Electrical Tech Note — 214

Biosystems & Agricultural Engineering Department
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MEASURING VOLTAGE, RESISTANCE AND CURRENT

A digital multimeter is the most common tool for measuring voltage and resistance. The typical multimeter can make both ac and dc measurements. It can usually measure voltage, resistance, and low levels of electrical current. For practical applications in the field a clamp-on ammeter is generally used to measure ac current. Proper use of these meters to measure voltage, resistance, and current is discussed using common digital meters. Most brands of digital meters work in a similar manner.

Making a Voltage Measurement: To make an ac voltage measurement turn the selector dial on the meter to the position with a sine wave above the V as shown in *Figure 214.1.* The letters VAC will appear in the upper right hand corner of the multimeter indicator screen. Direct current circuit voltage measurements are made with the selector switch pointing to the position with a straight line above the V. Make sure all voltage measurements are within the withstand rating of the meter. Digital voltmeters are usually auto-ranging. This means the meter has several internal ranges available, and the meter will automatically select the lowest range possible to make the measurement. Selecting the lowest possible range will insure the greatest accuracy of measurement.

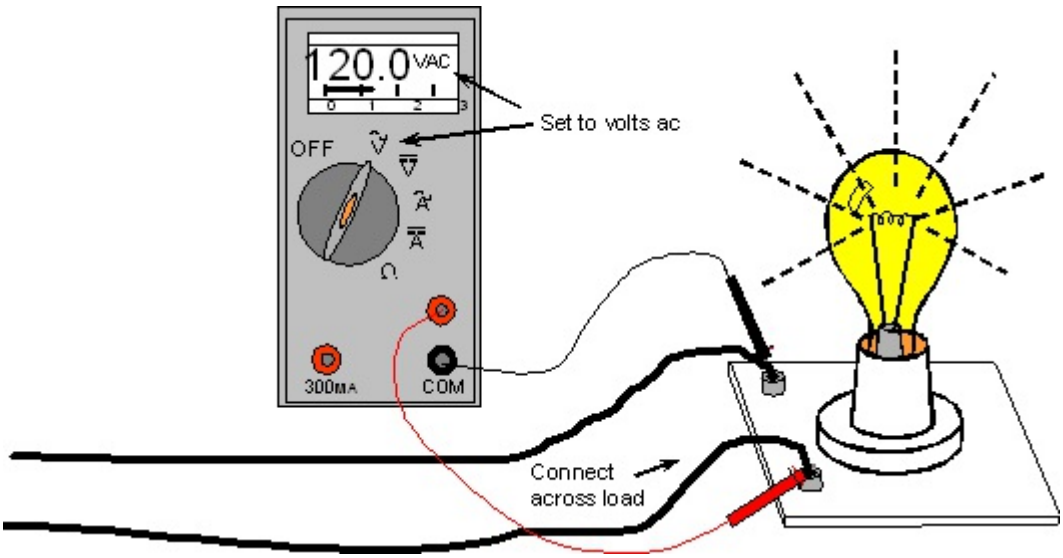

Figure 214.1 *Voltage of a lamp or other electrical equipment is measured by touching both circuit wires with the probes of the voltmeter.*

A voltmeter has a high internal resistance and can be connected directly across a circuit as long as the circuit voltage does not exceed the withstand rating of the meter. Measure voltage by touching one circuit terminal with one meter probe and the other circuit terminal with the other meter probe. When taking ac voltage readings it does not matter which probe touches which terminal. (For dc voltage the red is positive and the black is negative) *Figure 214.1* shows the proper way to measure voltage across a light bulb in a circuit.

