

Simplify CO₂ refrigeration management with an integrated control strategy

How key CO₂ system control networks deliver smooth performance and simplify management for end users and technicians.





Abstract

As the U.S. food retail industry accelerates its transition to lower-global warming potential (GWP) refrigerants, CO₂ refrigeration is quickly emerging as an increasingly viable path forward. Delivering a combination of low GWP, energy efficiency and reliability, CO₂ transcritical booster (TCB) system technologies offer centralized and distributed strategies for achieving retailers' next-generation sustainable refrigeration goals.

Compared to legacy hydrofluorocarbon (HFC) refrigerants, CO₂ (or refrigerant name R-744) has higher operating pressures and unique performance characteristics that may be unfamiliar to end users and their service technicians. Proper CO₂ system management requires a connected control ecosystem capable of integrating — and to a significant degree, automating — system operation and management of:

- Medium- (MT) and low-temperature (LT) loads and suction group superheat
- Flash tank pressures, high-pressure valves (HPVs) and bypass gas valves (BGVs)
- Case and/or evaporator performance management
- Subcritical and supercritical (aka transcritical) operational modes
- Adiabatic gas cooler, parallel compression and other energy optimization strategies

Although an increased reliance on electronic controls may be a new concept to some technicians, it is becoming a standard part of modern refrigeration system design and emerging refrigerant architectures. For those who may

be unfamiliar with this approach, it's important to understand the individual pieces of these critical control ecosystems and how they work together to simplify CO₂ TCB system startup, management and overall performance tuning. Key components of this control ecosystem include:

- System supervisory control
- High-pressure regulation and control of HPVs and BGVs
- Built-in capacity controls and compressor diagnostics
- Case controllers
- Leak detection sensors and devices

Recent advancements in CO₂ control technologies are providing the seamless integration of these components to enable holistic system visibility and application simplicity. This white paper will explore the key components of a CO₂ TCB control ecosystem and explain the important role each piece plays in building a connected network that is designed to help end users and their service technicians simplify CO₂ TCB system ownership, operation and maintenance — while helping to ensure optimum system performance.

Supervisory system control

As the centralized hub of a CO₂ TCB controls ecosystem, a CO₂-specific refrigeration system control platform performs a multitude of key supervisory functions. Its primary task is to integrate all system compressors, valves, case controllers and electronic components to provide:

- System-wide connectivity, communication and holistic visibility
- On-site and remote system management interfaces
- Adaptive machine-learning algorithms that continually fine-tune system performance

For retailers, the supervisory system control gives them peace of mind knowing that the refrigeration system will manage itself with little to no intervention. For technicians, this essential component gives them visibility to all moving pieces, parameters and performance characteristics while providing a robust toolset for CO₂ system management:

- Direct, guide and control startup sequences and procedures.
- Take corrective action on errant system pressures.
- Keep all sections of the refrigeration system operating in balance and at optimal pressures.
- Automate refrigeration load control.
- Stay informed of system performance faults with notifications and alarms.

A supervisory system control helps technicians streamline commissioning and startup procedures whether they're on-site or monitoring from a remote location. Unexpected power failures or planned maintenance require system shutdown and startup protocols that just follow a specific sequence of events. For example, CO₂ supervisory system control guides technicians through MT and LT compressor staging and helps them bring refrigerated cases back online in a reliable, predictable manner.

Adaptive, built-in and self-learning algorithms help stabilize operation and continually refine system performance. As the system transitions from subcritical to supercritical modes of operation with changing ambient temperatures, the supervisory system control automates the regulation of system pressures and the implementation of energy optimization design strategies.

With a supervisory system control at the helm, connectivity and communication among supporting system controllers enable seamless control network integration, as is explained in subsequent sections of this paper. This gives technicians visibility to case temperatures, superheat and defrost, high-pressure management and compressor performance.

This built-in control network connectivity supports proactive alarming and notification procedures, giving end users, technicians and support teams access to the system-level data they need to stay informed and take preemptive actions. For maximum effectiveness, alarm settings are customizable per user role and specific system configurations of each installation.

