DIRECT AND INDIRECT SAVINGS USING STEP MOTOR VALVES

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Mechanical, thermostatic expansion valves have served the air-conditioning and refrigeration industry well for many years. As the industry moves toward greater efficiency and the use of different refrigerants, electronic controls and electric valves are being used more often. The benefits of the electric valves can be realized in almost every part of the system, not just as expansion valves. Direct benefits accrue from the ability of the valves to operate with varying head and suction pressure. Indirect benefits result from increased product life due to the stability of the temperature in the refrigerated space.

DIRECT SAVINGS
ELECTRIC EVAPORATOR PRESSURE REGULATORS

CDS-9   **CDS-16**

Most of the direct savings attributable to the use of step motor refrigerant control valves can be realized as a result of energy efficiency. Significant savings can actually be garnered from a surprising source—Electric Evaporator Pressure Regulators, EEPRs. Conventional wisdom states that Evaporator Pressure Regulators (EPRs) cause additional suction line pressure drop and are therefore less efficient. Suction line pressure drop is, in fact, costly in terms of compressor energy usage. Table 1 shows that a 2 psi (0.13 bar) pressure drop in the suction line will translate into a capacity loss of 3.6% at 15°F (9.4°C) saturated suction temperature with R-404A. In mechanically based EPRs this is a significant factor because all mechanical EPRs use system pressure to operate and contribute to the pressure drop in the suction line. Step motor EEPRs, on the other hand, can be sized to contribute no pressure drop to the suction line by virtue of being externally, rather than system, powered. Properly sized, the step motor EEPR can have a pressure drop equal to a section of pipe of the same diameter as its connections. EEPRs can be applied on circuits running at, or very close to, common suction pressure without incurring a running penalty.

Rapid pulldown of the case temperature after defrost is another contribution of EEPRs to system efficiency. As Figure 1 shows, pulldown load after defrost is typically three times higher than the holding load of a refrigerated merchandiser. EEVs can also contribute to rapid pulldown after defrost, and a later section on EEVs will cover that in more detail.

During a defrost, the EEPR or mechanical EPR is closed and the evaporator pressure is high. As soon as the defrost terminates, the EEPR or EPR begins to open, quickly reducing pressure in the evaporator but not immediately reducing air temperature over the evaporator. The mechanical EPR will respond to pressure and will begin opening but will slow as the pressure in the evaporator drops to setpoint. The pulldown will be extended by this reaction.

EEPRs, on the other hand, are usually set to respond to air temperature instead of pressure. After a defrost, the EEPR will open fully and allow the refrigerant to evaporate at the saturated condition of the common suction to which it is connected. This results in the very rapid pulldown shown in Figure 2. The faster the pulldown, the less running time is spent by the compressor in re-establishing case temperature and the less the warming of the product. With EEPRs, pulldown to the required temperature may be 3 to 4 times faster than previously possible.

A further, and generally unexploited, advantage of EEPRs is possible due to the nature of the controllers used with them. Step motor EEPRs, while more precise than previous electric valve technology, still require electronic controllers and

Evaporator Temperature °F	R-22	R-404A	F-404A
	Suction Line Pressure Drop		
	2 psi	2 psi	1 psi
	Percent Compressor Capacity Loss		
40°	3.1	—	—
15°	5.1	3.6	1.8
-25°	17.6	8.8	4.4

Table 1
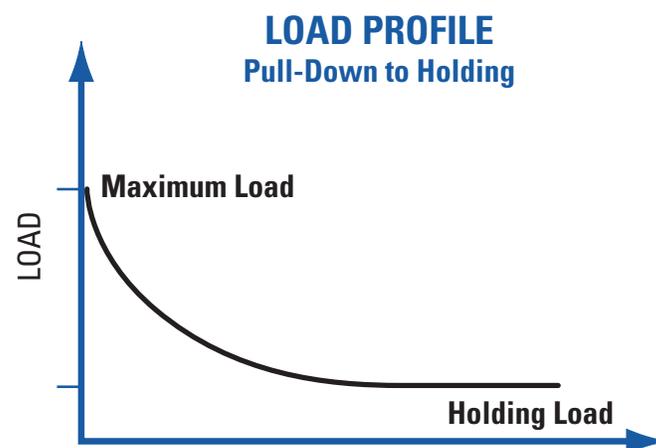
LOAD PROFILE
Pull-Down to Holding

Figure 1

sensors. These controllers and sensors may be standalone, but are more often part of a larger energy management system that controls all aspects of the refrigeration installation, including compressor and condenser control. This energy management system captures the temperatures in every case and circuit and the degree of opening of every EEPR. If given the proper algorithm, the system can allow suction pressure to rise if all cases have been satisfied on temperature and the EEPRs are in a more throttled or closed position. This increase in suction pressure reduces compressor compression ratio, increasing compressor efficiency greatly. Calculated gains are more than 10% for a 5°F (3°C) rise in suction pressure.

