OPERATION & CALIBRATION MANUAL

W SERIES WATT & WATT-HOUR TRANSDUCERS

By David W. MILLER
Edited and revised by William D. Walden December, 1998

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Preface to the W Operation and Calibration Manual

By William D. Walden
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The W Watt and Watt-hour Transducers

The W series of transducers are based on the PC5 watt transducers with the addition of an integrator to calculate watt-hours. The W watt and watt-hour transducers are true four quadrant multipliers for calculating electric power in watts and energy in watt-hours. The analog output signal is bi-directional. If the direction of power flow reverses as it may in a facility that has co-generation, the sign of the output reverses. The output for watt-hours is a relay contact closure or a TTL pulse depending on the model. The relay contact closure or TTL output for watt-hours is not bi-directional. If a bi-directional watt-hour transducer is required, consider using the OSI GH series of watt and watt-hour transducers. W watt transducers are calibrated at Ohio Semitronics, Inc. using standards that are traceable to the National Institute of Standards and Technology (NIST).

Like the PC5 series watt transducers, the W series watt and watt-hour transducers are unique in that these Hall effect transducers do an excellent job calculating power and energy where severe distortion or chopped current and voltage wave shapes exist.

Watt-hour transducers are available from Ohio Semitronics, Inc. in 1, 2, 2 ½ and 3 element versions, with analog output signals of 0 to ±1 mADC, 0 to ±5 volts, 0 to ±10 volts DC, 4 to 20 mADC and with either relay contact closures or TTL pulses for watt-hours.

Mr. David W. Miller

David W. Miller is Vice President of Ohio Semitronics, Inc. Dave has been with the company since its founding in 1964 and he personally designed most of the transducers that Ohio Semitronics, Inc. is presently building. He is responsible for our manufacturing.

CONTENTS

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WATT & WATT-HOUR TRANSDUCER
W SERIES

1. OPERATING PRINCIPLES

The power in an AC circuit is the product of the voltage, current, and power factor expressed as $P = EI \cos \grave{e}$ where $\grave{e}$ is the angle by which the current lags (inductive) or leads (capacitive) the voltage. Power is a measure of the rate at which work is being done. Watt (or power) transducers provide a means of measuring this and provide a signal proportional to the rate at which work is being done. The unit of electric power is the watt. Some convenient power conversions: 1 horsepower=746 watts, 1 watt = 3.41 BTU/hour, 1 watt = 1 DC ampere X 1 DC volt.

The W Watt and Watt-hour Transducers are based on the PC5 watt transducers that utilize Hall Effect multipliers to provide an output signal proportional to the electric power consumed in a load and a watt-hour output directly proportional to the time integral of power – watt-hours a unit of energy.

2. TYPES

W watt and watt-hour transducers are available in four types.

A **Single Phase (One Element)**

This type has one current sensor and one voltage transformer. This measures total power in a two-wire circuit.

B **Polyphase (Two Element)**

This type has two current sensors and two voltage transformers. This transducer will measure total power in a 1∅ 3W or 3∅ 3W Delta circuits without voltage or load restrictions.

C **Polyphase (2½ Element)**

This type has three current sensors and two voltage transformers. This transducer will measure total power in a 3∅ 4W circuit with balanced voltage and unrestricted load.
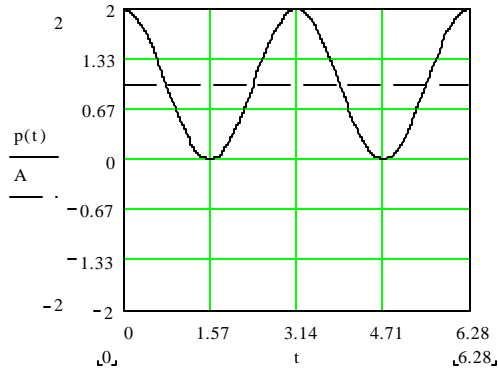
D **Polyphase (Three Elements)**

This type has three current sensors and three voltage transformers. This transducer will measure total power in a 3∅ 4W circuit without voltage or load restrictions.

3. RATING

3.1 STANDARD W OUTPUTS

The base unit Watt Transducer has an analog signal output of 50 millivolts for single phase, 100 millivolts for 3∅ 3W, 1∅ 3W or 3∅ 4W, 2 1/2 element, or 150 millivolts for 3∅ 4W. In each case output loading should be greater than 100K Ω. Figure 1 shows the output of the base PC5 Watt Transducer (on which the W is based). The sine wave shown is at

twice the source frequency. The "average dc" shown by the dashed line in the figures below is proportional to the true power and the sine wave shown as solid lines is proportional to the

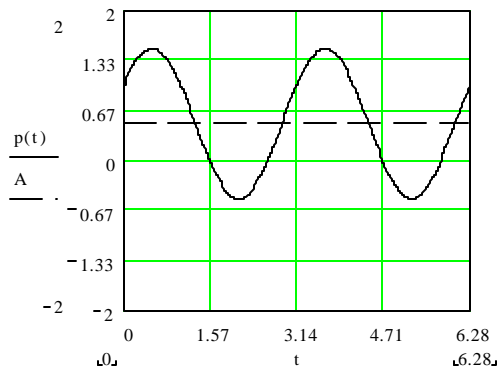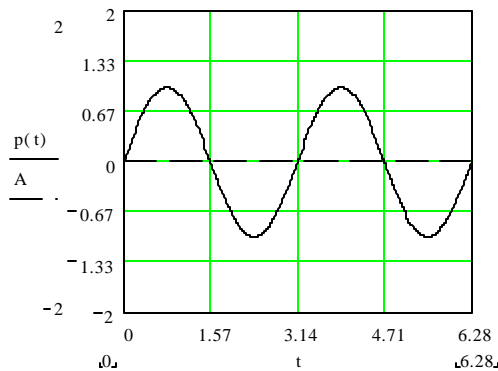**The Graphs at the left illustrate loads with the following characteristics:**

- Top Figure 1a – Load at unity power factor.
- Middle Figure 1b – Inductive load at 0.5 power factor.
- Bottom Figure 1c – Pure inductive load or zero power factor.

In all three cases the dashed line represents the real average power or the work being done by the load.

apparent power.

The AC ripple, which represents apparent power, is eliminated using the simple filter circuit shown below.

200 OHMS

Input   100 ufd   Output
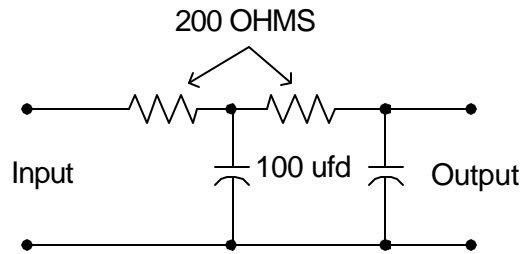
Figure 2

Figure 1a

Figure 1b

Figure 1c

In all cases the base outputs are filtered and amplified to provide 0 to 1mA, 0 to 5 volts, 0 to 10 volts or 4 to 20mA's by adding the option letter to the end of the model number when ordering the transducer. Base models (models with non-amplified outputs) are no longer available from Ohio Semitronics, Inc. except by special request.

OUTPUT OPTION Suffix Letter	OUTPUT
A	0 to ±1 mADC Self powered.
B	0 to ± 1 mADC Requires 120 volts AC instrument power.
C	0 to ± 10 Volts DC Self powered.
D	0 to ±10 Volts DC Requires 120 volts AC instrument power.
E	4 to 20 mADC Requires 120 volts AC instrument power.
E2	4 to 20 mADC Requires 24 volts DC in the external loop.
X5	0 to ±5 volts DC Requires 120 volts AC instrument power.
CX5	0 to ±5 volts DC Self powered.

Options A , C, & CX5 the self powered models should maintain the voltage within:
> *120 volt models: 85 to 135 volts AC*
> *240 volt models: 200 to 280 volts AC*
> *480 volt models: 380 to 550 volts AC*

The standard specification sheets show the Effective Range of the voltage and current. These inputs indicate the ranges over which the transducer will be within its specified accuracy. The rated output "RO" is the calibration point at which the 1mA, 5V, 10V or 20mA is obtained. All transducer outputs will over range by 20% as long as the voltage and current are in their effective range.

W Watt and watt-hour transducers are designed for nominal inputs of 120, 240/277 or 480 VAC. The effective range at the specified accuracy is 0 to 150, 0 to 300, or 0 to 600 VAC. These wide ranges do not apply to Options A, C, or CX5 which are limited as follows: 85 to 135 V for 0 to 150 V models, 200 to 280 V for 0 to 300 V models, and 380 to 550 V for 0 to 600 models.

3.3   CURRENT INPUTS

Standard models are rated from 1 through 1000 amperes. Models with input current up to 20 amperes connect direct to the terminal strips. Models above 20 amperes use a current transformer. Current connections are made through the window of the current transformer.

