

# Distributed scroll booster architecture for sustainable supermarket refrigeration

Achieving lower-GWP refrigeration and energy efficiency within a familiar operating footprint

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## Abstract

Global, national and regional mandates are driving significant changes in commercial refrigeration system design to minimize their global warming potential (GWP) and/or total equivalent warming impact (TEWI). Conventional large, centralized direct-expansion (DX) refrigeration systems, which typically utilize large charges of high-GWP hydrofluorocarbon (HFC) refrigerants, are prone to leaks and often suffer from declining system performance over their lifespan. While natural refrigerants like CO<sub>2</sub> (R-744) and propane (R-290) offer ultra-low-GWP levels, they also introduce operational complexities that many food retailers may not be prepared to address. Hydrofluoroolefin (HFO) refrigerant blends — such as R-513A — offer a simpler alternative while providing excellent performance characteristics and much lower GWP than HFCs. When used in emerging distributed booster architectures, R-513A can present a low-charge, flexible alternative to large centralized systems. This white paper will introduce the distributed scroll booster architecture, designed for use with R-513A to deliver significant sustainability improvements and lower lifecycle costs — all within a safe and familiar operating footprint for supermarket owners/operators and service technicians.

### Evolving refrigeration system design criteria

For more than 30 years, the evolution of commercial refrigeration system design has been largely driven by environmental sustainability initiatives. Recent design strategies are typically aimed at lowering the total equivalent warming impact through two approaches: 1) reducing direct emissions from refrigerant leaks, and 2) lowering the system's total energy consumption (i.e., its indirect emissions).

At the same time, many supermarkets are guided by their own aggressive corporate sustainability goals and actively plan for a transition to lower-GWP systems. But this journey introduces new challenges as operators try to find their ideal balance among sustainability goals, system costs and long-term serviceability considerations.

Depending on their unique operational goals and/or regulatory mandates, food retailers and convenience store operators find themselves at widely varying points along the sustainability continuum. Not all supermarket operators are ready to assume the lifecycle costs and service challenges that come with a system operating below 150 GWP. Unlike the past several decades when centralized DX systems were the prevailing architecture used in supermarkets, there currently is no single system architecture that addresses the wide range of sustainability objectives.

Among the leading options for achieving this diversity of system sustainability goals include utilizing lower-GWP refrigerants and deploying lower-charge, distributed systems. Refrigerant alternatives R-744 and R-290 offer ultra-low-GWP levels, but they also come with significant operating caveats and design limitations related to high operating pressure (R-744) and flammability (R-290).

Blends of HFO alternatives, such as R-513A, offer very similar performance characteristics to the low-pressure R-134a — only with a much lower GWP. And since R-513A is classified as an A1 refrigerant, it requires no special safety mitigation strategies in system design.

To support diverse sustainability requirements and the need for refrigeration flexibility, distributed refrigeration architectures are becoming a much-preferred alternative to large centralized DX systems. They support the goals of reducing direct and indirect emissions from refrigeration systems by utilizing reduced charges of lower-GWP refrigerants and system design strategies that maximize energy efficiencies.

### Balancing sustainability and serviceability

Refrigerant choice — a key component of system design — is an important consideration for owners/operators. When evaluating total lifecycle costs, operators must not only factor in the initial equipment investment and installation costs, but also the long-term costs related to maintenance and system serviceability.

Systems that are designed to use ultra-low-GWP refrigerants, like R-744 and R-290, present unique system maintenance and operational challenges. For example, since R-744 is a high-pressure refrigerant used in complex system architectures, operators must have access to qualified service technicians to keep the system running optimally. R-290, which is classified as a highly flammable A3 refrigerant, requires mitigation strategies as well as building and fire code approval from local authorities having jurisdiction (AHJ). R-290's very low charge restrictions also limit its application potential beyond self-contained cases.

R-513A offers a low-pressure, high-performance and high-efficiency alternative to these complexities. Designed as a replacement for R-134a, R-513A is an approved low-pressure substitute with zero glide that has been used in a wide variety of medium-temperature commercial refrigeration applications. With its A1 classification, it provides the lowest possible GWP (573) among available non-flammable refrigerant alternatives and presents no risk of ozone depletion. Compared to R-134a, R-513A provides a 56% reduction in GWP.

For operators and service technicians, R-513A's low-pressure characteristics provide a familiar operating envelope and require no special training, certification or safety mitigation measures. From a system design perspective, it provides the lowest boiling point of any refrigerant like R-134a, giving it more flexibility for use in low-temperature operation than other alternatives in a similar pressure range.