Figure 3 was generated from representative compressor data and illustrates these gains. Although not proven, theory suggests that temperature responsive EEPRs may act to delay or diminish the need for defrosts by reducing the temperature difference between saturated coil surface temperature and coil discharge air temperature. Closer temperature approaches lead to less dehumidification of the air and less build-up of frost on the coil. Defrosts are expensive in terms of the energy needed to melt the frost and the additional compressor run time needed to bring the cabinet down to the desired temperature. Less frost and fewer defrost cycles greatly improve overall system efficiency.

As the step motor technology matures, costs of implementing the technology lessen. The reduction in cost is primary, conveyed as the actual price of the hardware drops, or secondary, as a result of more functionality at similar cost. In the current state of the art, step motor EEPRs are competitive in installed cost with mechanical EPRs.

ELECTRIC EXPANSION VALVES

SEI-3.5   SER-5
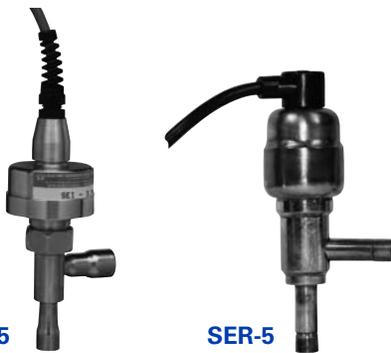
Previous comments have pointed out the savings realizable by the emergent technology of EEPRs. Electric Expansion Valves (EEVs) have been available for a number of years and are based on a variety of technologies; analog magnetic, heat motor and step motor, among others.

When used without EEPRs or even mechanical EPRs on supermarket-refrigerated cases, EEVs may not be the most efficient technology. Often used in loop systems where a large common suction runs at the lowest saturated suction temperature needed, EEVs will work well as superheat control devices. However, when acting as temperature controls in the
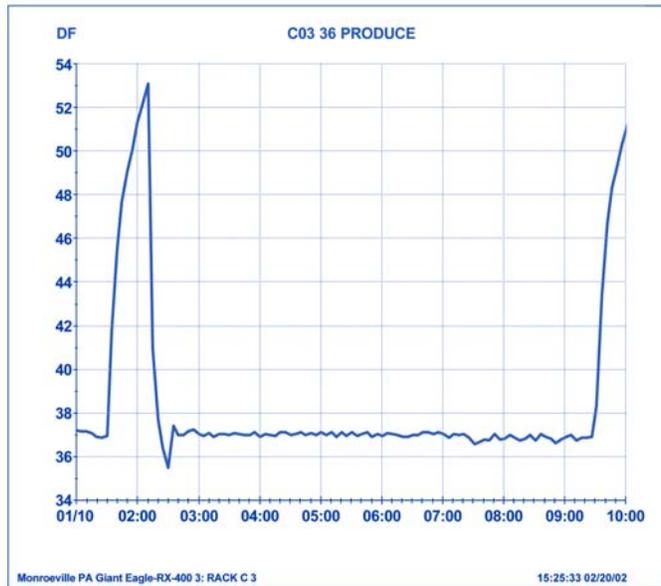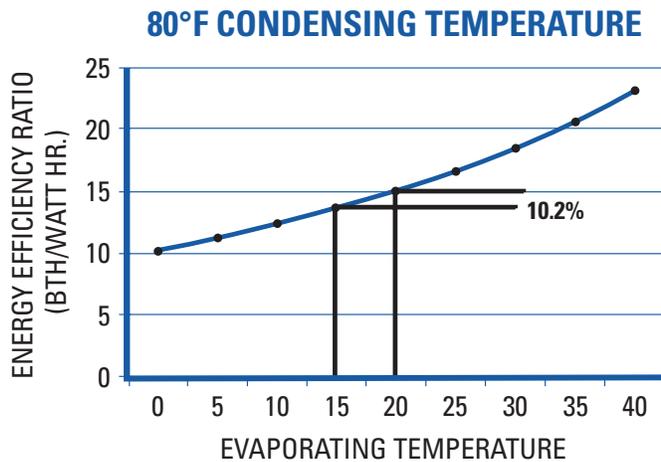

Figure 2

Figure 3

same applications, the EEVs may actually use more energy in the form of extended and more frequent defrosts. When called upon to control temperature, EEVs do so by raising superheat. This higher superheat causes initial passes of the coil to evaporate refrigerant at the common suction pressure, which may be considerably colder than required to meet discharge air temperature. This colder section builds more and harder frost. As the heat transfer ability of the frosted part of the coil is reduced by frost build-up, the frost line continues further into the coil. Without frequent and long defrosts, the coil may eventually be totally blocked.