(A)   Current Transformers

Most current transformers step the current down to 5 amperes. When specified by model number these current transformers are calibrated as part of the transducer and should not be interchanged among different transducers. Extending the leads of 5 ampere secondary current transformers is permissible as long as 12-gauge wire is used and the VA rating of the transformer is not exceeded. See Page 22, Technical Bulletin 101 for wire sizes.

3.2   VOLTAGE INPUTS

Only qualified personnel should install the current transformer. Do not apply line current through the window of the current transformer with the secondary leads open. A SEVERE SHOCK TO THE INSTALLER OR DAMAGE TO THE CURRENT TRANSFORMER MAY RESULT.

If necessary to operate the current transformer without the watt transducer, bolt the two secondary leads together and mark with a CAUTION tag.

4.   POWER FACTOR

All W watt and watt-hour transducers are corrected for power factors from 0 lead to unity to 0 lag (0° to ±90°) and are within the specified accuracy listed.

5.   FREQUENCY RANGE

The W watt and watt-hour transducers are designed to operate from 50 to 70 Hz. However, good results can be obtained from 40 to 400 Hz. See specification sheet for W4 Models when 400 Hz is required.

6.   SIGNAL SOURCE

A   Options A & B, 0 to 1 mADC constant current output, may be used to drive a 1 milliampere analog meter directly.
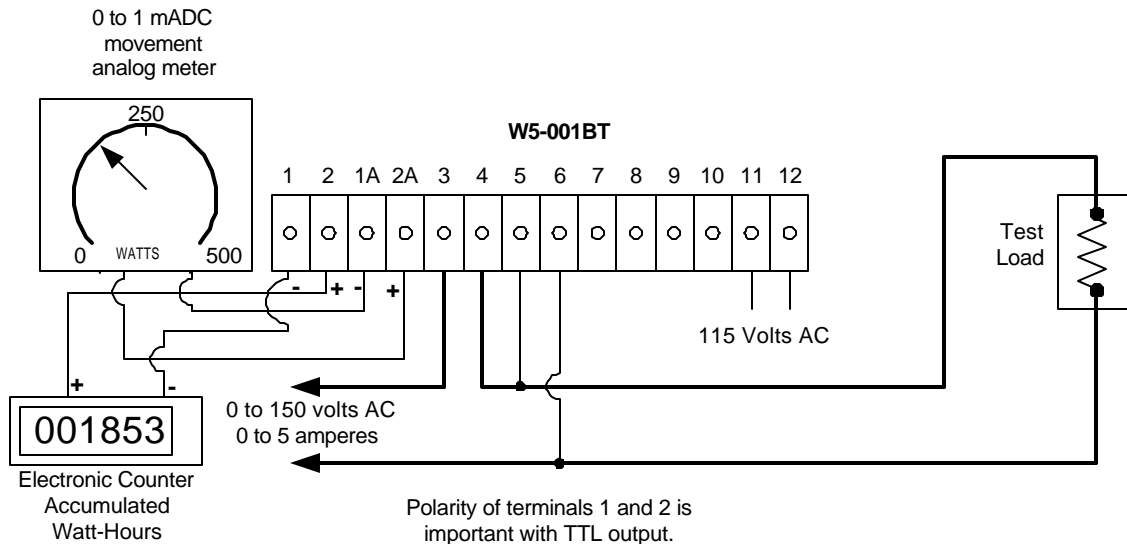

Figure 3

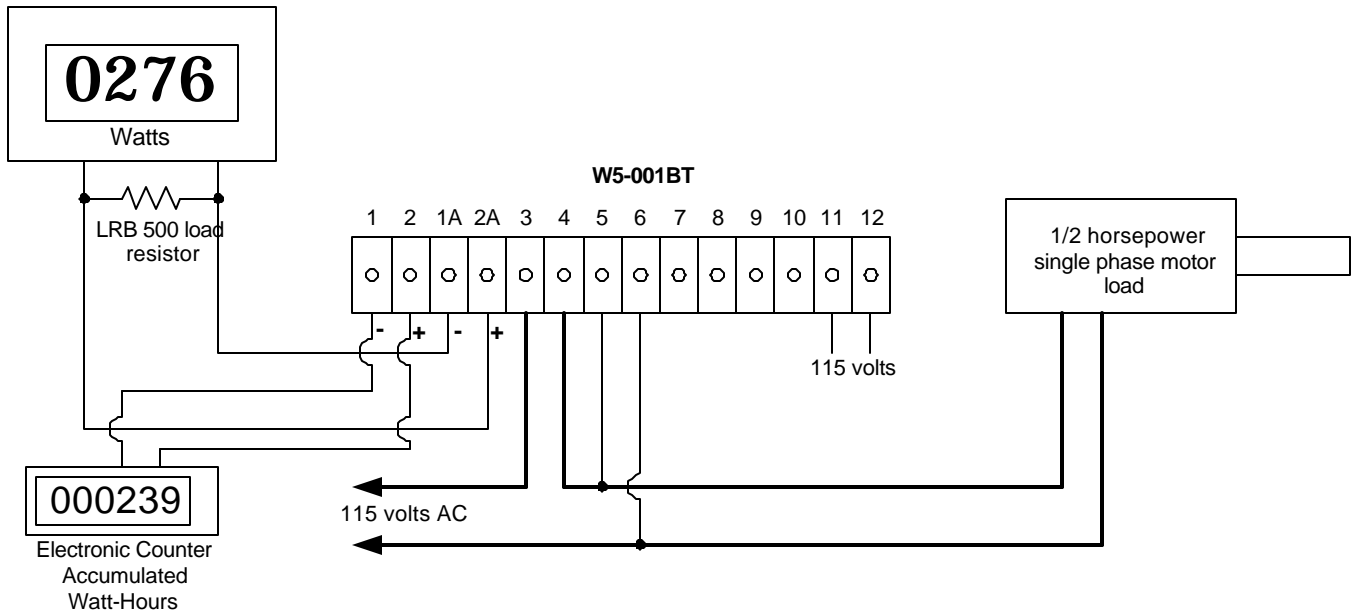Or, may be scaled for a digital meter using a load resistor.

Figure 4

The value of the load resistor may be calculated using Ohm's Law:

R = E/I Where E is the desired voltage and I is 0.001 (1 mADC).

B   Option C & D, 0 to 10 VDC constant voltage output, may be supply up to 5 mA into a 2000 Ω load.

C   Option E, 4 to 20 mADC output for industrial controls, has its own power source and may be used for loads from 0 to 1500 Ω.

D   Option E2, 4 to 20 mADC output requires 16 to 40 volts DC in the external loop.

E   Option T provides a TTL 5-volt DC pulse output rather than a relay contact closure for watt-hours. Pulse duration ranged from 10 milliseconds to 100

milliseconds depending on the pulse rate.

7.   READOUT INSTRUMENT

Analog instruments, which accept a 0 to 1mADC input, may be directly connected to the analog output terminals of the watt & watt-hour transducer with option A or B, to provide a direct reading in power. The Analog output may be used to supply signals for recorders, analog to digital converters, computers, digital panel meters, etc.

8.   SCALING

8.1

OSI has a complete line of watt transducers for various applications. These are designed for a particular voltage and current range, and are calibrated as a package. If a watt transducer is to be used with user supplied current and potential transformers, the following information will be helpful.

| MODEL | PHASE | ELEMENTS | REQUIRED | | CLOSURES/HOUR AT | CALIBRATED |
			PT's	CT's	CALIBRATED WATTS	WATTS AT 1mADC
W-001B	1∅ 2W	1	1	1	500	500
W-004B	1∅ 3W	2	* DIRECT	2	1000	1000
W-004B	3∅ 3W	2	2	2	1000	1000
W-7.5B	3∅ 4W	2½	2	3	1500	1500
W-007B	3∅ 4W	3	3	3	1500	1500

*Direct Connections for 120 V line to neutral. Refer to pages 23 through 25 for PT's & CT's connections.

Watt-hour/closure = [(calibrated watts) ÷ (closures/hour)] X CT$_{ratio}$ X PT$_{ratio}$.

The power measured in a circuit in which current and potential transformers are used is equal to the power rating of the watt transducer multiplied by both the current transformer and potential transformer ratios. If only current transformers are used, then multiply by the current transformer ratio.

Consider a W-004B rated at 5 amperes, 120 V, 3∅, 3W transducer calibrated for 1000 watts at 1 mADC. It is connected to a 480 VOLT, 200 ampere three phase power system. The potential transformer ratio is 480 to 120 or 4. The current transformer ratio is 200 to 5 amperes or 40. The full-scale power will equal 1000 X 4 X 40 or 160 kW. 0 to 1mA is proportional to 0 to 160 kilowatts.

