Understanding Compressor Modulation in Air Conditioning Applications

The key to addressing capacity and energy efficiency needs.

EMERSON

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Compressor Modulation Overview

CHAPTER One

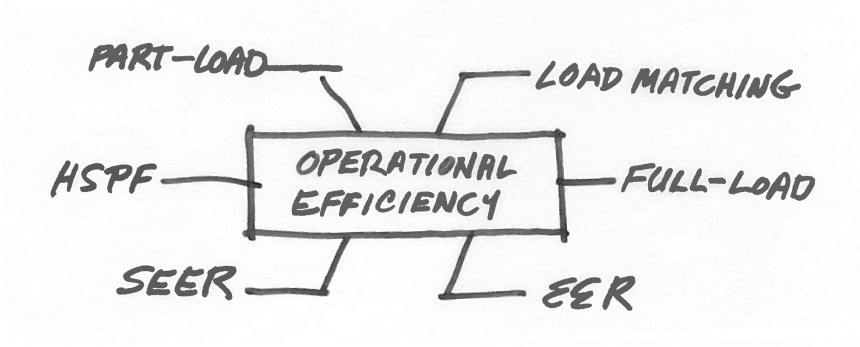
Executive Summary

HVACR compressor manufacturers strive to deliver high levels of efficiency, comfort, and reliability in a market that also demands affordability and compliance with environmental laws. Today a robust combination of regulatory requirements and customer preferences is driving manufacturers to achieve unprecedented levels of compressor efficiency without sacrificing reliability and comfort.

Compressor suppliers have responded to this demand by providing innovative products that can help air conditioning and refrigeration OEMs improve system efficiency through variable capacity technologies where the cooling capacity of the system is tied to the load, not an application's peak requirements. Modulation makes it possible to tailor compressor performance to changes in ambient conditions and system load, eliminating big swings in temperature and relative humidity levels throughout a building.

There are different paths to providing compressors that better meet system needs at less-than-peak conditions. One is by using mechanical methods to reduce the volumetric capacity of the compressor, reducing the amount of refrigerant that undergoes compression, and subsequently reducing the load on the motor, which stays at constant speed. Another approach involves varying the speed of the motor driving the compressor, which then requires some type of motor control electronics.

Although many modulation compressor solutions are already available, standards for air conditioning and refrigeration applications continue to evolve, making new technology enhancements and developments even more important. With this increased flexibility in choosing the particular modulation type that best meets system needs, the industry as a whole can truly benefit from the enhanced comfort, energy efficiency, reliability, and overall system value that modulating compressor technology affords.



Purpose of eBook

As the world's leading provider of heating, air conditioning and refrigeration solutions for residential, commercial and industrial applications, Emerson seeks to educate HVACR contractors and professionals about the latest developments in compressor modulation – how each technology works, the key benefits and the applications for which each is best suited.

The eBook is designed to educate contractors and end-users on the value of compressor modulation and its impact on their overall business. This first chapter will explain why compressor modulation is needed and provide a general overview of the types of technologies available today. The chapters that follow will take a deeper dive into each type of modulation technology with a final chapter on the types of applications for both commercial and residential. The eBook will also provide application examples of this technology and its success in the field today.

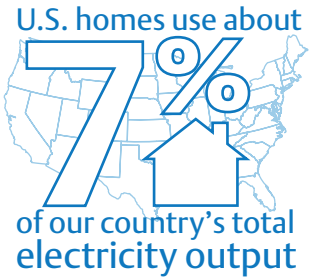
Why Compressor Modulation

Air conditioning units with conventional fixed capacity compressors are typically designed for peak load performance and usually have more capacity than is required for normal everyday usage. These units turn on and off frequently to reduce output under light load conditions. This can cause broad temperature swings and poor humidity control, as well as decreases in efficiency and overall reliability. In response, manufacturers have worked to develop technologies that specifically meet part-load challenges and provide higher efficiency, improved comfort, and better system performance.

Modulating compressor technologies adjust capacity either in stages (65%, 100%), or in a continuous fashion (10-100%) for applications with varying loads or changing ambient conditions. This technology also reduces compressor cycling, achieves higher part-load efficiency, and provides enhanced humidity control at lighter loads, where fixed-capacity systems tend to struggle. This new wave of modulating compressors provides a variety of unique solutions for both residential and commercial air conditioning applications.