When making a voltage measurement an analog scale will appear along the bottom of the readout screen. This analog scale will indicate how high the voltage reading is on the particular range being used by the meter. If the reading is near the top of the range the analog bar will extend all the way to the right of the readout screen. When the analog bar is less than 20% from the bottom of the scale (left hand side), the reading will be less accurate. The digital voltmeter readout screen is shown in *Figure 214.2.* The digital value on the voltmeter screen is the root mean square (rms) value of the voltage sine wave. Many digital voltmeters set to the ac voltage scale assume the voltage is a sine wave. If the voltage input to the meter is distorted and not a sine wave the reading on the screen is probably not accurate. When measuring voltage of a typical ac circuit, generally the wave distortion is minimal and the error in the reading is small. A voltmeter marked "**true rms**" will give an accurate reading of rms voltage even when the voltage wave is not a true sine wave.

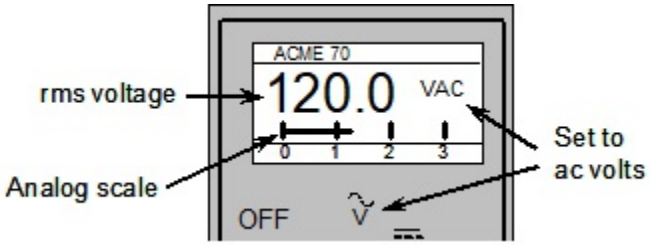

Figure 214.2. *The digital readout is the rms value of the ac voltage wave and the analog scale at the bottom of the screen indicates how much of the particular voltage range is being used for the value being measured.*

Making a Resistance Measurement: The multimeter can be used to make a resistance measurement, but there is a caution. Disconnect power to the circuit. Connect the circuit or component in the circuit to the ohmmeter. The meter has a battery that will pass current through the circuit or component. Set the meter selector to the resistance position which may say Ohms or it may give the symbol for resistance ohms. A resistance measurement is illustrated in *Figure 214.3.* The symbol M on the readout screen means millions of ohms. The **symbol k** on the readout screen **means thousands of ohms**. When finished making a resistance measurement, turn the meter off to save battery life.

The resistance of an electrical component is highly dependant upon the temperature. A resistance measurement made at room temperature may not be an accurate determination of the resistance of a circuit in operation. An example is an incandescent lamp. When measured at room temperature the resistance of the lamp will be much less than when the lamp was operating and the filament is hot. The resistance of the lamp cannot be measured directly when the circuit is energized, so the resistance must be determined by another method. For an incandescent lamp the current through the lamp and the voltage across the lamp can be measured. Then Ohm's law can be used to calculate the resistance of the lamp when it is operating. A similar technique can be used to determine the impedance of an inductive load such as a motor but the method is more difficult.