Now that we have the full-scale kilowatts we can calculate the watt-hours per closure using the formula from the previous page.

Watt-hour/closure = [(calibrated watts) ÷ (closures/hour)] X CT$_{ratio}$ X PT$_{ratio}$ or [1000 ÷ 1000] X 40 X 4 = 160 watt-hour/closure.

8.2   AMPERE TURNS

Adding turns through the window of the current transformers can change the ratio. Consider a 100-ampere transformer that you would like to use in a 25-ampere circuit. Wind four turns through the transformer window. The net result on a W-058B which has a normal full scale of 10 kilowatts and is supplied with a 100:5 current transformer, will be a watt transducer set up to give a full scale of 1 mA output at 2.5KW. The maximum current rating for the transformer or transducer will be 25 amperes. Figure 5 on page 7 shows 4 amp turns. Count only the turns that pass through the window of the transformer.
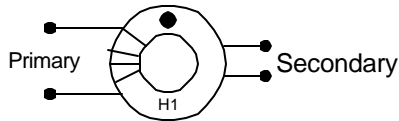
Figure 5

9.   CALIBRATION
Watt Section

All W watt and watt-hour transducers are factory calibrated and checked 100% for voltage and current linearity, power factor, and initial set point. Temperature is checked on random samples. Instrumentation used for calibration is traceable to N.I.S.T. (National Institute of Standards and Technology)

All W watt and watt-hour transducers are calibrated on single-phase with the current coils or current sensors in series and voltage transformers in parallel. Polarities are chosen to produce a positive analog output on terminal 2A of the transducer. Ideally, the transducer is energized from a precision instrument calibrator but adequate results are obtained by using commercial power and a single-phase 0.1% Wattmeter standard. The Wattmeter standard current circuit is connected in series with the current coils or sensor of the watt transducer under test. The voltage transformers are connected in parallel. Refer to Figures 11A & 11B on page 21.

Watt-Hour Section

Calibration of the watt-hour section requires the same inputs as shown in the watt section. Although the watt adjustment is based on instantaneous measurements for

the watt-hour adjustment, one must hold the voltage and current sources constant.

One calibrates the watt-hour section by adjusting the frequency of the voltage to frequency converter to a predetermined frequency. This frequency is determined by:

Frequency = (logic level X rated watts) ÷ (3600 X watt-hours per pulse)

The logic level is factory set. To determine the calibration frequency, refer to table 1 on page 26 for the correct frequency.

9.1   GENERAL

A   The Wattmeter standard must be capable of the desired range of input voltage and current required calibrating the particular W Watt Transducer.

Since all W watt and watt-hour transducers will be calibrated using a single phase source, the actual wattmeter standard reading will be 1/2 of the total specified output on a 2 element and 1/3 of the total specified output on a 3 element W watt and watt-hour transducers.

First Example: W-004B, 3∅ 3W has a specified output of 1mA proportional to 1KW.   Using   the   single-phase calibration method, the Wattmeter standard would be set at 500 watts full scale and the W would be calibrated for a 1mA output at the 500-watt point on the wattmeter.

Second Example: W-007B, 3∅ 4W has a specified output of 1mA proportional to 1.5KW. Using the single-phase calibration method, the Wattmeter standard would be set at 500 watts and the W-007B would be set to 1 mA at the 500-watt point on the Wattmeter standard. In each case, each element of W-007B is measuring the full-scale current & voltage.

B   A digital meter capable of 10-microvolt resolution for the base watt transducer with outputs of 50, 100, or 150 millivolts is required and digital meter capable of 1-millivolt resolution for all others.

C   A precision load resistor of 1K Ω, 0.05% should be used for the 1mA-output units, option A & B and a precision resistor of 500 Ω, 0.05% should be used for option   E.

D   If the full-scale line current required is not available; amp-turns through the current transformer or transducer window may be used. The windings must be distributed uniformly around the current transformer or transducer and not pulled tightly against the unit.

E   If current transformers are not calibrated with the W the following additional errors may be expected:

3%	50 and 100 ampere range.
1.5%	200 ampere range.
0.75%	400 & 600 ampere range.
0.3%	1000 ampere range and up.

F   Apply power to all voltage potential circuits for 20 minutes, (this includes 115 VAC instrument power if you have W with option B, D, or E) before calibration is attempted.

G   Calibration of the watt transducer should be made at or as close to unity power as possible.

H   Calibration of all standard W watt and watt-hour transducers is scaled for standard power levels such as 100, 500, 1000, 2000 Watts, etc. Refer to the W specifications for the "Watts at Rated Output".

9.2   ADJUSTMENTS

Overall calibration and zero adjustments are located through the lid underneath the plastic caps. If the lid has a black plastic cap over the zero opening, do not remove, this is not an adjustment. Balance adjustments for 2, 2½, and 3 element models are located inside the can. Refer to Figure 7 on page 18 for location.

W-20564 CIRCUIT BOARD

Zero

Cal

Zero

Fine
Course

20564
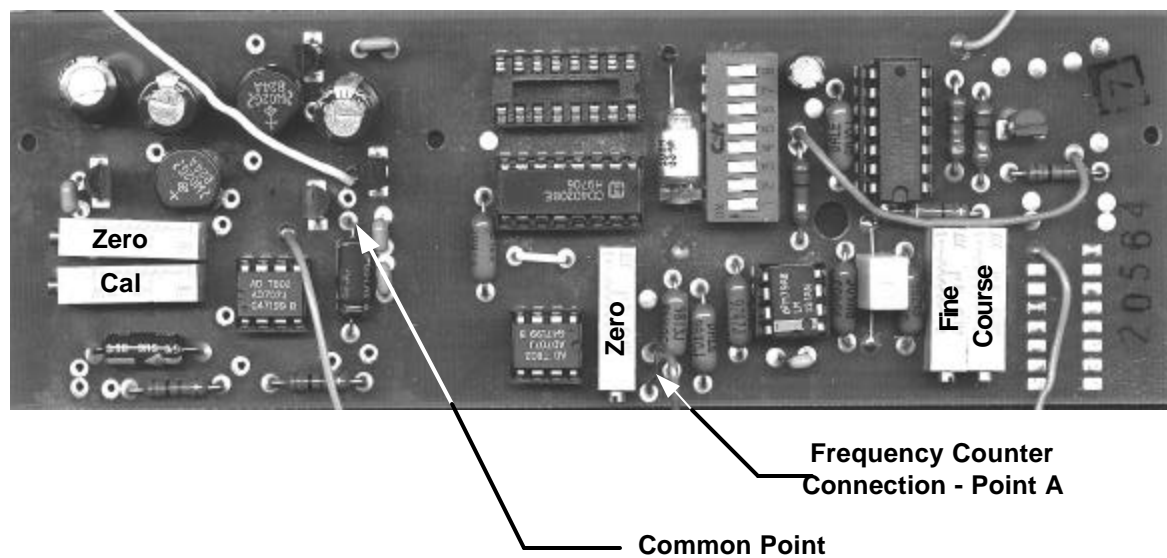
Frequency Counter
Connection - Point A

Common Point

Figure 6

A   Zero Offset:
Energize only the voltage coils and instrument power of the transducer. Adjust the output at terminal 1A & 2A within ±1 millivolts. This applies for W's with option A, B, C, and D. Option A and B must be loaded with a 1K Ω precision resistor. For E option, load the output with a 500 Ω precision resistor and adjust the "Zero" adjustment for 4mA or 2VDC ±2 millivolts.

Connect a frequency counter to the circuit board points as shown in figure 6 above. Adjust the trimpot labeled "Zero," which is located on the lid through the hole. To make the adjustment turn the trimpot until your frequency counter is counting 10 hertz. Now adjust it back until it reads zero hertz.

Note: If the frequency counter has open

or accumulated count mode, switch it to that mode and adjust the zero until the frequency counter stops.

B   Balance
This adjustment sets the internal calibration to provide a balanced output among elements. Balance of W watt and watt-hour transducers is not required on 1-element units, and is usually not necessary on 2, 2½, or 3 element units unless a part is replaced or the trimpot has been changed. Refer to page 10, Section 9.3 if balancing is not required. If adjustments are necessary, refer to Figure 7 on page 18 for internal circuit board locations of the balanced trimpots.

2 & 2½ Element

After the test connections are made as shown in Figure 9A, 9B or Figure 10A, reverse the polarity of the voltage on terminals 5 and 6 by switching the leads. (See pages 19 & 20 for figures 8, 9, & 10.)

Energize the voltage and current and adjust the power source for a full scale Standard Wattmeter reading. Now, adjust the internal balance trimpot for a zero output reading at terminals 1A & 2A.