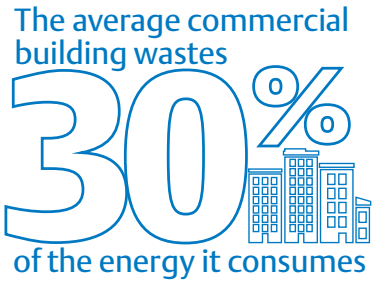
Residential Air Conditioning

The residential air conditioning market in particular continues to face an increasing need for enhanced energy efficiency and improved comfort. According to the U.S. Department of Energy, household air conditioning units in the U.S. use about seven percent of the total electricity produced in the country at a cost to homeowners of more than $22 billion. New tax incentives and utility rebates are making high efficiency systems that contain modulation technology more affordable for homeowners. These incentives have led to steady and increasing adoption of high-efficiency systems, including geothermal systems.



Commercial Air Conditioning

Modulating compressor technologies are also a good solution for the specific challenges facing the commercial air conditioning industry, including precisely managing varying temperature and humidity load requirements in the most efficient manner. As the main power consumer in rooftop systems, compressors account for over half of the system's total energy use, making them a primary target for improvements in efficiency.



Types of Compressor Modulation

While capacity modulation is still growing in adoption, Emerson Climate Technologies has identified four compressor modulation technologies that are helping manufacturers meet capacity and energy efficiency needs:

1. Multiple Compressors
2. Two-stage
3. Continuous
4. Variable Speed

Continuous modulation technology is ideal for applications like movie theaters that experience varying crowds, whether it's a matinee or a sold-out premier.

Multiple Compressors

The simplest delivery of modulation is by using multiple fixed compressors with the capability to operate together or individually, delivering several discrete capacity stages as needed. System capacity can be modulated by using multiple refrigeration circuits or by using multiple compressors in single-circuit systems. In a four circuit system, frequently used in packaged rooftops, individual compressors can be turned on and off to achieve a specific output. In chillers, six to eight compressors is the typical number per unit, which means, depending on the even or uneven combination, up to 12 capacity stages are available to match the load by cycling the compressors on and off.

Modulation Range

Technology	Full Load Efficiency	Part Load Efficiency	Applied Cost	Range
Manifolding	High	High	Medium	3-180 tons

Two-stage

Two-stage modulation is typically used on split and packaged systems under five HP, in which the compressor runs at either 65 percent or 100 percent capacity, depending on cooling/heating demand. This type of modulation offers better temperature and humidity control, improved part-load efficiency, and reduced on/off cycling, providing a highly efficient and reliable option for homeowners.

Modulation Range

Technology	Full Load	Part Load	Applied Cost	Range
Mechanical Unloading	Medium/ High	High	Low	2-5 tons

Continuous

Continuously variable modulation offers a unique way to modulate the capacity of the compressor from 10-100 percent so that the output precisely matches the changing cooling requirements of the space, and it does this without changing the speed of the motor. This approach to capacity modulation is as much as 30 percent more efficient than traditional hot-gas bypass and is capable of holding temperatures to within 0.5˚F.

Modulation Range

Technology	Full Load Efficiency	Part Load Efficiency	Applied Cost	Range
Mechanical Unloading	High	Medium	High	3-15 tons

Variable Speed

Variable speed systems modulate refrigerant flow by varying the speed of the compressor motor. The compressor motor speed determines the rate of refrigerant flow. Therefore, by varying the motor frequency, capacity can be modulated. Capacity output increases and decreases with motor speed.

Modulation Range

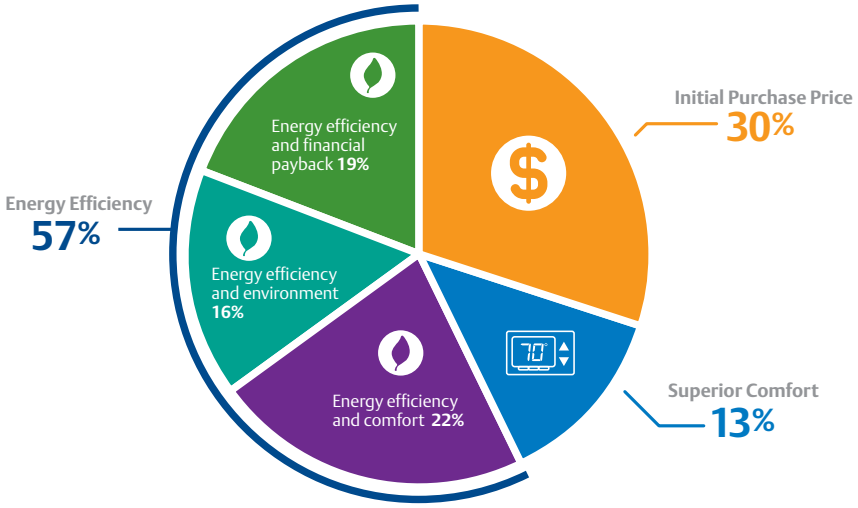
Technology	Full Load Efficiency	Part Load Efficiency	Applied Cost	Range
Speed Control	Medium	Highest	Highest	2-15 tons

Conclusion

In the coming chapters, Emerson hopes to broaden your knowledge of the range of modulation technologies on the market today. Our goal is to provide you with a better understanding of the extended value a higher efficiency product provides in comfort, energy savings and overall system performance/reliability. Your customers will appreciate your expertise in helping them evaluate the initial costs of a premium system vs. a more traditional fixed capacity approach as well.