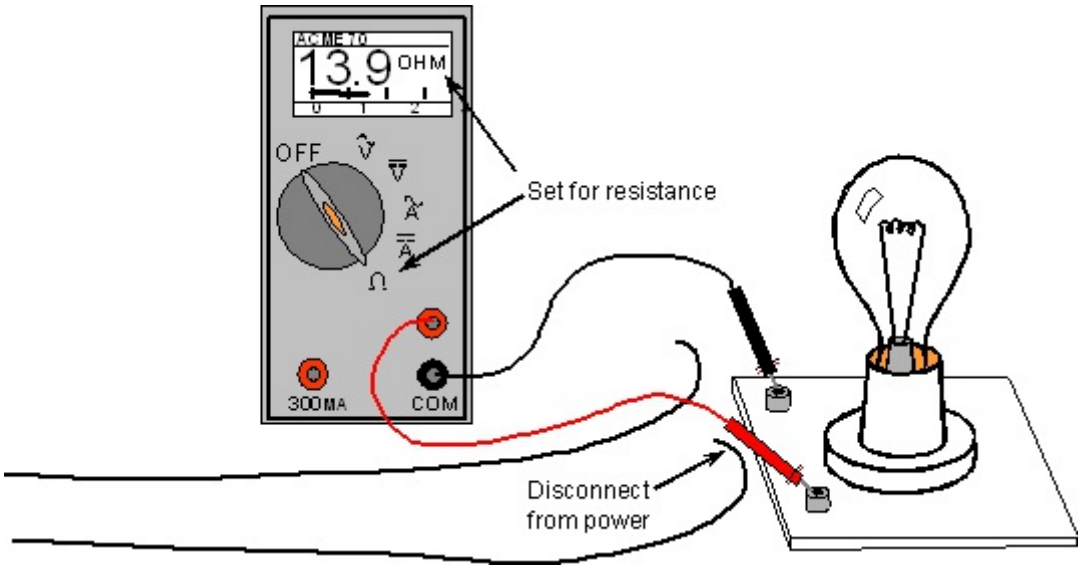

Figure 214.3. *Disconnect power from the circuit before makeing a resistance measurement.*

Voltage Measurements: Measuring ac voltage is an easy measurement. Most meters can measure both ac and dc voltage, resistance, and current although measuring current with a multimeter is not recommended since the current must flow through the meter. If the current exceeds the limit of the meter either a fuse will blow or the meter may be damaged. It is better to measure current in an ac circuit using a clamp-around meter that measures the magnetic field produced by the current flow. An ammeter that measures ac current will not measure dc current. To measure ac voltage set the meter to ac volts, turn on the circuit and use the probes to touch each of the wires of the circuit as shown in *Figure 214.4.*

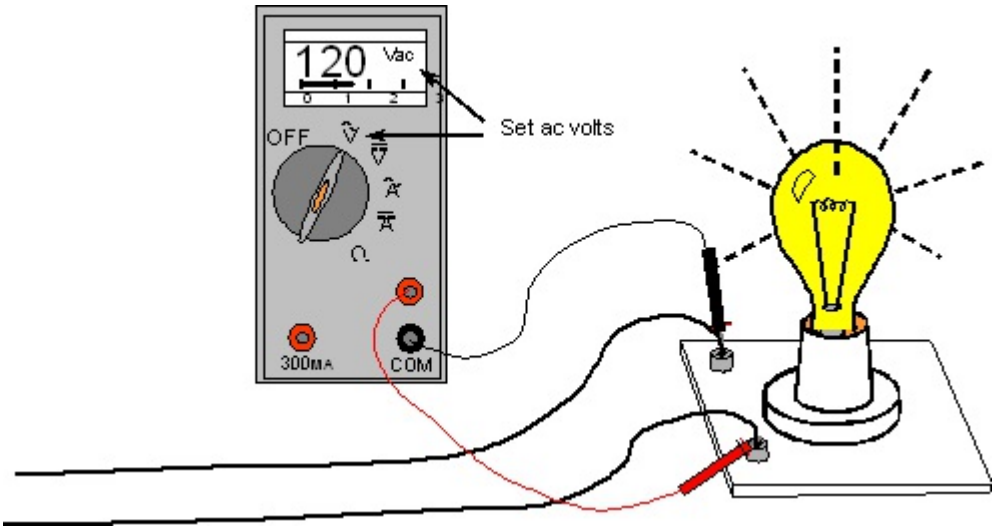

Figure 214.4. *Set the selector switch to ac volts and touch the probes to the terminals of the load. The probes must touch the metal terminals of the circuit and often those terminals are not accessible.*

Current Measurements (Amperes): There are two methods that can be used to measure current in an ac circuit. One method is to measure the current directly by passing the current through the meter. Care must be taken to make sure the current to be measured does not exceed the capability to the meter. Usually a fuse is placed in the circuit to make sure the meter is not damaged by excessive current. *Figure 214.5* is an illustration of an ammeter measuring circuit current. The meter must be connected into the circuit so the current must pass through the meter as shown in *Figure 214.5.* The other method of measuring current is to measure the magnetic flux around the wire caused by the current flow. That method is the most common method and damaging the meter is generally not a problem.