### R-513A: By the numbers

- GWP = 573 — per the Fifth Assessment Report (AR5) of the United Nations Intergovernmental Panel on Climate Change (IPCC)
- 56% GWP reduction compared to R-134a
- 55% GWP reduction compared to R-448A/R-449A
- Ozone depletion potential (ODP) = 0
- ASHRAE A1 safety classification
- Azeotropic blend with zero glide
- Performs well in all ambient conditions

## Distributed scroll booster: Elevating performance and sustainability

A distributed scroll booster architecture is designed for maximum application flexibility and optimized for use with a low-pressure refrigerant like R-513A. Configurations can scale from small, low-charge systems utilizing condensing units to larger systems of distributed racks charged with several hundred pounds of refrigerant (see Figure 1). One design feature that makes this booster architecture unique is its use of a single refrigerant (R-513A) for both low- and medium-temperature refrigeration loads. This approach simplifies system design while maximizing overall efficiencies.

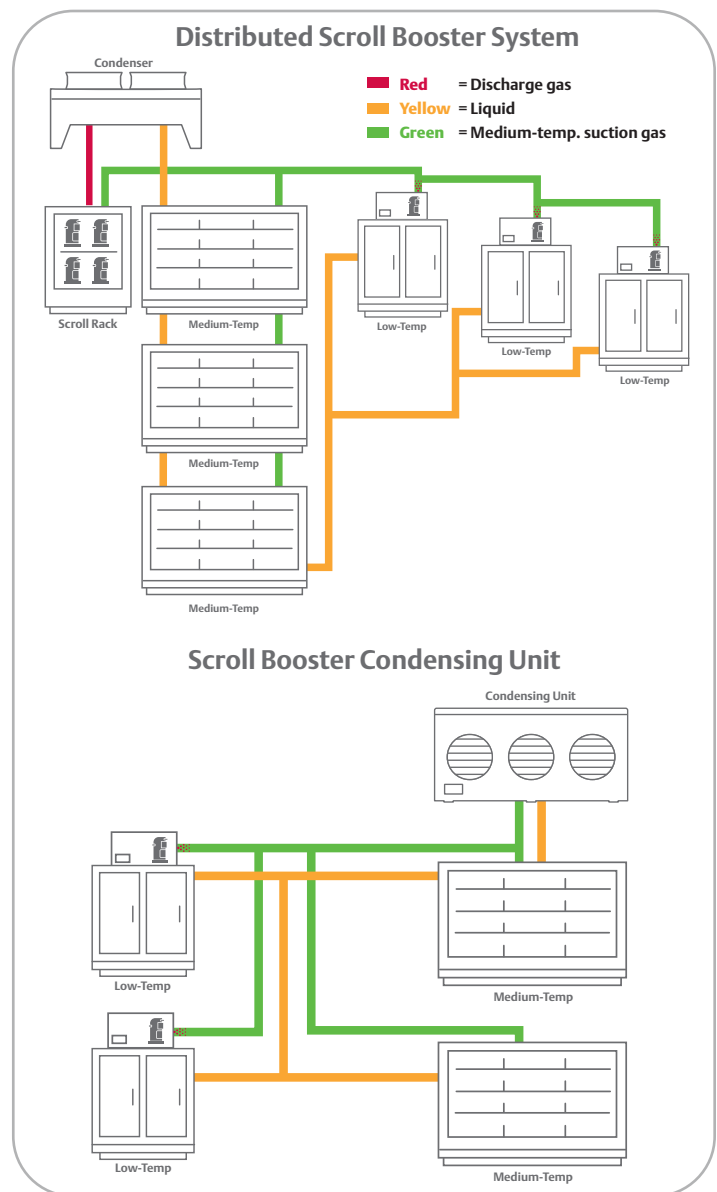


Figure 1: Distributed scroll booster system configurations

## Overcoming low-temperature challenges

Distributed scroll booster technology is designed to overcome the common challenges of operating a low-temperature system, which often include: requiring a compressor cooling strategy such as liquid injection; lowering compressor lifespan due to high compression ratios and discharge temperatures.

Instead, the distributed scroll booster's straightforward architecture leverages the advantages of R-513A's low-pressure, high-efficiency and key system components to provide:

- Lower discharge temperatures and compression ratios: 1.9:1 at -10 °F saturated suction temperature (SST) and 20 °F saturated discharge temperature (SDT)
- Reduced compressor strain and related maintenance issues
- Increased overall system efficiency and lifespan
- Reduced stress on pipes and fittings, which lowers the potential for leaks