Consumer research increasingly shows that initial purchase costs are not always the primary determinant of the system selected. The long-term benefits of savings in energy consumption and the short-term benefits of consistent comfort are growing in predominance. This presents an opportunity to introduce customers to new systems approaches, and to realize that products meeting only minimum energy efficiency standards are not their only choice.

Homeowner criteria for HVAC system replacement



Based on an independent survey conducted by Emerson Climate Technologies in 2010.

Two-stage Compressor Modulation

CHAPTER Two

Executive Summary

In the first chapter, we gave a high level overview of the need for modulation technology and the different types. In this chapter, we will take a deeper dive into two-stage modulation.

Two-stage modulation is one compressor technology that is widely used in mid-tier systems with higher SEER ratings, including both traditional air-to-air and water-to-air (geothermal) applications. The Copeland Scroll two-stage compressor from Emerson is ideal for high SEER performance and provides a simple, easy-to-apply solution to enhance system efficiency for both air conditioners and heat pumps. This type of compressor technology is typically used on split and packaged systems under 5 HP for residential and light commercial applications, but has recently expanded into 6-10 HP commercial applications.

Two-stage scroll compressors help reduce the energy consumed by the air conditioning system by operating at two-thirds capacity most of the time, and running at full capacity only on the hottest days – saving up to 60 percent on energy costs when compared with 13 SEER systems. This approach also maintains a more even indoor temperature and lower relative humidity for improved indoor comfort.

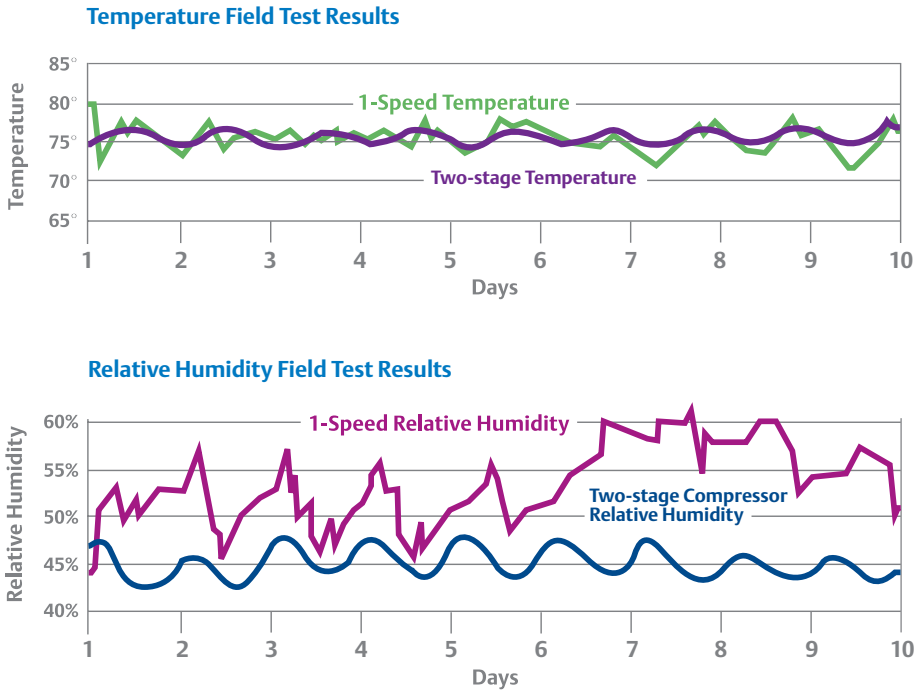
Part-load capacity

Full capacity

Benefits

Improved Humidity & Temperature Control

Typical residential air conditioning systems operate at 100 percent compressor output regardless of load. This leads can lead to short run cycles and increased humidity levels. Systems using a two-stage scroll compressor, normally operate at 65 percent of full capacity, allowing longer run cycles that reduce relative humidity and temperature fluctuations.



Field testing shows improved temperature and humidity control provided by Copeland Scroll two-stage compressors compared to fixed compressors.

As outdoor temperatures rise and demand for cooling increases, the thermostat will detect this and will signal the compressor to shift to 100 percent capacity until the interior temperature set point is reached.