3 Element 3Ø 4W

After the test connections are made as shown in Figure 9B or 9C, disconnect the lead from terminal 12 and connect it to terminal 11, shorting them together. Reverse leads going to terminals 9 & 10.

Energize the AC power source and adjust the Standard Wattmeter for a full-scale output. Adjust L2 balance trimpot for a zero output at terminals 1A & 2A.

Turn off the power source and change the connections. Remove terminals 9 and short to terminal 10. Reverse terminals 11 and 12.

Energize the AC power source and adjust the Standard Wattmeter for a full-scale output. Adjust L3 balance trimpot for a zero output at terminals 1A & 2A.

9.3   FINAL CALIBRATION

Before attempting the final calibration, read the section on calibration. Figures 8, 9, & 10 provide all the various standard test connection diagrams for the W watt and watt-hour transducers. As you can see, the voltage circuits are in parallel and the current circuits are in series.

All standard watt transducers are calibrated at even power levels, such as 100, 500, 1000, etc. Refer to "Rated Output" on the specification sheet for the calibration point.

The best method of calibration is to use a Precision Wattmeter Calibrator, if this instrument is not available, the set up shown in Figure 11A on page 21 will do if the Standard Wattmeter is used.

Two variacs are used in Figure 11A to give independent adjustment between the volt-age and current circuits. The voltage input, which is represented with the letter "E", requires a low current 1 ampere variac with a voltage range of 0 to 150, 0 to 300 or 0 to 600 VAC depending on the W input voltage under test. The variac for the current sensors must be capable of the current required by the W under test and the load should be resistive, such as cone heaters.

The following are examples of calibration of 4 types of W watt and watt-hour transducers. They are 1Ø 2W (1 element) and 3Ø 3W (2 elements), 3Ø 4W (2½ elements) and 3Ø 4W (3 elements).

A particular model number will be picked from each of the 4 types to show the standard procedure for calibration. Only the voltage, current and rated output change from model to model for that type of unit. Balance and zeroing adjustments must have been made previous to the final calibration. See 9.2A and 9.2B on page 9.

(A)   Example: 1∅ 2W, 1 Element

Model	W-010B
Voltage	120 VAC
Current	10 A AC
Rated Output	1 mA @ 1 kW
Load on Output Required	1 K Ω ± 0.05% Resistor
External Sensor Required	None
Test Connections Drawing	Figure 8A, Page 19
Standard Wattmeter Set-Up	120 V - 10 A FS 1000 W
Accuracy	± 0.5% FS

Refer to Figure 11A or 11B Calibration Test Set-Ups on page 21, make the required connections between the calibrator and the direct connections in Figure 8A on page19.

Energize the voltage and apply 120 VAC, now energize the current and apply the necessary current to obtain a 1000-watt reading on the Standard Wattmeter. Adjust the "CAL" trimpot (located in the W-010B lid) for a 1 V ± 0.001V reading at terminals 1A & 2A.

With the voltage maintained at 120 VAC, change the current such that the power reading goes from 0 to 1000 watts on the Standard Wattmeter. The output should not vary more than ±0.005V from the Standard Wattmeter reading. Likewise, hold the current at 10 amperes and change the voltage such that the power reading goes from 0 to 1000 watts on the Standard Wattmeter from 0 to 1000 watts.

Next, with the voltage at 120 VAC and the current adjusted for a 1000 W reading, change the power factor from unity to 0 for both lead and lag. Current, voltage, and linearity should be within ± 0.5% FS.

Connect a frequency counter to the test points shown in figure 2. Apply a 1000-watt load again and adjust the "CAL" trimpot located through the lid of the can for the calibrated frequency, which is shown in Table 1 on page 26. In this case it would be 4551 hertz ±5 hertz.

With the voltage maintained at 120 VAC, Change the current such that the power reading goes from 0 to 1000 watts on the Standard Wattmeter. The output should not vary more than ±0.005V from the Standard Wattmeter reading and the frequency should not change more than ±23 hertz over its linear range. (See graph on page 12.)

As a final test apply 1000 watts to the transducer. Connect an electronic or electromechanical counter to terminals 1 and 2. Record the count for an exact 6-minute interval. The counter will register 100 ±1 if the 1000 watt load was held constant.

Error limits for the Frequency
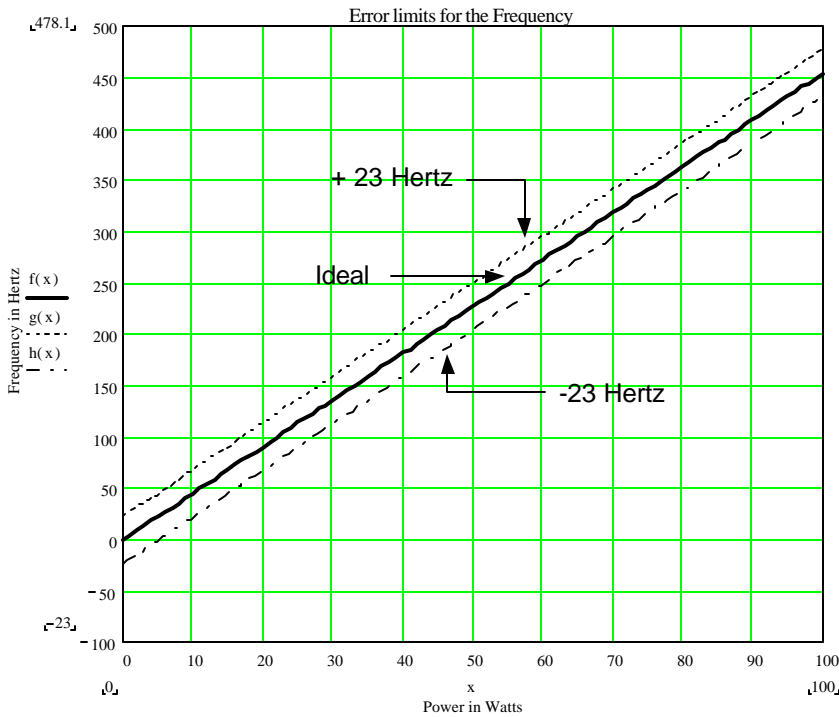
Graph showing allowable frequency deviation for rated accuracy from 0 to 100 watts. Entire range of 0 to 1000 watts is not shown because the plot lines would then be too close.

(B)   Example: 1∅ 3W, 3∅ 3W, 2 Elements)

Model	W-062D
Voltage	240 VAC
Current	100 A AC
Rated Output	10 V @ 40 kW
External Sensor Required	2 (Factory Supplied 100:5 current transformers)
Test Connections Drawing	Figure 9B, Page 19
Standard Wattmeter Set-Up	240 V, 100 A FS @ 20 kW or 240 V, 10 A FS @ 2 kW
Accuracy	± 0.50% FS

Refer to Figure 11A or 11B on page 21 Calibration Test Set-Ups, make the necessary connections between the calibration and Figure 9B on page 19.

Please note if the AC current source will not supply the 100 amperes, ampere-turns may be used. For instance 10 turns through the window of each current sensor will produce a 100-ampere current signal when 10 amperes are applied.

Energize the voltage at 240 volts and apply the necessary current to obtain either 20 kW or the 2kW reading if 10-ampere turns are used in the Standard Wattmeter.

Adjust the "CAL" trimpot, (please see figure 2) for a 10 V ± 0.50% FS ($\pm$0.005 volts) on terminal 1A & 2A.

Connect a frequency counter to the test

points shown in figure 6 on page 9 (Point A and Common). With 20 kW applied the frequency counter should read 4551 ±5 hertz. Adjust the "CAL" trimpot available through the lid of the can if necessary.

Voltage & Current Range Tests

Hold the current at 100 amperes and change the voltage such that the power reading goes from 0 to 20 kW. Next, with the voltage at 240 VAC, adjust the current such that the power reading goes from 0 to 20 kW. The output should not vary more than ±0.05 volts from the wattmeter standard (see the graph in the right column) and the frequency should not vary by more than ±23 hertz.

