ELECTRICITY: Basic Theory *Part 3*

By BRUCE BARKER, ACI

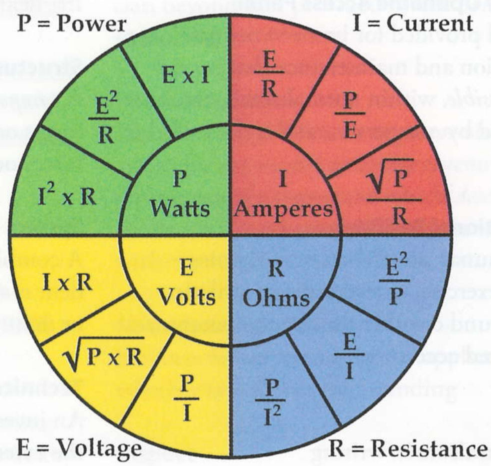
ONCE AGAIN, The Word invites you to travel into the dark realm of subjects that are sometimes misunderstood by home inspectors. The Word hopes you will find this trip informative and maybe a little entertaining.

This month we continue our discussion about electricity. The Word finds this subject interesting because the good inspector of electrical systems knows what is deficient, but the better inspector knows why it is deficient. Inspectors who understand why something is deficient make better calls and can better explain those calls to their clients.

Electricity Law and Order – A Review

Previously we learned about the Laws from Mr. Ohm and Mr. Watt as shown in Illustration 1. These laws describe how the basic characteristics of electricity in a home's electrical system (voltage, current and resistance) interact to perform work (power). Voltage is like water pressure. Current is like water flow rate. Resistance inhibits electricity's flow. Power is a measure of work performed. Change one characteristic and you change all the others. Note to the engineers: these descriptions of work and power aren't completely technically correct. They're close enough for our purposes.

Illustration 1



Ohm's and Watt's Laws

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A Crown Joule

There's another law that's perhaps more interesting than Ohm's and Watt's Laws and that's Joule's Law. Joule's Law expresses how heat develops in an electrical circuit. Heat is the enemy of electrical circuits. Heat breaks down insulation and sometimes the wires themselves. When insulation and wires fail, short circuits, ground faults, and fires are usually not far behind. Many of the deficiencies we call (over fusing, for example) have some of their basis in Joule's Law. Joule's Law is:

$$\text{Heat} = \text{Current}^2 \times \text{Resistance} \times \text{Time}$$

Joule's Law has some interesting features; the first being that voltage is not a factor in generating heat in an electrical circuit. A 1 ½ volt battery, under the right conditions, could generate enough current to start a fire. Ever see melted insulation on a neutral wire? The neutral wire is a current-carrying wire with no voltage (if everything is working as it should). Joule's Law explains why heat is generated when no voltage is present.

Another interesting feature is that heat increases exponentially as current increases. Two amps generates four times more heat than one amp (22 = 4), three amps generates nine times more heat than one amp (32 = 9) and so on. Joule's Law helps explain why over fusing can be so dangerous.

Resistance is an important factor in generating heat in an electrical circuit. Aluminum wire has a higher resistance than copper wire so more heat is generated in aluminum wire at a given current. Heat, as described by Joule's Law, helps explain why aluminum wire must be larger than copper wire. Resistance at loose or corroded connections can be much higher than at tight and clean connections. Heat, as described by Joule's Law, helps explain why loose and corroded connections are a problem.

Hot Boxes

Ever look inside a panelboard cabinet or a junction box and see it filled to the brim? Did you say anything about it? Joule's Law tells us that perhaps you should have said something.

Wires and devices get hot, as decreed by Joule's Law. More wires or devices equal more heat. Less free space in a cabinet, box or conduit equals less space to dissipate that heat. All this heat with no place to go could end in one of those fires you see on the evening news. You can't tell by looking whether a box or conduit is filled beyond its allowed limits. But if you see a cabinet or box that appears uncomfortably full, calling for evaluation might keep a TV news crew away from a home you inspected.