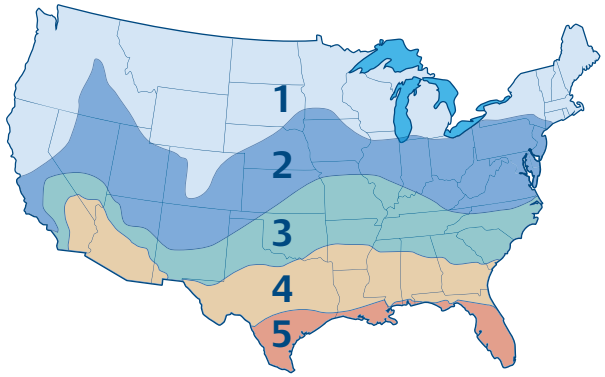
Benefits

Energy Savings

Over 40 percent of summer utility bills can come from operation of the air conditioner compressor. Systems equipped with a two-stage scroll compressor can help save up to 25 percent on energy costs as compared to conventional HVAC systems. With as much as a 200 watt reduction in power consumption, two-stage compressors can better meet market needs for 15-16 SEER systems and full-load EER ratings.

- Optimized for comfort and energy savings
- Excellent part-load efficiency

Cooling Zones



Zone 3 air conditioning energy savings				
	New SEER			
Old SEER	13	14	15	18
6	434	461	484	538
8	233	259	282	336
10	112	138	161	214
12	31	58	81	134

(In dollars)

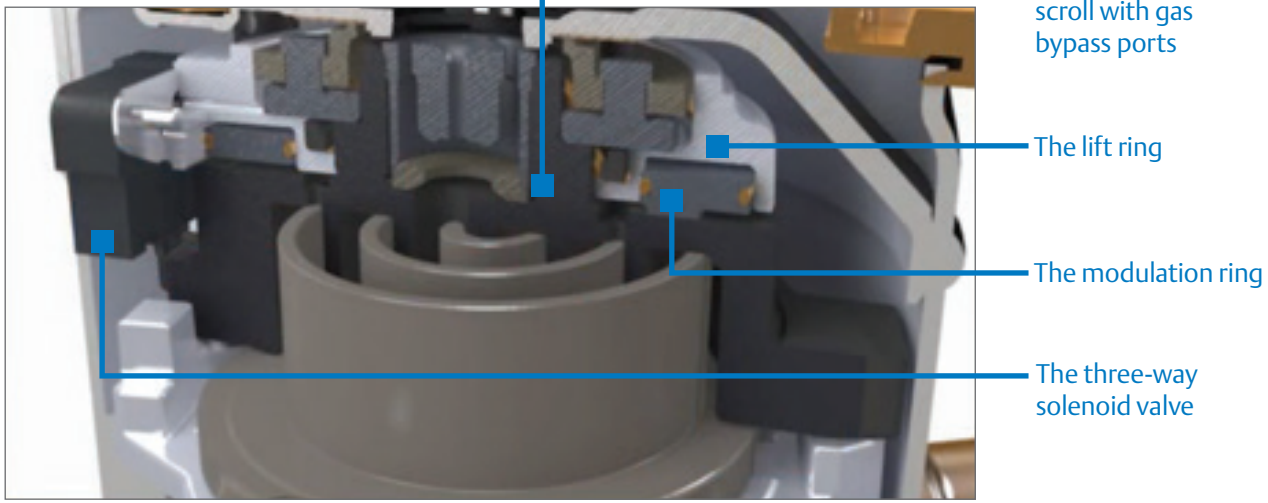
By replacing a 10 SEER system with a high efficiency 15 SEER system, homeowners can save nearly $161, that's 40 percent more than the minimum 13 SEER system.

How it Works

Two-stage modulation adjusts compressor capacity by bypassing a portion of the gas in the scroll back to suction. By doing so the compressor can closely match heating or cooling demand, while reducing energy consumption by up to 25 percent compared to fixed capacity systems. Because the modulating compressor tracks the required load more closely, it also cycles less frequently, decreasing summer humidity levels and increasing comfort.

A two-stage scroll compressor uses internal pressure to actuate the modulation scheme, requiring only a low voltage signal from the thermostat to the controlling solenoid valve on the compressor. When actuated, output shifts from 65 percent to 100 percent capacity to adjust for increased load requirements.