Power Factor Check

With the voltage set at 240 volts adjust the current such that 20 kW is applied to the transducer. Now change the power factor from unity to zero for both lead and lag. As the power factor is changed, the linearity must remain within ±0.5% of rated output or within ±0.05 volts.
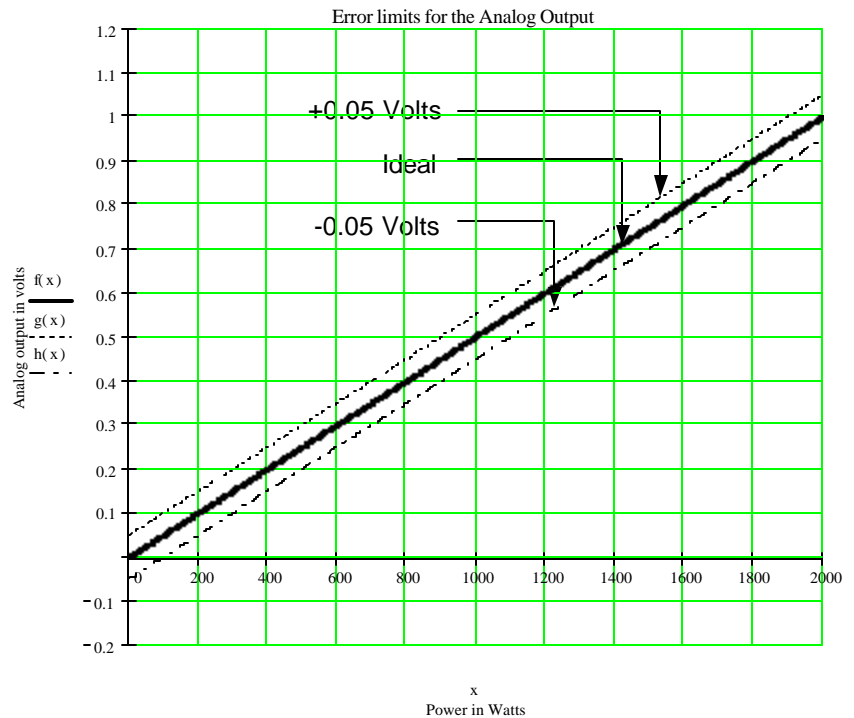
Graph showing allowable analog deviation for rated accuracy from 0 to 2000 watts. Entire range of 0 to 20,000 watts is not shown because the plot lines would then be too close.

Final Check

Connect a counter to terminals 1 and 2 of the transducer. Apply 20 kilowatts (or 2 kW if you are using 10 turns through the current transformers) to the transducer. While holding the applied power constant, record the count registered on the counter for exactly 6 minutes. You should have recorded 200 ±2 counts on the register.

This completes the calibration check of the W-063B watt and watt-hour transducer.

(C)   Example: 3∅ 4W, 2½ Element)

Model	W-7 .5D
Voltage	120 VAC
Current	5 A AC
Rated Output	10 V @ 1500 kW
External Sensor Required	None
Test Connections Drawing	Figure 10A, Page 20
Standard Wattmeter Set-Up	120 V, 5 A FS 500 W
Accuracy	± 0.5% FS

Refer to Figure 11A or 11 B on page 21 Calibration Test Set-Ups, make the necessary connections between the calibration and Figure 10A on page 20.

Energize the voltage at 120 volts and apply the necessary current to obtain 375 watts on the Standard Wattmeter.

Adjust the "CAL" trimpot, (please see figure 6 on page 9) for a 10 V ± 0.50% FS ($\pm$0.005 volts) on terminals 1A & 2A.

Connect a frequency counter to the test points shown in figure 6 (Point A and Common). With 375 watts applied the frequency counter should read 6827 $\pm$7 hertz. Adjust the "CAL" trimpot available through the lid of the can if necessary.

Voltage & Current Range Tests
Hold the current at 5 amperes and change the voltage such that the power reading goes from 0 to 375 watts. Next, with the voltage at 120 VAC, adjust the current such that the power reading goes from 0 to 375 watts. The output should not vary more than $\pm$0.05 volts from the wattmeter standard and the frequency should not vary by more than $\pm$68 hertz.

Power Factor Check
With the voltage set at 120 volts adjust the current such that 375 watts are applied to the transducer. Now change the power factor from unity to zero for both lead and lag. As the power factor is changed, the linearity must remain within $\pm$0.5% of rated output or within $\pm$0.05 volts.

Final Check
Connect a counter to terminals 1 and 2 of the transducer. Apply 375 watts to the transducer. While holding the applied power constant, record the count registered on the counter for exactly 6 minutes. You should have recorded 112 $\pm$2 counts on the register.

This completes the calibration check of the W-7.5D watt and watt-hour transducer.

(D)   Example: (3∅ 4W, 3 Element)

Model	W-007A
Voltage	120 VAC
Current	5 A AC
Rated Output	1 mA @ 1500 Watts
Load On Output Required	10 K Ω ± 0.05%
External Sensor Required	None
Test Connections Drawing	Figure 10B, Page 20
Standard Wattmeter Set-Up	120 V, 5 A FS @ 500 W
Accuracy	± 0.5% FS

Refer to Figure 11A or 11B on page 21 Calibration Test Set-Ups, make the necessary connections between the calibration and Figure 10B on page 20.

Energize the voltage at 120 volts and apply the necessary current to obtain 500 watts on the Standard Wattmeter.

Adjust the "CAL" trimpot, (please see figure 6 on page 9) for a 10 V ± 0.50% FS ($\pm$0.005 volts) on terminals 1A & 2A.

Connect a frequency counter to the test points shown in figure 6 (Point A and Common). With 500 watts applied the frequency counter should read 6827 $\pm$7 hertz. Adjust the "CAL" trimpot available through the lid of the can if necessary.

Voltage & Current Range Tests
Hold the current at 5 amperes and change the voltage such that the power reading goes from 0 to 500 watts. Next, with the voltage at 120 VAC, adjust the current such that the power reading goes from 0 to 500 watts. The output should not vary more than $\pm$0.05 volts from the wattmeter standard and the frequency should not vary by more than $\pm$68 hertz.

Power Factor Check

With the voltage set at 120 volts adjust the current such that 500 watts are applied to the transducer. Now change the power factor from unity to zero for both lead and lag. As the power factor is changed, the linearity must remain within $\pm$0.5% of rated output or within $\pm$0.05 volts.

Final Check
Connect a counter to terminals 1 and 2 of the transducer. Apply 500 watts to the transducer. While holding the applied power constant, record the count registered on the counter for exactly 6 minutes. You should have recorded 150 $\pm$2 counts on the register.

This completes the calibration check of the W-007A watt and watt-hour transducer.

10.   INSTALLATION

The W may be installed in any position and in an environment of not more than +60° C or less than -10° C.

For best accuracy the current carrying cable should be centered in the window of the current transformer.

Caution must be observed when installing the current transformers. See section 3.3A.

11.   TROUBLESHOOTING

The majority of the problems can usually be traced to improper connections. The following list gives some common problems and solutions.

PROBLEM: No Output
SOLUTION:
    1   115 VAC Instrument power not connected. This applies only to Options B, X5, D, or E.
    2   Voltage not connected.
    3   Defective readout.
    4   On 3∅ 3W or 1∅3W units, could have reverse polarity either on voltage or current circuit.

PROBLEM: ½ Output
SOLUTION: All 50-ampere Watt Transducers require two turns through the window of the current transformers.

PROBLEM: 1/3 Output
SOLUTION: 3∅ 4W units, polarity of one

phase reversed.

PROBLEM: Doesn't Seem Calibrated
SOLUTION:
    1   Calibration point is at the "Rated Output" not Effective Watts or Full-Scale range.
    2   "CAL" adjustment has been changed.

    3   Customer relies on voltage and current for power measurement. This method is only accurate in a resistive load.
    4   Most industrial loads are either inductive or capacitive. This causes a phase shift in the current relative to the voltage. For instance with a phase shift of 30°, the true power would be 86.6% of E X I. This is derived by P = E X I X COS(30°) The cosine of 30° is 0.866, so one can see that 86.6% of E X I is the maximum power obtainable.

Note that an unloaded induction motor will run at very low power factor. What this means is that very little power (compared to the rated motor power) is required to keep the motor running at constant speed. In other words, **the motor is not doing any work.** Power in watts is the measure of the rate at which work is being done.

Electric motors often have a power factor rating. This rating is for the fully loaded motor only and will not apply to an unloaded or partially loaded motor.