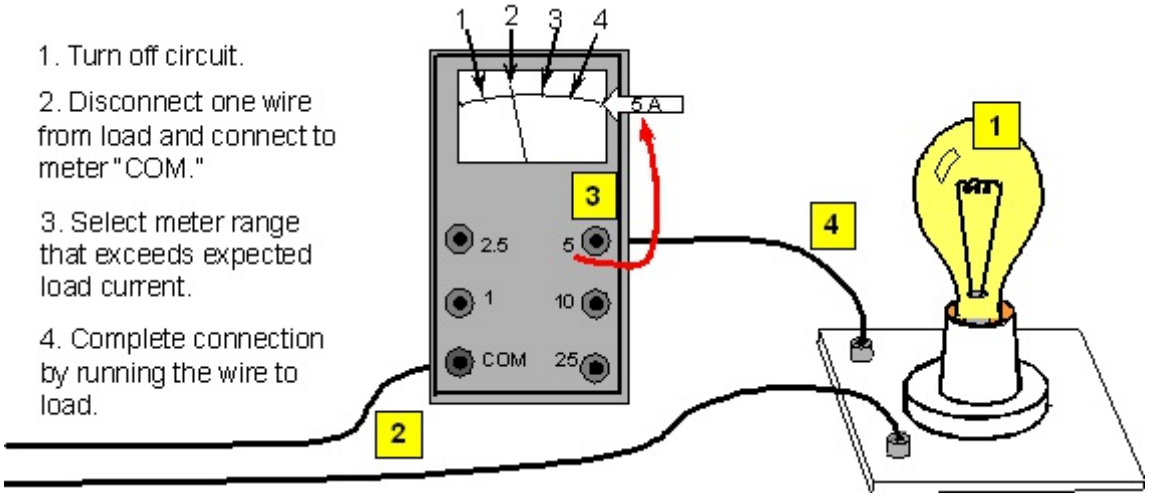

Figure 214.5. *Disconnect one wire of the load and reconnect it to the meter common terminal to measure the current flow through the meter*

Using a Clamp-on Ammeter: Electrical current flowing in a wire produces a magnetic field to build up around the wire. With alternating current this magnetic field is in constant motion which means it can be detected by a coil placed around the wire The more current that flows in the wire, the stronger the magnetic field. A device called a clamp-on ammeter can be used to measure the current flowing in a wire by clamping the jaws around one of the circuit wires. The clamp-on ammeter measures the current by measuring the strength of the magnetic field around the wire. A typical clamp-on ammeter is shown in *Figure 214.6.* Digital clamp-on ammeters are usually auto-ranging. They start with the highest range and work down to the lowest range sufficient to measure the current flow. This process takes several seconds. Sometimes it will be necessary to set the ammeter to the correct range in advance. There is a range button on the meter for this purpose.

Electronic equipment tends to cause a distortion of the sine wave current in an ac circuit. It is not uncommon for the current flow to be of some form other than a sine wave. When the current is not a sine wave the ammeter must be of the "**true rms**" type in order to obtain an accurate measurement of current. See *Tech Note 231* for more about sine wave distortion. Digital ammeters frequently have an analog scale at the bottom of the readout screen (see *Figure 214.6*). There are clamp-on ammeters that will accurately measure current flow even to a fraction of a milliampere.