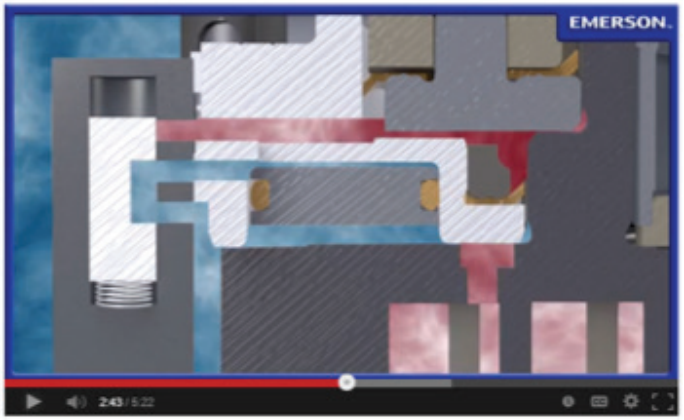
Two-stage compressors include four main components



How it Works

While operating at partial capacity, the solenoid valve is de-energized allowing pressurized gas to enter the left chamber under the modulation ring, raising it vertically. As the ring is lifted, the bypass ports in the stationary scroll are exposed allowing a portion of the gas in the scroll to return directly to suction.

To shift to full capacity, the solenoid valve is energized by a signal from the thermostat, stopping gas from entering the lift chamber and relieving the trapped gas back to suction. When the pressure under the modulation ring is removed, the resulting imbalance forces the modulation ring down onto the stationary scroll locking the bypass ports resulting in full capacity operation.



Conclusion

Precision in humidity and temperature control, coupled with substantial energy savings, make a two-stage scroll compressor a practical choice for many homeowners. With the compressor running at either 65 or 100 percent capacity depending on the need, on/off cycling is reduced and the system delivers superior part-load efficiency that optimizes comfort.

While improved comfort and efficiency are key benefits for all modulation technologies, there are several advantages a two-stage scroll compressor provides in comparison to other modulating technologies.

Advantages of two-stage compressor modulation

Installation Costs	Most cost effective method of modulation for systems under 5 HP
Reliability	Comparable to fixed scroll systems
Efficiency	Enables OEMs to deliver better comfort and SEER at reasonable applied costs
Oil Management	None
Electromagnetic Interference Issues	None

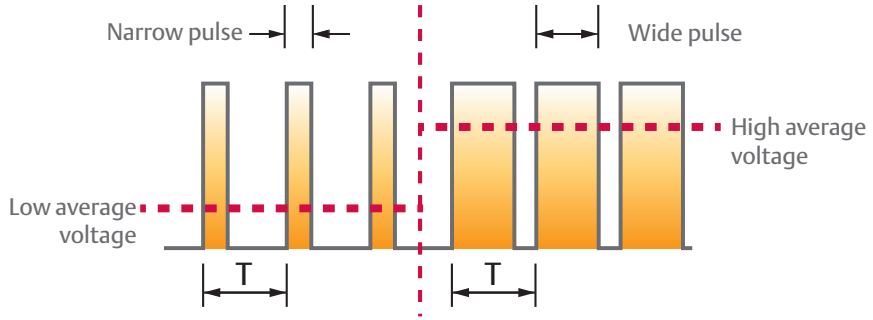
Continuous Compressor Modulation

CHAPTER Three

Executive Summary

Modulating compressor technologies will adjust capacity either in stages or in continuous fashion when compressor loads are varying as well as in changing ambient conditions. The continuously variable modulation is found in scroll compressors with a digital technology known as pulse width modulation, which offers a unique solution for the specific needs of commercial air conditioning applications. This type of technology focuses on providing the highest quality of comfort through temperature and humidity control and provides potential energy savings through operation advantages not measured by Seasonal Energy Efficiency Ratio (SEER) and Energy Efficiency Ratio (EER) rating systems. Comfort is only achieved through power reduction of the compressor in conjunction with power reduction of the fan system, modulating simultaneously.

Pulse width modulation waveform



Modulation is achieved with a cycle time based on Pulse Width Modulation (PWM) control of a solenoid valve that operates a piston fitted rigidly to the upper scroll. The compressor capacity is controlled by modulating the solenoid valve input over time (T).