Figure 7 showing the position of the balance control on the boards of the W series watt transducers.
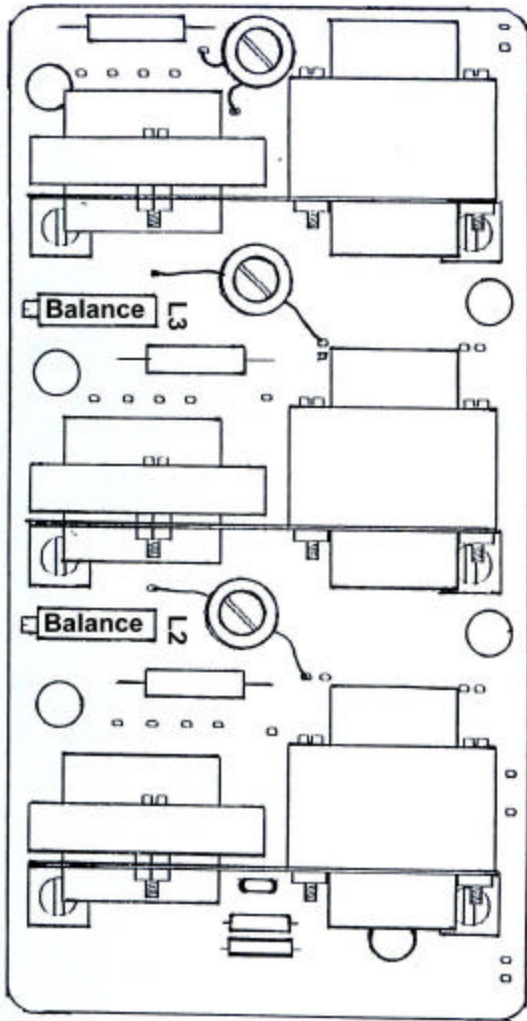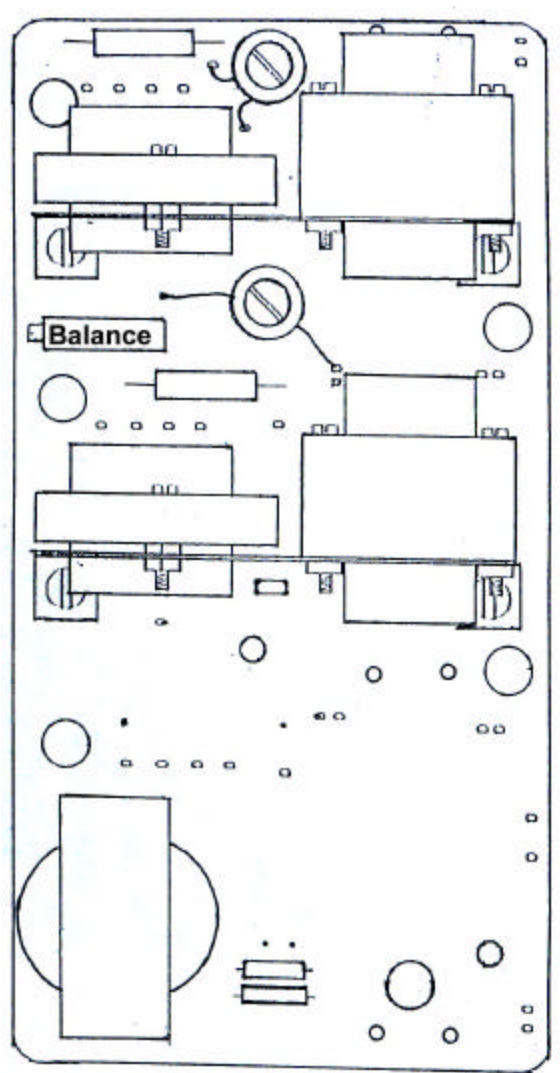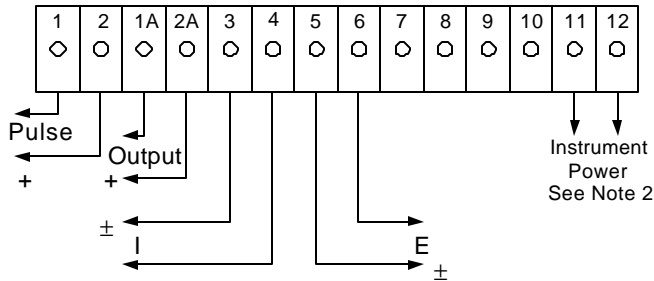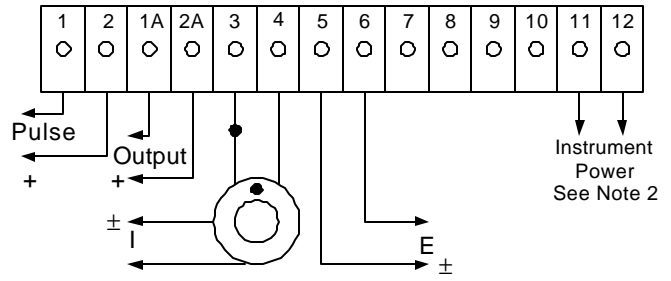

Figure 7A All 3 element models.

Figure 7B All 2 and 2 1/2 element models.

(a) Using direct connections

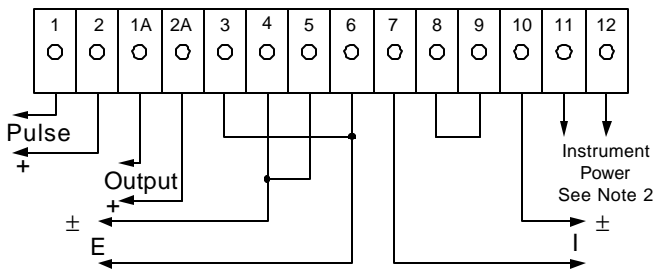Analog output on terminals 1A and 2A

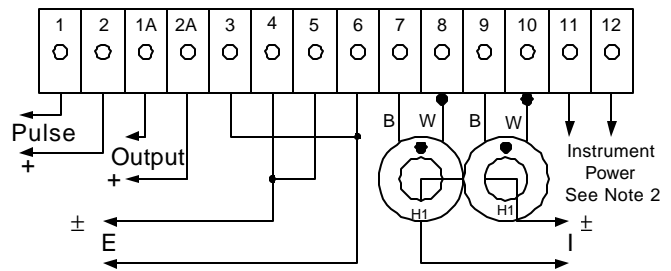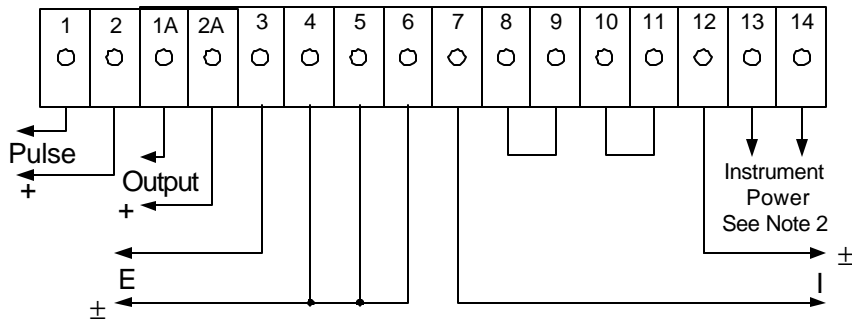Pulse or relay contact closure on terminals 1 and 2

(b) Using a current transformer

Analog output on terminals 1A and 2A

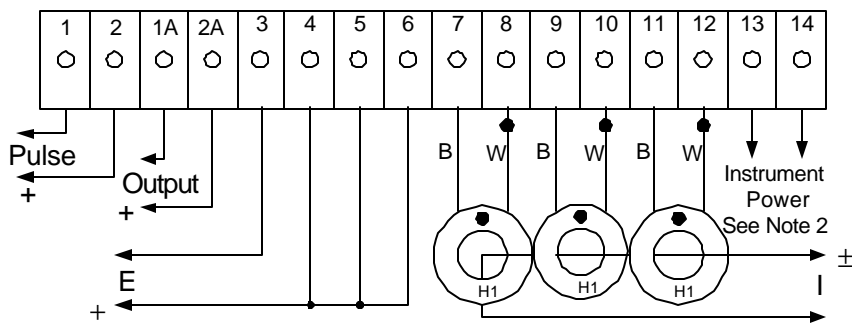Pulse or relay contact closure on terminals 1 and 2

Figure 8
Test Connection for 1 phase, 2 wire, 1 Element Watt Transducer.