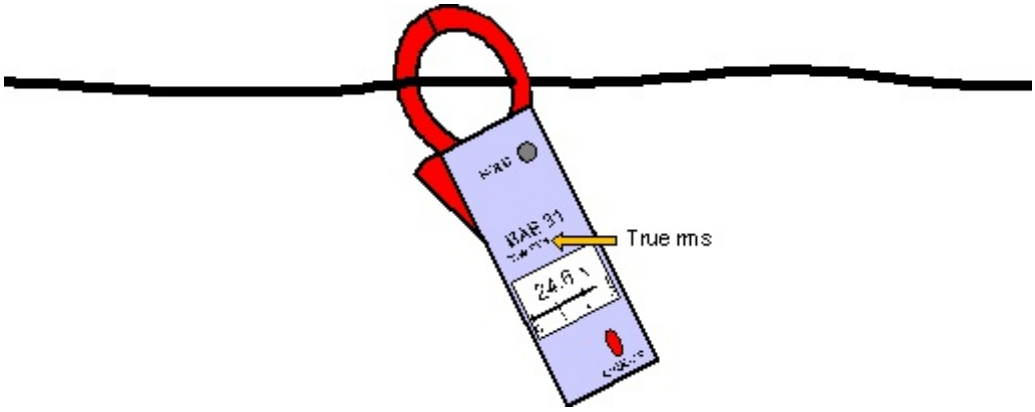

Figure 214.6 *A clamp-on ammeter can be used to measure the ac electrical current in amperes flowing in a wire always accurately if labeled "**True rms.**".*

It is important to know how to properly use a clamp-on ammeter. Refer to *Figure 214.7* for the proper method of measuring current in an ac circuit. Place **only one** of the circuit wires through the jaws of the clamp-on ammeter. The current in one of the circuit wires is flowing in the opposite direction as the current flowing in the other wire. If both wires pass through the jaws of the clamp-on ammeter the magnetic field of one wire will cancel the magnetic field of the other, and the ammeter will register zero amperes. When clamping the meter around all of the wires of a circuit the reading will be zero. If the reading is not zero then current is returning to the source by some path other than the circuit wires.

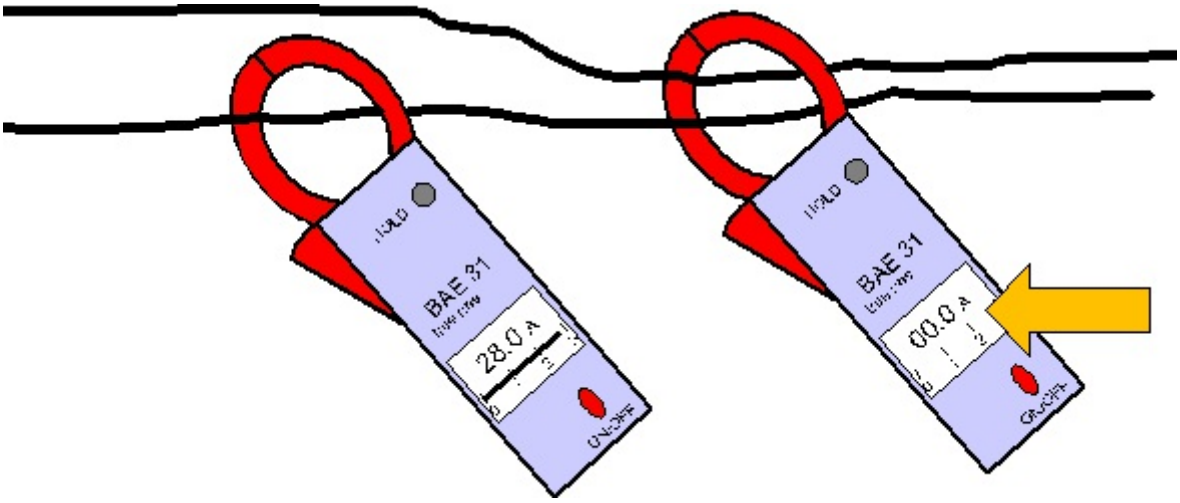

Figure 214.7 *Place only one of the circuit wires through the jaws of the clamp-on ammeter.*

Sometimes the current flowing in the circuit wire is so small that the needle of the clamp-on ammeter barely moves. You can trick the meter. All the meter senses is magnetic field. The meter has no way of compensating for the number of times the wire is looped through the jaws of the meter. Looping the wire through the meter jaws two times doubles the strength of the magnetic field sensed by the meter. The actual current flow in the circuit is

the reading on the ammeter divided by the number of loops of wire through the meter jaws. When a current reading is less than 20% of the ammeter range, the wire sometimes can be looped through the meter jaws several times to get the reading high enough to be determined accurately by the ammeter. This method of increasing accuracy of a current measurement is illustrated in *Figure 214.8.*