On balance, step motor EEVs may be used very effectively in some standalone applications or in systems with saturated suction temperatures close to coil evaporating temperatures. In those instances, smoothness of control and ability to follow load changes provide for increased product integrity and may decrease compressor cycling. Pulse width modulated EEVs on smaller systems may not produce the smoothness of suction pressure needed to prevent excessive compressor cycling.

As alluded to earlier, EEVs can contribute to rapid pulldown after defrost. Conventional thermostatic expansion valves must not be oversized because of their limited ability to control well at reduced loads. A recent exception to this are extended multi-capacity valves (EMC). The EMC style has both pulldown and holding ports and can match changes in load better than traditional TEVs. Figure 4 shows a representative internal view.
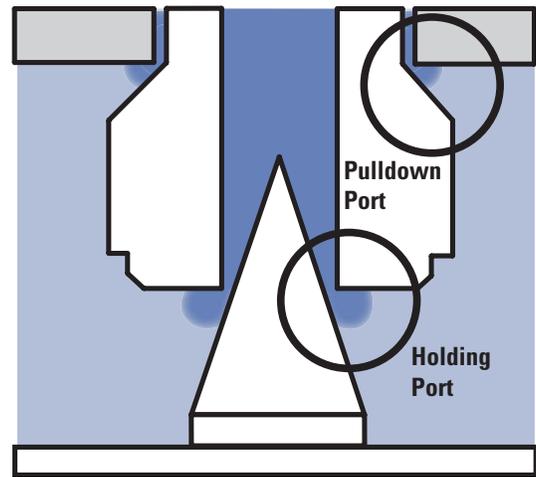
EEVs, however, due to their precision, linear flow curve, and repeatability can be greatly oversized and yet maintain superheat setpoint at low loads. See Figure 5 for a typical step motor EEV flow curve. In practice, valves with nominal capacities of 1-1/2 to 3 times that required for holding load can be applied without concern. After defrost, the valves can be driven to a wide or nearly wide open position, admitting the larger volume of liquid refrigerant needed to meet the high pulldown load. Once temperature setpoint is met, the EEV can modulate to the lower mass flow needed.

Beyond question are the savings that can be realized with EEVs as a result of head pressure float. Numerous published reports, including those of Carel SPA in Italy and ARS (Arizona Power Systems) in the USA, cite savings of up to 20% average over time by reducing condensing pressure. A number often quoted is a 2% savings per degree of decrease in condensing temperature. Paybacks of 0.3 to 3 years are estimated by the U.S. Department of Energy. While it is easy to understand this relationship due to its effect on compression ratio and COP, conventional systems using Thermostatic Expansion Valves (TEVs) may not be able to capitalize on these savings. TEVs are generally sized at a specific pressure drop or difference between condensing pressure and suction pressure. Large reductions in condensing pressure effectively cause the TEV to be undersized and it may not be able to meet the refrigeration load. Conversely, a TEV sized for the low condensing pressure condition will be oversized at the higher condensing pressure and may modulate erratically or overfeed, sending liquid refrigerant to the compressor. Because EEVs are driven to a position electronically they have the ability to modulate over very wide changes in pressure drop and load.

A further complication of reduced condensing pressure and temperature is the increased possibility of loss of subcooling and attendant flash gas formation. EEVs can be oversized to advantage in this instance by allowing flash gas to be quickly purged by the larger port, which can then be modulated back to the required mass flow.

As suggested above, the data gathered from the sensors inherent in a system using EEPRs can be used with an algorithm to float suction pressure for energy savings. In a similar manner, the data gathered from EEV controllers can be processed to create a demand defrost algorithm. As frost begins to form on an evaporator, airflow is disrupted, but the valve will attempt to keep superheat constant. Due to the loss of heat transfer ability of the evaporator, the valve will modulate closed to prevent floodback. The valve position data, along with other system pressure and temperature data can provide enough
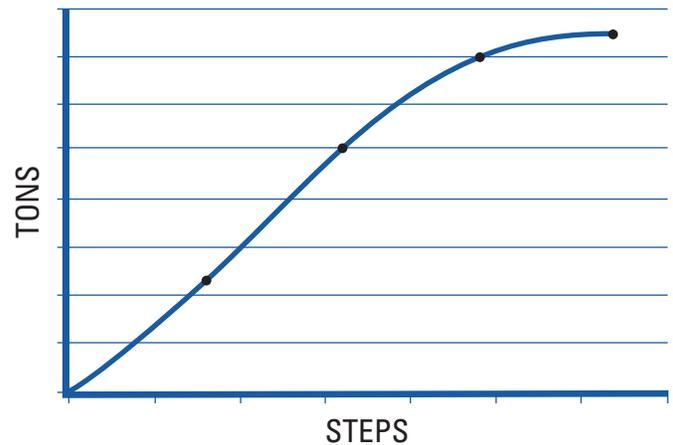

