Westinghouse

Type V-2 Transducers

Forward

This Application Data consists of three parts published separately but interdependent insofar as the use of any one part is concerned.

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Type V-2 Transducers

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Section A

1. General Information

The type V-2 transducers are designed specifically as accessories to Westinghouse panel instruments to provide the means for measuring complex electrical variables. The transducers convert these measurands to proportional dc outputs which can be measured by simple conventional dc instruments,

Although designed basically for compatibility with Westinghouse instruments, the V-2 transducers may be used with any manufacturers' instruments if their terminal resistance is modified to suit the transducer's load requirements. The transducers may also be used for inputs to control or data acquisition systems, to computers, telemeters, or recorders. Usually a load resistor and filter accessory is required for these applications.

2. Available Types

Watts
Vars
Frequency
Power Factor (phase angle)
Voltage (rms compensated)
Current (rms compensated)
Voltage (suppressed zero ac)
Speed (pulse or frequency)
Temperature (10 ohm RDT)
Motor Load (In-phase current)

3. Terminology

The following terms are used in discussion of transducers. Definitions are conformed to ANSI C39.1 Instrument Standards wherever possible.

(a) **Accuracy**: The limit, expressed as a percentage of full output value, that errors will not exceed when the transducer is used under reference conditions. (Frequency, power factor, and suppressed zero transducers are special cases. See subsequent text).

(b) **Loss (Burden)**: The apparent power (volt-amperes) required by a transducer circuit at full output.

(c) **Nominal Current, Voltage:** The normal values used for design purposes; e.g., 5 amps, 120 volts.

(d) **Response Time:** The time required for output to rise from zero to 99% of full rated value when the input is suddenly increased from zero to full value. The definition is similarly stated for partial load changes.

(e) **Working Voltage to Ground:** The highest peak voltage which may exist between a transducer terminal and ground.

(f) **Dielectric Test:** The rms value of a 60 Hz sine wave which the transducer will stand for 60 seconds without flashover or damage.

(g) **Rated Voltage, Current, Watts, etc.:** Those values at which a device will develop full output.

(h) **Ambient Temperature Influence:** That change in output, expressed as a percent of full output, which may be caused by changes in ambient temperature from 25°C.

(i) **Extreme Temperature Influence:** That change in output, expressed as a percent of full output, which may occur at specified high and low temperatures.

(j) **Frequency Influence:** That change in output, expressed as a percent of full output, which may occur because of a deviation from design frequency.

(k) **Power Factor Influence:** That change in output, expressed as a percent of full output, which may occur because of a deviation from unity power factor.

(l) **Linearity:** The deviation from an absolute proportionality between input and output expressed as a percent of full output value.

(m) **Ripple:** A measure of the rectified ac component in a dc output.

$$\%\ \text{ripple} = \frac{\text{rms of ac}}{\text{average output voltage}}$$

(n) **Permissible Overload:** The voltage or current which the transducer can sustain continuously or momentarily (1 second) as stated without damage.

(o) **Maximum Voltage or Current:** The absolute value, or the percent of nominal, at which the transducer can be used at rated accuracy.

(p) **Standard Conditions:** Rated voltage, current and frequency, as applicable, at 25°C.

(q) **Load Resistance:** The resistive load which must be connected across a transducer for correct performance.

(r) **Self-Contained Rating:** The input to an instrument or transducer in terms of the secondary current and voltage actually seen by the device.

$$\text{Self-contained rating} = \frac{\text{full scale primary rating}}{\text{pt x ct ratios}}$$

(s) **Single-Phase Test Watts:** That value of single-phase watts input, at standard conditions, which will, with all voltage coils in parallel and all current coils in series, yield rated output. Coils are connected additively.

$$\text{Single-phase test watts} = \frac{\text{self-contained rating}}{K}$$

where K=1 for 1-phase, 2-wire (1 element)
K=2 for 3-phase, 3-wire (2 element)
K=4 for 3-phase, 4-wire (2½ element)

(t) **Scale Watts:** The primary watts corresponding to the full output of the transducer.

Scale watts =
self-contained rating x ct ratio x pt ratio

(u) **Rated Output (Wattmeter):** The full output of the transducer when energized at rated input watts. Type VP2-840 transducers have a standard rated output of 50 mV into 50 ohms load resistance. These values may be varied for special applications (see "Scaling", Paragraph 6. Section B).

(v) **Rated Input (Wattmeter):** Self-contained rating (see "Available Transducer Ratings", Part II).

4. Accuracy

Transducers are rated at ±1% of full rated output at the reference conditions applying to each transducer type. When calibrated in combination with an instrument, the error of the transducer may be compensated for, making the accuracy rating of the combination equal to that of the instrument alone.

The limit of such combinations is ±1% of instrument scale, but the usual combinations are ±2% corresponding to the accuracy class of standard panel instruments. When calibrated as combinations, matching serial numbers are used on the transducers and the instruments.

5. Mounting

All transducers are identical in height and depth. All are 3-inches wide except the single-phase var transducer which is 5½ inches. Mounting holes will adapt to predrilled holes on ½, ¾ or 1½ inch centers. Transducers may be mounted in any position, individually or gang mounted without effect on calibration.

6. Load Resistors

Whenever resistors are to be added in the transducer output circuit they may be any commercial wire-wound resistor or metal-film resistor type rated ½ watt, 1% accuracy, having a temperature coefficient of 50 parts per million or less. Similar materials should be used in any spool wound resistors.

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7. Construction
Solid-state components are mounted on circuit boards. The assemblies are not potted, so they can be repaired or modified readily. The steel shells are removable without need to remove the transducers from the panel or to disturb adjacent units.

8. Adjustments
Most normal adjustments are made on potentiometers accessible through holes in the terminal board. The transducers need not be removed from the mounting panel, nor do covers need to be removed. A standard Phillips or flat blade screwdriver serves as an adjusting tool. Specific adjustments are described under the sections to follow.

9. Indicating Instruments
Combinations of instruments and transducers are cataloged in the price lists for panel instruments (43-300), and for switchboard edgewise instruments (43-200). Separate instruments may be negotiated with either blank scales or pre-printed scales. With pre-printed scales, the random selection of instruments and transducers will result in an accuracy rating of ±3% for the combinations. Specific requirements are noted under the following sections.

Section B

Watt Transducer – Type VP2-840

1. Operating Principles

(a) The power in an ac circuit is the product of current, voltage, and power factor expressed as:

$W = EI \cos\theta$

Therefore, a device to measure watts must be capable of multiplication. A Hall-effect element is such a device. It is the basis of the type VP2-840 watt transducer.

(b) The Hall effect, for purposes of this discussion, is that characteristic of a certain crystal such that when it is conducting current (control current) and is placed in a magnetic field, a potential difference is produced across its opposite edges. The potential difference is proportional to the product of the control current, the strength of the field and the cosine of the phase angle between the control current and magnetic flux. By putting the crystal in a magnetic structure such that an ac current generates the flux, and an ac voltage produces the control current, we have a multiplying device. It produces an output proportional to $EI \cos\theta$ (power). This is in essence the Hall generator watt transducer. In Figure 1, the load current I_{ac} produces a proportional flux through the crystal in the air gap. The load voltage E produces a proportional control current through the crystal. The output is proportional to the product of the two and the phase angle between them.

(c) Actually the output of the Hall generator consists of a dc voltage proportional to true power (watts), plus a double frequency ac voltage proportional to the volt-amperes in the circuit. The readout device used with the VP2-840 transducer is normally a permanent-magnet, moving-coil instrument which does not respond to the ac component. When the transducer is used with devices which do respond to ac, the double frequency component must be filtered out. Filters, type VF2-876, are provided especially for this purpose.

(d) The output of a Hall element decreases with increasing temperature. The watt transducers are temperature compensated with a thermistor-resistor network in the output circuit. The load resistance is part of the network, therefore it is fixed for a particular transducer.

2. Types
VP2-840 transducers are built in three types:

(a) Single-phase, one current-coil (1-element): This transducer has one current

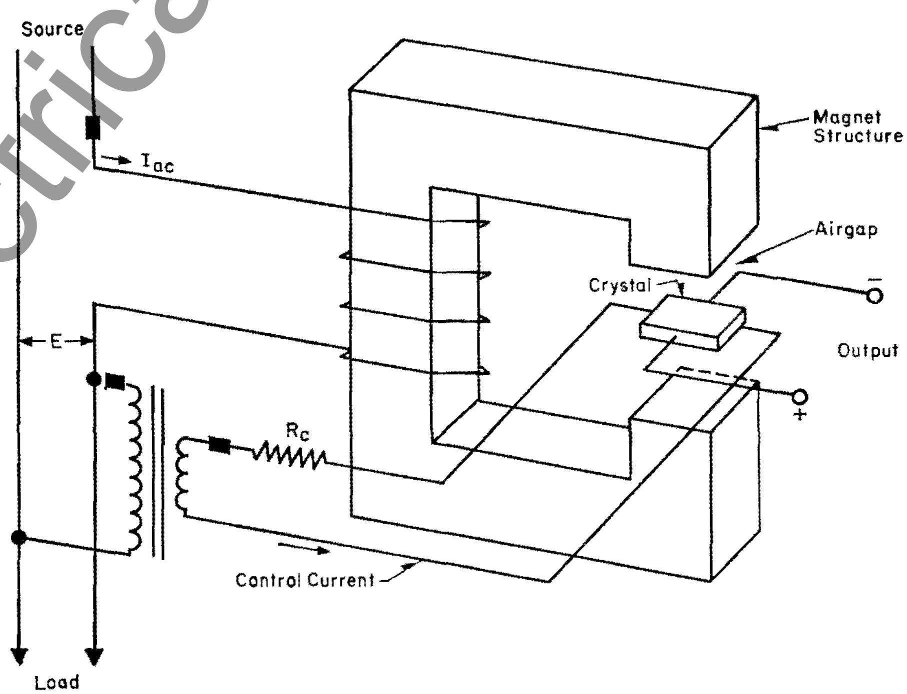

Figure 1: Hall watt transducer.

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coil and one potential coil. It measures watts in single-phase, two-wire circuits, but may be used for balanced polyphase as well. (See Figure 4).

(b) Polyphase, two current-coil (2-element): There are two current coils and two potential coils for the measurement of three-phase, three-wire power. They are also used on single-phase, three-wire, and on certain three-phase, four-wire applications (where the potential transformers are connected line-to-line). The outputs of the two Hall elements are connected in series. (See Figure 5).

(c) Polyphase, three current-coil (2½ element): This transducer has three current and two potential coils. The two Hall elements each have two current coils with one coil in each element being connected in series to form the third current coil. (See Figure 6). This transducer, theoretically, is accurate on balanced voltages only. However, electrical power systems or equipment will not tolerate a degree of unbalance which would cause errors outside the accuracy rating of the transducer. Therefore, there is no practical need for a three-element device. The error due to as much as 15% unbalance is in the order of 0.002 of reading; negligible in any commercial power measurement.

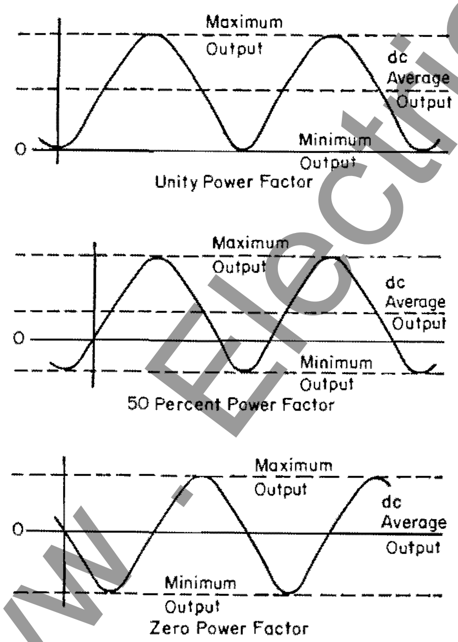

Figure 2: Basic output of watt transducer element (unity 50% and 0 power factor.)

3. Ratings

(a) Output-Input

Standard VP2-840 transducers are factory calibrated so that they will develop an isolated output of 50 millivolts dc into a 50 ohm load resistance with inputs:

1-element.................... 500 watts
2-element.................. 1000 watts
2½-element................. 1500 watts

The 60 Hz models may be used for 50 Hz service with some reduction in accuracy. (See Part II).

(b) Voltage Input

The VP2-840 transducers are designed for a nominal input of 120 volts. They may be operated continuously at 150 percent of rated voltage or as low as zero voltage if the current is decreased proportionately. If an attempt were made to maintain rated volt-ampere input at reduced voltage, the electromagnet in the Hall device would saturate. This saturation becomes appreciable at 125% of rated current. Figure 7 shows the effect of smaller voltage deviations at constant volt-ampere input.

Transducers are made up on special order for 240 volts and, in single-phase only, for 480 volts. In most cases, it is preferable to use the stock 120-volt transducers with auxiliary potential transformers. Never use resistors to drop voltages to Hall transducers. Internal transformers are used to reduce the nominal voltages to the few volts actually impressed on the crystals. A resistor in series with a transformer primary will give erroneous results. The watt rating of a transducer will increase proportional to the increase in rated voltage.

(c) Current Input

Standard transducers are rated at 5 amperes nominal. They may be adjusted as described in Paragraph 7 of this section for full output from 4 to 6.25 amperes at 400 to 625 watts per element. When special calibrations are ordered, the transducer may be marked with some other value of current. This should be considered as the maximum rating, as it may be at the threshold where any increase will cause saturation of the electromagnet in the Hall element with resultant large errors. The electromagnets for the Hall elements are made up in a number of nominal current ratings to accommodate wattmeter currents from 0.5 to 10.0 amperes. Thermally, the current coils are good for 200% current continuously and 500% for 5 seconds.

4. Readout Instruments

Analog instruments may be connected directly to the output terminals of the watt transducers for direct indication of power.

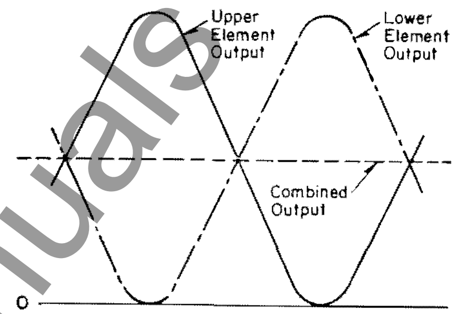

Figure 3: Output of polyphase transducer under balanced load condition, unity power factor.

Instruments should be of the millivoltmeter type, rated 50 mV and having a terminal resistance of 50 ohms. There is a difference between this kind of instrument and a 1 mA, 50 ohm milliammeter, which will have almost all its resistance made up of copper, thus making it temperature sensitive in a voltage source circuit such as the VP2-840. A millivoltmeter has typically only about ¼ of its resistance in copper. Instruments for use with the VP2-840 can be made from a low resistance 0-1 mA milliammeter by adding resistance in series with the moving element. The lower the resistance of the moving element the better the temperature coefficient of the completed instrument as a millivoltmeter.

When ordering a transducer and matching instrument for use as an indicating wattmeter it is necessary only to specify the desired full scale marking of the instrument, the configuration of the primary circuit (eg. 3-phase, 3-wire), and the ratios of the current and potential transformers. The factory will determine the proper transducer rating. If the transducer connections are not as shown in Figures 4, 5 and 6, a sketch of the circuit should be included. In selecting a value for full scale kw, reference should be made to the "Table of Preferred Ratings" on pages 13 and 14 of Price List 43-200.

For a more complete discussion of instruments used with transducers, see Instruction Leaflet 43-800.3 (Modification of V-2 Transducers).

5. Signal Source

V-2 transducers may be used to supply signals to potentiometric recorders, active instruments, analog to digital converters, etc.

The transducers can supply a 0-1 mA current signal into 50 ohms, or they can supply a 0-50 mV signal into a high impedance load of 50,000 ohms or more. These high impedance inputs are usual for active instruments. They usually require filtered signals for which a standard filter is available expressly for use with the VP2-840. It has a 50 ohm input resistance and comes with an optional output adjusting rheostat. See Section L, Filters (Page 27).

6. Scaling

(a) A watt transducer is usually connected to a power circuit through current and potential transformers. These establish a relationship between the primary watts of the circuit and the secondary watts which the transducer sees. The transducer usually feeds into a readout device which is scaled to match the level of primary watts.

The basic formula for scaling a wattmeter is:

$W_{fs} = W_{sc} \times r_{ct} \times r_{pt}$

where:

W_{fs} = maximum watts on scale

W_{sc} = self-contained rating of 5 amps 120 volts transducer

W_{sc} = 500 watts for single-phase 1-element for the standard unit

W_{sc} = 1000 watts for polyphase 2-element for the standard unit

W_{sc} = 1500 watts for polyphase 2½-element for the standard unit

(for 240-volt transducer multiply by 2; for 480-volt by 4)

r_{ct} = current transformer ratio

r_{pt} = potential transformer ratio

(b) Consider a standard 3-phase, 3-wire transducer rated 5 amps, 120 volts and calibrated to 50 mV output at 1000 watts. It is connected to a 7200 volt system through 60:1 potential transformers and 400:5 current transformers. The product of the transformer ratios is 4800, so the full scale reading of a 50 mV readout instrument would be 4800 kilowatts. This is an odd scale, difficult to mark and to read. A 0-5000 kilowatt scale would be more practical, but to achieve this, either the instrument end scale value or the transducer calibration must be changed.

(c) Changing instrument end scale value is practical within limits. In the example in (b):

With standard calibration:

4800 primary KW = 1000 input W = 50 mV output

5000 primary KW = 1000 input W = 52.1 mV output

The sensitivity of a 50 mV, 50 ohm instrument is 1000 ohms per volt (one ohm per millivolt), so it is merely necessary to add 2.1 ohms of series resistance to get the 52.1 mV end scale. The resistance change also affects the transducer output so the transducer load should be corrected to 50 ohms with a shunt resistor.

$\left(\frac{1}{R} = \frac{1}{50} - \frac{1}{52}, R = 1250\right)$. In this case the change is negligible.

The practical limit is ±5 ohms.

If the instrument circuit resistance is changed, it will upset the temperature compensation for both the transducer and the instrument. For load resistance changes over the range of 45-55 ohms, the transducer error will be within 0.5% for a ±10°C change from 25°C. For the transducer-instrument combination, this is typically a ±0.8% error for a ±10°C change. For these combinations, the net effect is that an increase in 5 ohms of circuit resistance will increase full-scale watts approximately 8 percent. Decreasing the resistance 5 ohms will decrease full scale watts approximately 8 percent. Intermediate values are proportional. **The actual resistance changes should be determined by test of the instrument in combination with the transducer.** It is possible to change the instrument to 52.1 mV end-scale by demagnetization. This should be attempted only by a qualified instrument modification shop. The advantage is that the resistance, and with it, the temperature compensation remains unchanged.

Were the desired scale to be lower rather than higher as in example (b), it would be necessary to change the end-scale value of the instrument to less than 50 mV. This requires the shunting of the swamp resistor inside the instrument. Temperature compensation will be affected so the 5% limit must be observed.

