ADAPTING TO
Electric Refrigeration
CONTROL VALVES

A Technical Review Committee member
presents a brief history of solenoid, pressure
regulating, and electric expansion valves.

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The designs of electric refrigeration control valves have evolved over the past century from relatively simple solenoid valves, to more complex mechanical designs, such as pressure regulating valves and to electric expansion valves that allow for more precise refrigerant flow control. This article takes a closer look at these valves, their designs, how they work and what they are used for.

Solenoid valves
The first electronic refrigerant flow control valve to be adopted by designers of refrigeration systems was the ubiquitous solenoid valve. Developed by ASCO Numatics in 1910, it provided a simple and reliable means to shut off or allow for fluid flow.

The benefit of using a solenoid valve in a refrigeration system is apparent. It replaces a manual valve being used to shut off or allow for refrigerant flow, and provides an automatic means for doing so. The solenoid valve is a rather simple device, and consists of a coil, valve body, enclosing tube, and a plunger/stem that is actuated by the coil's magnetic field. See figure 1.

The most common type of solenoid valve is “normally closed.” This style of valve remains closed until its coil is energized. The “normally open” solenoid valve operates in the reverse manner. This style of valve remains open until its coil is energized.

Most solenoid valves are pilot operated. With the floating disc type solenoid valve, the plunger simply opens or closes a pilot hole in the disc. The combination of the plunger and the inlet pressure to the valve act on the disc to open or close the main port. Using a pilot design keeps power requirements for the coil to a minimum.

The smallest capacity solenoid valves are often direct acting, which is to say the plunger itself opens and closes the main port of the valve. The small port size of these valves keeps power requirements for the coil to a minimum without the need to use a pilot design. Examples of common solenoid valve applications include:

Liquid line shut off/pump down: A solenoid valve in the liquid line can improve system efficiency and help prevent floodback to the compressor. In this application, a normally closed solenoid valve is wired to the compressor contactor so that it opens when the compressor is running. During compressor off-cycle, the valve closes, preventing refrigerant from migrating to the low side of the system.
The system designer may elect to go one step further and have the compressor run for a period of time after closing the solenoid valve to remove additional refrigerant from the low side of the system. A low-pressure switch is normally used to shut off the compressor. This application is known as a “pump down cycle.”

**Temperature control:** The solenoid valve can provide basic temperature control by shutting off or allowing refrigerant flow into the evaporator coil. This approach to temperature control is more common with systems having multiple evaporator coils in parallel.

**Hot gas defrost:** Refrigeration systems that accumulate frost on the evaporator coils require a defrost cycle. Hot gas can be used for this purpose, and a hot gas solenoid valve is used to control the flow of hot gas for duration of the cycle. In addition, ice cubers commonly use a hot gas solenoid valve to control the duration of their ice harvest cycle.

**Hot gas bypass/capacity control:** A solenoid valve may be used to allow hot gas flow into the inlet of the evaporator coil or directly into the suction line to the purpose of system capacity control. This application is common with larger capacity air conditioning systems using fixed speed compressors. The solenoid valve is typically used in conjunction with a hot gas bypass regulating valve.

**Heat reclaim:** A solenoid valve may be used to control hot gas flow into a heat reclaim condenser coil. This coil may be piped in parallel or series to the normal condenser coil, and it provides an economic means to use heat being rejected by the refrigeration system.

**Reversing valve:** A specially designed solenoid valve used for reversing the refrigeration cycle in a heat pump system.

**Pressure regulating valves**
Pressure regulating valves and thermostatic expansion valves remained largely mechanical designs through the 1970s. This was primarily due to the fact they worked well and were very reliable. Their control function lends themselves well to a mechanical design, unlike the solenoid valve which has a function like that of a switch and did not have a simple mechanical equivalent.

During the 1980s, however, there was growing interest among food retailers to store food products at more precise temperatures. With supermarkets employing parallel rack refrigeration systems, this meant having evaporator pressure regulating (EPR) valves provide more precise discharge air temperature control. Their interest was two-fold. By maintaining close temperature control, the food retailer could re-
duce its shrinkage of fresh meat and produce and increase product longevity, resulting in improved profit margin. The other issue was the growing government regulations and guidelines into this area.

In 1982, the Retail Food Sanitation Code was developed by the Association of Food and Drug Officials (AFDO) published jointly with the U.S. Food and Drug Administration (FDA). This document set forth guidelines for the proper handling of retail food, including the temperature at which refrigerated and frozen food should be stored. Subsequent iterations of the “Food Code” followed in 1993, 1995, 1997, 1999, 2001, 2005, 2009, and 2013. According to the FDA, all 50 U.S. states plus the District of Columbia have adopted guidelines following one of these versions of the Food Code beginning with the 1995 version. See figure 2 on page 29. It is important to note that the Food Code is not enforced by the FDA. It is simply a guideline they provide for the states to use in their own food safety laws.

