The final part of this series breaks down a more complex schematic. The two large diagrams are a composite of a large, fictitious, two-stage heating/cooling rooftop unit. The unit has been broken down into two separate schematics due to its size. Figure 1 represents the power circuits and higher-voltage control circuits, and Figure 2 depicts the low-voltage circuit and control systems. To clarify, analyzing this diagram is easier to do in steps.

STEP 1—Compressors/indoor fan motor: At the top of Figure 3 are the two motor compressors and the indoor-fan motor. According to the original notes with the legend, (which were modified for the article) these motors are protected from single-phasing, which is accomplished by the internal thermal protection provided (see Figure 4).

Compressor A is energized through contactor CC-1 (line 48), which is controlled by the control relay contacts CR-1b. The coil to this relay (CR-1) is located on line 150. Compressor B is energized through contactor CC-2 (line 69), which is controlled by the control relay contacts CR-2b. The coil of this relay is on line 147. These two control relay coils (CR-1 and CR-2) are energized when Y1 and Y2 are closed, respectively (line 161).

The next load in sequence is the IFM. Its contactor coil IFMC (line 78) is controlled by several devices that will bring on the indoor fan as required. These are the contacts IFRH (line 78), IFRC (line 81) and CR-7 (line 84), respectively. If only the G terminal is made by a field-supplied thermostat, the IFRC coil (line 139) is energized, closing the IFRC contacts on line 81, which then energizes IFMC on line 78.

When the thermostat calls for cooling at Y1 by energizing CR-1 on line 150, this closes CR-1a and CR-1b (lines 40 and 48, respectively), and opens CR-1c and CR-1d (lines 72 and 131, respectively). Opening CR1d prevents the heating system from energizing when in cooling.

When the thermostat calls for the second stage of cooling at Y2, the CR-2 coil energizes and in turn closes CR-2a, CR-2b, and

Figure 1
CR-2d. It opens CR-2c and CR-2d at the same time. By closing CR-2d, the unit is sure to have the first stage of cooling operating.

If the cooling load changes slightly, the capacity control (CCN) at line 98 will open, causing the UNSLV to energize and unloading the No. 1 compressor’s first stage of cylinders. When contacts CR-1c and CR-2c open, the crankcase heaters are de-energized. When coils CR-1 and CR-2 are de-energized, the contacts CR-1c (line 73) and CR-2c (line 75), respectively, will close and energize the crankcase heaters.

**STEP 2—Condenser-fan motors:** The next series of components on the main power-supply line are the condenser-fan motors. These are controlled according to ambient temperature and refrigerant-pressure controls in the 115-V control circuit (shown in Figure 4). Note that the lines that they affect are shown next to the controls.

When Y1 calls for the first stage of cooling, compressor A is energized, and the OFCM-1 (line 37) also is energized through contacts CR-1a (line 40). If the air temperature is warm enough, the ATS (line 40) will close and bring on the OFCM-2 (line 40). When and if the load requires the second stage of cooling, Y2 will energize compressor B. The OFCM-3 (line 42) will energize through contacts CR-2a (line 42). If the refrigerant temperature gets too high, the FPS (line 46) will close, bringing on the OFCM-4 (line 46).

**STEP 3—Cooling protection devices:** Any cooling system must use some device(s) to protect the major components from destruction. This unit uses two identical safety circuits so it is only necessary to describe one circuit. Circuit A’s safety devices are the same as circuit B’s. The first series of safety con-
STEP 4—Heating sequence: When the thermostat calls W1 on the terminal block at line 161, HR-1 at line 145 is energized. HR-1a closes and starts the logic of TDR-3 at line 138. HR-1b closes and energizes IDFM at line 133. This causes the IFM to start (line 86), which closes CSa and CSb (line 99). Simultaneously, HR-1c (line 131) closes and allows voltage to be applied to the first stage of the IGN (line 128). This is made possible through the contacts of CSa.

The IGN (line 115) proves the flame through FS. Proving the flame turns off the spark through a pilot gas flame. The flame sensor (FS) on lines 109 and 120, the IGN (line 106) is mounted directly to the printed circuit board on the IGN and cannot be serviced. This is illustrated in Figure 5 and is noted by the dashed line around the N/O switch. The IGN closes the GV-1 (line 102) through contacts GVR-1 (line 113). The GVRs (line 103) are wired in series—ASR-1, OFC-1, HPS-1 and then LPS-1.

The ASR-1 is an N/C set of contacts that will open when any of the other safeties open. It will stay open as long as the ASR-1 coil has current flowing through it. Power has to be removed to reset it. The OFC-1 will open if the net oil pressure goes below 20 psig. It has a time delay of two minutes to allow the oil pressure to build up in the compressor. The HPS-1 control opens at 325 psig. The LPS-1 has a time-delay TDR-1 to prevent nuisance low-pressure control trips during low-load or low-ambient starts (explained in original legend notes).

There are two sets of safety controls that prevent the heating system from operating at the same time as the cooling system. The first are the N/C contacts CR-2c and CR-1d (lines 128 and 130, respectively). The second are the N/C contacts CR-2f and CR-1e (lines 143 and 145, respectively).

STEP 5—Heating-sequence safeties: Following are four common safety controls for the heating portion of this unit due to its complexity.

1. **Over temperature**: If the heat exchanger should go over its temperature range and become too hot, the limit switch (LS) on line 101 will open the N/C circuit. This opens the circuit to RS-1 at line 102, preventing the first stage of heating to function. It also opens the circuit to RS-2 at line 112, preventing the second stage of heating to function. Simultaneously, the LS switch closes the N/O circuit (line 100) energizing the relay coil CR-7 (line 100). When CR-7 energizes, CR-7 contacts close (line 84), and the IFMC (line 78) is energized, which turns on the indoor fan until the heat exchanger cools down.

2. **Combustion air flow**: If for any reason the inducer fan IDFM (line 84) should stop, the two centrifugal switches CSa and CSb (line 87) will open. This will remove the power from the GVR-1 (line 103), preventing the first-stage heating to function. This also will remove the power from GVR-2 (line 113), preventing the second-stage heating to function. Simultaneously, the LS switch closes the N/O circuit (line 100) energizing the relay coil CR-7 (line 100). When CR-7 energizes, CR-7 contacts close (line 84), and the IFMC (line 78) is energized, which turns on the indoor fan until the heat exchanger cools down.

3. **Indoor air flow**: If the IFM should stop (broken belt, defective motor or power supply), there are provisions to prevent the heating system from operating. Once the air flow stops, the AFS-1 (line 103) opens and removes power from the GVR-1 (line 103). The AFS-2 also will open, which will remove the power from GVR-2 (line 113) and prevent the second-stage heating to function.

4. **Gas proving**: If for any reason the flame is removed from the flame sensor (FS) on lines 109 and 120, the IGN will open and de-energize the GVRs on line 125. This will open the two gas valves.

This schematic had two separate control voltages. There was a transformer (TRANS-1) to take the line voltage to 115 V, and a second control transformer (TRANS-2) to drop the 115 V to 24-V control voltage. Note that the relays and their contacts are at many different points on the diagram. Figure 7 is an example of the component layout for the schematics in Figures 1 and 2.

Although complex, breaking down large schematics into individual parts and circuits makes it easier to read and interpret. With a little time and patience, any diagram can be used as an effective tool for troubleshooting.

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