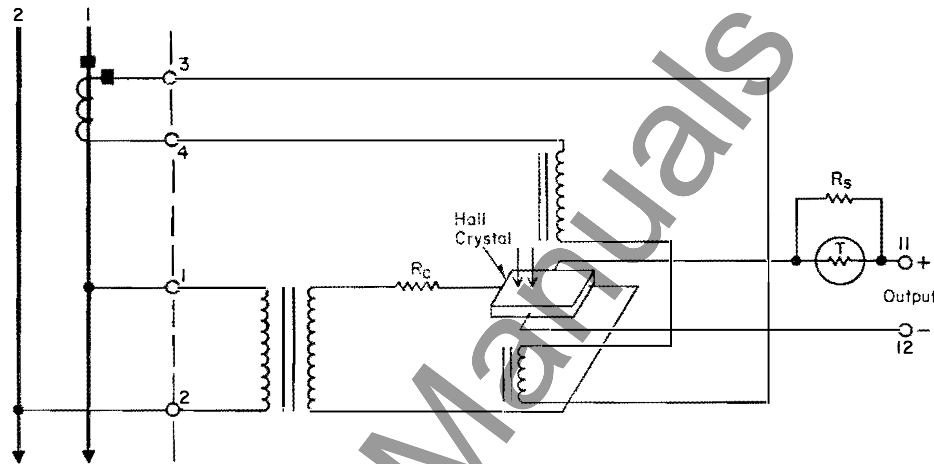

Figure 4: Internal and external wiring of single-phase watt transducer.

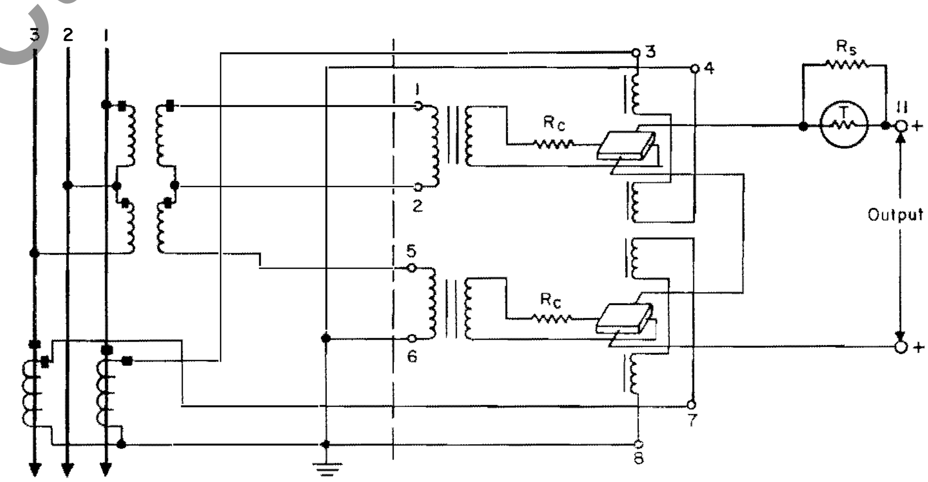

Figure 5: Internal and external wiring of 3-phase, 3-wire watt transducer.

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(d) Recalibrating the transducer is a more satisfactory method of scaling. It is recalibrated to yield nominal output with a non-standard input.

Using the example (b):

With standard calibration 4800 primary kW=1000 input W=50 mV output. Desired calibration 5000 primary kW=1041 input W=50 mV output.

The standard 2-element transducer is calibrated 1000 watt input equals 50 mV output. It must be recalibrated to 1041 watt at 50 mV. This method of scaling leaves the temperature compensation unimpaired and keeps the instrument standard. Actual calibration procedures are covered in paragraph 7. The transducers have trimmers which are intended for original factory calibration. These are used also for recalibration, but the exact limits of adjustment are variable. By an internal resistance change, the adjustment may be extended to the limits of the transducer current coils as listed in Part II.

(e) Non-standard Ranges: Transducers may be built on special order with coils for current inputs as low as 40 mA or as high as 10 A. These will have the full 50 mV output with a nominal 120 volt potential. When a transducer is to be used at less than its rated mV output, it may be recalibrated for maximum accuracy at the lower value. The procedure is described in paragraph 7 of this section.

Consideration should be given to the use of the more expensive amplified transducers where the instrument modification or transducer calibration is impractical or occasional. Westinghouse types VP3-840 (0-10 V) or VP4-840 (0-1 mA) are not load sensitive within broad limits. They are adjustable 0 to 110 percent. These transducers, when operated at reduced output, will degrade the overall accuracy of the measurements. Accuracy is expressed as a percent of full output at 1 mA output; a transducer with ½% accuracy will yield 2% accuracy if operated at 0.25 mA at full scale on the indicating instrument.

(f) A variable ratio current transformer allows the use of a standard transducer and a standard instrument with all of the scaling done by varying the turns ratio of the transformer. A single paired transducer and instrument can be used for any kilowatt load if the instrument is marked 0-100%, 0-125% or 0-150% Percent Load. The same devices are used with only a scale change if the instrument is to be marked in actual load kilowatts. There is a complete discussion of this in Application Data 43-510 which was written especially for motor load indicators with which the variable-ratio current transformer scheme is almost universally used. If Application Data 43-510 is not available, somewhat the same transformer data is included in Descriptive Bulletin 44-112 covering the Westinghouse Type ECI variable-ratio current transformer. The formulas in Application Data 43-510 are based on wattmeter scales equal to 150 percent of full rated load. Commercial wattmeters are usually some other full scale value determined by service conditions. The application data for variable ratio transformers is based on: I_{pri}, the primary current required to develop 5 amperes secondary current. Therefore the basic formula is modified to:

$$I_{pri} = \frac{W_{fs} \times 5}{W_{sc} \times r_{pt}}$$

where:

$I_{pri} = r_{ct} \times 5$

Where loads are balanced, it is generally adequate to use a single phase transducer.

To get a current in phase with an available voltage, a double primary hookup is used, so connected to reverse one current and add it vectorially to the other. The resultant is in phase with the voltage across the two lines involved. For this scheme, the current transformer primary ratings are exactly half of those for polyphase 2-element transducers making the formula:

$$I_{pri} = \frac{W_{fs} \times 2.5}{W_{sc} \times r_{pt}}$$

7. Recalibration

All VP2-840 watt transducers are factory calibrated to develop an output of 50 mV into 50 ohms at rated input watts. They may be recalibrated within the limits of the current coil capacity of each design. Part II (page 29) lists the upper and lower limits of current, test watts and self-contained rating for each value of nominal current input. From this table, it is apparent that a 2-element, polyphase 2-current-coil standard self-contained rating of 1000 watts would be a nominal 5 amp design with a usable current range of 4.00 to 6.25, single phase test watt range of 400 to 625, and a self-contained rating range of 800 to 1250 watts. A variable calibration resis-

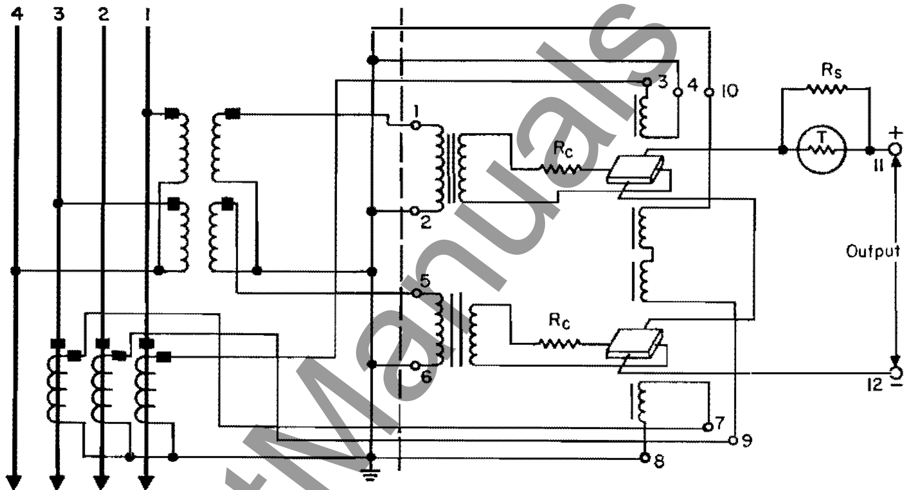

Figure 6: Internal and external wiring of 3-phase, 4-wire watt transducer.

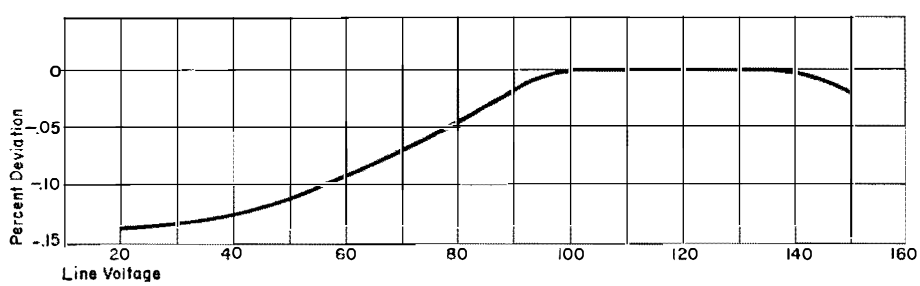

Figure 7: Voltage characteristic.

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tor and a fixed (soldered into the circuit board) resistor on each element will allow adjustment throughout the range.

Variable resistors may be reached by inserting a screwdriver through holes in the terminal board.

All wattmeters and watt transducers are calibrated on single-phase with all current coils in series aiding and all potential coils in parallel. Polarities are chosen to produce a positive output from each element as current circuits are energized. Ideally, the transducer is energized from a precision instrument calibrator (a regulated source of current and voltage in phase) but adequate results are achieved by using commercial power and a single-phase portable instrument of .5% accuracy class. The wattmeter current circuit is connected in series with the current coils of the transducer and its voltage circuit across the voltage coils of the transducer. The load may be varied on the test circuit in any convenient manner – the nearer to unity power factor the better. Output is measured with a potentiometer as the mV drop across a 50 ohm resistor (See Paragraph 6 of section A), or it may be measured with a low resistance (15 ohms or less) portable standard 1 mA instrument padded up to 50 ohms, or a millivoltmeter, 0-50 mV with a sensitivity of 1000 ohms per volt.

To calibrate, energize the potential coils of the Hall elements for a 30-minute warmup. Then, energize the potential coils one at a time. Adjust the potentiometer trimmers to 25 mV per element for polyphase transducers. with rated single phase test watts applied. Single element transducers adjust to 50 mV. Now test with both elements energized on the polyphase transducer. The output should be 50 mV. If not, repeat the individual adjustment and the combined check. The two element outputs must always be balanced.

If there is not sufficient range in the potentiometers to get rated output at the desired test watts, it will be necessary to change the 3-watt fixed resistors on the edge of the circuit board. This resistance must not be reduced below 5 ohms. This resistance will change output current in inverse proportion. The limitations of each design must be observed. The coil current must never be allowed to exceed the limits in the table in Part II, if the transducer is being calibrated for use on reduced voltages.

8. Remote Indicators
Lead resistance is a negligible factor, generally, when the readout instrument is located near the transducer. The lead resistance becomes additional load resistance and, as such, affects calibration in the ratio of 5 ohms equals 8% change. This becomes more workable as 0.6 ohms = −1% error. If #12 wire were used for hookup, the transducer and indicator could be 130 feet apart for −1% error. Error due to as much as 5 ohms lead resistance can be calibrated out of the system, so actually the two components can be hundreds of feet apart. For these conditions, the lead resistance should be specified on the order, or a field recalibration should be performed. There will be an added influence of up to 1% for a 20°C change in temperature of the leads. Where the determination of lead resistance or field recalibration is likely to be a problem, it would be well to consider the more expensive constant current or voltage output transducers, type VP4-840 or VP3-840.

9. Totalization
In the case of quantitative measurements, it is sometimes desirable to add (totalize) or subtract (differentiate) them. This is most common with watt or current transducers to obtain gross outputs, or with speed transducers to determine slip or stretch. The techniques are generally applicable wherever transducer outputs are linear with respect to a quantitative input.

In totalization for inputs to high impedance devices such as potentiometric recorders, the transducer outputs are converted to

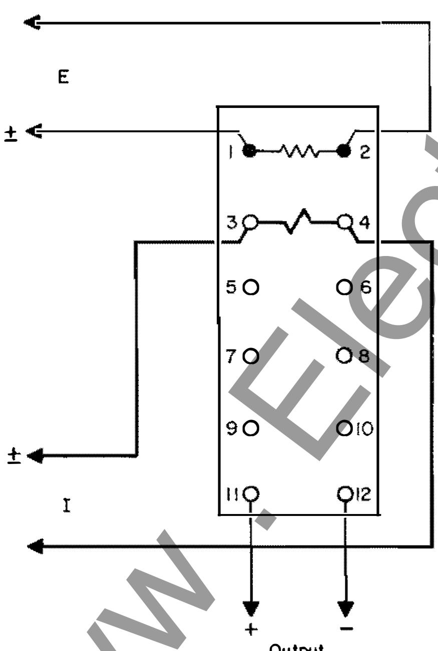

Figure 8: 1-phase, 2-wire single-phase test connections.

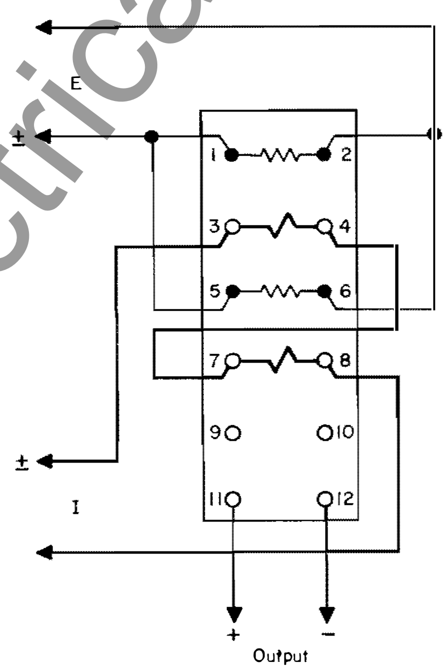

Figure 9: 3-phase, 3-wire single-phase test connections.

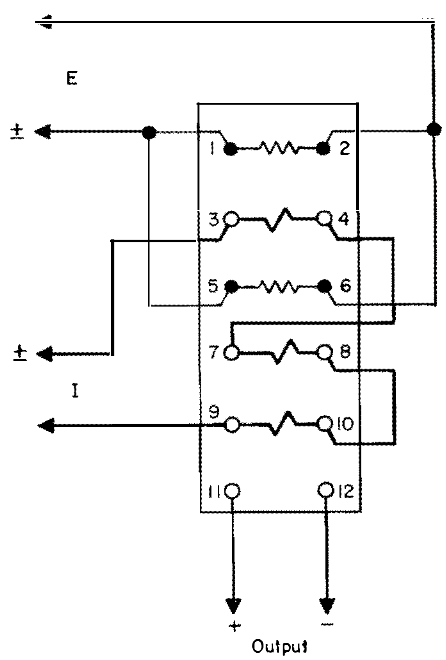

Figure 10: 3-phase, 4-wire single-phase test connections.

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millivolts and then filtered. These outputs are then connected additively or subtractively, as required.

Filter unit (see Section L, Part I) style number 715B261A09 or 715B261A10 may be used if the transducers are connected to identical current or current and potential transformers. If, however, the transformer ratios are different it will be necessary to use style number 715B261A11. This filter unit has a 0-100% voltage adjustment. These transducers must be scaled so that the ratio of units output to units primary input remains a constant.

For example, on a 14.4 kV system we are to totalize kilowatts on three transducers 3-phase, 3-wire, 5-amp, 120-volt calibrated 1000 watts input equals 50 mV output into 50 ohms. The transducers share the 120:1 potential transformers but use 600:5, 400:5 and 200:5 current transformers respectively (See Figure 12). We must use the Style Number 715B261A11 filter and adjust the output potentiometers so that with 1000 watts input the 600:5 unit will have its normal 50 mV output. The 400:5 will have $\frac{400}{600}$ x 50 or 33.3 mV and the 200:5 will have $\frac{200}{600}$ x 50 or 16.7 mV. The full scale output will be 50 + 33.3 + 16.7 or 100 mV. The signal must be fed to a device with 50,000 ohm or more impedance.

It is customary to work up totalization problems using a scale constant (K_s) calculated from the sum of the values to be totalized, divided by the full scale millivolts of the indicating device. The sum may be modified to round off the total to a standard dial marking value. It may be reduced if there is a load factor less than 1, or it may be increased if there is an overload capability. To take the example in the preceding paragraph:

Total current 600+400+200=1200 amps

Normal fs for wattmeter 1200:5 ct and 120:1 pt = 30 MW (See wattmeter selector table page 14, Price List 43-200).

Instrument end scale 100 mV (should be a standard value for the type of instrument used).

Scale constant $K_s = \frac{30\text{ MW}}{100} = .3$ MW/mV

The MW rating of the circuits will be proportional to the current transformer ratios.

600 amp circuit=15 MW

adjust transducer output to: $\frac{\text{circuit rating}}{K_s}$

$= \frac{15}{.3} = 50$ mV

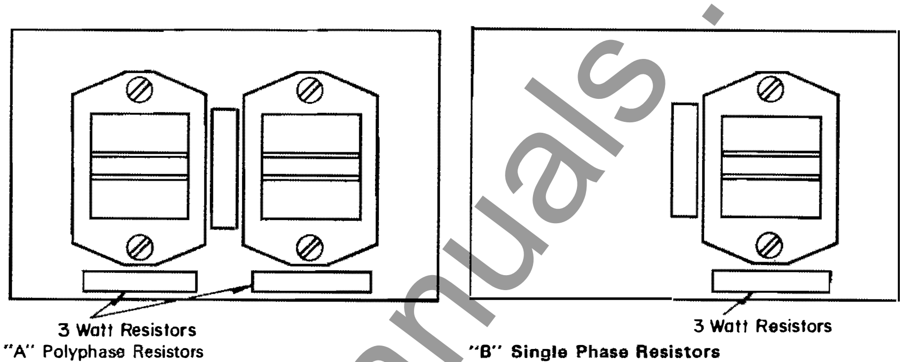

Figure 11: VP2-840 watt transducer calibration resistors.

400 amp circuit=10MW

adjust transducer output to: $\frac{10}{.3} = 33.3$ mV

200 amp circuit=5 MW

adjust transducer output to $\frac{5}{.3} = 16.7$ mV.

Were the totalized full scale value chosen as 25 MW or 40 MW the K_s would change, but the individual circuit ratings would change proportionately so the end result in terms of mV output adjustment would remain the same. They will change only if the mV for the full scale totalized value changes. The limiting factor is the maximum 50 mV output of the individual transducers. In the example given, the full scale of totalized millivolts could not be 200 as the transducers cannot develop 100 mV or 66 mV. 100 mV totalized is the maximum in the example.

Where it is desired to totalize into an indicating instrument the filters need not be used. With identical watt transducers fed from **identical transformers** it is necessary only to connect the outputs additively (or subtractively). The resistance of the measuring circuit must be the rated load resistances of the transducers times the number of transducers. The full scale value of the instrument is the sum of the individual full scale outputs. Note that the individual systems to be totalized must be identical.