Figure 4

SEI CAPACITY

Figure 5

information to allow the control system to make decisions about whether a defrost is necessary. Over time, the savings in electrical use by skipping or delaying a defrost can contribute effectively to total system conservation.

INDIRECT SAVINGS

The paths to direct savings cited before are based on decreases in installed or running costs while indirect savings are based on loss prevention. The lack of liability claims or decreases in product loss also represent significant ongoing savings.

As the above demonstrates, EEVs and EEPRs can contribute significant energy savings in supermarket refrigeration systems. The electric valves are not standalone control devices but are, instead, part of an electronic control system. The system is comprised of the valves along with sensors and microprocessors containing algorithms and memory elements. All these components can, and should, be used for more than just valve control and energy savings. The precise, repeatable, and steady temperature control that these systems offer will pay continuing dividends in the form of product integrity and shelf life.

According to ASHRAE deterioration of refrigerated product is hastened by three factors; temperature above optimum storage temperature, temperature variation during storage and relative humidity.

Optimum storage temperatures for various products can be found in a number of sources but the ASHRAE Handbook, Refrigeration, Chapter 10, lists the optimum storage temperature of many products, including meat and vegetables, in the 32 to 36°F (0 to 2.2°C) range. Obviously, this is near to freezing and many products are subject to chilling injury if temperatures drift too low. Temperatures that are too high are also damaging to products. Deterioration rate of fruits and vegetables may double with just a 7°F higher storage temperature. Softening, loss of flavor, color change and tissue breakdown as a result of temperature deterioration makes products unsaleable. Additionally, according to ASHRAE, variations of 2-3°F (1-2°C) are enough to damage most products.

Meat is not only subject to the above but may be more affected by relative humidity. Beef, pork and lamb are optimally stored at 85 to 90% relative humidity at 32°F (0°C). An increase in storage temperature will also necessitate an increase in the humidity level to prevent desiccation and loss of sale weight.

Food products subject to any of these three conditions are likely to become unattractive or unpalatable. Loss of revenue and increase in disposal costs result from unsold perishables. In the case of meat, milk and flowers, this will be detrimental to already small margins on these commodities.

Along with loss of product integrity resultant from the cited factors, temperature variation or elevation will lead to increased possibility of spoilage. In the United States, the Food Marketing Institute (FMI), in their yearly survey of consumer attitudes and concerns, inquires about a number of issues. Responses about food safety have held relatively constant with 70% of respondents listing it as very important.

Cases of sickness and death resulting from food borne pathenogens are very costly in litigation and claims loss. The Food and Agricultural Organization of the United Nations (FAO) has stated that the number of days before slime development on meat drops from 10 days for product kept at 32°F (0°C) to just 3 days when 5°F (3°C) higher.

The technology used to control and monitor electric refrigeration valves can be adapted or extended to provide temperature traceability. The adoption of HACCP (Hazard Analysis and Critical Control Point) regulations in many countries means that temperature monitoring must be incorporated into the refrigeration equipment. The cost of adding this feature to the electric valve controllers is incremental. The savings due to loss prevention can be sizable. A Colorado State University study for the American Meat Institute Foundation predicts that the result of HACCP implementation will result in a savings in health benefits of over $26 billion in the United States alone.

CONCLUSION

Refrigeration accounts for up to 15% of the electrical energy consumption of the United States and, presumably, most developed countries. So, small improvements in efficiency will have great overall effects on electrical demand. Supermarkets, in particular, are concentrated consumers of power but are under close supervision and are highly maintained. Direct savings in energy and installed costs are easy to quantify. Less easy to measure are the indirect savings due to longer shelf life, less spoilage and waste, and less money paid in claims for illness from contaminated food. Unquestionably, both types contribute to the well being of the food distribution chain and economy.

The new millennium has exacerbated challenges to our industry. We are asked to reduce energy usage while ensuring safety in the food chain. But the new millennium has also brought the progress in technology to meet these challenges. Electronic controls and step motor operated valves comprise a system to help provide safe and abundant food while minimizing the energy consumed.