(a) Direct connections

Analog output on terminals 1A and 2A

Pulse or relay contact closure on terminals 1 and 2

(b) Using current transformers

Analog output on terminals 1A and 2A

Pulse or relay contact closure on terminals 1 and 2

Figure 9
Test connections for 1 phase, 3 wire & 3 phase, 3 wire, 2 Element Watt Transducers
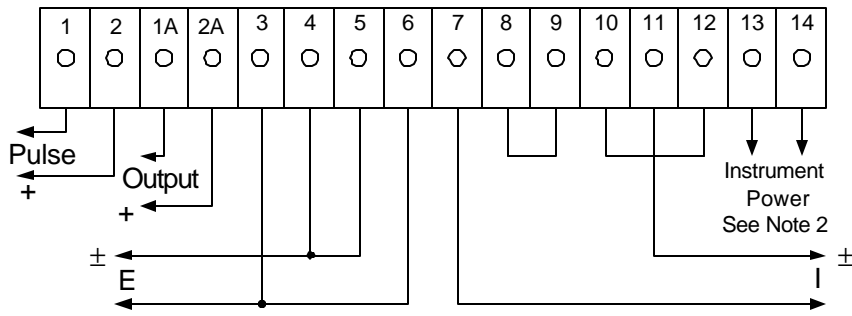
(a) Direct connections for 2 ½ element W
Analog output on terminals 1A and 2A
Pulse or relay contact closure on terminals 1 and 2

(b) Direct connections for 3 element W
Analog output on terminals 1A and 2A
Pulse or relay contact closure on terminals 1 and 2

(c) Using current transformers with a 3 element W
Analog output on terminals 1A and 2A
Pulse or relay contact closure on terminals 1 and 2

Figure 10
a) 3 Phase, 4 Wire 2 ½ element Watt Transducer Connections.
b) 3 Phase, 4 wire 3 Element Watt Transducer Connections.
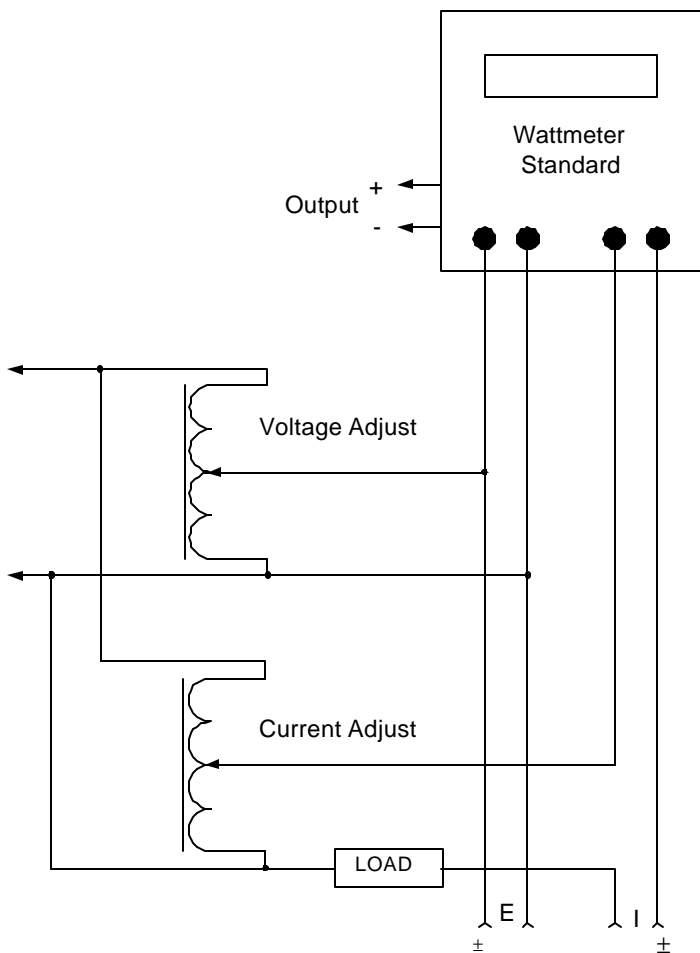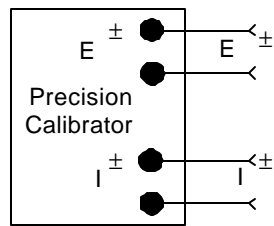c) 3 Phase, 4 wire 3 Element Watt Transducer Connections.

Figure 10a

Figure 10b

Using a precision Calibrator such as the Rotek 800A or 811A is the prefered method of calibration.

Rotek Instruments Corp.
390 Main St.
Waltham, MA 02254
781-899-4611

Notes:

1) 50-ampere models require two (2) primary turns through the current transformer window.

2) PC5 models with the suffix B, D, E, or X5 require 120 volts AC instrument power.

3) The following indicates a connection between the PC5 watt transducer and the calibrator.

Transducer ⟶>— Calibrator
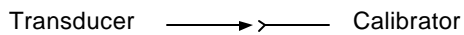
USING CURRENT AND POTENTIAL TRANSFORMERS WITH WATT TRANSDUCERS

TECHNICAL BULLETIN NO. 101

CONNECTIONS

One of the most commonly overlooked connections is that between the watt transducer and the current transformers. Power measuring transducers and meters are polarity sensitive.

Current transformers are marked with both primary and secondary polarity marks. The "H1" on the body of the current transformer is for the primary current through the opening. The "H1" must face the line or the source of the current. The secondary leads or terminals are labeled with an "X1" and an "X2." The "X1" corresponds to the polarity "H1" of the primary.

Current transformers supplied as part of OSI watt transducers have white and black secondary leads. The white lead is the X1 lead and the Black is the X2 lead.

In OSI connection diagrams the dots in the diagrams refer to the H1 for the primary and the X1 for the secondary.
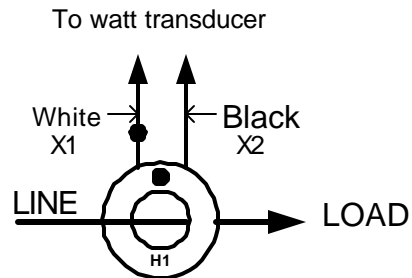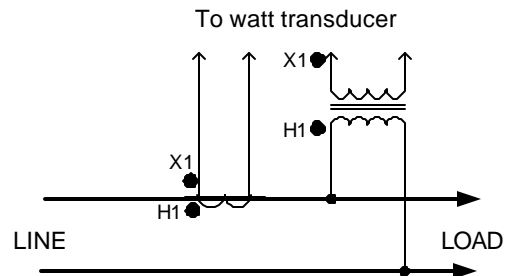
Figure 1 Current Transformer with Polarity Marks.

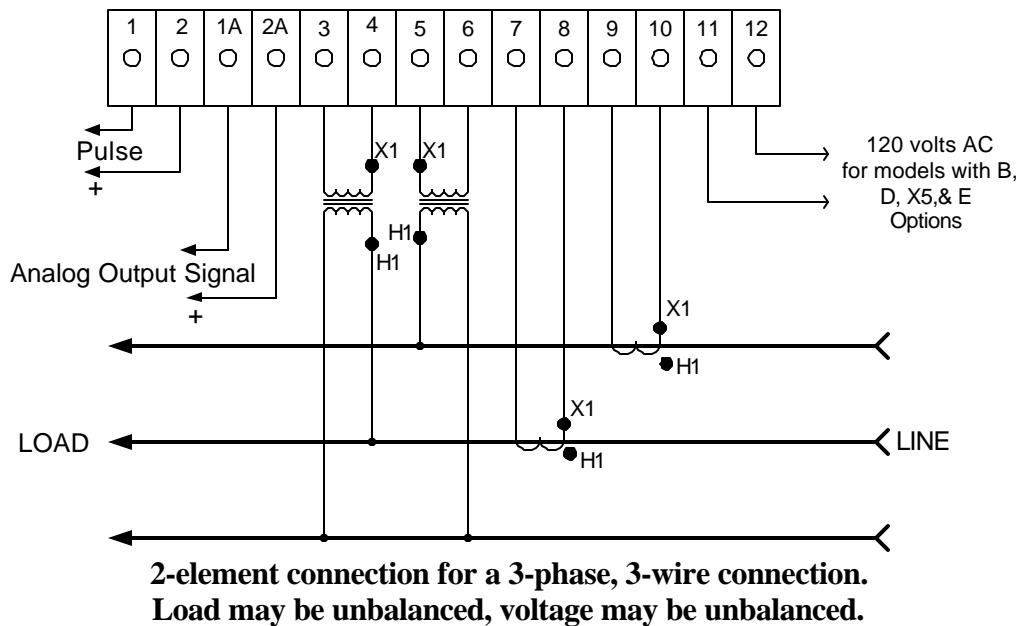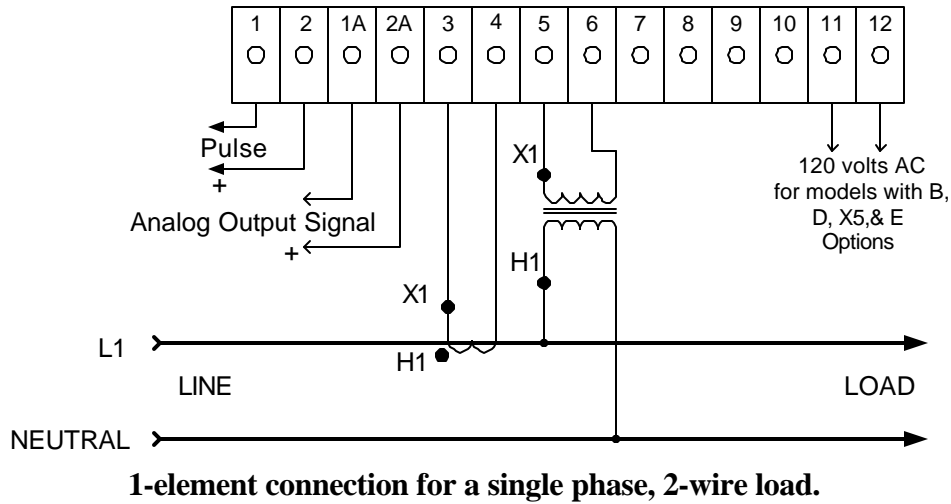Figure 2 Current Transformer and Potential Transformer with Polarity Marks.