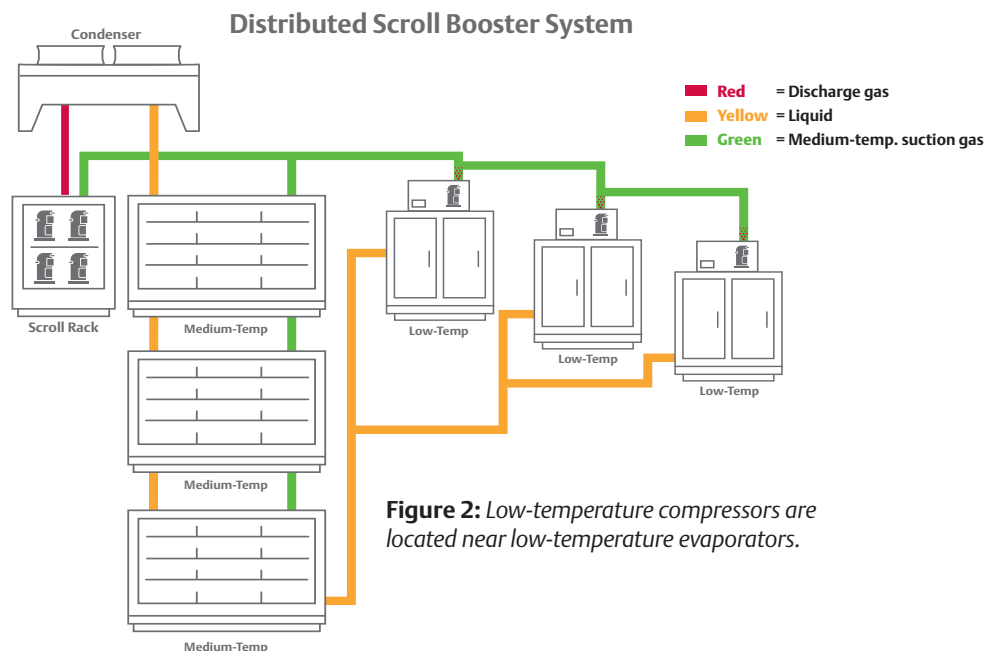
## Mechanics of a distributed scroll booster system

The core of the system is comprised of one or more medium-temperature compressors coupled with one or more low-temperature compressors. Medium-temperature

compressors can either be located within a condensing unit or in a standard rack configuration. Condensers can be located remotely or integrated into the system and placed indoors or outdoors. Low-temperature compressors are placed near the low-temperature evaporators, which helps to reduce refrigerant charge, piping and associated costs (see Figure 2). For example, in supermarket reach-in freezers, this could be directly on top of or beside the case or remotely near the load.

This system design strategy provides a performance boost by discharging the low-temperature compressor directly into the nearest medium-temperature compressor's suction line. The lower discharge temperatures of the low-temperature scroll compressor minimize the suction gas temperature of the medium-temperature unit and allow the medium-temperature compressors to operate within their design limits without the need for additional cooling.

The net result of boosting low-temperature compressors directly into the medium-temperature compressors is an overall system efficiency gain while keeping the mechanical load on the low-temperature compressors very low. Compared to conventional systems, where the low-temperature scrolls are subject to the most demanding high-compression ratios and high-discharge temperatures, the distributed scroll booster system operates at consistently low and predictable values.



**Figure 2:** Low-temperature compressors are located near low-temperature evaporators.

## Distributed scroll booster: Performance analyses

Thermodynamic analyses of a distributed scroll booster system in Los Angeles demonstrate its performance characteristics compared to other supermarket system architectures. Using a centralized DX as the baseline for comparison, Figures 3 and 4 evaluate the annual energy, peak load and lifecycle climate performance (LCCP) of these systems. The loads used for analyses were 100,000 Btu/hr (29.3 kW) for the medium-temperature and 33,000 Btu/hr (9.67 kW) for the low-temperature. SST for the low-temperature is -25 °F (-31.7 °C) and 20 °F (-6.7 °C) for the medium-temperature.