Copeland E3 supervisory control: Designed for CO₂ applications



The E3 for CO₂ applications is designed to seamlessly integrate control networks to provide a full range of CO₂ system management capabilities, plus essential customization, configuration and advanced data science techniques.

Touchscreen or remote interface — Provides detailed, real-time, system-wide visibility via on-site touchscreen display or remote, web-enabled access.

Customization — Supports multiple end user profiles to give end users and technicians access to the system-level management and control functions they need.

Floorplan views — Deliver centralized overview and clear visualization of all refrigeration circuits and cases, access to case control network drawings and ability to exercise supervisory system control from one screen.

Smart alarms — Streamline alarms and notifications of system status and pressure warnings, leveraging machine-learning algorithms to detect system anomalies before they become larger issues.

- Enable end users to stay aware of emerging system issues that may impact food quality and safety.
- Guide technicians of all skill levels through issue resolution with contextual prompts that simplify troubleshooting and diagnostics.
- Support the creation of custom, pre-defined messages for individual installation and application requirements.

Holistic control — Integrates with all Copeland and many third-party CO₂ system controllers (i.e., adiabatic gas cooler controller) and provides supervisory control over HVAC, lighting and an entire facility's equipment ecosystem.



High-pressure controller and valves

Managing CO₂ pressures in various sections of the refrigeration system is a key function of the control ecosystem, and the high-pressure controller plays a central role in this task. It helps to regulate system pressures and the performance of related components — including gas cooler operation, flash tank, HPVs, BGVs and EEVs — and coordinate compressor staging.

Integration with these key pressure-management components provides visibility to gas cooler outlet temperatures, flash tank BGV and HPV positions (e.g., percentage open and historic performance), and pressure control. Thus, the high-pressure controller contributes to the regulation of a system's MT and LT circuits, as well as supporting leading sustainable design strategies, such as:

- Parallel compression
- Dual heat recovery
- De-superheater



Compression control and VFDs

Onboard compressor protection and diagnostic electronics, combined with variable frequency drive (VFD) control over compressor racks, are integral to CO₂ TCB system operation. Compressor electronics have advanced to provide protection, diagnostics and connection with the supervisory system control. Within a connected control ecosystem, this enables visibility to compressor and rack performance data, such as compressor discharge temperature, current and fault history.

The integration of VFDs with compressors helps to optimize CO₂ TCB system performance and maximize energy efficiencies, but these VFDs must be designed to

support the high startup currents and high pressures native to CO₂ systems. Pre-configured communication protocols help to simplify setup, provide access to system data — such as fault codes, running amperage, voltage and setting parameters — and enable VFD management from the supervisory control.

For example, Copeland VFDs, EVM/EVH series have many built-in features designed to support CO₂ refrigeration technicians:

- Bluetooth communication and onboard web server enable virtual, on-site access to control settings via connectivity to a smartphone or field device.
- Quick start menu enables application setup within minutes.
- Built-in system control functions support basic controls such as temperature sensors and setpoints.

Technicians can also consult the Copeland Mobile app for VFD and compressor-related information:

- See recommended pairings of Copeland compressors and VFDs.
- Check product availability and locate a local distributor.
- Access a library of application/engineering bulletins.



Case controllers

A connected network of case controllers is essential for helping end users maximize food quality and safety and provide the optimized control they need to meet their sustainability goals. Case controllers communicate with the supervisory system control to provide visibility to a case's operational parameters, alarm status and evaporator performance data. For retail end users, this enables:

- Micro-management of individual cases
- Macro-management of case network and system-level performance
- Optimized suction pressures to drive energy savings
- Reduced labor requirements by eliminating mechanical expansion valve adjustments

Recent advances in CO₂ case controller technologies enable control network communication while providing streamlined temperature, superheat and evaporator pressure management in refrigerated display cases and walk-in boxes.

For example, the Copeland CC200 is a microprocessor-based, stand-alone case controller that integrates with the E3 and is designed to provide smooth case control, consistent suction pressures and improved temperature precision in CO₂ systems.