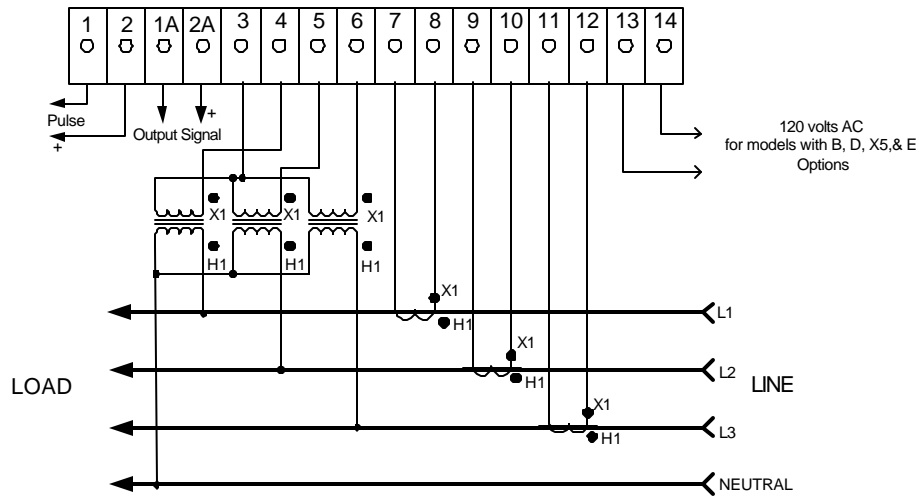## EXTENDING SECONDARY LEADS OF CURRENT TRANSFORMERS

It is very important to keep the electrical resistance in the secondary circuit of current transformers to a minimum. The following chart gives the maximum secondary lead length for typical current transformers.

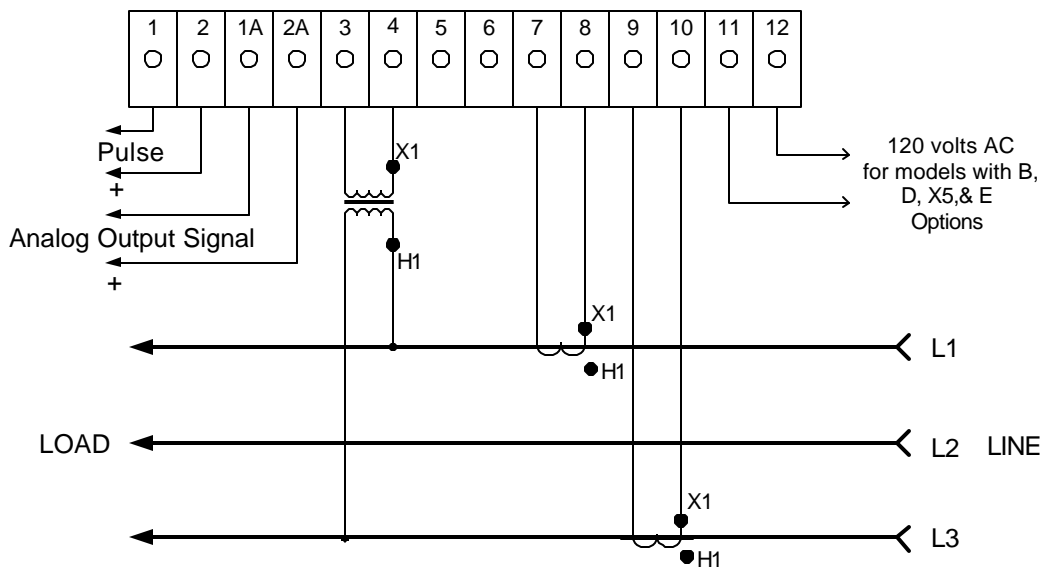| CT CURRENT RATIO	10 GAUGE WIRE	12 GAUGE WIRE	14 GAUGE WIRE
100:5	20 feet	15 feet	10 feet
200:5 through 400:5	40 feet	30 feet	20 feet
600:5 and higher	80 feet	60 feet	40 feet

TB101.12.98

W CONNECTION DIAGRAMS FOR USE WITH BOTH CURRENT AND POTENTIAL TRANSFORMERS

1-element connection for a single phase, 2-wire load.

**2-element connection for a 3-phase, 3-wire connection.
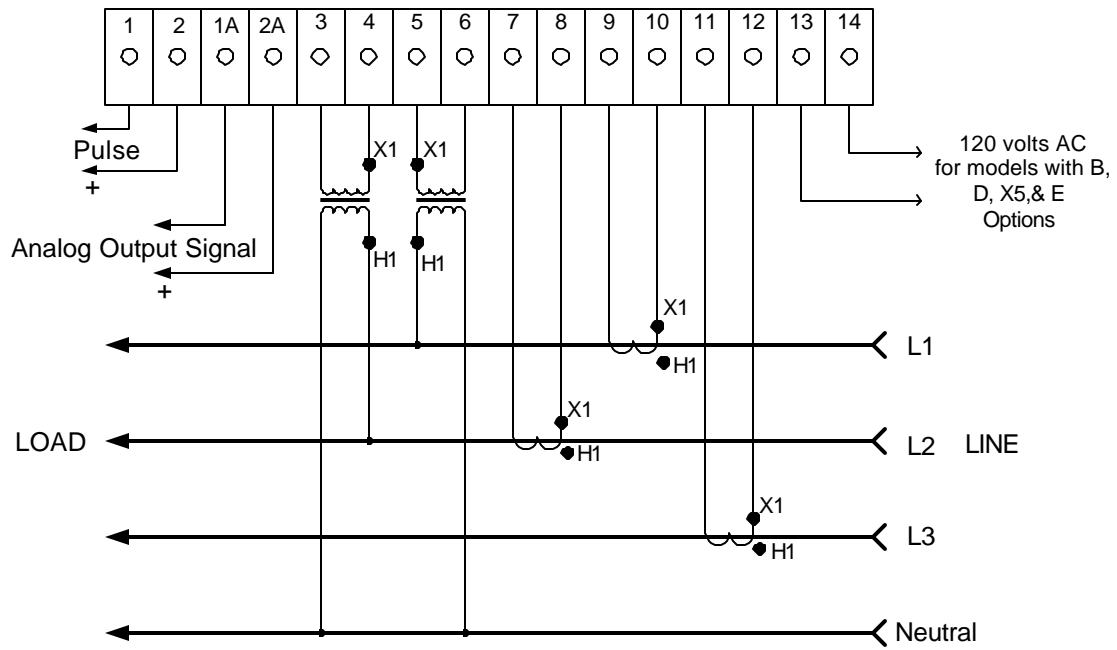Load may be unbalanced, voltage may be unbalanced.**

3-element connections for a 3-phase, 4-wire load.

1 ½-element connections for a balanced 3-phase, 3-wire load.

2 1/2 element connections for a 3-phase, 4-wire load.

TABLE 1

WATTS @ RATED OUTPUT	W-H PER COUNT	LOGIC LEVEL	FREQUENCY IN HERTZ	WATTS @ RATED OUTPUT	W-H PER COUNT	LOGIC LEVEL	FREQUENCY IN HERTZ
100W	0.1	16384	4551	40KW	10	4096	4551
250W	0.1	8192	5689	60KW	10	4096	6827
500W	0.1	4096	2276	80KW	10	2048	4551
1KW	1	16384	4551	100KW	10	2048	5689
1.5KW	1	16384	6827	120KW	10	2048	6827
2KW	1	8192	4551	160KW	100	8192	3641
3KW	1	8192	6827	180KW	100	8192	4096
4KW	1	4096	4551	200KW	100	8192	4551
4.5KW	1	4096	5120	240KW	100	8192	5461
5KW	1	4096	5689	300KW	100	8192	6827
6KW	1	4096	6827	320KW	100	4092	3640
8KW	1	2048	4551	360KW	100	4092	4096
9KW	1	2048	5120	400KW	100	4096	4551
10KW	1	2048	5689	480KW	100	4096	5461
12KW	1	2048	6827	600KW	100	4096	6827
15KW	10	16384	6827	800KW	100	2048	4551
18KW	10	8192	4096				
20KW	10	8192	4551				
30KW	10	8192	6827				

The above table lists the calibration frequency required for calibrating all standard W Series Watt & Watt-hour Transducers. To find the frequency, match the watts in the "Watts at Rated Output" column in the table with the same column on the W Series specification list.