The watt and var transducers are direction sensitive so it is possible to use this totalizing scheme where power flows change direction to determine net flows in

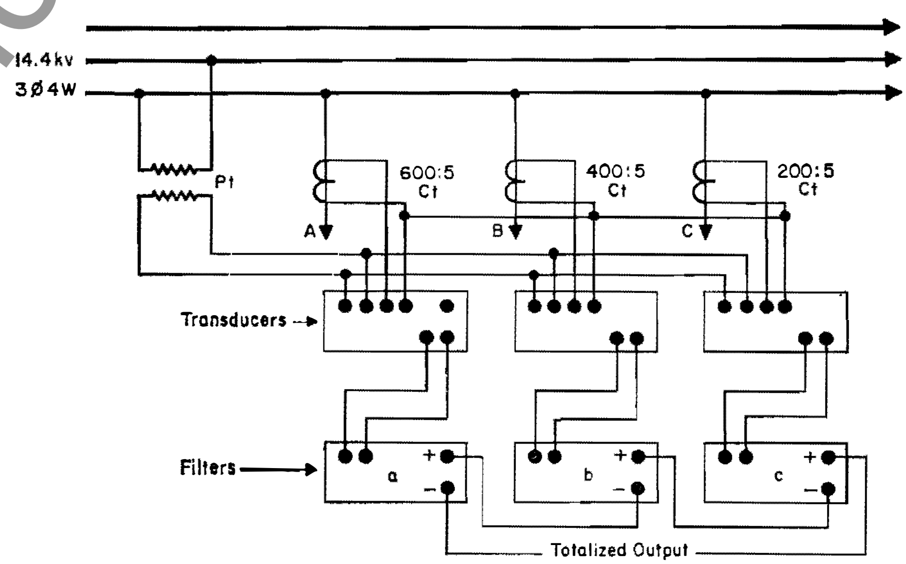

Figure 12: Totalizing three feeder circuits with different current transformer ratios using style number 715B261A11 filters with adjustable output. For the current transformer ratios shown, the outputs are adjusted to a=50 mV, b=33.3 mV and c=16.7 mV for a totalized full scale output of 100 mV into a high impedance load.

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either or both directions. For bi-directional reading, a zero-center instrument is used.

Where minimum cost is not an overriding factor it is preferable in totalization schemes to use the amplified constant current transducers such as types VP4-840 and VV4-840. These are not load sensitive, so a standard instrument can always be used and scaling is simply a matter of calibration adjustment to proportion output mA to transformer ratios. There are two adjustment ranges, ±10% and 0-110% of rated output.

10. Specifications and Technical Data

See page 29, Part II.

11. External Connections

See page 38, Part III.

12. Dimensions

See page 37, Part III.

Further Information

Basic Information:
Instruction Leaflet 43-840.2,
Application Data 43-840

VP2-840 Watt Transducer:
Instruction Leaflet 43-840.3

VV2-840 Var Transducer:
Instruction Leaflet 43-840.5

Modifications:
Instruction Leaflet 43-800.3

Prices:
Price List 43-861

Description:
Descriptive Bulletin 43-861

Section C

Var Transducer – Type VV2-840

1. General Information

Watts, or true power, as measured by the VP2-840 watt transducer are the product of in-phase voltage and current: Vars, or reactive power, are the product of voltage and that portion of the current which is 90° out of phase with the voltage. Conventionally, this phase shift is accomplished with a separate polyphase phase-shifting transformer or single-phase reactor. Type VV2-840 transducers, however, have internal phase shifting circuitry. Otherwise, they are the same as VP2-840 watt transducers.

With the exception of calibration and scaling information, the material in Section B applies to type VV2-840 var transducers as well as to the watt transducers.

2. Scaling

Most varmeters are installed in combination with wattmeters using common current and potential transformers. This necessitates the current coils of their associated transducers being in series.

(a) Standard Scales: A watt indication is usually left-zero and a var indication center-zero, with the end-scale values of the varmeter being one-half of the end-scale of the wattmeter (eg. 0-1000 watts and 500-0-500 vars). Occasionally there is a requirement for offset zero (eg. 200-0-800 vars). Any of these is practical so long as the full-scale (sum of both end-scale values) of the varmeter and wattmeter are identical. The output of a VV2-840 transducer is direction sensitive in that a reversal of power flow will reverse the polarity of the output. Therefore, where a 50 mV, 50 ohm instrument is used as a left-zero wattmeter indicator, a 25-0-25 mV or 10-0-40 mV instrument is used with the center-zero and offset-zero indicators in the above examples. Each of these is a mechanical modification of a 50 mV instrument, so the load resistance remains 50 ohms.

(b) Non-Standard Scales: When a varmeter is required with a full-scale value (the sum of the two end-scales) different from the full-scale value of the wattmeter, there will be problems. A varmeter 1000-0-1000 to operate with a 0-1000 wattmeter will require a 50-0-50 mV instrument with 50 ohms total resistance. This is a possible modification on a 50 mV, 50 ohm millivoltmeter, or on a low resistance milliammeter 1-0-1 mA. When the requirement is for a lower rated varmeter, however, the transducer capabilities will govern. With a 0-500, a 250-0-250 or a 100-0-400 scale requirement on a varmeter to be used with a 0-1000 scale wattmeter, the indicator will have to be a 0-25 mV basic instrument. The var transducer will have half the output of the watt transducer. A 0-25 mV temperature compensated instrument with 50 ohms terminal resistance is not available in many instrument lines. The job can be done with a 500 uA microammeter adjusted to 50 ohms (see Section A, Paragraph 6) terminal resistance but, temperature compensation will be bad. Of course, watt and var meters may readily be scaled within the range of the self-contained ratings of the transducers as listed in Part II. For example, if a 2½-element wattmeter has a nominal 5 amp rating, it has a self-contained rating capability of 1252 to 2087

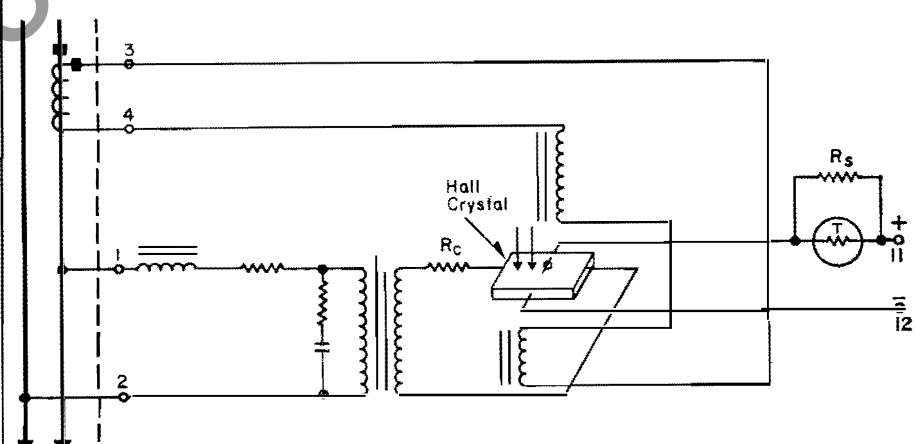

Figure 13: Internal and external wiring of single-phase var transducer.

Type V-2 Transducers

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General Information,
Operating Principles and Applications

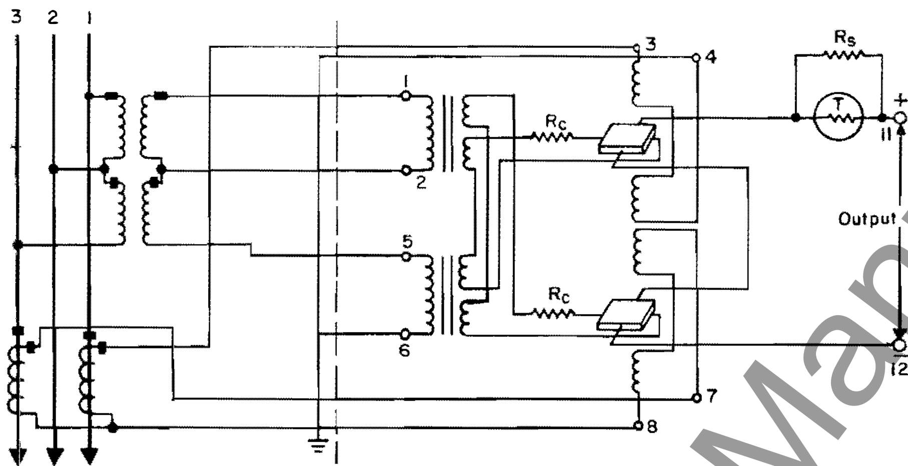

Figure 14: Internal and external wiring of 3-phase, 3-wire var transducer.

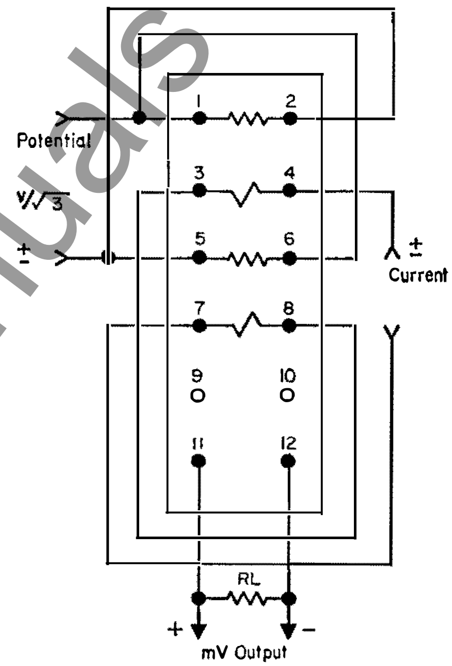

Figure 16: 3-phase, 3-wire single-phase test connections.

watts or vars. The 5 amp standard transducers can be calibrated for 2080 watts and 653-0-653 vars. The same comments as above apply if the transducer is to be used without an indicating instrument. In such cases the scale in the examples is 50 mV=1000.

(c) Recalibration: The procedure for calibration of var transducers is considerably more complex than that for watt transducers. General considerations are the same but because the transducer was designed with a phase-shift circuit, this circuit must be made ineffective to accommodate calibrating equipment common to watt transducers. In effect, the var transducer is made to act like a watt transducer and then calibrated as a watt transducer.

Single-element, single-phase 120 volt transducers are calibrated by first unsoldering the black lead of the potential transformer going to the resistor cards. Connect the transducer per Figure 18A, and energize voltage circuit for at least 30 minutes prior to calibration. Calibrate full-scale watts at approximately unity power factor by adjustment of rheostat. Then resolder black lead of potential transformer. **Do not readjust rheostat.** The reactive compensator of the transducer is adjusted by connecting the transducer per Figure 18B. Apply 100 volts at rated frequency to terminals 1 and 2. Adjust resistor cards until the voltages per Figure 18B are obtained. (Use voltmeter with a resistance of 1 megohm or more).

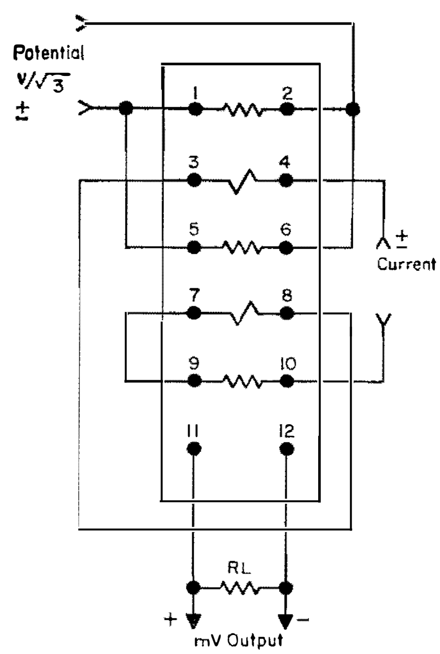

Figure 17: 3-phase, 4-wire single-phase test connections.

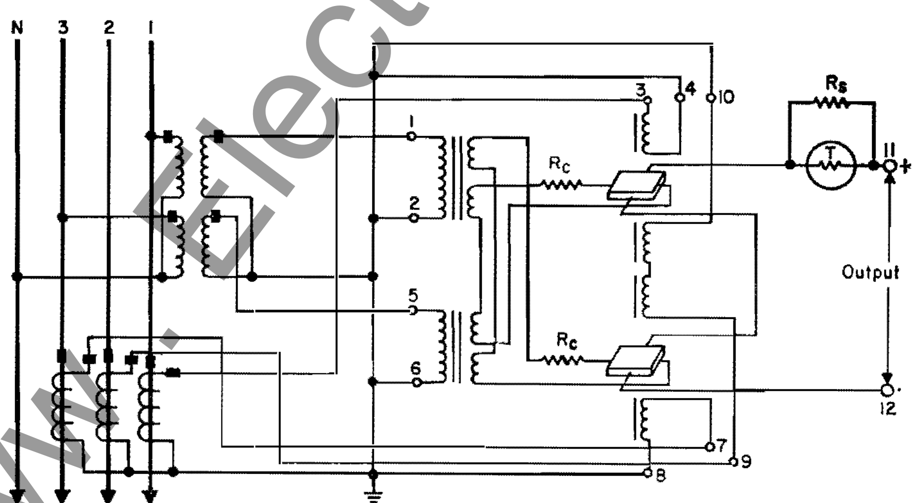

Figure 15: Internal and external wiring of 3-phase, 4-wire var transducer.

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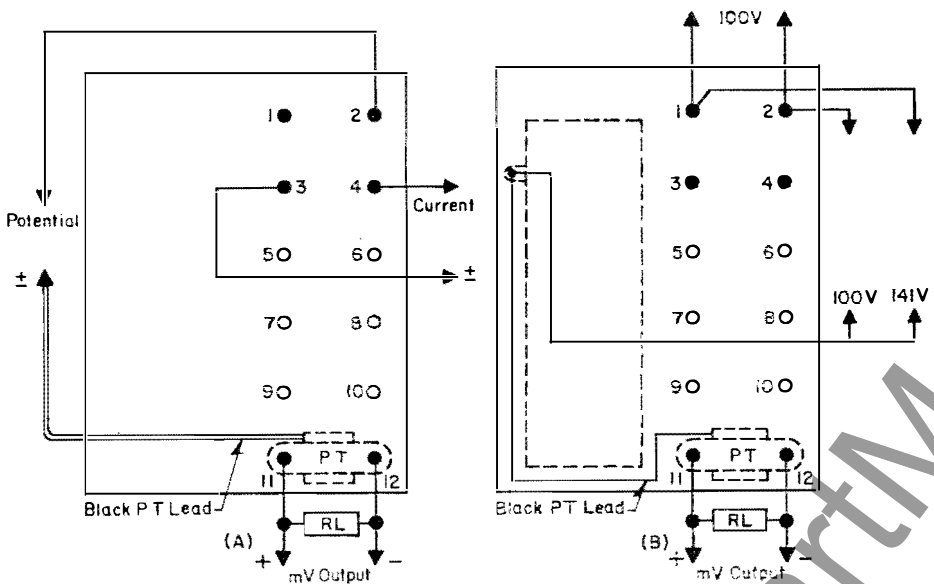

Figure 18: 1-phase, 2-wire single-phase test connections.

2-element three-phase three-wire transducers are calibrated by connecting them as shown in Figure 16 to a source of single-phase voltage and current at unity power factor. Disconnect the current from terminals 7 and 8 and adjust the current to given the required single-phase, opposed-potential calibration watts. Adjust the rheostat between terminals 5 and 6 to get one-half of the desired full-scale millivolt output. Reconnect the current to terminals 7 and 8. Again adjust the current to get the required single-phase opposed-potential calibration watts. Adjust the rheostat between terminals 9 and 10 to get full-scale millivolt output.

2½ element three-phase – Remove the screws between the terminal blocks, and slide off the cover. Disconnect the yellow lead going to printed circuit board connection point #13 (identified on the board itself) and the purple lead going to printed circuit board connection point #15 and reverse them so that the purple lead goes to point #13 and the yellow lead goes to point #15. Connect the transducer as shown in Figure 17, except reverse the connections to terminals 7 and 8. Adjust the current to give the single-phase opposed-potential calibration watts as required, and adjust the rheostat between terminals 5 and 6 to give one-half the full-scale millivolt output. Now disconnect the current connections to terminals 7 and 8 and reverse them again, so that the test connections are exactly as shown in Figure 17. Reapply the specified single-phase opposed-potential calibration watts to the transducer and adjust the rheostat between terminals 9 and 10 to give full-scale millivolt output. Without changing any adjustments, reverse the yellow and purple leads so that the yellow lead goes to point #13 and the purple lead goes to point #15. Replace the cover.

Type V-2 Transducers

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General Information,
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Section D

Current Transducer – Type VI2-841

1. Operating Principle

The VI2-841 transducer converts an ac current input to a proportional dc current of low magnitude. It consists of a current transformer with a loading resistor feeding through a calibrating rhesotat to a full-wave rectifier. There is an R-C network in the circuit for waveform error compensation to compensate for errors due to moderate waveform distortion. (This compensation method is known as 120° commutation).

2. Waveform Compensation

The perfect sine wave alternating current has the relationship shown in Figure 20. Electrical power measurements are made in terms of the rms values which yield true power or "heating effect" of a current. These values are measured directly by the dynamometer or iron-vane mechanisms used in conventional ac instruments. The rectifier type instruments used in test sets and in lower-cost switchboard instruments respond to the average values only. In effect, the measured values on this class of instrument are increased by a factor of 1.11 in marking up dials. Thus, rectifier instruments read rms values only when used on perfect sine waves.

On power systems a pure sine wave is rare. Close to the source, the voltage wave tends to be clean but the current wave is distorted. The opposite is true of the far end of a system, generally. Distortions of waveform are caused by harmonics generated in equipment, partial wave utilization of controlled firing rectifiers, capacitors, etc. They tend to be smoothed out by delta-wye transformations and by the filtering effect of lines and certain equipment. But, all told, waveform is uncertain, usually bad, and makes for questionable measurements using rectified measuring devices. Typical current and voltage transducers are such devices.

In the type VI2-841 transducer, an approximate rms compensating network has been added to make the transducer reasonably close to rms responding, regardless of the waveform aberrations commonly found on ac power systems.

ANSI C39.1 uses a variable third-harmonic content as a reference standard for performance of instruments on non-sinusoidal waveforms. It uses:

$$\% \text{ Harmonic Content} = \frac{\text{rms of harmonic}}{\text{rms of fundamental}}$$

to define the waveform.

The harmonic content of industrial power circuits is a wide variable. 5-10% is not uncommon. There are local circuits which run into the 20% area and beyond.

Plotted in Figure 21 is a curve of the error of average sensing devices such as rectified transducers or rectifier instruments, and the curve for the approximate rms compensated type VI2-841 current transducer.

3. Ratings

Standard VI2-841 transducers are rated 5 amp input. There are models for 60 Hz and 400 Hz. The 60 Hz unit may be used on 50 Hz. The output is 1 mA linear, into 10,000 ±1% ohms load resistance. The output is isolated from the measured circuit through an input transformer.