The CC200 is among the next generation of case controllers designed to support low-, medium- and dual-temperature refrigerated cases, while simplifying every aspect of CO₂ case management:

- Lighting, evaporator fans and defrost heaters
- Liquid line solenoid valves (LLSVs), stepper valves and pulse-width modulated (PWM) valves
- Integrated electronic evaporator pressure regulator (EEPR) control
- EEV control algorithms keep superheat stable and air temperature on target for CO₂ evaporators
- Control PWM and stepper expansion valves from one device
- Manage CO₂ high-pressure shutdown and restart timer sequence
- Support multiple CO₂-rated evaporator pressure transducer ranges
- Integrate seamlessly with E3 for CO₂ applications or as a stand-alone device

For technicians, having visibility to case- and network-level performance is essential for monitoring, diagnosing and troubleshooting system performance issues. The CC200 provides a range of capabilities specifically designed to support technicians' and retailers' concerns.

- Adaptive superheat algorithms provide continuous control improvements throughout the system lifecycle.
- Demand defrost feature adapts to operate precisely when needed — during periods of high-ambient temperatures, humidity or door-opening traffic — saving energy compared to schedule-based strategies and avoiding costly service calls.
- Plug-in expansion modules accommodate up to three evaporator coils per case, eliminating the need to run separate wiring for power and communication.
- Bluetooth enables remote connectivity and integration with the supporting mobile app for remote diagnostics and troubleshooting.

The seamless integration of the E3 and CC200 delivers additional capabilities and operational benefits to end users and technicians:

- Access to all CC200 parameters, alarms and the abilities to perform manual defrosts and override valves

- Visibility to each individual CC200 case temperature, pressure, valve, superheat and I/O point — with the option to graph datasets
- Onboard current transducer (CT) — which is built into the CC200 fan relay circuit — enables current monitoring of evaporator fan motor and delivers fan motor failure alarms to the E3.
- Dedicated defrost heater CT input facilitates current monitoring of the evaporator defrost heater and provides defrost heater failure alarms to the E3.



Leak detection

Although R-744 has a GWP of 1, system leaks can cause a variety of potential performance and safety issues. CO₂ TCB systems must be designed for early identification of leaked refrigerant in each system section, especially those near enclosed and/or occupied spaces, such as racks in machine rooms and walk-in coolers and freezers (WICFs) used by staff.

For retailers, minimizing leaks is essential for achieving optimum performance, maintaining accurate system pressures, preserving refrigerant charge, and reducing Scope 1 GHG emissions. In addition, effective leak detection helps retailers meet their daily operational goals:

- Maintaining accurate setpoints
- Avoiding product loss and degradation
- Maximizing energy efficiency
- Minimizing refrigerant replacement costs

Technicians need to be notified immediately of leaks to prevent pressure fluctuations, loss of charge and the potential for system faults. To enable system-wide visibility to refrigerant leaks, leak detection sensors and equipment must be integrated into the control ecosystem and communicate with the supervisory system control.

Individual leak detection devices should have alerting capabilities that issue audible alarms (horns) and/or trigger flashing lights to indicate the detection of refrigerant at a designated parts per million (PPM) setting. Because R-744 is heavier than air, leaks will begin to gather near the ground level. Thus, leak detection sensors should be located near the ground level.

Copeland leak detection devices facilitate seamless connection to the E3 control, which includes native functionality to perform a variety of related system safety management functions:

- Generating alarms
- Enabling early detection of slow leaks
- Activating pressure-relief valves in the event of a power outage

Benefits of Copeland control system integration

Complete control system integration is an essential aspect of CO₂ system management and operation. Copeland combines the E3 supervisory control, onboard compressor controls, CC200 case controllers, high-pressure controllers, HPVs, BGVs and EEVs into a seamlessly connected and communicating controls ecosystem. This approach delivers a variety of technician and end user benefits.