A related effort which examines the production processes regarding food safety is HACCP (Hazard Analysis and Critical Control Points). Its inception occurred during the 1960s as part of the U.S. space program. In 1997, HACCP principles were standardized by the NACMCF (National Advisory Committee on Microbiological Criteria for Foods), and the principles include the monitoring and recording of food storage temperatures to verify that they are being properly controlled. Modern versions of the Food Code include guidance for food retailers for voluntary compliance with HACCP principles.

The electric EPR valve typically uses a step motor actuator to control its operation. The controller for the valve is normally connected to a temperature sensor, and it is designed to simply regulate the valve to accurately control discharge air temperature. A mechanical EPR valve, on the other hand, can only indirectly control air temperature since it only controls evaporator pressure. As a result, its temperature control is less precise.

The reader is encouraged to read the article on electric EPR valves written by Dave Demma in the August 2010 issue of RSES Journal. This article explains in detail how the electric EPR can provide improved temperature control compared to its mechanical counterpart. This article can be found in the RSES Journal archives: http://www.rses.org/rsesjournal/archive.aspx. There also is a Service Application Manual (SAM) with a chapter on Electric Valves for Refrigerant Control, which can be found at www.rses.org.

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**Electric expansion valves**

Efforts to improve refrigerant flow using electrical designs did not stop with the EPR valve. The 1980s also saw efforts to develop electric expansion valves (EXVs) to achieve more precise refrigerant flow control.

By design, the mechanical thermostatic expansion valve (TXV) regulates flow by controlling superheat at the outlet of the evaporator. As with the electric EPR, the EXV is regulated by a controller, and it is also designed to control superheat. The controller for the EXV requires more sophistication than that of the electric EPR which normally controls only discharge air temperature.
There are two popular EXV designs: the pulse modulated and step motor. The pulse modulated type EXV is a solenoid valve with a small port area designed to be cycled frequently to control refrigerant flow. A replaceable outlet orifice is typically used with this valve which allows the maximum capacity of the valve can be changed.

The controller for this type of valve uses a technique known as pulse-width modulation (PWM). Controllers typically use a fixed 6 sec cycle time, and then determines within each cycle how long the valve must remain open to achieve proper refrigerant flow control. The percentage of time the valve is open is referred to as the duty cycle. If the valve is open all the time, it has a 100% duty cycle. If the valve is closed all the time, it has a zero-duty cycle. The step motor type EXV regulates refrigerant flow by positioning its valve pin in and out of its valve port. In this respect, it operates like the TXV.

Step motor EXVs used with R-410A ductless mini-split systems such as shown in figure 3 on page 30 will typically have 500 steps, which provides excellent flow control. Some step motor EXVs, however, may provide as many as 6,000 steps, particularly with those motors used in large capacity EXVs.

Step motors
Step motors used with EXVs are available in two types: unipolar and bipolar. Bipolar motors offer greater torque, and are normally used with larger capacity EXVs. Smaller capacity EXVs used in residential air conditioning systems normally use the unipolar motor which allows for simpler circuitry to control.

The controller for both types of EXVs must sense superheat to properly control the valve. In this respect, the controller is more sophisticated than that used with an electric EPR. A common control method is for the controller to mimic TXV operation and a temperature sensor and pressure transducer is connected to the controller for this purpose.

The controller takes the pressure reading from the transducer and converts it to refrigerant saturation temperature and then calculates the superheat from the difference between it and the reading from the temperature sensor.

Another method to control the EXV is the two-temperature method. This method replaces the pressure transducer with a second temperature sensor. The second sensor is placed in a specific location on the evaporator surface to measure the refrigerant’s saturation temperature directly. This approach is generally not as accurate as using a pressure transducer, but it does provide a lower cost solution.

A third method which is sometimes used for applications requiring close temperature control without the need for an EPR requires two temperature sensors and a pressure transducer to be connected to the EXV controller. One temperature sensor and the pressure transducer provide the superheat control as stated previously. The second temperature sensor is placed in the refrigerated fixture. The controller has the capability to both superheat and discharge air temperature control.

Both the electric EPR and the EXV offer refrigerant flow control solutions that can assist with the compliance of food safety regulations and guidelines. The fact that they require sensors and controllers makes them a more expensive alternative to their mechanical counterparts.

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