4. Readout Instrument

The transducer should be connected to a 1 mA instrument through enough resistance to make the total circuit resistance 10,000 ohms. A voltmeter rated 0-10 volts with a sensitivity of 1000 ohms per volt is satisfactory if the terminal resistance is 10,000 ohms ±100 ohms. This is not always the case because inaccuracies in voltmeter resistors are compensated by demagnetization rather than an exact trimming of resistors. The transducer can drive a direct-acting recorder.

5. Signal Source

When used as an input to an A/D converter or an active type instrument requiring a millivolt signal, the transducer output circuit must be loaded with two resistors. One resistor will provide the drop (e.g., 50 ohms for 50 mV and the second will provide the padding to the required 10,000 ohm load (See Section A, Paragraph 6). Any voltage up to 10 volts is available so long as the transducer terminals see 10,000 ohms.

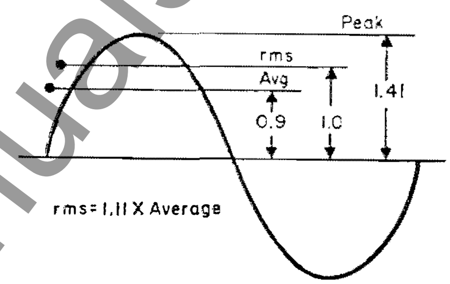

Figure 20: Ac waveform characteristics.

6. Scaling

Indicating instruments are usually selected with end-scale values equal to the current transformer primary rating. Ratios may be changed by changing the instrument rating. For example, if a 2.5 amp full scale is required on a readout instrument, a 0-500 uA range is used rather than the standard 0-1 mA.

7. Recalibration

There is a ±1% trimming rheostat located under the hole adjacent to terminal #7. This is intended for use in calibrating transducer-instrument combinations to the accuracy of the instrument alone. To change the input current rating requires a change in transformer. The same result, with some sacrifice in accuracy is achieved as indicated in Paragraph 6 on scaling.

8. Remote Indicators

The indicating instrument may be at a great distance from the transducer. Of the 10,000 ohms of load resistance, at least 3000 ohms can safely be in leads without too great a temperature error. This would allow any conceivable length of the typical hook-up leads. When the lead resistance exceeds 100 ohms, the resistor in the output terminal must be reduced a corresponding amount. 100 ohms will allow several miles of lead wire of the sizes typical to commercial installations.

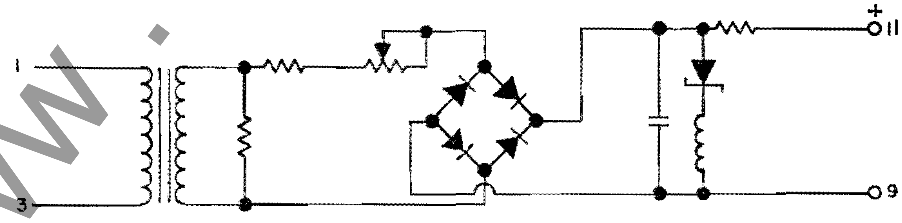

Figure 19: Single range current transducer.

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9. Totalization

Where the outputs of VI2-841 transducers are to be totalized into a high impedance device such as a potentiometeric recorder or A/D converter it is necessary to convert output to a filtered voltage signal. Each transducer requires a filter and a load resistor.

Filter unit Style Number 715B261A09 has provision for a load resistor on the terminal board. If current transformers are are identical a 10,000 ohm resistor is used (see Section A, Paragraph 6), making the output 10 volts. The outputs are then connected additively to an instrument having a high impedance input with a full scale equal to the algebraic sum of the transducer outputs.

Where the current transformers are not identical the load resistors must be split to proportion output in accordance with transformer ratios.

If, for example, it is necessary to add outputs from transducers connected to 600:5, 400:5 and 200:5 current transformers the load resistor on the first would be 10,000 ohms for 10 volts output (see Section A, Paragraph 6). The second resistor would be split 6667 and 3333 with the output across the 6667 ohm resistor. The 200:5 unit would use the same resistors but the output would be across the 3333 ohm resistor. (See Figure 22).

Where an indicating instrument only is to be used and current transformers are identical, the transducer outputs may be connected in parallel. Each transducer must be loaded with 10,000 ohms in series with its output terminals and the summing instrument (See Figure 23). The indicating instrument will be a milliammeter with a full scale value equal to the algebraic sum of the transducer outputs.

If the current transformers are not identical the simplest solution lies in the use of auxiliary current transformers, connecting their outputs in parallel to a single transducer. The auxiliary current transformer ratio should be proportioned so that the total output from all circuits is 5 amperes. Another solution is to use voltage addition as for a high impedance voltage input and feed this into a constant current amplifier. Such are available from several sources.

10. Specifications and Technical Data

See page 30, Part II.

11. External Connections

See Page 39, Part III.

12. Dimensions

See page 37, Part III.

Further Information

VI2-841 Current Transducer: Instruction Leaflet 43-841.4.

Modifications: Instruction Leaflet 43-800.3.

Prices: Price List 43-860

Description: Descriptive Bulletin 43-861.

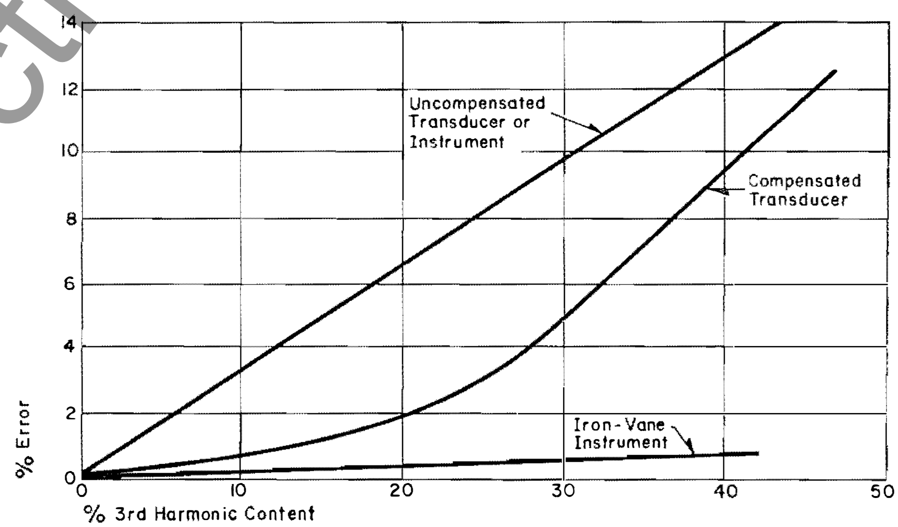

Figure 21: Comparative performance of rms-compensated and umcompensated rectifier type ac transducers when reading rms values.

Type V-2 Transducers

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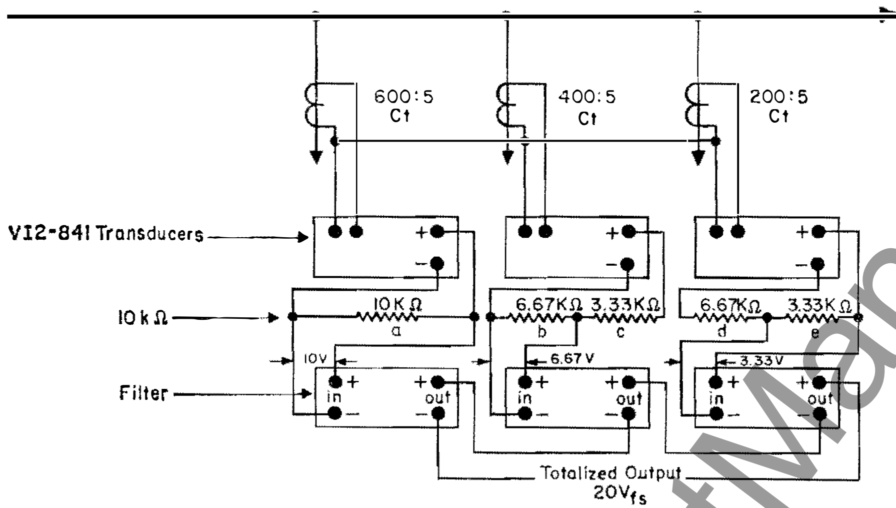

Figure 22: Totalizing three feeder circuits with different current transformer ratios. Filters are style number 715B261A09. Resistors a, b, and e mount between terminals 5 and 7 of the filters. Resistors c and d mount between 11 or 9 and 7 of the transducers.

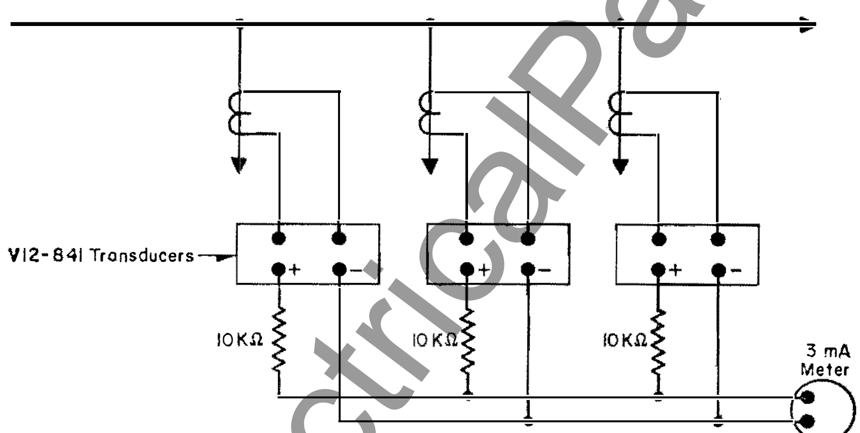

Figure 23: Totalizing three feeder circuits with identical current transformers into an indicating instrument.

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Section E

Voltage Transducer – Type VE2-841

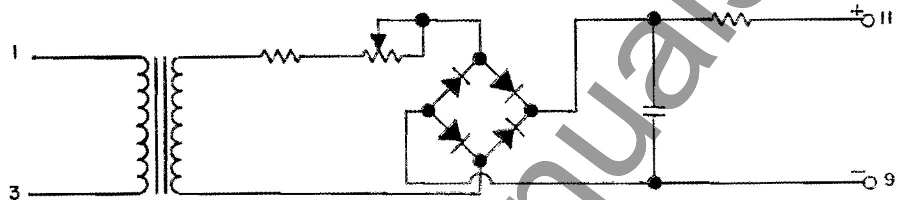

Figure 24: Single range voltage transducer.

1. General

The VE2-841 voltage transducer is exactly the same as the VI2-841 current transducer except for the input transformer and the omission of the transformer loading resistor. All comments in Section D also apply to the type VE2-841.

Type V-2 Transducers

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General Information,
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Section F

Suppressed-Zero Voltage Transducer-Type VE2-841

1. Operating Principle
The suppressed voltage transducer employs the same basic operating principle as the regular voltage transducer with the addition of a Zener regulating circuit which permits the device to put out a positive signal only above a design threshold.

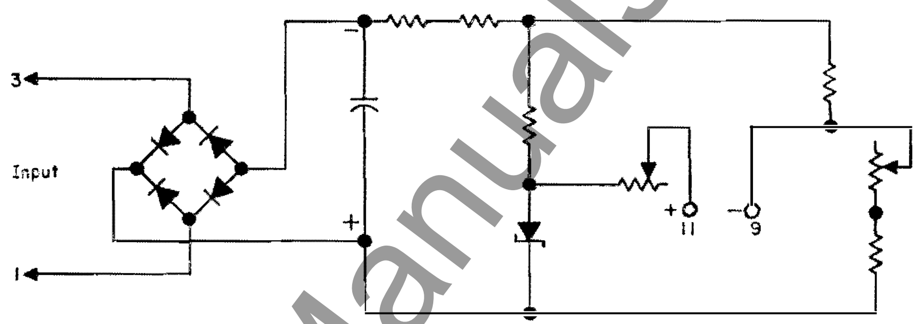

Figure 25: Ac suppressed voltage transducer.

2. Ratings
The output is 500 uA into 280 ohms ±10% non-isolated. The standard range is 110-130 volts. There is a dc and an ac model. The output is non-linear. The ac model is used from 25 to 1000 Hz.

3. Readout Instrument
A standard 0-500 uA microammeter must be specially calibrated in combination with the transducer.

4. Signal Source
The suppressed zero transducer is generally not suitable for use with computers and control devices unless the non-linearity of the output can be accommodated in the receiving equipment.

5. Scaling
No modifications can be made in the input-to-output relationship without a special design. Instrument scales are always the product of the standard 110-130 and the potential transformer ratio.

6. Recalibration
This transducer is intended for instrument use only since its output is non-linear and scale distribution should be determined for each transducer.

If the instrument resistance is lower than the 280 ohms specified, the transducer output can be padded up by the addition of a series resistor equal to the rated load resistance minus the instrument resistance. This series resistor can be mounted between terminals 5 and 11 (see Section A, Paragraph 6). The lead originally going to terminal 11 should be connected to terminal 5. The nameplate load resistance rating should be changed accordingly. The instrument is connected to terminals −9 and +11. Without recalibration, the 110-130 volt transducer-instrument combination accuracy equals the transducer's accuracy (±1/3 of center value) plus 1/6 the instrument's accuracy; e.g., transducer plus 2% 20/20 instrument gives overall accuracy of 1/3 + 1/6x2% = 2/3 of center value.

If the instrument resistance is within the output load limits, the transducer can be recalibrated as follows:

1. The instrument must be supplied with its nominal dc full scale sensitivity calibrated to within its accuracy class rating.
2. Connect transducer-instrument combination per nameplate.
3. Calibrate left end-scale by adjusting rheostat through hole adjacent to terminal 9 and right end-scale by adjusting rheostat through hole adjacent to terminal 1. Check left end-scale and repeat if necessary.
4. Determine scale distribution and mark instrument scale accordingly.
5. Change nameplate accordingly and serialize instrument-transducer.

7. Remote Indicators
The indicator may be remotely located provided the combined resistance of leads and instrument is held at 280 ohms ±10%. This will allow up to well over a thousand feet using #12 or #16 hookup wire.

8. Specifications and Technical Data
See page 5, Part II.

9. External Connections
See page 39, Part III.

10. Dimensions
See page 37, Part III.

Further Information
VE2-841 Voltage Transducer:
Instruction Leaflet 43-841.4
Modifications:
Instruction Leaflet 43-800.3
Prices:
Price List 43-860
Description:
Descriptive Bulletin 43-861

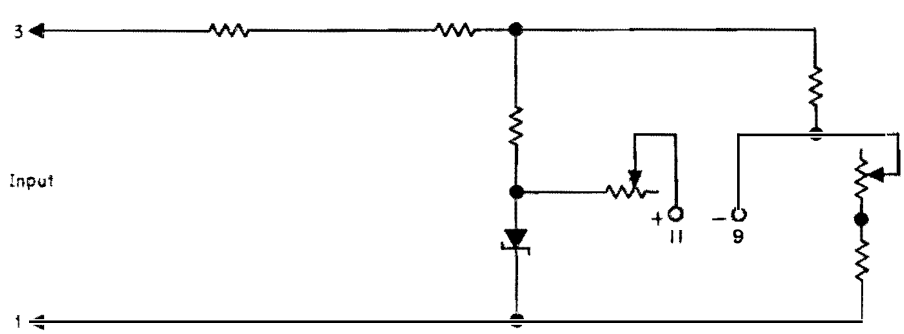

Figure 26: Dc suppressed zero voltage transducer.

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Section G

Frequency Transducer – Type VC2-841

1. Operating Principle

The VC2-841 transducer provides a linear dc output on each side of a null point within the frequency span of the device. This makes the transducer essentially fail-safe when used with an indicating instrument. The schematic diagram for the Type VC2-841 transducer is shown in Figure 27. An input voltage of 120 volts ac is applied between terminals one and three. Resistor R1 limits the input voltage which is then clipped by the Zener-diode bridge network (D1, D2, D3, D4, Z1) producing a near square wave of constant amplitude voltage at this point. Resistors R9 and diode D8 are used to balance the loading of the Zener circuit. On one half-cycle of the signal, capacitor C1 discharges through diode D6 and R2 (the output load calibrating resistor) against the zener voltage.

The combination of diode D7, capacitor C3, and resistor R3-R8 produce a nulling current at the junction of diode D6 and resistor R2 which balances the circuit to provide zero output at the point 30% of the frequency span up scale from the lowest frequency of the span.

The integrated discharge current of capacitor C1 changes with input frequency (i= 2 fce), causing a proportional change in the output. Capacitor C2 is used to filter out part of the ac ripple in the output. The transducer is calibrated for specific load resistances (see page 31, Part II).

The transducer produces an output which is load sensitive beyond a 10% variation from the calibrated load.

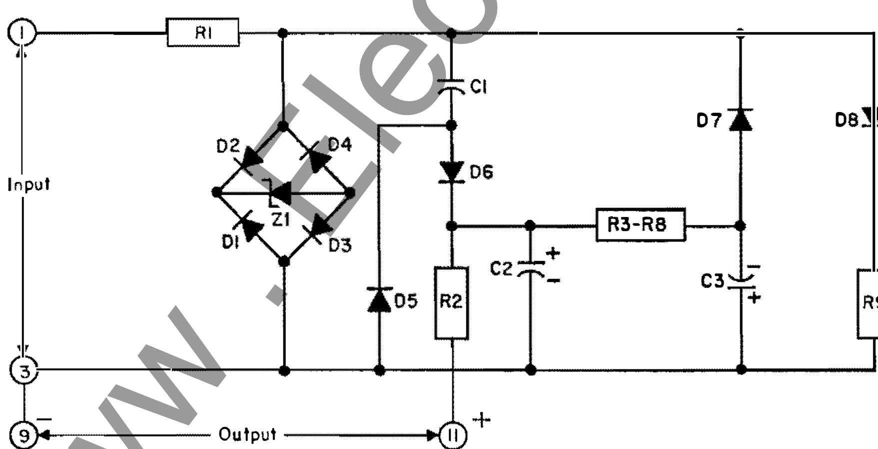

Figure 27: Frequency transducer schematic.

2. Ratings

(a) Standard Frequency Ranges are:
59-61, 58-62, 55-65, 50-70, 48-52, 45-55, 45-65, 390-410, 380-420, 350-450 and 20-30 Hz.

(b) Inputs
120 volt nominal is standard; 240 volt is available.

(c) Output
There is a point where the output of the transducer is zero. This point is offset from the nominal frequency in order to prevent indication of nominal frequency when there is no input voltage. Standard transducers have the null point at 30% of the frequency span upscale from the low frequency end of the span. The output is linear within its range and is 50 uA per Hz for 50 or 60 Hz center frequencies and 5 uA per Hz for 400 Hz center frequency. There is positive dc output for frequencies above the null point and negative dc output for frequencies below the null point (see page 31, Part II). On special order zero output can be set at the lowest frequency of the span and the full output at the highest frequency of the span. Output will be the arithmetic sum of the end-scale values as shown in Part II. (e.g., for 55-65 Hz range, the output would be 0-500 uA).

The output is not isolated from the input. Input terminal #3 is internally connected to output terminal #9. If isolation is required, a small 1:1 transformer should be used at the input. If the source has one side grounded, this grounded side should preferably be connected to the input terminal #3.