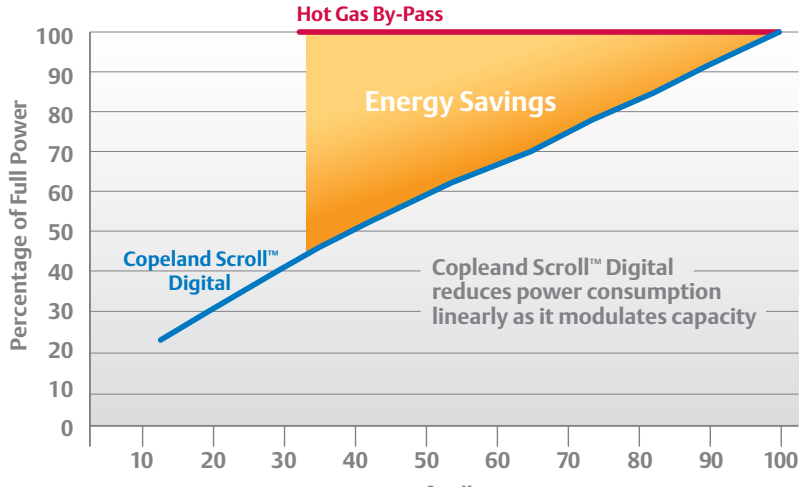
Benefits

With the ability to match varying loads, scroll compressors that utilize digital technology are particularly beneficial for commercial applications that see large daily temperature fluctuations and cooling loads, such as schools, restaurants, and movie theaters. And, because of their ability to maintain precise temperature control, they provide a good solution for applications in hospitals, museums, or telecomm facilities.

These compressors also feature enhanced controls and protection for additional reliability, as well as deliver tighter humidity control. Ultimately, continuous modulation offers improved load matching and provides significant energy savings as compared to hot gas bypass options.

Energy Savings

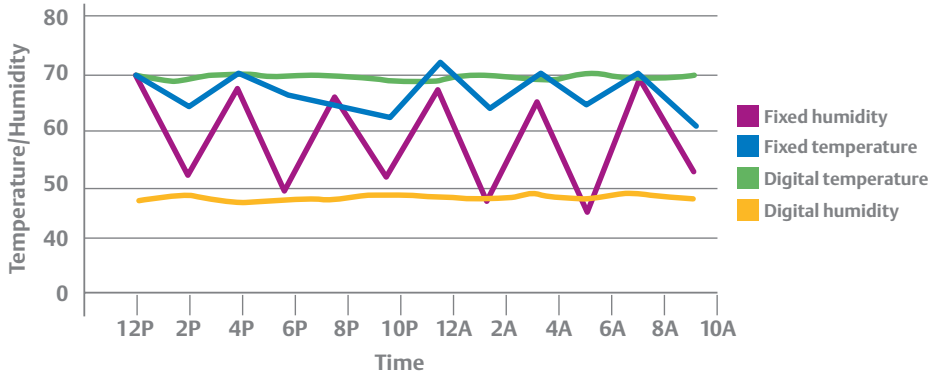
Systems with continuous compressor modulation are intelligent and automatically adjust their energy consumption according to the needs of the application. Field tests show that by using an air conditioning system with this technology, building owners can reduce annual energy consumption by as much as 30-40 percent over traditional hot gas bypass, translating into lower operating costs.



Improved Temperature & Humidity Control

The quick pull down of room temperature and swift adjustment to demands are key factors for customer comfort. Scroll compressors with continuous modulation can adjust from 10 to 100 percent capacity (or vice versa) instantaneously by varying the relative durations of loaded and unloaded cycle times. This means reacting to changes in system demand much faster, without having to pass through intermediate speed changes.

HGBP System Behavior vs. Digital



Systems with digital scroll technology are able to maintain tighter temperatures and humidity levels over fixed capacity compressors.

Improved Reliability

System reliability is a paramount concern for all global markets. Reliability can be a significant challenge due to voltage fluctuations and low availability of training for installation and service technicians. Developing markets can also face challenges with modulating systems due to the increasing use of electronics. Furthermore, the use of various bypasses, such as hot gas bypasses and liquid bypasses, can add another layer of complexity.

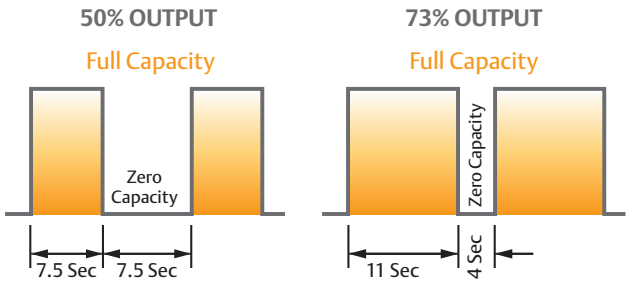
Continuous modulating compressors can be used in a variety of applications, including single-circuit packaged systems or multi-circuit rooftop systems. And, because the compressor offers a capacity range of 10 to 100 percent, it doesn't need to start-stop as often as a traditional compressor, improving overall reliability and reducing maintenance costs.

