# Optimized Thermal Expansion Valves for R-410A Systems

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EMERSON
Climate Technologies

# Overview

## Introduction

By 2010, the United States must phase out ozone-depleting refrigerants and transition to hydrofluorocarbon (HFC) refrigerants like R-410A for new heating, ventilation and air conditioning (HVAC) systems. The change to R-410A has initiated a redesign of HVAC systems, and thermal expansion valves (TXVs) designed to operate with the higher-pressure R-410A refrigerant are needed.

To meet this need, Emerson Climate Technologies has developed the Emerson® C-Series Thermal Expansion Valve, the first TXV designed and optimized specifically for use in R-410A systems. This paper explains how the C-Series TXV can provide significant advantages for air conditioning and heat-pump applications.

## Contents

This paper contains the following topics:

# Recent HVAC market changes

## SEER legislation

Prior to the 13 SEER (Seasonal Energy Efficiency Ratio) regulations that took effect in 2006, most HVAC systems used fixed-orifice devices. Since then virtually all residential systems have been redesigned for the higher efficiency standards. As a result:

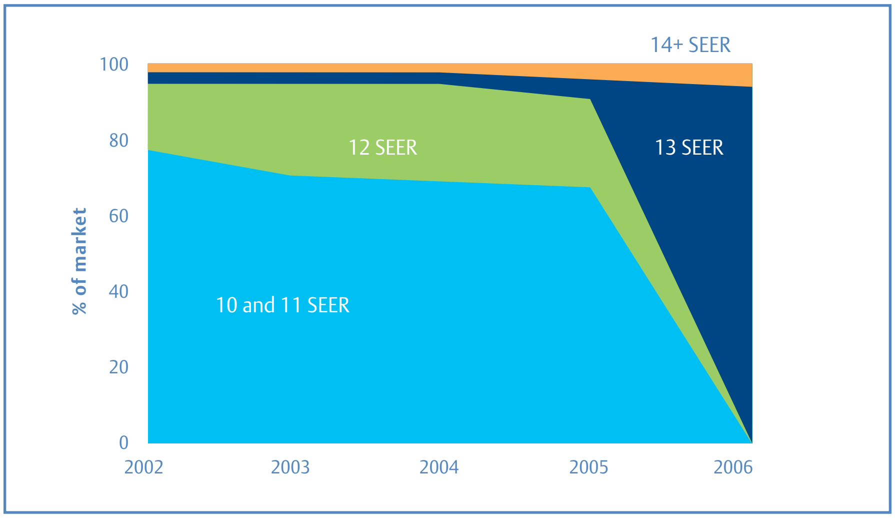
- Indoor and outdoor coils have increased in size
- More efficient compressors are being used
- TXVs have replaced fixed-orifice devices

## Trends in HVAC system efficiency

Figure 1 shows the marketplace's transition from 10, 11 and 12 SEER to the more energy-efficient 13 SEER equipment required as of January 23, 2006.

*Figure 1*

**Transition to 13 SEER Timeline**




## Upcoming refrigerant change

In 2010, the United States, in accordance with the Montreal Protocol, must phase out all ozone-depleting, chlorine-based refrigerants on new equipment. By 2010, common ozone-depleting hydrochlorofluorocarbon (HCFC) refrigerants like R-22 will transition to HFC refrigerants like R-410A and R-404A, for air conditioning and refrigeration systems.