3. Readout Instruments

The standard transducer uses a microammeter with zero at 30% of span upscale. A green mark at this point serves as a zero reference. Continuous indication at this green line indicates an inoperative instrument. The end-scale values vary with transducer frequency range. These values are listed in Specifications in Part II, page 31, of this application data. Instruments should be serialized with their matching transducers.

4. Signal Source

Where millivolt signals are required for input to active instruments, control systems, etc., the transducer may be resistance loaded with two resistors in series. The first should give the desired mV drop at the full-scale output of the transducer. The modified transducer with zero at the low end of span is often used for this application; e.g., with a 55-65 Hz transducer the output is 0-500 uA into 280 ohms. For a 0-50 mV signal there should be a 100 ohm dropping resistor with a 180 ohm padding resistor across the transducer terminals.

The output is dc with ac ripple of the same frequency as the input signal and ripple magnitude of approximately 20% peak-to-peak of full scale output. This ac ripple introduces no error and is not objectionable when applied to conventional indicating instruments. Where the output level of the transducer is insufficient, it may be fed through an amplifier to get a suitably high signal level. In this case, a filter should be used on the output before amplification. Filter modules, Type VF2-876, may be added when minimum output ripple with millivolt output is required. Filter modules may only be used with loads of 50,000 ohms or greater.

5. Scaling

Instruments are scaled to match the transducer span. This span may be changed with changes to the circuit boards. See Instruction Leaflet 43-800.3.

6. Recalibration

The transducer is supplied calibrated according to information shown on the nameplate. If the transducer is used with a load other than for which it was calibrated, the calibration will be affected. Standard transducers have zero output at 30% of span upscale.

Type V-2 Transducers

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Minor calibration on certain wide-span transducers is accomplished by first setting the null frequency value by adjustment of the rheostat reached through the hole adjacent to terminal 11. End-scale values are then calibrated by adjustment of the rheostat reached through the hole adjacent to terminal 7. Narrow-span transducers (i.e., 58-62 and 59-61 Hz) use calibrated resistor spool for end-scale calibration and a rheostat for null frequency calibration.

7. Remote Indicators
The tolerance on load resistance is ±10%. The leads between the transducer and readout instrument can be several thousand feet long without exceeding the tolerance. Adjustment to compensate for lead resistance may be made by recalibration on the job, as in paragraph 6.

8. Specifications and Technical Data
See page 31, Part II.

9. External Connections
See page 38, Part III.

10. Dimensions
See page 37, Part III.

Further Information
Type VC2-841 Frequency Transducer:
Instruction Leaflet 43-841.3.

Modifications:
Instruction Leaflet 43-800.3.

Prices:
Price List 43-860.

Description:
Descriptive Bulletin 43-861.

Section H

Power Factor Transducer – Type VF2-841

1. Operating Principle
The VF2-841 power factor transducer provides a dc output proportional to the phase-angle between current and voltage on a balanced ac power system. The transducer operates on the "zero-crossing" principle in which the output is proportional to the time elapsed between the instant that the voltage passes through zero and the current passes through zero.

There is no real agreement on a definition of power factor in power measurements. One definition is that power factor is the cosine of the phase-angle between current and voltage. A "zero-crossing" device can make a single-phase measurement on a perfect sine wave within this definition. A second definition is that power factor is the relationship of true power to reactive power; i.e., $\frac{kw}{kva}$. This definition holds regardless of waveform but measurements under this definition require complex instrumentation. The two definitions coincide only for single-phase measurements with perfect sine waves.

A polyphase power factor measurement involves three voltages and three currents which are likely to vary in magnitude, in phase-angle, and in waveform. The measurement is made theoretically correct only by measuring watts and volt-amperes and adding them vectorially. Figure 28 shows an exaggerated polyphase vectorial addition. The polyphase power factor is $\frac{AC}{AB}$. Obviously, a transducer sensing one voltage and one current cannot make an equivalent measurement.

A polyphase power factor meter or transducer, therefore, measures only approximate power factor. In the case of the VF2-841 transducers, the measurement is made using a current in one phase and the voltage across the other two phases. The measurement is correct only for perfectly balanced conditions and perfect waveform. Inaccurate as it is, it is the only type measurement which can be made by a single, direct-reading, passive instrument. It is, therefore, a common measurement.

The internal schematics for the Type VF2-841 transducer are shown in Figure 29 and Figure 30 for 3-phase and single-phase models respectively. The proper voltage (see page 32, Part II) is applied between terminals 5 and 7. The resistor R1 limits this input voltage which is then stepped down by transformer T1. Resistor R2 limits the current output of transformer T1 and provides phase compensation. Zener diodes D1 and D2 clip the secondary voltage of transformer T1, producing a near square wave of constant amplitude voltage at this point. This voltage triggers transistors Q1 and Q2, which are connected in a modulator configuration. A 2-5 amp ac current is applied to terminals 1 and 3 and to transformer T2. The voltage from this current transformer secondary is clipped by Zener diodes D3 and D4 and switched to resistors R5 and R6 by transistors Q1 and Q2. These transistors are operated only in a switching mode and require no zero balancing. The voltage and current applied to the transducer are shifted 90° externally in the 3-phase systems by cross-phasing and in single-phase systems by an internal phase-shifter network. There is zero dc output at unity power factor since the voltages across R5 and R6 are equal and opposite. There is no output when the input current is off. The transducer output

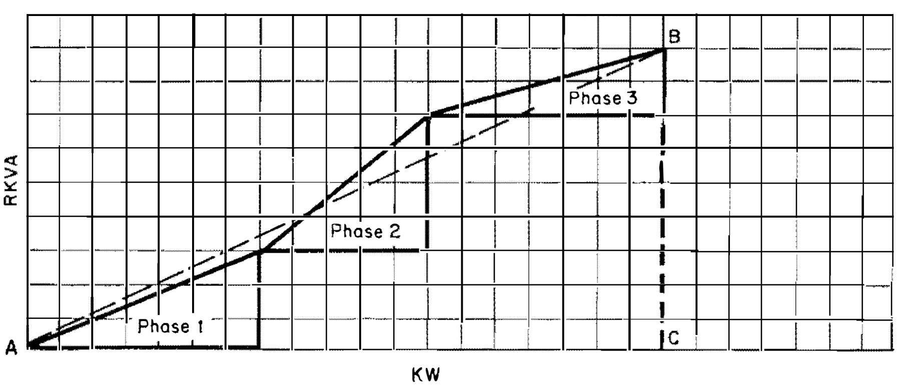

Figure 28: Vectorial determination of 3-phase power factor.

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for leading power factor values between unity and zero is positive. Conversely, the output is negative for lagging power factor values between unity and zero.

2. Types and Ratings

The single-phase transducer is rated 5 amp, 120 volt nominal. The polyphase is rated 5 amp, 120 volt for 3-phase 3 wire and 208 volt for 3-phase 4-wire.

In each case, the output is 0.5-0-0.5 mA into a load resistance of 110 ohms maximum. These values correspond to 0.5 lag – 1.0 – 0.5 lead power factor.

The output is linear with respect to phase angle.

The accuracy of the VF2-841 is 1% of phase angle above 40% of rated current and rated voltage and 2% of phase angle for 20 to 40% of rated current and rated voltage (60 Hertz sine wave input only). Inasmuch as the power factor is proportional to the cosine of the phase angle, the accuracy of the transducer in terms of power factor is a broad variable. The transducer is calibrated for load resistance of 110 ohms. If it is used with a different load resistance, calibration will be affected.

The VF2-841 transducer was designed specifically for use with the Westinghouse 20/20 line of panel instruments. However, it can be used with pivot-and-jewel instruments and taut-band instruments as long as the instrument's terminal resistance is within the load resistance range of the transducer (see page 32, Part II). Without recalibration, the transducer-instrument combination accuracy equals the transducer accuracy plus the instrument accuracy in terms of percent of scale length. The transducer and 20/20 panel instrument can be ordered together as a serialized pair (instrument and transducer are specifically calibrated together). This combination provides an economical yet accurate (2% of scale length) power factor indication. The VF2-841 is for use on balanced systems only. The output of the power factor transducer for unbalanced conditions is not accurate, but measured power factor under unbalanced conditions is essentially meaningless, as pointed out in paragraph 1 of this section.

3. Readout Instruments

Any zero-center milliammeter with a terminal resistance less than 110 ohms is satisfactory. The scale may be marked linearly in phase-angle but more often is drawn as a cosine scale and marked in power factor. Modification can be made for terminal resistances from 110 ohms up to 5000 ohms.

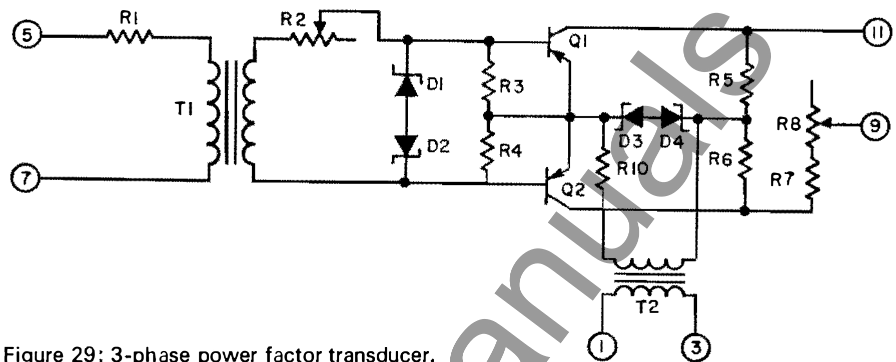

Figure 29: 3-phase power factor transducer.

4. Signal Source

The VF2-841 may be used as an input to active instruments, amplifiers, computers and the like if they can accommodate the Cosine θ scale. Such devices usually require a millivolt signal. For a 50-0-50 mV output, the transducer should be loaded with a 100 ohm resistor. The output of the VF2-841 is dc with an ac ripple of twice the input frequency and ripple magnitude of approximately 20% peak-to-peak of full scale output. If filtering is necessary, the VF2-841 power-factor transducer should be used with a VF2-876 filter unit which has a load resistor. The base dimensions of the transducer are such that the VF2-841 and other types of V2 transducers and filter units can be gang-mounted horizontally or vertically on either standard racks or on conventional control panels. There is no interaction between gang-mounted transducers.

5. Scaling

The transducer is designed for an output of 1 milliamp for a phase-angle change of 120° or 8.33 uA per degree. Standard transducer output is ±0.5 mA for 0.5 lag – 1.0 – 0.5 lead power factor or minus and plus 60° phase shift. Maximum obtainable output is for minus and plus 78.5° phase shift or 0.2 lag – 1.0 – 0.2 lead power factor (±0.65 mA). The transducer can be recalibrated.

6. Recalibration

Minor calibration adjustment is accomplished by first adjusting for zero output at unity power factor by adjustment of the rheostat reached through the hole adjacent to terminal 7 in the terminal board. End-scale leading and lagging values are then calibrated by adjusting the rheostat reached through the hole adjacent to terminal 11.

If the desired output resistance is greater than 110 ohms but less than 5000 ohms, the transducer can be recalibrated. Resistor R7 (see Figures 29, 30 and 31) must be replaced with a resistor (½ watt ±100 P/M temperature coefficient or better) equal to 7500 ohms minus the instrument terminal resistance. Connect the transducer-instrument per nameplate information and external connections as shown in Part III, page 38. Energize the transducer at rated voltage and two-thirds rated current and calibrate as previously stated for 100% and end-scale power factor values.

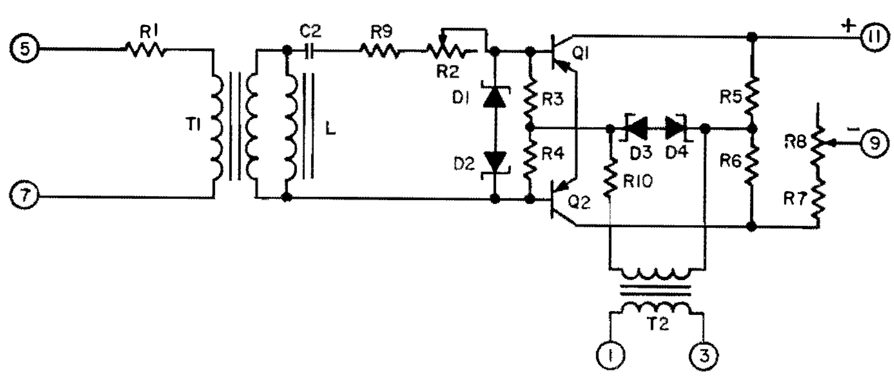

Figure 30: Single-phase power factor transducer.

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The voltage input rating of the VF2-841 transducer can be changed by changing the resistor R1 (see Figures 29, 30 and 31) per Part II, paragraph 7, page 32. This resistor should be rated at 5 watts and have a temperature coefficient of ±20 P/M or better. Recalibrate the transducer as previously stated.

Three-phase, 4-wire transducers are the same as 3-phase, 3-wire transducers except for the input voltage resistor R1. The line-to-line voltage of the 3-phase, 4-wire systems is equal to $\sqrt{3}$ x the line-to-neutral voltage.

7. Specifications and Technical Data
See page 32, Part II.

8. External Connections
See page 38, Part III.

9. Dimensions
See page 37, Part III.

10. Further Information

Type VF2-841 Power Factor Transducer:
Instruction Leaflet 43-841.5.

Modifications:
Instruction Leaflet 43-800.3.

Description:
Descriptive Bulletin 43-861.

Prices:
Price List 43-860.

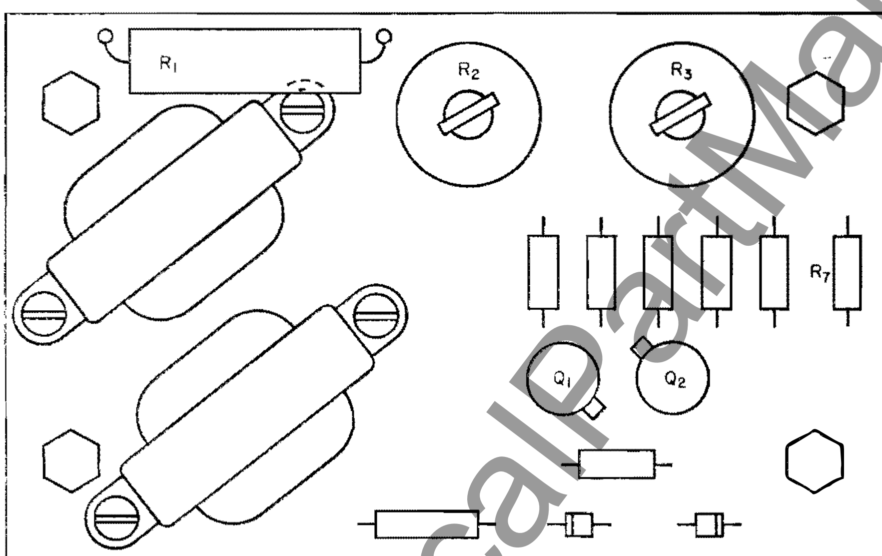

Figure 31: Power factor transducer circuit board.

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Section I
Temperature Transducer – Type VT2-841

1. Operating Principle
The VT2-841 temperature transducer develops a current output related to the temperature of a resistance temperature detector coil (RTD). The output is non-linear with respect to the Fahrenheit or centigrade scales in which a temperature indicating instrument is usually calibrated.

A complete RTD thermometer system consists of transducer, dc indicating instrument, detector coils, selector switch, and connecting leads.

The RTD coils are made of copper wire to an exact resistance of 10 ohms at 25°C. They are located at the points where the temperature is to be measured. The coils are mounted in the equipment by the manufacturer of the generator, motor, transformer, etc., and are not supplied with the transducer. Usually several RTD coils are used with a single transducer connected through a selector switch.

When connected to the transducer, the RTD coil becomes one leg of a Wheatstone bridge. As the coil resistance changes the balance of the bridge is upset and a voltage is produced across the output almost proportional to temperature. A transducer-instrument combination is checked by connecting an internal test resistor in place of the detector coil. This test resistor will make the dc meter read at a test point marked by a green line. Resistances of a standard copper RTD coil rated 10 ohms at 25°C will be:

Degrees Centigrade	Resistance-Ohms
0	9.037
10	9.422
20	9.807
30	10.192
40	10.577
50	10.962
60	11.374
70	11.732
80	12.117
90	12.502
100	12.887
120	13.657
140	14.427
150	14.812
160	15.197
180	15.967
200	16.737

The transducer contains a power supply as well as the bridge circuitry. The standard input is 120 volt, 60 ±0.5 Hz. The power supply element is shown in Figure 32.

Resistor R1 loads the transformer secondary and allows some adjustment of the input to the rectifier circuit. This is the end-scale adjustment for an indicating instrument.

Resistor R2 allows adjustment of the power input to the bridge circuit. When calibrating the VT2-841 with an external instrument, this is the primary adjustment for the end-scale deflection of the instrument mechanism.

Zener diode z is a voltage regulator. The input voltage influence on the VT2-841 accuracy is:

0.5% maximum with ±10% variation from the nominal 120 volts.

2% maximum with ±20% variation from nominal 120 volts.

Schematically, the bridge circuit is shown in Figure 33.

R5 is a variable depending on temperature range: 100°C=12.117 ohms; 150°C= 12.887 ohms; 200°C=14.812 ohms. The RTD is 10 ohms nominal. L1, L2 and feeder leads are calibrated to maintain balance. With changes in RTD resistance the bridge is unbalanced and current flows through the meter. For calibration test a resistor of negligible temperature coefficient substitutes for the RTD.

The circuit for a typical multiple point installation is shown in Figure 34.

2. Types
Only the design for a 10 ohm copper RTD is currently offered. Now that the universal motor protectors, formerly available only with 120 ohm nickel detectors, are available for 10 ohm copper there seems little need for any other RTD material. The user should make the decision on detector type before ordering motors or generators. If other than 10 ohm copper RTD's are specified or permitted, it will restrict the types of temperature relaying which will share RTD coils with the temperature indicators.

3. Ratings
Standard transducers are rated 120 volt, 60 Hz power supply, 0-100°C, 0-150°C or 0-200°C to yield 1-0-1 mA into 30 ohms. The frequency is critical. The tolerance for rated accuracy is ±0.5 Hz which may be a problem on isolated small power plants.

4. Readout Instrument
Any zero-center milliammeter 1-0-1 mA with a terminal resistance of 30 ohms. (Lower resistance milliammeters can be padded to 30 ohms). The instrument must be calibrated with the transducer as a matched serialized pair.

5. Signal Source
The VT2-841 transducer, because of its nonlinearity is generally not suitable for input to active instruments or computers or data systems unless the system can be programmed for the individual transducer characteristics.

6. Scaling
To change the temperature scale of the transducer requires a redesign. This can be done if quantities are involved. The scales can be changed to Fahrenheit by shortening scales to the nearest suitable end-scale number. There is no possibility of narrowing ranges without redesign of the bridge circuit.