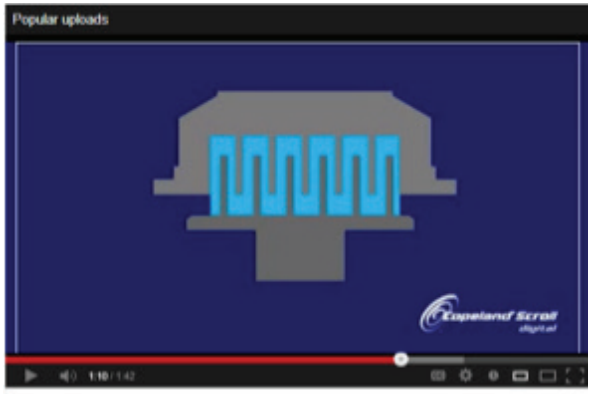
How it Works

A scroll compressor with continuous modulation operates in two stages – the "loaded state" during which the solenoid valve is normally closed, and the "unloaded state" during which the solenoid valve is open. In the loaded state, the compressor operates like a standard scroll and delivers full (or 100 percent) capacity and mass flow. However, during the unloaded state, there is zero percent capacity and no mass flow through the compressor. The scrolls are separated in a periodic cycle to obtain a time-averaged compressor capacity based on the ratio of loading and unloading times.

For example, in a 15-second cycle time, if the loaded state time is 7.5 seconds and the unloaded state time is 7.5 seconds, the compressor modulation is (7.5 seconds x 100% + 7.5 seconds x 0%) 15 = 50 percent. If for the same cycle time, the loaded state time is 11 seconds and the unloaded state time is 4 seconds, the compressor modulation is 73 percent. The capacity is the time averaged summation of the loaded state and the unloaded state. By varying the loaded state time and the unloaded state time, any capacity between 10 and 100 percent can be delivered by the compressor.

Loaded and unloaded state





Conclusion

Including this technology in a product line provides the customer with a unique approach to achieving precision, cooling a given space without resorting to discrete stages or changing the speed of the motor. An ideal replacement for hot gas bypass in commercial applications, continuously variable modulation products are available in single compressors from 3 to 15 HP. In addition, a continuously modulating compressor can be 'tandemize' with a fixed capacity scroll compressor. This combination offers a very simple solution to deliver continuous capacity modulation while providing precise humidity and temperature control.

Advantages of continuous compressor modulation

Modulation Capability	Precise capacity matching capability provides continuous modulation between 10% and 100% capacity, the widest available capacity modulation range available
Temperature Control	Precise and smooth control is achieved, limiting any fluctuations in temperature
Humidity Control	Precise and smooth control is achieved, limiting any fluctuations in setpoint
Efficiency	High system efficiency is obtained by matching capacity with cooling/heating demand
Oil Management	None, since compressor motor runs at constant speed
Electromagnetic Interference Issues	None, since no motor frequency variation is needed
Reliability	Comparable to fixed scroll systems

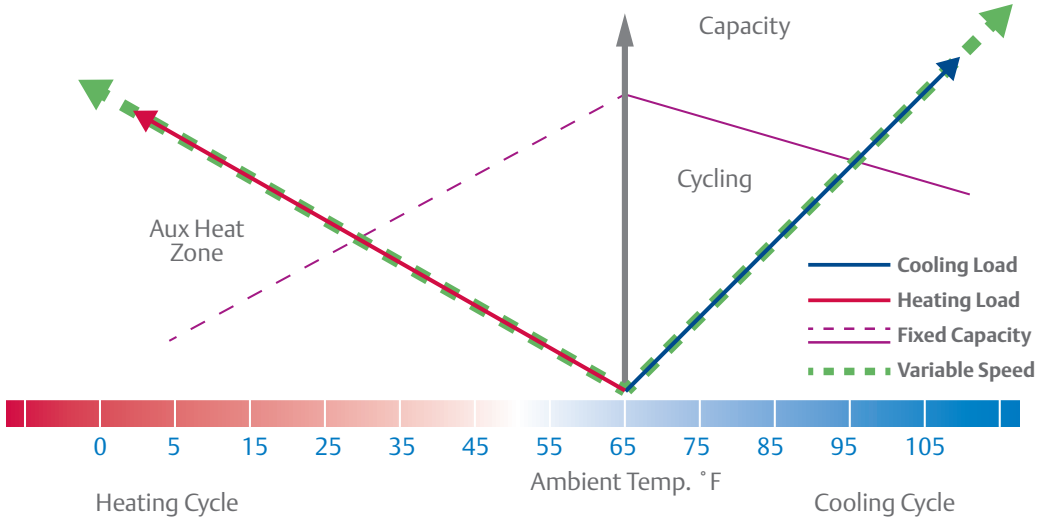
Variable Speed Compressor Modulation

CHAPTER Four

Executive Summary

Variable speed compressors offer the highest part load efficiencies over any other modulation technology. This technology is specifically designed to be highly efficient in both residential and commercial applications. Variable speed technology regulates the heating and cooling capacity of a particular space, and provides an effective way of maintaining the optimal indoor environment. By continuously adjusting its output to match loads, variable speed compressors offer breakthrough energy savings with exceptional year round comfort, lower summer humidity levels and better temperature control.