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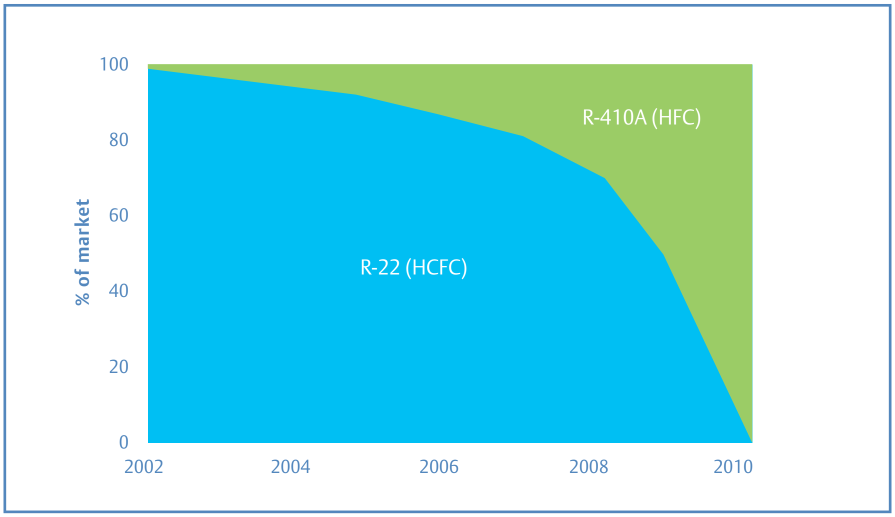
# Recent HVAC market changes (continued)

### R-410A conversion by 2010

Figure 2 shows that by 2010, all new HVAC systems will be required to use HFC refrigerants like R-410A.

*Figure 2*

**R-410A Conversion Timeline**




### Effects of refrigerant change

The change to R-410A has initiated another redesign for HVAC systems. Coils, compressors and TXVs designed to operate with the higher-pressure R-410A refrigerant are needed. Growing consumer interests in energy conservation and environmental issues are contributing to product and system changes as well. As a result, the market is trending toward more efficient, high-SEER systems with dual- or variable-speed fans and compressors.

# Functions of expansion devices

**TXV function**

Thermal expansion valves (TXVs) are precision devices designed to regulate the rate of refrigerant-liquid flow into the evaporator of a refrigeration or air conditioning system. These valves meter the refrigerant's flow rate in exact proportion to the rate of evaporation of the refrigerant in the evaporator.

**Disadvantage of past systems**

In pre-13 SEER systems, which used a fixed-orifice device, the flow rate was a function of the pressure differential across it. Consequently the orifice had to be chosen or optimized at one particular operating condition. As the ambient temperatures changed, the discharge and suction pressures also changed, resulting in flow rates through the orifice that were no longer optimized for these new conditions.

**Advantages of using TXVs**

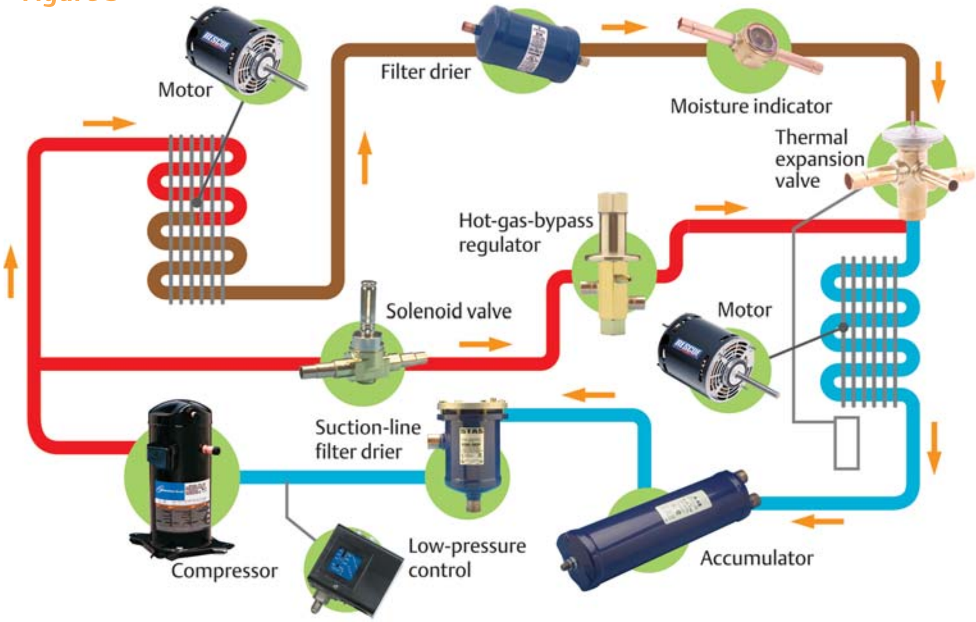
A thermal expansion valve, however, does not suffer from this disadvantage. A TXV opens and closes in response to the superheat at the evaporator outlet. As a result, it adjusts its flow rate to balance with the actual load and operating conditions. This enables systems with TXVs to operate at ideal efficiency levels, regardless of operating conditions.