7. Recalibration
After all connections have been made, apply voltage and put the selector switch on the test position. The instrument should read at the green line of the dial. If it does not, the instrument's mechanical zero adjuster should be turned with a screwdriver until the pointer deflects to the green line. If the deviation is beyond the range of this adjustment, either the instrument will need

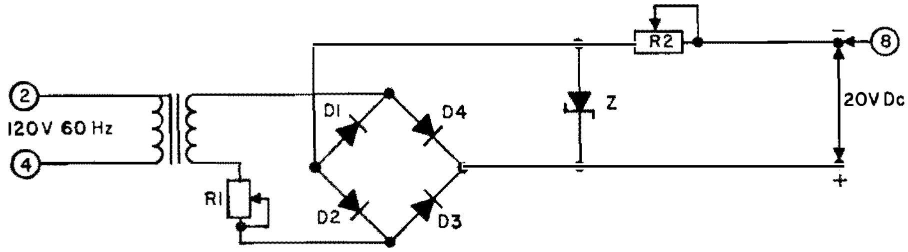

Figure 32: Internal power supply of temperature transducer.

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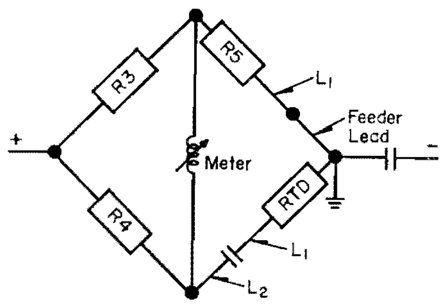

Figure 33: Schematic bridge circuit for temperature transducer.

recalibration or some error in the connections has been made and should be checked out and corrected. The test point is not the mechanical zero or de-energized position of the instrument.

The VT2-841 transducer is usually supplied calibrated to a serialized instrument. The output is non-linear and the null point of the transducer (exploring coil temperature point where output of transducer is zero) is not necessarily the same for all transducers. Transducers supplied with serialized instruments need no further calibration. Transducers supplied calibrated to full scale output and no serialized instrument are to be used with center zero 1 mA, 30 ohm dc instruments. All lead resistors must be per Figure 34. Distribution of instrument scale is determined by first adjusting the mechanical zero point of the meter so that it reads correctly at the right and left end-scale points with the corresponding exploring coil resistance (±1/10%) per table in Paragraph 1, page 22. Mark a green line at test point (transducer test resistor substituted for exploring coil). Then determine scale distribution by substitution of correct exploring coil resistance per table paragraph 1, page 22.

Mark instrument scales accordingly and serialize transducer instrument combination.

8. Remote Indication
It is preferable for the control switch and the transducer to be near to the instrument. If, for some reason, the readout instrument is to be remote from the transducer, the limitation is the 30 ohms in the meter circuit. Milliammeters as low as 20 ohm terminal resistance are not unusual. This leaves 10 ohms for instrument leads which will carry the meter hundreds of feet away.

9. Specifications and Technical Data
See Part II, page 32.

10. External Connections
See Figure 34 of this section or Figure 20, page 40, Part III.

11. Dimensions
See page 37, Part III.

12. Further Information
Type VT2-841 Transducer:
Instruction Leaflet 43-841.6.
Prices:
Price List 43-860.
Description:
Descriptive Bulletin 43-861.

Switchboard Thermometers:
Descriptive Bulletin 43-270.
RTD's 10 Ohm Copper Obtained from:
Minco Products, Inc.
7300 Commerce Lane
Minneapolis, Minn. 55432
There are models for factory or field installation in stators, strapping on pipes, immersion in liquids, etc.

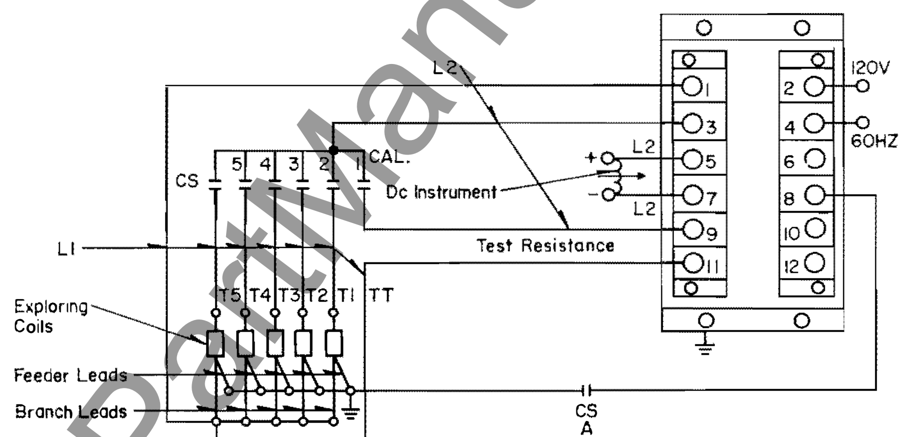

Figure 34: Multi-point external connection of temperature transducer.

1. L-2 leads and branch leads should not exceed 0.02 ohm each.
2. Switch contacts to exploring coils must make before break. (Switch Westinghouse style number 663A488G01 for 5 exploring coils).
3. Individual L-1 leads should have a resistance of 0.3 ohms for standard instruments. Other resistance values are available on special order up to 3 ohms. In either case, the variation in resistance should not exceed ±0.1 ohms.
4. All L-1 leads must be within 0.02 ohm of the same resistance.
5. Each resistance tolerance or limit stated will limit errors from this source to less than one percent. Any increase will cause an approximately proportional error.
6. Feeder leads must be within 1 ohm of the same resistance.
7. Control switch contacts Cal. 1, 2, 3, 4 and 5 close in position as indicated. Contact A is open in OFF position; closed in all other positions.

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Section J

Speed Transducer – Type VR2-841

1. Application

The VR2-841 speed transducer is a self-contained, externally-powered (120 volt, 60 Hz) all-static device. It converts cycles or pulses per second into a linear dc current output. It is intended for use with dc indicating meters.

The usual source of pulses is from a variable reluctance magnetic pickup fitted into the machine to be speed-measured. The pickup is installed in proximity to an iron or steel part which serves as a tooth or a notch to pass the face of the pickup at least 25 times per second with a velocity of 25 inches per second or more. A shaft may be fitted with a notched wheel to generate pulses. Such are listed in Westinghouse Price List 43-500.

A wheel with 15 notches minimum or a gear with 15 or more teeth will permit measurement down to 0-100 rpm. Below this speed the pulse device would need more notches, or would need to be driven through a speed increaser. Any pulse source can be used if it satisfies the following conditions:

FS (Full Scale) Frequency	Minimum Input Pulse Duration
0-1,500 to 0-14,000 . Hz	50 microseconds
0-750 to 0-1,500 Hz	70 microseconds
0-400 to 0-750 Hz	110 microseconds
0-180 to 0-400 Hz	135 microseconds
0-90 to 0-180 Hz	320 microseconds
0-50 to 0-90 Hz	600 microseconds

The full scale frequency (FS) is a function of the notches or pulses per revolution and the rotational speed of the machine.

$$\text{FS Frequency} = \frac{\text{rpm x notches/revolution}}{60}$$

Other input pulses can be used. If the signal is an ac wave, it may vary from 1 to 40 volts peak-to-peak (14 volts rms, sine wave) or from 0.5 to 20 volts, if dc pulses.

2. Operating Principle

In Figure 35 the section identified as "Power Supply" is a conventional regulated source of low voltage dc. Output 5 volts, filtered.

In the "Switching Circuitry" segment, pulse signals across 1 and 3 terminals are amplified and conditioned. The output circuitry is a capacitor charge-discharge circuit taking the variable frequency pulses and converting them to a rectified dc output. The dc varies proportionally to frequency because the integral of the constant-charge pulses from C2, C5, and C6 varies with frequency. Because the capacitors have a fixed charging time, there is a minimum pulse duration requirement.

R10, R11, and R12 are for temperature compensators. R13 is for output calibration.

The transducer is load sensitive. It is ordinarily calibrated 0-1 mA into 100 ohms.

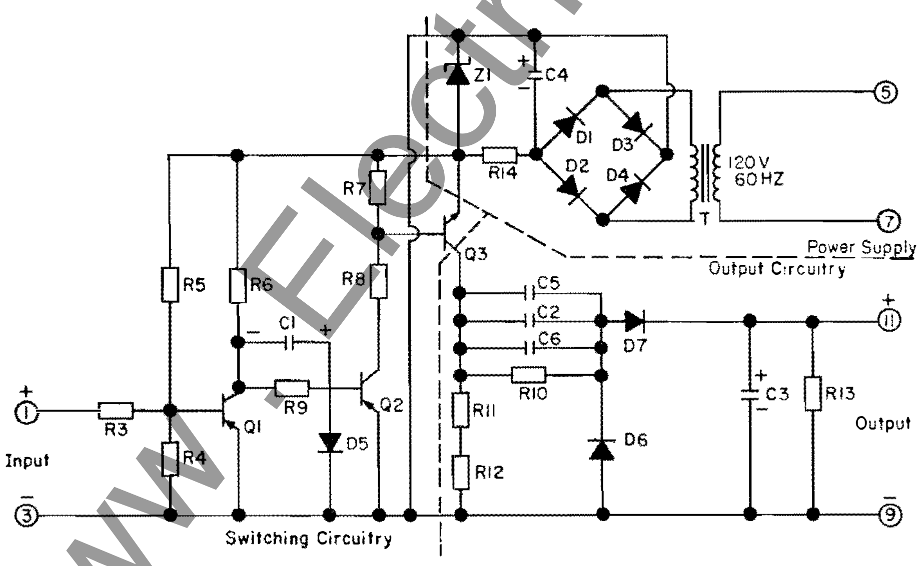

Figure 35: Pulse transducer schematic.

3. Pulse Sources

Westinghouse lists an Electro Model 3045 as a standard pickup in Price List 43-500. It incorporates this pickup into the Type B801 pulse generator together with any of a number of pulse wheels. The wheels are sold separately in the same price list.

Standard wheels are 4.784 inches in diameter. They have 6, 12, 15, 20, 30, 40, 50, 60, 70, 78, 80, 90, 100, 110 or 120 notches. Several manufacturers have a variety of magnetic pickups. These include:

Electro Products Laboratories, Inc.
6125 W. Howard St.
Chicago, Illinois 60648

Honeywell, Inc.
2701 Fourth Ave. So.
Minneapolis, Minn, 55408

Power Instruments, Inc.
7352 No. Lawndale Ave.
Skokie, Illinois 60076

Any ac generator, make-break contact or oscillation may be used as well.

4. Ratings

Several transducers are required to cover the pulse range:

0-7000 to 0-14,000 Hz or pulses/second
0-3000 to 0-7000 Hz or pulses/second
0-1500 to 0-3000 Hz or pulses/second
0-750 to 0-1500 Hz or pulses/second
0-400 to 0-750 Hz or pulses/second
0-180 to 0-400 Hz or pulses/second
0-90 to 0-180 Hz or pulses/second
0-50 to 0-90 Hz or pulses/second

Ordinarily a transducer is factory calibrated for a specific pulse rate. It is not field adjustable but is shop adjustable within the above ranges. This is discussed further in Paragraphs 7 and 8 of this section. Standard output is 1 mA into 100 ohms (100 mV). Shop adjustments can be made to 1 mA, 220 ohms.

5. Readout Instrument

The VR2-841 transducer is matched exactly to a 20/20 100 mV instrument (1 mA sensitivity and 100 ohms terminal resistance), as shipped.

It may be used with any other type or brand of milliammeter with a terminal resistance of 20 ohms or less by padding the resistance to 100 ohms using a nichrome or other low temperature coefficient resistor. For instrument resistances up to 50 ohms (or 60 ohms with a slightly increased temperature influence) the instrument circuit should be padded to 220 ohms but a transducer modification is required. The

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modified transducer may be ordered for 220 ohm load or a standard transducer may be modified as described in Instruction Leaflet 43-800.3. Higher-than-standard resistance on milliammeters are a standard modification.

6. Signal Source
The output is pulsed dc. Signal conditioning is required when the transducer supplies an active instrument or a computer. The VF2-876 filter will reduce output ripple.

7. Scaling
Transducers are specified usually at a pulse input rate corresponding to the characteristics of the machine being monitored.

For speed measurement where a notched disc is mounted on the measured shaft:

$$\text{Calibrated Pulse Rate (Per Sec.)} = \frac{\text{rpm x notches on wheel}}{60}$$

Where the pulse wheel is geared the rate is adjusted by the gear ratio. For linear speed measurement the pulse rate is calculated as shown in this example:

The problem: to indicate the speed of a strip in a rolling mill in feet-per-minute on a switchboard mounted indicator remote from the machine. The strip passes over a 24" diameter roller, which is driven by a motor running at 1750 rpm through a gear reduction of 5:1. The pinion on the motor has 20 teeth and the gear on the roller shaft has 100 teeth.

Investigation reveals that the reluctance type pickup device can be mounted in close proximity to the teeth on the 100-tooth steel gear (magnetic material).

With the motor running at full load speed of 1750 rpm the feet per minute of the strip can be determined by:

$$\frac{1750}{5} \times \frac{24}{12} \times \pi = 2200 \text{ fpm}$$

Impulses per second would be:

$$\frac{100 \times 350}{60} = 583.3 \text{ ips}$$

As the standard calibration is 1 milliampere for full scale deflection of the indicating instrument, the full scale rating would be 1 milliampere at .636 volts, based on the following:

$$583 \times \frac{2400}{2200} = 636 \text{ ips at 2400 fpm for full scale.}$$

Provision can be made for roll wear compensation by connecting a rheostat in series with R13. It is then necessary to specify the minimum and the maximum pulse rates.

The transducer can be scaled as a frequency meter. It is especially appropriate where scales such as 0-75 Hz are required on nominally 60 Hz equipment. The input pulse rate in this case is specified as an ac frequency.

In the above example, full-scale frequency equals 75 Hz. Usually the input voltage for such frequency meters is to be 120 volts. The transducers can be so specified or modified per Paragraph 8.

8. Recalibration
The VR2-841 can be recalibrated for any frequency within its range by changing the value of R13. The ranges are shown in Paragraph 4 of this section. For example, a 200 Hz or pulse per second input can be recalibrated for anywhere from 180 to 400.

Input voltage level can be changed. The input voltage of the standard VR2-841 transducer is 0.5 to 20 volt positive pulse or 1 to 40 volts positive pulse ac wave. The input voltage range can be changed to 220 volt positive pulse or 40 to 440 volt positive pulse ac wave by the addition of a series 150,000 ohm ±5%, 1 watt carbon resistor in position R1 (See Figure 36) and reconnection of the load going to circuit board point 1 to circuit board point A. No recalibration is necessary.

9. Remote Indicators
An additional 2 ohms of instrument leads may be added to the standard transducer and 100 mV instrument without exceeding the normal error. Remote indicator leads of a thousand feet or more between transducer and meter can be accommodated by special calibration. The lead resistance becomes part of the instrument resistance as discussed in Paragraph 5 of this section.

10. Specifications and Technical Data
See page 33, Part II.

11. External Connections
See page 39, Part III.

12. Dimensions
See page 37, Part III.

Further Information

Type **VR2-841 Instructions:**
Instruction Leaflet 43-841.7.

Modifications:
Instruction Leaflet 43-800.3.

Transducer Prices:
Price List 43-860.

Speed Measurement Systems Prices:
Price List 43-500.

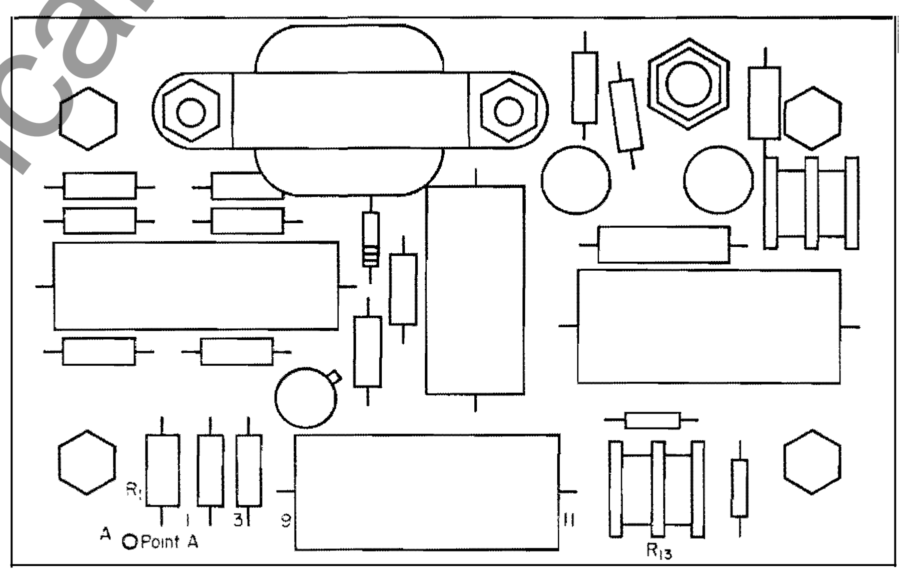

Figure 36: Speed transducer circuit board.

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Section K

Motor Load Transducer – Type VW2-841

1. Application
Many types of motor loads cannot be correctly measured from line current because of a change in power factor with load. While a watt transducer such as the VP2-840 can convert true power to a proportional output such transducers are somewhat costly, particularly in polyphase where a minimum of two current transformers and usually two potential transformers are needed. The type VW2-841 transducer produces a signal proportional to I cos θ which is, of course, proportional to true power. It is a less costly and more flexible device than the watt transducer.

2. Application and Operation
Refer to Application Data 43-510 for full information on the principles of operation and application of the VW2-841.

3. Ratings
A single design covers all current ranges – 120, 240 or 480 volts.

4. Output
1 mA into 200 ohms.

5. Scaling
The basic scale is 0-150%. It is related to the motor characteristics with a variable-ratio (doughnut) current transformer. A fine ±5% adjustment can be made by changing the value of an input resistor.

6. Indicating Instrument
Any 0-1 mA instrument padded up to 200 ohms.

7. Remote Indicator
The leads from transducer to meter can be 2 ohms without perceptible error. Higher resistances can be accommodated by transducer modification allowing leads of several thousand feet.

8. Specifications and Technical Data
See page 33, Part II, and Application Data 43-510.

9. External Connections
See page 39, Part III.

10. Dimensions
See page 37, Part III.

Further Information
Instructions:
Instruction Leaflet 43-841.8.

Modifications:
Instruction Leaflet 43-800.3.

Application:
Application Data 43-510.

Prices:
Price List 43-300.

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Section L

Filters – Type VF2-876

1. Application

The VF2-876 filters are for use with transducers with dc outputs having unwanted ac ripple. The output indicating instrument must be of high impedance in respect to the input impedance. The output instrument should have 50,000 ohms minimum for a 50-ohm input load. A typical application is a null balance potentiometer or A/D converter.

The style number 715B261A09 filter as shown in Figure 37 contains an inductor and capacitor filter network with provisions for connecting an external input load resistor. External connections are made per Figure 38.

The style number 715B261A10 filter as shown in Figure 39 contains an additional 50-ohm ±½%, ½ watt input load resistor. External connections are per Figure 37.

The style number 715B261A11 filter contains two potentiometers for fine and coarse (0-100%) adjustment of the voltage output, see Figure 41. The input resistance is 50 ohms ±½%. External connections are per Figure 40.

2. Specifications

Response Time:
Less than 200 milliseconds.