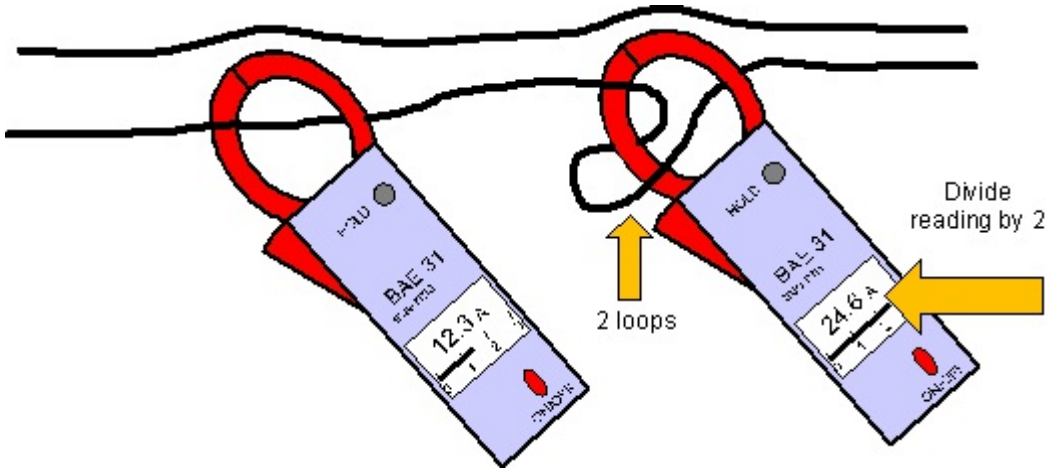

Figure 214.8 *When the wire is looped through the ammeter jaws two times the ammeter will read double the actual current flowing in the circuit.*

Measuring dc Current: The clamp-on ammeter will not measure current in a direct current (dc) circuit because the magnetic field around the wire is static and not in motion. The magnetic field must be in motion for it to be detected by the sensor coil of a clamp-on ammeter. To make a direct current measurement the circuit current must flow through the meter. The multimeter can be used for this purpose provided the circuit current does not exceed the maximum dc current rating of the meter.

To make a dc current reading first open the circuit at the point where the current measurement is desired. Polarity is important with a dc current measurement. *Figure 214.9* shows a simple dc circuit with a multi-meter used to measure the dc current.

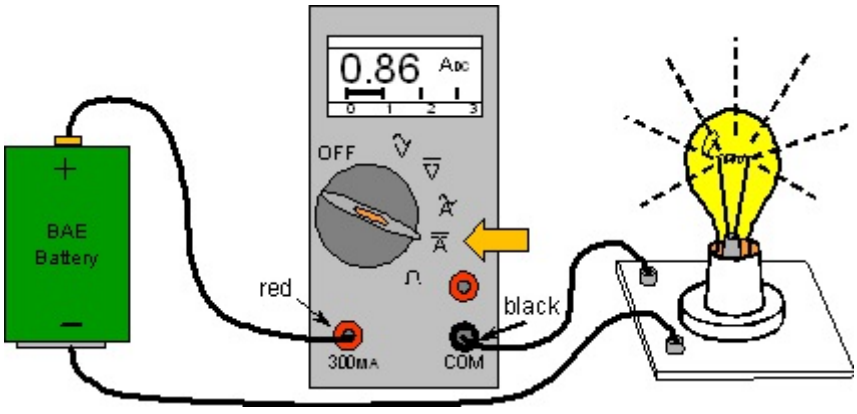

Figure 214.9 *When making a measurement of dc current make sure the current will not exceed the limit of the meter and make one wire of the circuit pass through the meter.*

Measuring Power (Watts): A watt-meter must measure both voltage and current at the same time. Older watt-meters have four terminals, one set that measures voltage (*Figure 214.4*) and one set that measures current (*Figure 214.5*). First identify the watt-meter terminals that measure current. Second, connect the wires to measure current as shown in *Figure 214.8.* The remaining two terminals are for measuring voltage. Connect those two terminals across the power input terminals of the load (dashed line of *Figure 214.10*).