In addition, the TXV closes tightly when the compressor is not operating. This prevents pressure equalization during the off cycle, allowing the system to return to optimum efficiency more quickly when the compressor is restarted. It also leads to additional energy-efficiency gains.

**TXV location**

Figure 3 shows the location of the thermal expansion valve in an air conditioning system.

*Figure 3*



# TXVs and R-410A applications

## Changes to original designs

The first TXVs used in systems with R-410A refrigerant were based largely on platforms originally designed for older systems using R-22 refrigerant. To make these valves suitable for R-410A, the most common design changes were aimed only at meeting higher mechanical-strength requirements. Typical changes included:

- Increasing power-element thickness
- Adding diaphragms to the power element
- Modifying the sensing-bulb charge to suit R-410A temperature/pressure characteristics

## Designs not optimized

Although these changes made the TXVs suitable for use with R-410A systems, the performance of these valves was not **optimized**, which resulted in compromised system performance.

## New optimized design

Due to the need for an optimized TXV for use with R-410A refrigerant, Emerson has developed the first TXV designed specifically for R-410A. The C-Series TXV is a performance solution for residential and light commercial R-410A applications.

# Characteristics of Emerson® C-Series Thermal Expansion Valves
## Optimized control for R-410A pressure-temperature curve

### Unique operating characteristics of R-410A

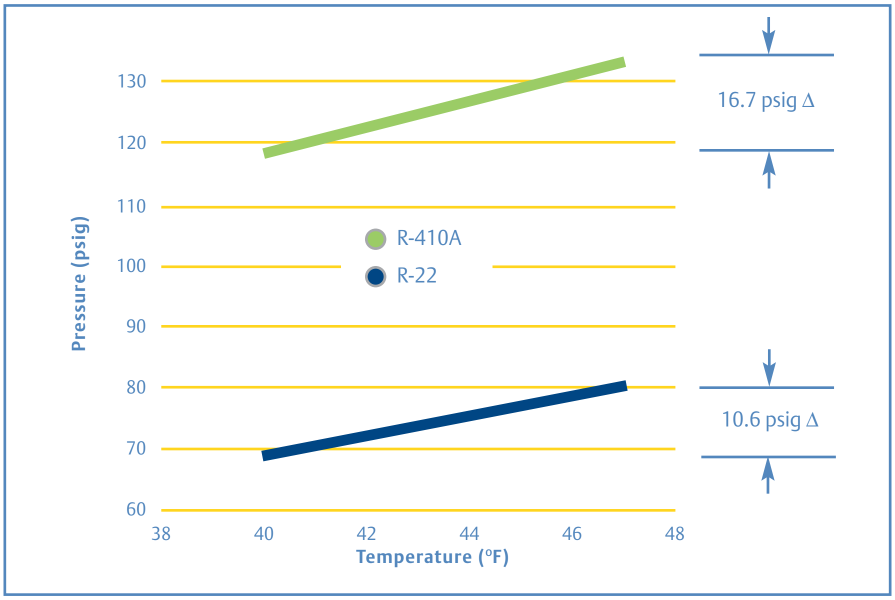
The unique characteristics of the R-410A refrigerant were the key consideration in the design of the C-Series TXV. These characteristics include operational pressures typically 50 percent higher than R-22. Most existing TXV designs are adequate for these higher pressures; however, another characteristic of R-410A, the pressure-temperature curve, requires significant attention in the design of the TXV, to ensure that the system operates efficiently. The pressure differential for R-410A refrigerant at normal evaporator operating temperatures (40 degrees Fahrenheit to 47 degrees Fahrenheit) is about 16.7 pounds per square inch gauge (psig), versus about 10.6 psig for R-22.