- 1. Holistic visibility** — Provides centralized, consolidated views of a refrigeration system and all dynamic parameters impacting performance; removes blind spots; streamlines system management and control; and facilitates troubleshooting.
- 2. Customizable** — Enables flexible control network configurations and end user role designations; supports application-specific optimization, not one-size-fits-all limitations.
- 3. On-site or remote access** — Provides the best of both interface options, allowing off-site experts to guide on-site technicians through diagnostic procedures.
- 4. Automatic or manual control** — Supports hands-off retail operation while enabling the manual controls to help technicians make critical system changes when needed.
- 5. Continuous performance improvement** — Continually fine-tunes system performance via adaptive, self-learning algorithms; improves equipment reliability, temperature stability and energy efficiency.
- 6. Single-source simplicity** — Streamlines control system components under the Copeland brand to ensure maximum compatibility, communication and resulting data-driven insights.



Connected controls meet retail sustainability goals

Much more than simply a CO₂ TCB refrigeration system control, the E3 is a fully functioning energy management system (EMS) designed to help retailers meet their sustainability goals — in individual stores and across the enterprise.

Heat reclamation

To maximize the sustainability potential of CO₂, the E3 and the high-pressure controller enable retailers to deploy heat reclaim strategies in their facilities for a variety of purposes, such as HVAC, hot water and concrete slab heating. Systems can be designed to control and manage system pressures to regulate the intensity and volume of heat — continually adjusting gas cooler head pressures to optimize the coefficient of performance (COP) and help to produce the most optimal BTU/W ratio.

Energy and enterprise optimization

By integrating the E3 with Copeland's Connect+ enterprise management software, retailers can implement energy optimization programs across their network of stores. The E3's communication capabilities enable retailers to turn their facilities into grid-interactive buildings (GIBs), participate in demand response arrangements with local utilities, and even leverage multiple GIB locations to operate as a virtual power plant — all of which work toward lowering energy costs and increasing sustainability across the enterprise.

With Connect+, retailers can identify which stores are exceeding their corporate energy efficiency standards and address the outliers:

- Quickly view which stores are using too much energy based on historical models.
- Prioritize and rank those stores by severity.
- Drill down into individual stores to identify root causes of excess consumption.
- Expedite the abilities to evaluate issues and perform corrective actions as needed.

In addition to energy optimization, the E3 and Connect+ support a variety of enterprise retail operational goals, including:

- **Food quality and safety** — Optimize system performance via continuous commissioning and setpoint management, alerting retailers when temperature deviations are occurring.
- **Condition-based maintenance** — Monitor equipment conditions in real time to detect trends and performance anomalies; limit unnecessary maintenance calls and prevent failures.
- **Responsive issue resolution** — Robust alarm management gives facility managers the abilities to quickly identify issues and prioritize resolution.

Driving sustainability through our commitment to continuous improvement

As more companies implement sustainable refrigeration systems and the adoption of CO₂ refrigeration increases over the next several years, Copeland is committed to the continuous improvement of our CO₂ compression and controls technologies. Our integrated approach to CO₂ TCB system control, compression and high-pressure management products is designed to deliver maximum component compatibility and optimum system performance for end users and technicians — supporting holistic visibility, control and automation to simplify the application of sustainable CO₂ refrigeration.

We will continue to fine-tune our CO₂ control ecosystem around the E3 supervisory control platform, helping our customers to achieve significant improvements in system performance, energy efficiency and ease of use. Over the past few years, we have invested millions of dollars in a CO₂-intensive engineering and research facility, while we continue to leverage a 40,000 square foot innovation center with a fully functioning CO₂ TCB system and supermarket lab. Most recently, we have completed research that explores how climate impacts CO₂ TCB system efficiencies and validates which design optimization strategies are best suited for specific climates.

As we discover new ways to optimize CO₂ system performance and refine our control ecosystems — while leveraging our supermarket lab to help customers validate, test and trial CO₂ technologies — Copeland will continue to upgrade our customers' capabilities and maximize their system investments. To learn more about the E3 and explore our complete ecosystem of connected control products, please visit our website.

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