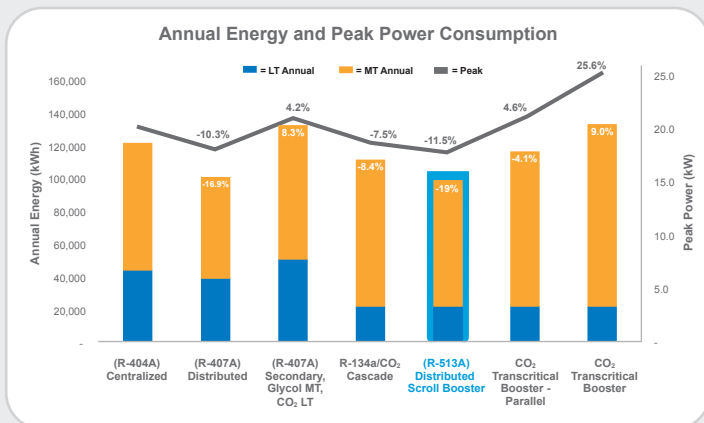


Figure 3: Comparison of annual energy and peak power consumption

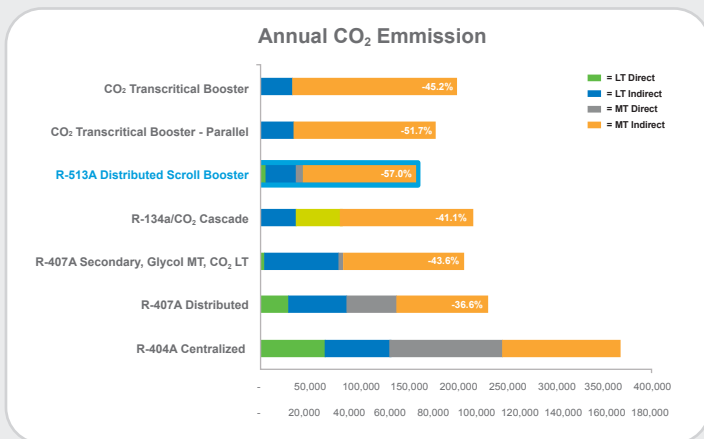


Figure 4: Lifecycle climate performance

## Proof of concept: Gem City Market

The combination of high performance, sustainability and serviceability made the distributed scroll booster an ideal choice for a new small-format supermarket built in a food desert in Dayton, Ohio. The project involved collaboration among the affected Dayton community, city officials and commercial refrigeration industry leaders, who donated their respective expertise and resources to the project.

- **Chemours** — Opteon™ XP10 (R-513A) refrigerant
- **Hussmann** — medium-temperature Protocol™ systems, refrigeration units and display cases with CoreLink, micro-channel condensers, unit coolers and extensive commercial refrigeration expertise
- **Emerson** — Copeland™ scroll compression technology, Copeland scroll booster low-temperature modules, Lumity™ site supervisor facility management control, XM case controls, electronic expansion valves (EEVs) and expertise in distributed scroll booster architecture

The collaboration with Gem City Market stakeholders took place within The Helix Innovation Center, an Emerson facility located on the University of Dayton campus. The team designed a custom configuration of the distributed scroll booster system according to the store's unique footprint, floor plan and refrigeration requirements.

The inherent advantages of the refrigeration system aligned well with the market's financial, operational and environmental sustainability goals of:

- Low-GWP refrigeration
- Long-term energy savings
- Low operating costs
- Familiar servicing footprint

The store opened in spring 2021.

## Conclusion: Wide industry potential and benefits

The unique combination of a low-pressure, low-GWP refrigerant and a simple, distributed architecture based on familiar operating principles fills an urgent need within the larger food retail market. For operators who seek to meet their sustainability goals without introducing unnecessary serviceability complexities, a distributed scroll booster system is an ideal choice.

While its design flexibility lends itself to store formats of varying sizes, its benefits check many key boxes on the list of modern supermarket refrigeration priorities:

- Lower-GWP, A1 refrigerant (R-513A)
- Reduced refrigerant charge
- Lower leak rates due to lower-pressure system
- Lower utility costs
- System familiarity with technicians and end users
- Low total cost of ownership (from lower annual energy consumption and LCCP)
- Secure remote facility monitoring capabilities

In the future, as even lower-GWP refrigerants (such as A2Ls) are approved for use by applicable codes and standards, the distributed scroll booster system can be adapted for use with ultra-low alternative refrigerants (less than 150 GWP).

For more information about the distributed scroll booster architecture, please contact this paper's authors.

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Andre has more than 35 years of industry experience in sales, marketing, training and business development of HVACR system architectures and applications with compression and component technologies. He is a certified Mechanical Engineering Technologist C.E.T. (since 1984), and is a member of AHRI, ASHRAE and RSES.



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Dr. Charles Allgood is the technology leader — refrigerants with Chemours in Wilmington, Del. He currently leads the company's technical support, training and applications development for the Opteon™ and Freon™ refrigerants and is a frequent speaker at many HVACR industry events.

Prior to joining DuPont, he worked as a research chemist for the National Institute of Standards and Technology. He has held a variety of research, technical service and market development assignments during his 25+ years in the refrigerants industry.

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As the vice president of the core and distributed cases product line at Hussmann, Andres Lacassie is responsible for the development and delivery of the company's largest product portfolio, including Insight Multideck, Reach-In, Smart

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Andres earned a bachelor's degree in communication from the University of New Orleans and an MBA in international marketing from the University of Dallas.

## About Emerson

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