### Pressure-temperature curves comparison

Figure 4 compares the pressure differentials (or pressure-temperature curves) for R-410A and R-22.

*Figure 4*

**Pressure Differentials for R-410A and R-22**

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## Optimized control for R-410A pressure-temperature curve (continued)

### Problems with other TXVs

TXVs that were originally designed for the R-22 pressure-temperature curve will respond too quickly to changes in evaporator temperature and pressure, when used with R-410A.

This fast-response characteristic typically leads to superheat hunting. When the evaporator superheat is unstable, a lack of heat transfer from the incoming air to the coil leads to longer run times – to satisfy the thermostat settings – and loss of system efficiency.

### Performance benefits of C-Series TXV

The C-Series TXV, designed specifically for R-410A applications, will have faster evaporator pulldown and more stable superheat, keeping the optimal amount of liquid refrigerant in the evaporator during operation. Having the optimal amount of refrigerant in the coil makes the transfer of latent and sensible heat from the incoming air to the coil much more efficient.

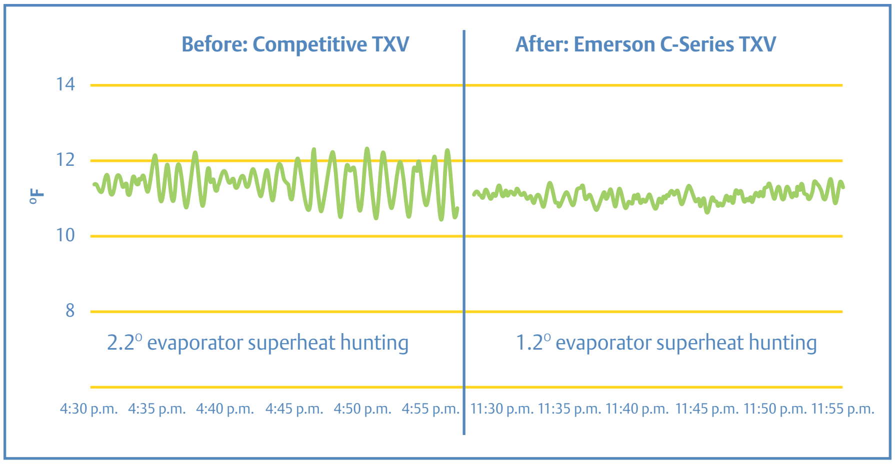
Due to these efficiency gains, original equipment manufacturers (OEMs) may be able to design systems with smaller coils or less system charge.

### C-Series TXV versus other TXVs' superheat control

Figure 5 compares superheat stability on a five-ton indoor coil, before and after the originally specified TXV was replaced with a C-Series TXV.

*Figure 5*

**C-Series TXV Superheat Stability**




### Compressor protection

In addition to the performance benefits, tighter evaporator superheat control ensures consistent superheat at the compressor inlet, preventing damage that can result from incondensable liquid's and/or high-temperature gas's entering the compressor.

# Improved internal check valves for greater system efficiency

## Introduction

A key consideration when designing a TXV for split-system heat-pump applications is the performance of the internal check valve.

## How check valves function inside TXVs

On the indoor coil, check valves are closed in cooling mode and open in heating mode, to allow reverse refrigerant flow through the TXV. These check valves must have low seat leakage, for good Coefficient of Degradation ($C_d$) performance, and must flow freely when the flow is reversed, to maintain system capacity and efficiency.

## Design options

There are various check-valve designs in service: Some use check balls; some use plungers with o-ring seals; and others incorporate nylon slides that act as check mechanisms. The C-Series TXV has a patent-pending check-plate design that is more temperature, chemical and wear resistant than competing designs. Most important, it has 60 percent more flow at a two psig pressure drop than the nearest competitive model.