Reduction in Ripple:
Output ripple is ½% of input ripple at 120 Hz.

Insulation Test:
2600 volts, 60 Hz from terminals to case.

3. Dimensions

See page 37, Part III.

Further Information

Instructions:
Instruction Leaflet 43-876.1.

Modifications:
Instruction Leaflet 43-800.3.

Prices:
Price List 43-860.

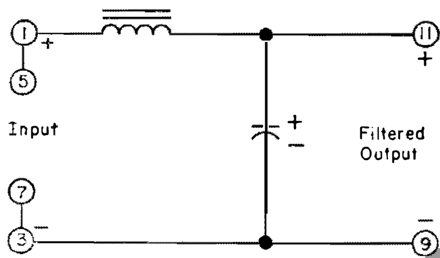

Figure 37: Style number 715B261A09 filter schematic.

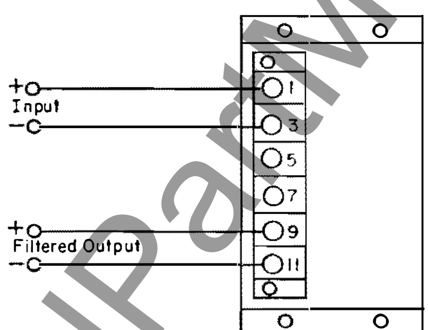

Figure 38: Style number 715B261A09 filter external connections.

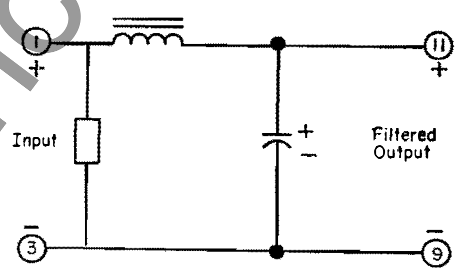

Figure 39: Style number 715B261A10 filter schematic.

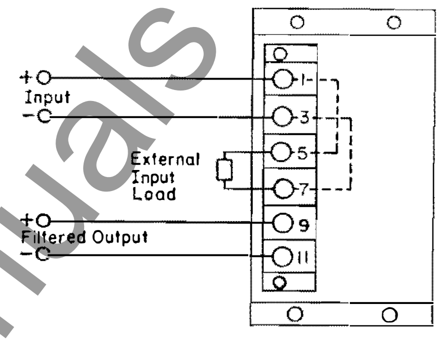

Figure 40: Style numbers 715B261A10 and 715B261A11 external connections.

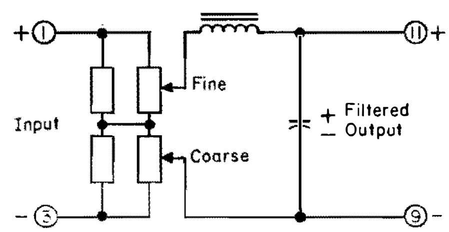

Figure 41: Style number 715B261A11 filter schematic.

Type V-2 Transducers

Part I
General Information,
Operating Principles and Applications

Westinghouse Electric Corporation
Relay-Instrument Division: Newark Plant, Newark, N.J. 07101
Printed in USA

Westinghouse

Type V-2 Transducers

Part II
Specifications and Technical Data

1. Standards

There are no ANSI standards on electrical transducers. However, as these transducers are used generally as accessories for electrical measuring instruments, the standard ANSI C39.1 "Requirement for Electrical Indicating Instruments" is used insofar as is practical. Case dimensions generally conform to IEEE Standards.

2. Type VP2-840 Watt Transducer and VV2-840 Var Transducer

(a) Specifications

Standard Input.................5 amp, 120 volt nominal, 60 Hz

Optional Input.................60 or 400 Hz (60 Hz model operable on 50 Hz with approximately .5% additional error at full scale and low power factor, continuous operation)
500 watts single-phase
1000 watts 3-phase 3-wire
1500 watts 3-phase 4-wire

Special Input..................Ratings per Table (b) below
480 volt single-phase only (multiply watts x 4)
240 volt (multiply watts x 2)

50 Hz
Maximum Current 125% of nominal
Maximum Voltage 150% of nominal

Output.........................50 mV (1 mA) adjustable approximately 10% (see Part I, Section B7, page 7)

Load Resistance................50 ohms ±3%

Linearity......................±1% included in accuracy rating

Accuracy.......................±1% at reference conditions with 50 ohm load

Loss (Burden) Per Element:
Current Circuit................2.0 vA at 0.20 power factor at rated current
Potential Circuit..............1.0 vA at 1.00 power factor at rated voltage

Response Time..................Full output 0.05 second

Warm-Up Time...................30 minutes

Ambient Temperature Influence....±0.5% maximum with ±10°C from 25°C

Extreme Temperature Influence....−1.5%, 25°C to 65°C
+2.5%, 25°C to −20°C

Frequency Influence............±0.5% maximum between 54 and 66 Hz or between 360 and 440 Hz

Power Factor Influence.........±1% maximum for a change from 1.00 pf to 0.50 lag or lead

Dielectric Test................1500 volts rms

Working Voltage to Ground......1100 volts peak

Permissible Overload
(Percent of Rating):
Current Circuit................Continuous 200%
5 seconds 500%
1 second 1000%
Voltage Circuit................Continuous 150%

Ripple.........................Single phase is sinusoidal with zero reference displaced. Polyphase ripple depends on balance of measured circuit (see Part I Section B, Paragraph 1C Page 4 and Section L, Page 27).

(b) Typical Ratings for Standard Type VP2-840 Watt and VV2-840 Var Transducers

Type	Nominal Current	Useable Current Range	Single-Phase Test Watts①	Self-Contained Rating
1-Element Single-Phase, 1-Current Coil	3.5	3.00 to 3.99	300 to 399	300 to 399
	5.0	4.00 to 6.25	400 to 625	400 to 625
	7.5	6.26 to 8.99	626 to 899	626 to 899
2-Element Polyphase, 2-Current Coil	2.0	1.64 to 2.49	164 to 249	328 to 499
	3.0	2.50 to 3.99	230 to 399	500 to 799
	5.0	4.00 to 6.25	400 to 625	800 to 1251
	7.5	6.26 to 10.0	626 to 1000	1252 to 2000
2½-Element, Polyphase 3-Current Coil	3.0	2.28 to 3.12	228 to 312	912 to 1251
	5.0	3.13 to 5.21	313 to 521	1252 to 2087
	6.0	5.22 to 6.90	522 to 690	2088 to 2763

① For VV2-840 var transducers, the single-phase test watts are:
1-Element – The same as for watt transducers.
2-and 2½-Element – Divide watt transducer test watts by 1.73.
See Part I Section C, Paragraph 2C for an explanation of var transducer test watts

March, 1973
Supersedes AD 43-860, pages 29 and 30, dated September, 1971
E, D, C/2043/DB

Type V-2 Transducers

Part II
Specifications and Technical Data

3. Type VI2-841 Current Transducer

(a) Specifications

Standard Input..................0-5 amps

Special Input..................Single and multi-ranges up to 20 amps

Frequencies..................60 Hz (useable on 50 Hz and 400 Hz)

Output......................1 mA, isolated

Load Resistance...............10,000 ohms ±1%

Linearity.....................±1%, included in accuracy rating

Accuracy.....................±1% at reference conditions with 50 ohm load

Loss.........................0.2 volt amperes

Warm Up Time.................Negligible

Response Time................0.15 seconds, maximum

Ambient Temperature Influence....1% maximum for ±10°C change from 25°C

Extreme Temperature Influence....2%, 25°C to 65°C
2%, 25°C to −20°C

Frequency Influence.............±1.0% for maximum for ±10% change in frequency

Dielectric Test................1500 volts rms

Working Voltage to Ground.......1100 volts peak

Permissible Overload
(Percent of Rating).............Continuous, 200%
5 seconds, 500%
1 second, 1000%

Ripple.......................48% (see Part 1, Section L, page 27)

Maximum Current..............6 amps

4. Type VE2-841 Voltage Transducer

Same as for VI2-841 (Paragraph 3) except:

Standard Input.....0-150 volts
Loss.............0.2 volt-amperes
Response Time.....2.0 seconds

5. Type VE2-841 Suppressed Zero Voltage Transducer

Same as for VI2-841 (Paragraph 3) except:

Standard Input.....110-130 volts
Loss.............0.5 volt-amperes
Accuracy....................0.33% of center value

Westinghouse

Type V-2 Transducers

Part II
Specifications and Technical Data

6. Type VC2-841 Frequency Transducer

(a) Specifications

Standard Input.....120 volts
Special Input......240 volts

Output:

Range	Output	Load Resistance	Maximum Resistance Obtainable By Adjustment
59-61 Hz	−30-0-+70 uA	866 ±10%	1000
58-62 Hz	−60-0-+140 uA	214 ±10%	500
55-65 Hz	−150-0-+350 uA	280 ±10%	400
50-70 Hz	−300-0-+700 uA	92 ±10%	200
45-55 Hz	−150-0-+350 uA	280 ±10%	400
45-65 Hz	−300-0-+700 uA	92 ±10%	200
390-410 Hz	−30-0-+70 uA	866 ±10%	1000
380-420 Hz	−60-0-+140 uA	214 ±10%	500
350-450 Hz	−150-0-+350 uA	280 ±10%	400
48-52 Hz	−60-0-+140 uA	214 ±10%	500
20-30 Hz	−150-0-+350 uA	280 ±10%	400

Linearity......................±2% of span (included in accuracy rating)

Accuracy.....................±2% of span

Loss (Burden).................4 volt-amperes

Voltage Influence...............±0.5% of span, 10% voltage change
±2% of span, 20% voltage change

Ambient Temperature Influence... ±1% of span. For ±10°C change from 25°C

Extreme Temperature Influence....2% of span, 25°C to 65°C
2% of span, 25°C to −20°C

Dielectric Test.................1500 volts rms

Working Voltage to Ground.......1100 volts peak

Permissible Overvoltage..........Continuous, 120%
5 seconds, 200%
1 second, 200%

Warm Up Time................3 minutes

Ripple.......................33⅓% rms at the highest frequency and maintains the same voltage output as dc output decreases

December, 1971
Supersedes AD 43-860, pages 31-32, dated September, 1971
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Type V-2 Transducers

Part II
Specifications and Technical Data

7. Type VF2-841 Power Factor Transducer

(a) Specifications

Input:

Type	Voltage	Input Resistor R1 (±5%, ±20 Pulses Per Minute)	Power Factor	Phase Angle
1-Phase 2-Wire	120	14,100 ohm	0.5 lag-0-0.5 lead	−60°-0-+60°
1-Phase 2-Wire	240	28,700 ohm	0.5 lag-0-0.5 lead	−60°-0-+60°
3-Phase 3-Wire	120	14,100 ohm	0.5 lag-0-0.5 lead	−60°-0-+60°
3-Phase 3-Wire	240	28,700 ohm	0.5 lag-0-0.5 lead	−60°-0-+60°
3-Phase 4-Wire	208	24,000 ohm	0.5 lag-0-0.5 lead	−60°-0-+60°
3-Phase 4-Wire	415	48,000 ohm	0.5 lag-0-0.5 lead	−60°-0-+60°

Input voltages can be changed with resistor modifications.

Output........................−0.5 mA -0-+0.5 mA

Frequency......................60 Hz

Load Resistance................110 ohm, can be modified for up to 5000 ohms

Linearity.......................±1% with respect to phase angle, included in accuracy rating

Accuracy......................Accuracy can be stated only for perfect sine wave, balanced current, rated voltage, and balanced power factor. It is given as a percent of phase angle. Power factor varies as the cosine of phase angle so the accuracy with respect to power factor is a variable.

Loss.........................Potential circuit, 1 VA
Current Circuit at 5a, 1.8 VA

Warm Up Time.................Negligible

Response Time.................0.1 Second

Dielectric Test.................1500 volts rms

Ambient Temperature Influence....±0.5% for ±10°C Change from 25°C

Extreme Temperature Influence....±1%, 25°C to 65°C
±1%, 25°C to −20°C

8. Type VT2-841 Temperature Transducer

(a) Specifications

Power Input...................120 volts

Temperature Detectors............10 ohm at 25°C, copper

Output........................1-0-1 mA into 30 ohms

Frequency.....................60 ±0.5 Hz

Frequency Influence.............±0.5 Hz ±1% of scale length

Linearity......................Non-linear, instrument specially calibrated

Accuracy......................At standard conditions, ±1% of scale length

Voltage Influence...............0.5% maximum for ±10% from 120 volts
2% maximum for ±20% from 120 volts

Response Time................0.1 second

Warm Up Time.................30 seconds

Ambient Temperature Influence....±0.5%, with ±10°C change from 25°C

Dielectric Test.................1500 volts rms

Working Voltage to Ground.......1100 volts peak

Ripple.........................48%

Westinghouse

Type V-2 Transducers

Part II
Specifications and Technical Data

9. Type VR2-841 Speed Transducer

(a) Specifications

Standard Input . . . . 1-40 volts ac peak-to-peak, 0.5-20 volts dc positive pulse

Special Input . . . . 40-440 volts ac peak-to-peak

Ratings . . . .

Full Scale Frequency Range	Minimum Input Pulse Duration
0-1500 to 0-14,000 Hz	50 microseconds
0-750 to 0-1500 Hz	70 microseconds
0-400 to 0-750 Hz	110 microseconds
0-180 to 0-400 Hz	135 microseconds
0-90 to 0-180 Hz	320 microseconds
0-50 to 0-90 Hz	600 microseconds

Linearity . . . . ±1%, included in accuracy rating

Accuracy . . . . ±1% at reference conditions

Loss (Power Supply) . . . . 4 volt-amperes

Response Time . . . . Full output, 0.1 second

Warm Up Time . . . . 30 seconds

Ambient Temperature Influence . . . . ±1%, with 10°C change from 25°C

Extreme Temperature Influence . . . . ±2%, 25°C to 65°C
±2%, 25°C to −20°C

Supply Voltage Influence . . . . ±0.5% maximum with ±10% voltage change
±2% maximum with ±20% voltage change

Overload Voltage . . . . Continuous, 150%
5 seconds, 200%

Dielectric Test . . . . 1500 volts rms

Working Voltage to Ground . . . . 1100 volts peak

10. Type VW2-841 Motor Load Indicator

(a) Specifications

Standard Input . . . . 5 amps, 120/240/480 volts

Output . . . . 1 mA into 200 ohms

Frequency . . . . 45-65 Hz

Linearity . . . . ±2%, included in accuracy

Accuracy . . . . ±2% with power factor above 0.3

Loss . . . . Voltage circuit: 120-volt connection, 2 VA
240-volt connection, 4 VA
480-volt connection, 8 VA
Current circuit: 5 amps, 1.0 vA

Response Time . . . . 0.1 second

Ambient Temperature Influence . . . . 10%, with ±10°C change from 25°C

Extreme Temperature Influence . . . . 2.0%, 25°C to 65°C
2.0%, 25°C to −20°C

Dielectric Test . . . . 1500 volts rms

Working Voltage to Ground . . . . 1100 volts peak

Permissible Overload . . . . Current 6.25 amps maximum
voltage 150% of rating

Type V-2 Transducers

Part II
Specifications and Technical Data

Westinghouse Electric Corporation
Relay Instrument Division, Newark Plant, Newark, N. J. 07101
Printed in USA

Westinghouse

Type V-2 Transducers

Part III
Outline Dimensions, Drilling Plans, Wiring Diagrams.

Index by Figure Number

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Type V-2 Transducers

Part III
Outline Dimensions, Drilling Plans, Wiring Diagrams.

Westinghouse Electric Corporation
Relay-Instrument Division: Newark Plant, Newark, N. J. 07101
Printed in USA

Westinghouse

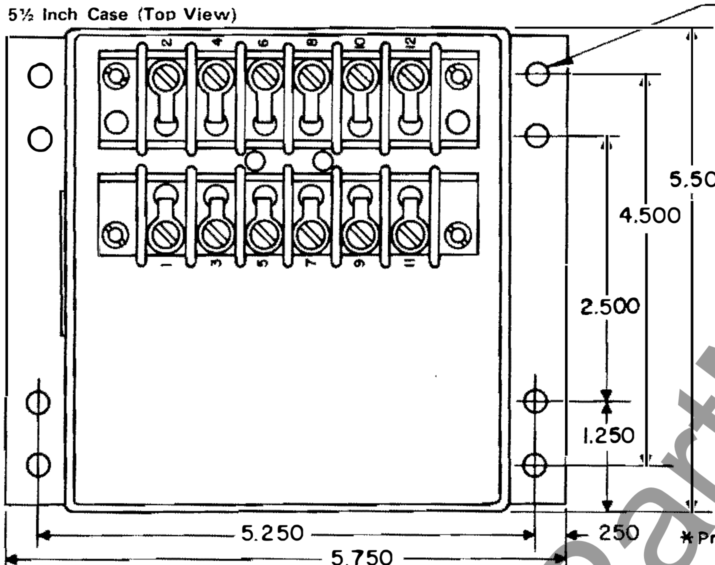
Type V-2 Transducers

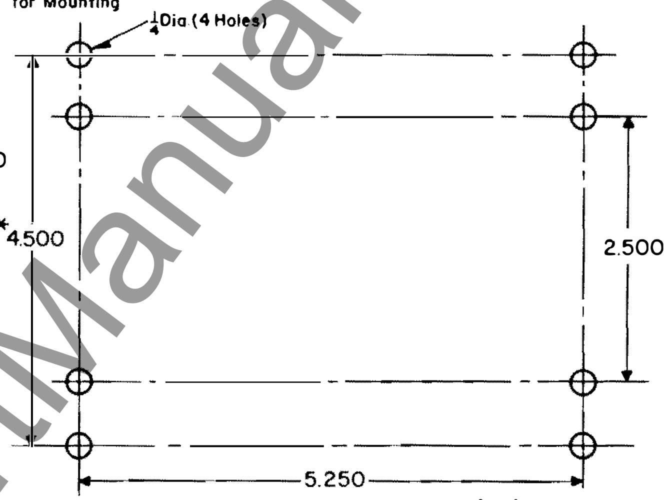
Part III
Outline Dimensions, Drilling Plans, Wiring Diagrams

Type V-2 Transducers

Outline Dimensions and Drilling Plans in Inches

5½ Inch Case (Top View)

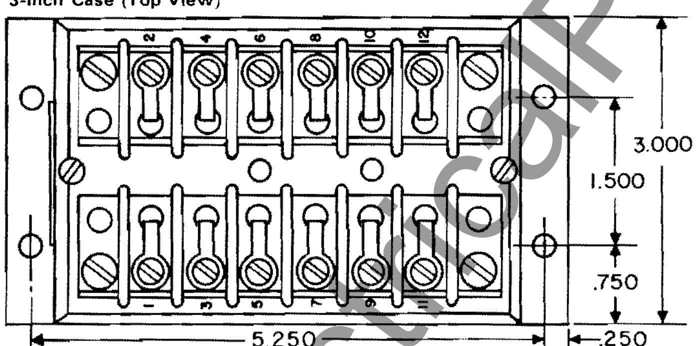


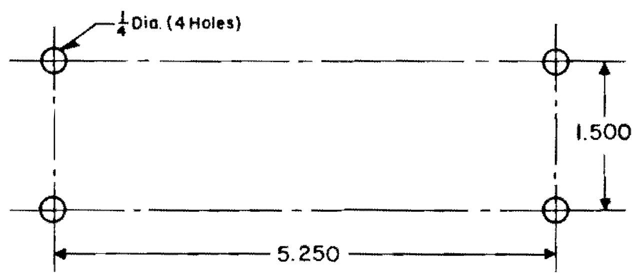


* Preferred Mounting Holes

Drilling Plan Fig. Ia 202C864

3-Inch Case (Top View)