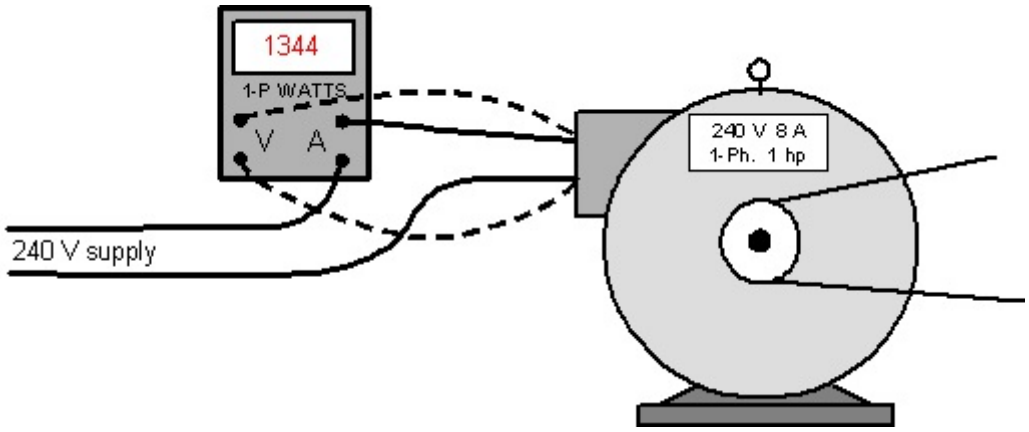

Figure 214.10. *This wattmeter requires the current to flow through the ammeter part of the meter and the voltage part of the meter is connected to the load to measure the voltage.*

Current can be measured with a device called a current transformer as shown in *Figure 214.6* with a clamp-around ammeter. Current can be measured with a watt-meter that has a current transformer to measure current as shown in *Figure 214.11.*

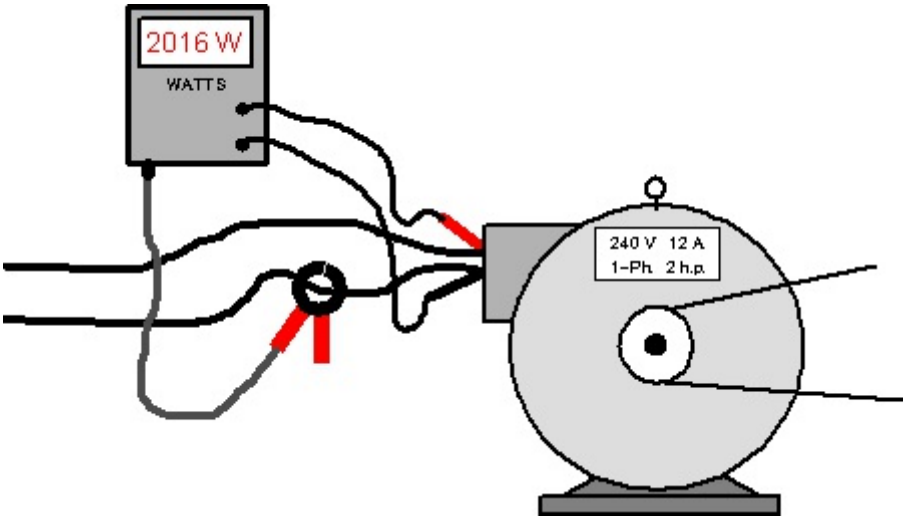

Figure 214.11. *Wattage of a load such as this motor can be measured by clamping the current transformer around one of the wires and connecting the voltmeter terminals to the input terminals of the motor to measure voltage.*