## Increased system efficiency

The potential benefits of maximizing flow (or reducing pressure drop) through the TXV's check valve are increased system efficiency and reduced applied costs. Some heat pumps feature external check valves, to maximize refrigerant flow around the TXV in an effort to improve system efficiency. Laboratory tests have shown that SEER gains of 0.5 are possible, when replacing the competitive TXV and the external check valve with a C-Series TXV with internal check valves.

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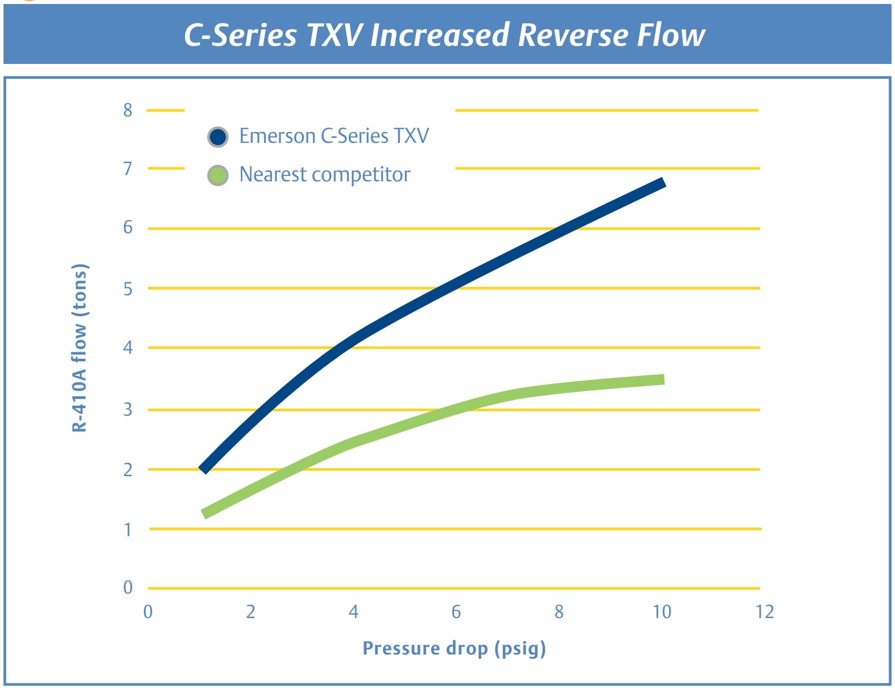
# Improved internal check valves for greater system efficiency (continued)

**C-Series TXV vs. nearest competitor's**

Figure 6 shows that the Emerson C-Series TXV provides increased reverse flow, which contributes to increased system efficiency.

*Figure 6*




**Reduced costs**

Using a C-Series TXV may help OEMs reduce applied costs. As previously discussed, due to its increased reverse-flow capacity, the C-Series TXV may eliminate the need for external check valves. In addition, the increased reverse-flow capacity, in combination with the C-Series TXV's superior superheat control, may allow OEMs to use less indoor and outdoor coil and less refrigerant.

# Improved TXV reliability

## Reliability expectations

In addition to designing a TXV tailored to the unique pressure-temperature characteristics of R-410A refrigerant and incorporating check valves with greater reverse-flow capacity, it is essential that the TXV be reliable. Due to increased usage of TXVs, there is greater focus on reducing first-year failures in the field. It is the industry expectation that factory-installed TXVs last for the life of the system.

## Most common failure mode

The most common failure mode found in field-returned TXVs is loss of power-element charge, which causes the system to lose cooling capacity. Typically charge is lost when it leaks out of the various brazed and crimped joints in the sensing-bulb tube or from cracks in the diaphragm.

## Preventing loss of power-element charge

Proper TXV design and manufacturing processes can affect the sensing-bulb assembly's leak resistance and the diaphragm's fatigue resistance. The loss of power-element charge through the sensing bulb's various joints can be addressed through the proper design of brazing, crimping and charge-leak testing processes. In addition, automated brazing processes used in the assembly of the C-Series TXV minimize porosity and metallurgical changes in the copper, to help prevent charge leaks.