Beware of General Rules

We learned in inspector school that the upper ampacity limit for circuits using copper wires is 15 amps for #14, 20 amps for #12, 30 amps for #10, 40 amps for #8, and 55 amps for #6. Limits for aluminum wires are 5 amps less than for the same size copper wire except that #14 aluminum wire may not be used, and #6 aluminum wire is limited to 40 amps. So any circuit using these wires should be protected by an overcurrent protection device at or below these limits, right? That's right in many cases. What the instructor probably didn't tell you is that wire upper ampacity limits are valid only under prescribed conditions. The allowed ampacity of wires can be more or less than these limits depending on the circuit they protect, how they're installed, and on the type of wire insulation.

These upper ampacity limits apply to most of the wiring we see in most modern homes. These upper ampacity limits are almost always valid for #14, #12 and #10 wires. These wires are covered by special rules that apply only to these wire sizes. The upper ampacity limits are almost always valid for wires that are part of NM cables (usually referred to by the trade name Romex). NM cables are also covered by special rules that apply only to NM cables. These cables are what we usually see for most branch circuits in modern homes, with the notorious exception of the Chicago area.

These upper ampacity limits do not apply to wire sizes #8 and larger that are not part of an NM cable. A common example is individual wires pulled in conduit or tubing. To find the upper ampacity limits of these wires, you need to know the wire size, wire material and insulation material. Knowing this, you go to IRC Table E3705.1 or NEC Table 310.15(B)(16). Here you find that the upper ampacity limit for #8 copper wire with THHN insulation is 55 amps. That's quite a bit more than the same wire contained in NM cable.

Now if you want to go way beyond the scope of a home inspection, you need to take the upper ampacity limits of wires (and NM cables) and reduce them based on the number of wires run close together and the air temperature where the wires are run. This is called derating for proximity (number of wires) and ambient temperature. Derating gets complicated. Let's leave it to the electricians and code geeks.

Before we leave this topic, let's address a common point of confusion. Wire size and overcurrent protection for circuits serving air conditioning and heat pump condensers are based on the minimum and maximum circuit ampacity ratings on the condenser's label. The maximum rating is usually larger than the limit for the size of wire serving the equipment and allows for the current surge required to start the compressor.

Photo 1 is of the label on The Word's shiny new heat pump condenser. The circuit serving this condenser could use wires as small as #12 copper as shown by the minimum circuit ampacity. The overcurrent protection device should be no more than 30 amps as shown by the maximum overcurrent protection device. The upper ampacity limit for #12 copper wire is usually 20 amps, but rules allow the circuit to be protected by up to a 30-amp device.

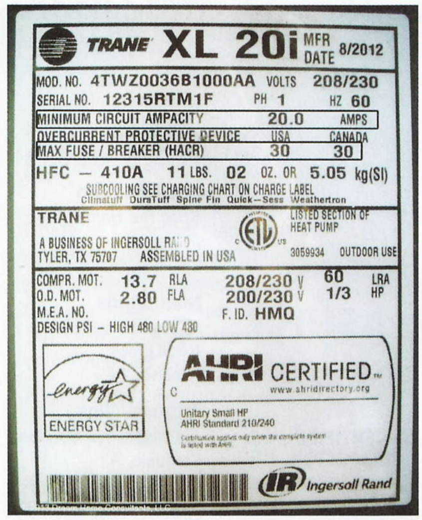

Photo 1: The label from a new heat pump condenser.

Full Circle

We've learned that heat is the enemy of electrical circuits. We want to avoid creating heat when possible, and when it's not possible, we want to dissipate the heat so it doesn't damage the insulation or the wires. We put limits on the current a wire can carry because heat increases exponentially as current increases. We put limits on the number of wires and devices that may be installed in close proximity because wires and devices in close proximity have less air around them to dissipate heat.

The Bottom Line

What we've discussed in these last three columns goes beyond what you need to know to perform a competent inspection; but The Word believes that ASHI members want to do more than a competent inspection. Those who go above and beyond will be rewarded, and now you have some tools to go above and beyond mere competence.

Memo to Zeus: The Word does not reside on Mt. Olympus (just at its base) and welcomes other viewpoints. Send your lightning bolts or emails to Bruce@DreamHomeConsultants.com. The thoughts contained herein are those of The Word. They are not ASHI standards or policies. ■

Bruce Barker operates Dream Home Consultants. He has been building and inspecting homes since 1987. He is the author of "Everybody's Building Code" and currently serves as chair of the ASHI Standards Committee. To read more of Barker's articles, go to ***www.dreamhomeconsultants.com****.*