Drilling Plan Fig. Ib 410C916

5½ Inch And 3-Inch Case (Front View)

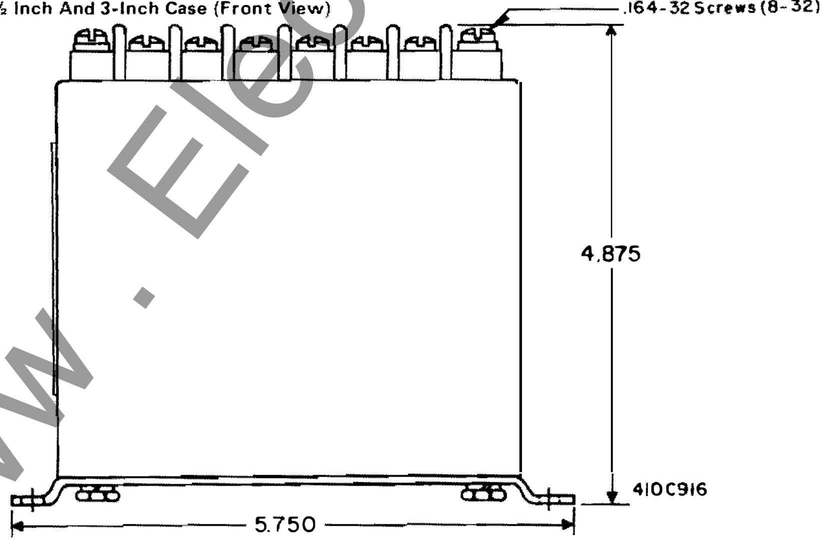


Fig. 2

August, 1971
Supersedes AD 43-860 Part III, pages 21-22, dated September, 1970
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Type V-2 Transducers

Part III
Outline Dimensions, Drilling Plans, Wiring Diagrams

Wiring Diagrams

Watt (Var) Transducer, VP2 – (VV2-) 840, 1-Phase, 2-Wire

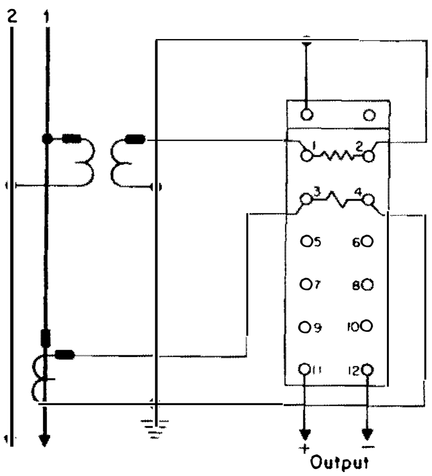

Fig. 3 836A940

Watt (Var) Transducer, VP2 – (VV2-) 840, 3-Phase, 3-Wire

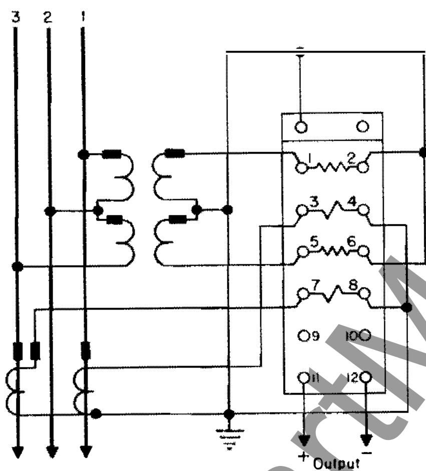

Fig. 4 836A941

Watt (Var) Transducer, VP2 – (VV2-) 840, 3-Phase, 4-Wire

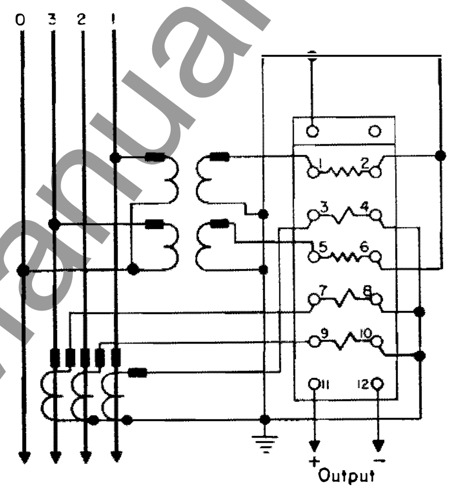

Fig. 5 836A942

Frequency Transducer, VC2-841

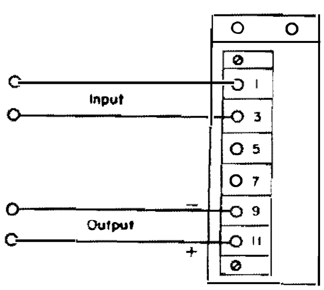

Fig. 6 861A564

Filter, VF2-876

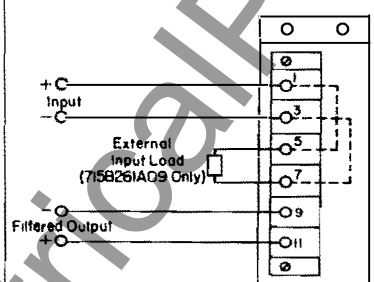

Fig. 7 876A547

Power Factor Transducer, VF2-841, 1-Phase, 2-Wire

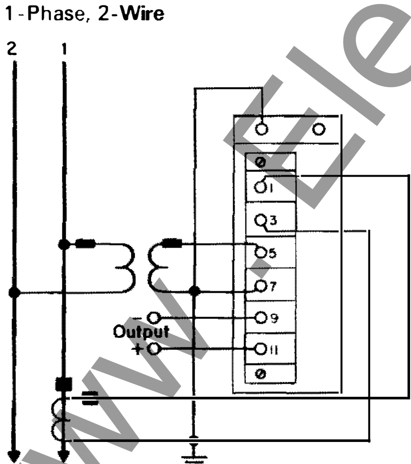

Fig. 8 877A787

Power Factor Transducer, VF2-841, 3-Phase, 3-Wire

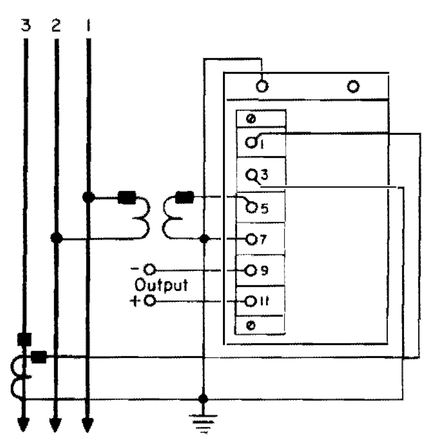

Fig. 9 877A788

Power Factor Transducer, VF2-841, 3-Phase, 4-Wire

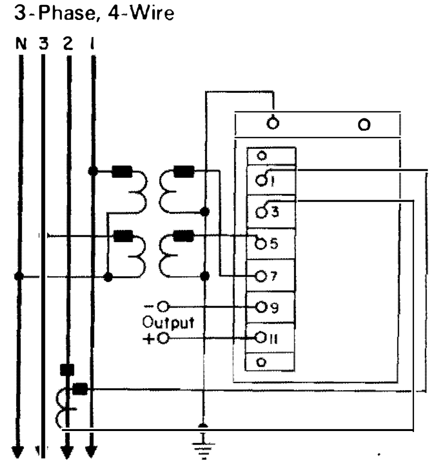

Fig. 10 877A788

Westinghouse

Type V-2 Transducers

Part III
Outline Dimensions, Drilling Plans, Wiring Diagrams

Volt (Amp) Transducer, VE2-(V12-) 841, RMS Values

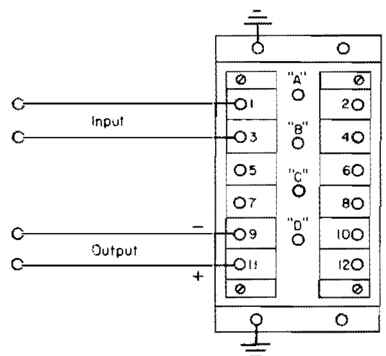

Fig. 12 861A669

Speed Transducer, VR2-841

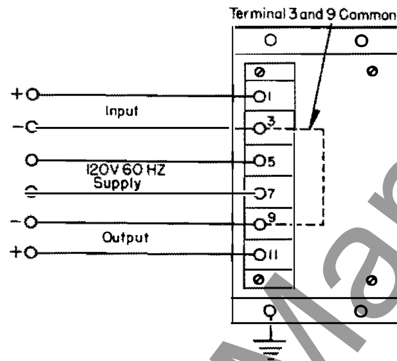

Fig. 13 863A126

Motor Load Transducer, VW2-841, 1-Phase, 2-Wire, 120 Volts

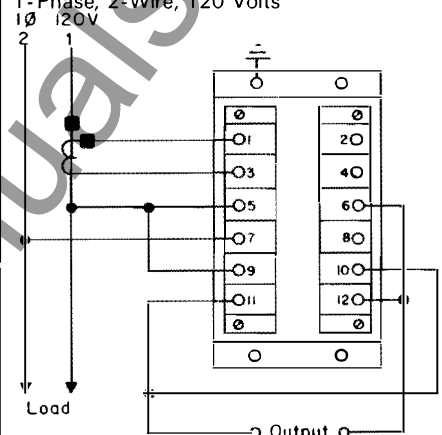

Fig. 14 876A464

Motor Load Transducer, VW2-841, 1-Phase, 2-Wire, 240 Volts

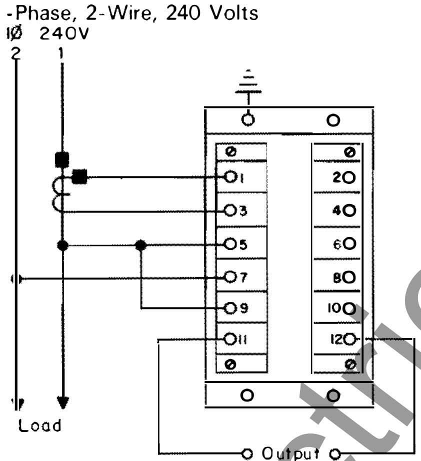

Fig. 15 876A458

Motor Load Transducer, VW2-841, 1-Phase, 2-Wire, 480 Volts

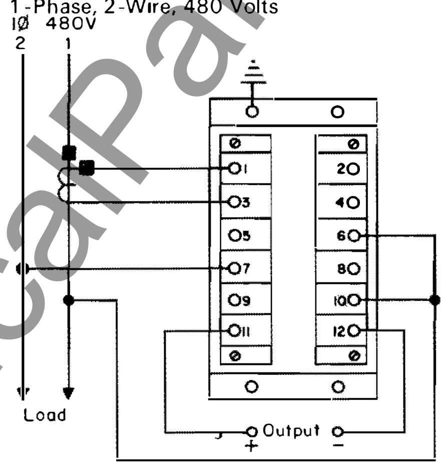

Fig. 16 876A459

Motor Load Transducer, VW2-841 3-Phase, 3-Wire, 120 Volts

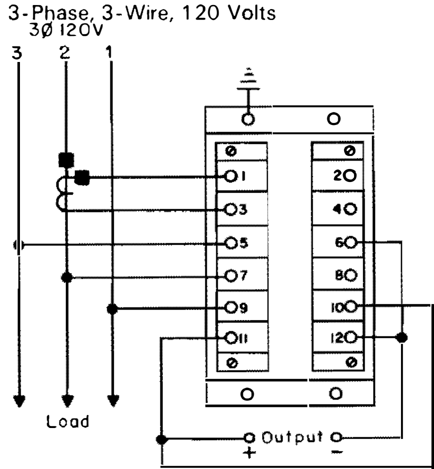

Fig. 17 876A465

Motor Load Transducer, VW2-841, 3-Phase, 3-Wire, 240 Volts

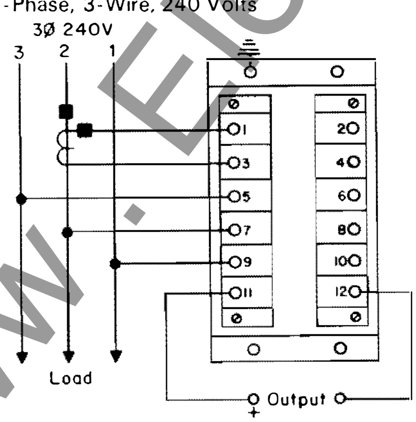

Fig. 18 876A460

Motor Load Transducer, VW2-841, 3-Phase. 3-Wire, 480 Volts

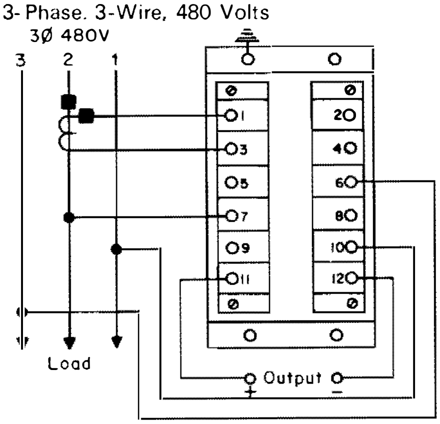

Fig. 19 876A461

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Type V-2 Transducers

Part III
Outline Dimensions, Drilling Plans,
Wiring Diagrams

Temperature Transducer, VT2-841, Connections

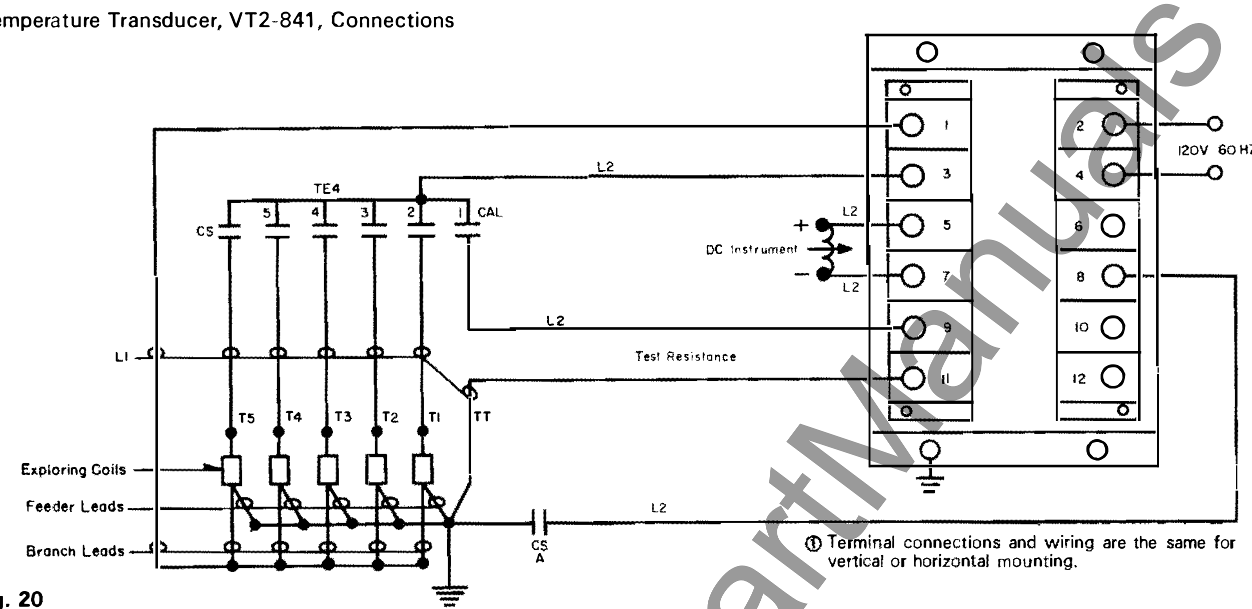

Fig. 20

1. L-2 leads and branch leads should not exceed 0.02 ohms each.
2. Switch contacts to exploring coils must make before break (Switch Westinghouse Style Number 663A488G01 for 5 exploring coils).
3. Individual L-1 leads should have a resistance of 0.3 ohms for standard instruments. Other resistance values are available on special order up to 3 ohms. In either case, the variation in resistance should not exceed ±0.1 ohms.
4. All L-1 leads must be within 0.02 ohm of the same resistance.
5. Each resistance tolerance or limit stated will limit errors from this source to less than one percent. Any increase will cause an approximately proportionate error.
6. Feeder leads must be within 1 ohm of the same resistance.
7. Control switch contacts Cal. 1,2,3,4,5 close in position as indicated. Contact A is open in off position, closed in all other positions.

Fig. 20 862A639

Temperature Transducer, VT2-841, Internal Schematic

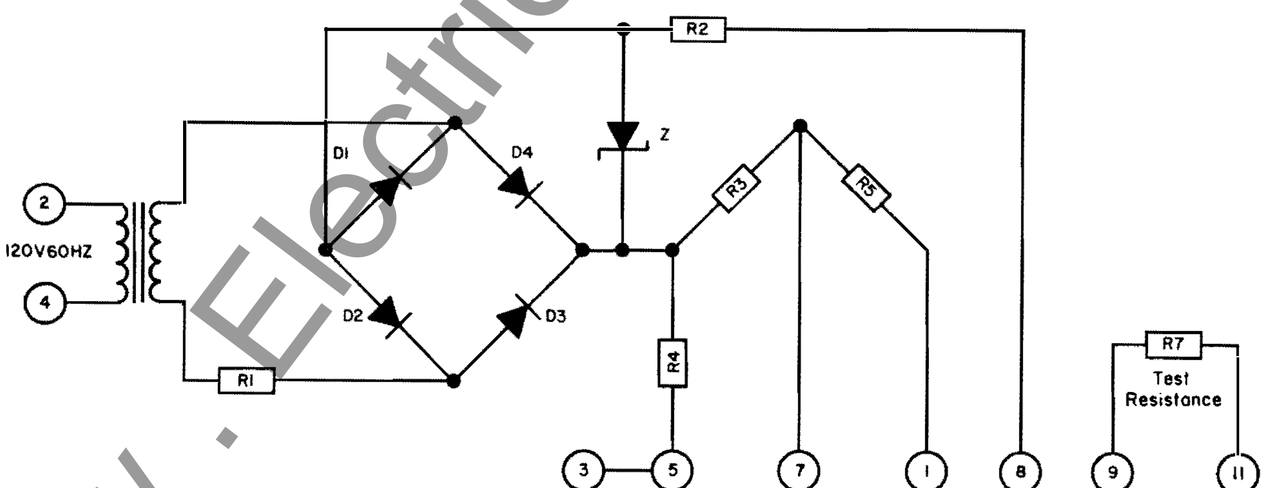

Fig. 20a 862A638

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