In addition to taking steps to prevent charge leaks from occurring, TXV manufacturers can take strides to improve detection of charge leaks, by installing equipment that detects primary power-element charge constituents, rather than trace gases added for leak-detection purposes.

## Preventing fatigue failures

A comprehensive test of competitive TXVs and finite element analysis has reinforced the proposition that TXVs with embossed (convoluted) diaphragms, such as the C-Series TXV, are less susceptible to fatigue failures. The convolution effectively moves the diaphragm's flex points farther away from the heat-affected zone of the power element's weld joint.

In addition, the size of the heat-affected zone is directly attributed to the type of welding process used. Tungsten inert gas (TIG)- and plasma-welding processes have much larger heat-affected zones than laser-welding; thus, TIG- and plasma-welding processes theoretically yield lower reliability results than laser-welding.

## Computerized manufacturing process controls to improve quality

### Introduction

To ensure the initial quality of complex control devices like TXVs, manufacturing processes must be designed to eliminate variation in key valve characteristics.

### Problems with conventional processes

Conventional TXV manufacturing processes tend to be dependent on the operators to install the correct parts, use the correct test parameters and apply the correct labels to the valve. Operator-dependent processes create more variation in valve performance, more OEM line rejects and higher first-year field service claims than are tolerable in today's business environment.

### C-Series TXV manufacturing process controls

The C-Series TXV manufacturing process is electronically controlled and integrated, to minimize the impact that operators have on outgoing quality. Critical steps in manufacturing processes include seat-leak testing, charge-leak testing and static-superheat setting. These steps and others are controlled by a fully integrated serialized numbering system that automatically inputs test parameters to the equipment, based on each TXV's unique specifications.

This serialized numbering system ensures that critical operations on each valve are successfully completed, before applying the product information to the power element.

### Automatic quality verification

At the end of the manufacturing process, the integrated database system confirms that the valve has passed all critical operations and quality checkpoints. Only if all checkpoints are passed is the product information laser-marked onto the power element. The laser-marking becomes each valve's seal of quality.

## Conclusion

### Improved system efficiency

Improvements in superheat control and internal-check reverse flow on Emerson C-Series TXVs are leading to real-world HVAC system-efficiency improvements. More stable superheat is conducive to more efficient heat transfer. Additionally, higher flow rates (lower pressure drop) through the internal check valve increase overall system efficiency.

### Improved reliability

Design and manufacturing technology improvements used in the Emerson C-Series TXV yield more reliable product with fewer OEM line rejects and field claims.

### TXV selection considerations

TXVs will continue to be a critical component of HVAC systems, beyond 13 SEER and the 2010 conversion to HFC refrigerants. OEMs and contractors alike should be aware of the available TXV options, as well as which TXVs have the best overall design and manufacturing to yield optimal performance and reliability, ensuring success in today's high-SEER R-410A environment.

# About Emerson Climate Technologies

**HVACR solutions leader**

Emerson Climate Technologies, a business of Emerson, is the world's leading provider of heating, ventilation, air conditioning and refrigeration solutions for residential, industrial and commercial applications. The group combines best-in-class technology with proven engineering, design, distribution, educational and monitoring services to provide customized, integrated climate-control solutions for customers worldwide. Emerson Climate Technologies' innovative solutions, which include industry-leading brands such as Copeland Scroll and White-Rodgers, improve human comfort, safeguard food and protect the environment. For more information, visit **EmersonClimate.com**.

**Emerson Climate Technologies Flow Controls Division**

Emerson Climate Technologies Flow Controls Division is a leading manufacturer of valves, controls and system protectors commonly applied in air conditioning and refrigeration systems worldwide. The company continues to pioneer the control of refrigerant flow through innovative, high-performance components, such as thermal expansion valves and filter driers. Emerson Climate Technologies Flow Controls Division is headquartered in St. Louis. For more information, visit **Emersonflowcontrols.com**.

