from 500 to 70,000 rpm have been measured, with no upper limit found.

3. Good resolution is possible since reliable instruments may be built to allow a differential indicator range of 5 percent of the top speed value:

Figure 4 shows generators, instruments, and circuit network box used for this development. The speed range is $30 \times 100 = 3{,}000$ rpm and the differential range is 5 percent of this, or 150 rpm.

4. The speed indications of the instruments will follow the speed of the generators for all speed changes usually met in industry.

5. The indications of the speed indicators are not influenced by the difference in speeds.

6. The indications of the speed indicators are independent of each other.

7. The indications of the speed indicators, or the differential indicator, are not influenced by the phase relation of the generator outputs.

8. The effect of ambient temperatures is small for the speed indicators and less for the differential indicator.

Acknowledgments

The author wishes to acknowledge the contributions of Mr. R. W. Gilbert for his suggestions on the basic circuit, and Mr. V. B. Kwast for his information on the test results.

References:

[1] *"Electric Tachometers,"* A. H. Wolferz, WESTON ENGINEERING NOTES, Weston Electrical Instrument Corporation, 1949, Volume 4, No. 2, p. 1.

[2] *"Bearingless Tachometer Generator Using a Frequency Responsive Network,"* J. A. Heacock, A. H. Wolferz, WESTON ENGINEERING NOTES, Weston Electrical Instrument Corporation, 1953, Volume 8, No. 2, p. 1.

E. N.—No. 114 —*A. H. Wolferz.*

"Westonia"

WE WERE reviewing a tabulation of patents issued to Dr. Weston the other day and wonder if engineers generally realized that there were issued to him a total of 330 patents over a period of 54 years.

The first patent was in 1875, and covered an anode for nickel-plating made of compacted powder and essentially following the procedure of sintering used today. His last patent was issued in 1929, on the Weston radio-phone plug. Between these extremes we find the early patents covering the art of electroplating, then veering into dynamo-electric machines, arc lights, incandescent lights, electric distribution systems, and then into instruments.

The first instrument patent appears to have been in 1885, although there had been previous patents issued to him on integrating or ampere-hour meters, and in 1883, he had obtained a patent on a speed indicator with a rotating magnet dragging around a disc—essentially the basis for almost all automobile speed indicators up to the present day. (Patent 277,179.) Patent 334,145, issued in January 1886, shows one of the first rectangular moving coils with a frame and a bi-filar suspension operating in the field of an electro-magnet. Early in 1888, patent 381,304, reissued as Re 10,944, covered the use of the alloy manganin along with its use in series with a copper coil for temperature compensation. Patents on instruments followed thick and fast with 16 issued in 1888, on an enormous variety of instruments ranging from a modified tangent galvanometer to recording instruments. In 1890, patent 427,022 covered such details as opposed spiral springs for control, their mountings, a mirror scale, and other items we take for granted today.

The matter of compensation for the resistance variation of copper with temperature apparently took a great deal of time and many proposals were made and patented; patent 480,981, issued in 1892, showing a measuring instrument with a carbon negative coefficient resistor of a type frequently used today.

We may think of adapters for vacuum tube bases and test gear as something recent but patent 480,900, issued in 1892, showed an attachment plug with various adapters as required for the several types of lamp bases in use at the time.

Patent 494,827, issued in 1893, seems to be the first disclosure of the cadmium-mercury Standard Cell. The rights under this patent were dedicated to the public by Dr. Weston in view of the acceptance of this cell as a World Standard for voltage on the part of the International Electro-Technical Commission in 1904. Patent 495,501, issued in 1893, covers his shunt. Just that. We may think of a shunt as an obvious device but the fact remains that a patent was issued on the idea and apparently it had occurred to nobody previously.

When the Weston Plant was built in its present location, a rather special type of saw-tooth roof was designed along with a particular way of hanging the line shafting. So patent applications on these items were made and they were issued in 1907.

There is much present interest in solar energy and ways and means of storing it. It is of interest to note that patents 389,124 and 389,125 were issued to Dr. Weston in 1888, these patents covering respectively, the apparatus for and the art of utilizing solar radiant energy. The apparatus consists of a bank of thermocouples to be heated by the sun, with the rays coming through a lens to concentrate them. The output of the thermopile was arranged to charge a storage battery at such times as the generated potential was sufficiently high to actuate a charging relay. Essentially these patents contain all of the elements used in such systems today except for the photocells which are of relatively recent origin.

As engineers we are continually amazed at the items covered by these patents and periodically, if the subject matter of one of them is not being used continuously, some special application requires that the old art be reviewed and we find the answer in these old patent files.

NEW PUBLICATIONS ON INSTRUMENTS AND MEASUREMENTS

TWO publications came off the press toward the end of 1955 which should be of interest to everyone concerned with the making of electrical measurements.

The American Standard for Electrical Indicating Instruments, identified as document C39.1-1955 of the American Standards Association in its latest revision, now also is considered as a Standard of the National Electrical Manufacturers Association, their publication number EL-1-1955. This is a revision of the previous issue of 1951, with rather minor changes mainly consisting in explanatory notes, minor changes in procedure and changes in wording to make the context conform with the Standards terminology of N.E.M.A.

No changes were made in any of the accuracy requirements or limits so that for the individual who has merely a casual interest in measurements the revised document will hardly be needed. But for those concerned with the purchase and use in quantity of electrical indicating instruments, the latest issue should be used and it may be obtained from the American Standards Association, 70 East 45th Street, New York 17, N. Y., at a price of $2.00. Alternatively copies may be obtained from the National Electrical Manufacturers Association, 155 East 44th Street, New York 17, N. Y.

The second publication is the *Master Test Code for Electrical Measurements in Power Circuits,* identified as document number 552 of the American Institute of Electrical Engineers and dated November 1955. It is also identified as *Power Test Code 19.6 of the American Society of Mechanical Engineers,* dated 1955.

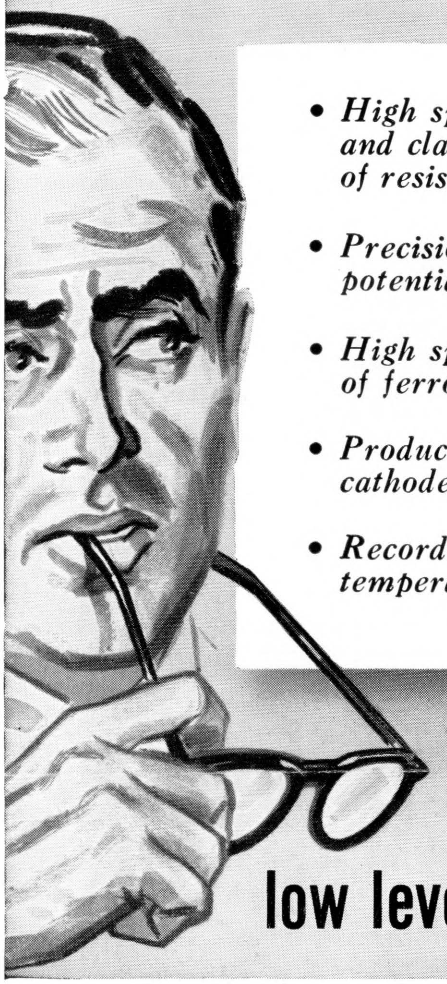
Although this Test Code was developed at the request of the Power Group of the A.I.E.E., the A.S.M.E. Power Test Code supplement on Instruments and Apparatus of 1934 served as the basis of the work. Much material was taken from other codes such as the A.I.E.E. Test Code 502 on single phase motors. Throughout the development of the document there was close co-operation between experts of the A.S.M.E. and those of the A.I.E.E.

It is to be noted that while the Standard mentioned above defines the instruments, this Test Code tells how they are to be used and as such is a valuable supplementary publication. Accuracies are discussed and there are many suggestions as to methods of improving the over-all accuracy in making measurements of voltage, current and power.

There are some nineteen diagrams, mostly of the more elaborate types of connections into polyphase power systems and since the document is not propriety but rather carries the sponsorship of the Mechanical and Electrical Engineering Societies, it is a valuable reference.

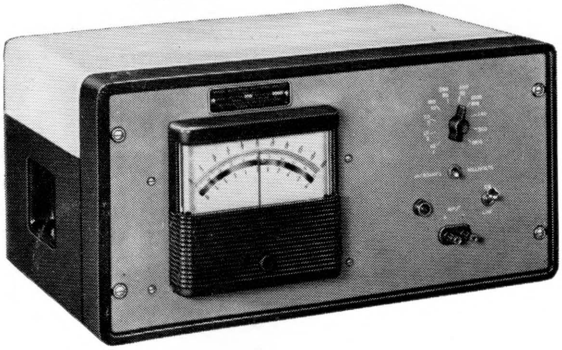
This *Master Test Code* lists at $1.20 and may be obtained from the American Institute of Electrical Engineers at 33 West 39th Street, New York 18, N. Y., as document number 552, or from the American Society of Mechanical Engineers at 29 West 39th Street, New York 18, N. Y., as document PTC-19.6.

These or similar problems puzzling you?



- *High speed inspection and classification of resistive elements*
- *Precision control of minute potentials and currents*
- *High speed inspection of ferromagnetic materials*
- *Production testing of cathode ray tube brightness*
- *Recording extremely low temperature differentials.*
- *Continuously recording rate of temperature change in jet engine test stands*
- *R.M.S. regulation of a-c oscillators and generators*
- *Multiplication of two a-c or d-c signals to provide a precision product*
- *Precision low power factor measurements for production inspection of transformers and motors*

The INDUCTRONIC® SYSTEM of low level MEASUREMENT and CONTROL



Model 1475 Multi-Range Inductronic D-C Amplifier provides amplification of a complete span of direct current and voltage ranges of either polarity with no sacrifice in fundamental accuracy or speed. Has seven current ranges, from 10 to 1,000 microamperes — and ten voltage ranges, from 1 to 1,000 millivolts. All ranges immediately available by the turning of a switch; and an additional seventeen ranges become available by a knob adjustment which changes the instrument from zero left to zero center. Accuracy 1%. Accessories such as recorders and additional indicators can be inserted in the output to a total of 5,000 ohms without affecting accuracy or calibration.

Practical solutions to the above, and many other problems of low-level measurement and control have been supplied by the WESTON Inductronic System . . . an entirely *different* method of d-c amplification. Utilizing the deflection of a permanent magnet moving coil system, it converts extremely low-level d-c to a proportionate a-c signal and amplifies it to a *usable degree* . . . then reconverts to a d-c level. The system operates at a frequency of 200 KC, and provides a high order of sensitivity, accuracy and speed. And because of circuit simplicity, the system is stable and virtually maintenance free. To learn how you can apply the Inductronic System in research or production, call your nearest Weston representative, or write direct for bulletin B-36-B.