**Emerson C-Series TXV**

The C-Series TXV is the first in the HVACR industry designed and optimized specifically for use in R-410A systems, making it critically important as the industry moves closer to 2010, the deadline for eliminating production of new systems designed for R-22 and other HCFC refrigerants. The C-Series TXV features the most precise superheat control in the industry, resulting in greatly enhanced compressor protection. This and other benefits stem from Emerson's leading-edge manufacturing process, resulting in a high-performance, extremely reliable thermal expansion valve optimized for R-410A. When combined with the award-winning, contractor-preferred Copeland Scroll® compressor, the C-Series TXV becomes a critical element in the industry's most energy-efficient R-410A systems.

**For more information**

For more information, visit **Emersonflowcontrols.com**.

# About the authors and contributors to this paper

## Authors

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Al Maier has over 30 years of refrigeration systems and components design experience. He is vice president of application engineering for Emerson Climate Technologies Flow Controls Division (formerly Alco Controls) in St. Louis, Missouri. He has held several positions at Emerson Climate Technologies, Inc. (formerly Copeland Corporation), including director of application engineering, general manager of Integrated Products and engineering manager of Integrated Products. He has an associate's degree in electronics technology from the Academy of Aeronautics and a bachelor of science degree in engineering from Long Island University. He is a member of ASHRAE (American Society of Heating, Refrigerating & Air Conditioning Engineers) and chairman of the engineering committee of ARI's (Air-Conditioning and Refrigeration Institute) valves and accessories section.

### John Klein

John Klein holds a bachelor of science degree from Southeast Missouri State University and a master of business administration degree from Webster University. He has over 10 years of quality, manufacturing and application engineering experience, including five years of experience in the air conditioning and refrigeration industry. He has worked closely with suppliers and customers in quality assurance, and more recently in an application engineering role. He is also an associate member of ASHRAE, a Six Sigma Black Belt and a certified quality engineer through ASQ (American Society for Quality). While at the Flow Controls Division, he has participated in several product launches and product improvement initiatives, with emphasis on thermal expansion valves. He is responsible for technical support of all Emerson flow controls products for major air conditioning OEM accounts.

## Contributors

### Austin Childs

Austin Childs is currently vice president of engineering for Emerson Climate Technologies Flow Controls Division. He has over 18 years of industry experience, designing and leading design teams to create new HVAC products. Prior to his current role, he spent 15 years at Emerson Climate Technologies, Inc. – Air Conditioning Division on scroll- and reciprocating-compressor design projects. He graduated from Ohio Northern University with a bachelor of science degree in mechanical engineering and a master of business administration degree from Xavier University.

### Christine Li

Christine Li has 13 years of experience in the HVAC industry and has worked in the United States, Canada, New Zealand and China. She has been a product design engineer for the Flow Controls Division since 2005. She was the primary design engineer for the C-Series TXV product launch. She has a bachelor's degree and a master's degree in engineering in HVAC and refrigeration from Xi'an Jiaotong University in Xi'an, China.

### Chris Schroeder

Chris Schroeder graduated from Iowa State University with a bachelor of science degree in mechanical engineering and from the University of Iowa with a master of business administration degree. He has 20 years of experience in the HVACR industry and has held positions in design engineering, application engineering and product management. He is the business unit leader for Emerson's TXV platforms, leading the C-Series TXV development project. He is also responsible for the management of global TXV product platforms. During his career, he has presented on various industry topics at Gas Appliance Manufacturers Association (GAMA).

### George Sciuto

George Sciuto is the manager of thermal expansion valve engineering for Emerson Climate Technologies Flow Controls Division and has 28 years of experience with Emerson, in various aspects of HVAC. He has held several positions in system-protector product engineering. He has also been involved in the design and development of regulators, solenoids, ball valves and TXVs. A member of ASHRAE since 1989, he was involved in the development of ASHRAE Standard 63.2. He also holds several patents related to system protectors. He has a bachelor's degree from Webster University in St. Louis.

*About Emerson*

Emerson (NYSE: EMR), based in St. Louis, is a global leader in bringing technology and engineering together to provide innovative solutions to customers through its network power, process management, industrial automation, climate technologies, and appliance and tools businesses. Sales in fiscal 2006 were $22.6 billion. For more information, visit **emerson.com**.

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