Fixed speed vs. Variable speed capacity



With less cycling and longer run times, variable speed compressors are able to maintain precise temperature control (roughly within 1/10th of a degree).

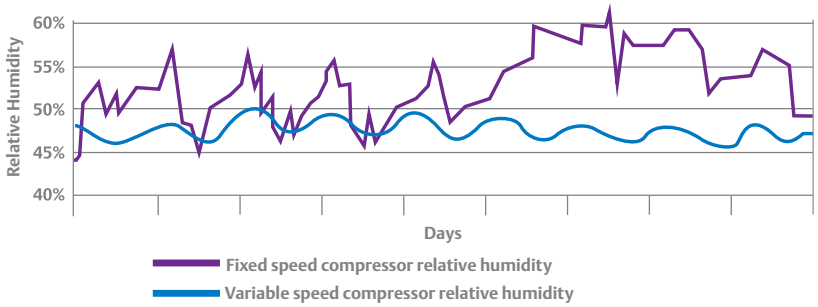
Benefits

With a variable speed compressor, systems can deliver significant improvement in year-round comfort for homeowners and end-users. By maintaining capacity at low ambient temperatures, systems equipped with variable speed can supply continuous hot air, which is essential for heat pumps. In addition, summer humidity control is significantly improved with up to 75 percent capacity reduction.

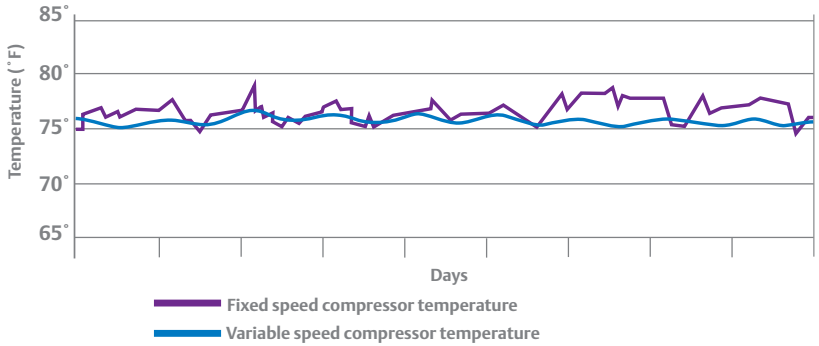
Improved temperature & humidity control

Variable speed compressors are able to match loads better than fixed capacity systems. This capacity allows for improved humidity control, while simultaneously reducing the cycling losses typically associated with fixed capacity systems.

Lower Summer Humidity Levels



Better Temperature Control

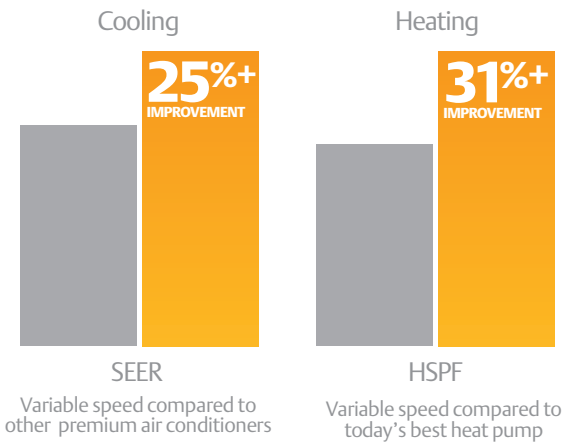


Benefits

Improved efficiency
With variable speed compressors, high system efficiency is obtained by matching capacity with cooling/heating demand, which enables:

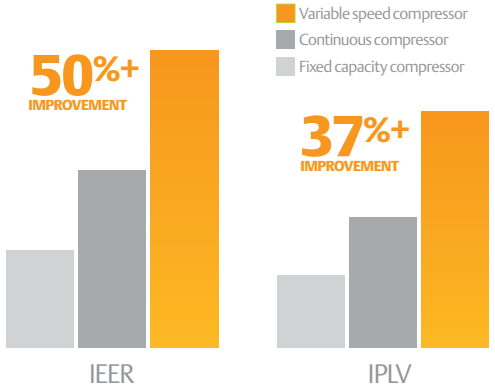
- Maximum cooling efficiency or SEER (Seasonal Energy Efficiency Rating)
- 7:1 turndown for better light load efficiency and dehumidification
- Heat pumps to achieve 31 percent greater efficiency than today's best heat pump and 69 percent more efficiency than the DOE (Department of Energy) minimum efficiency

Cooling & heating comparison



Saves homeowners up to 40 percent on energy costs

Part load comparison

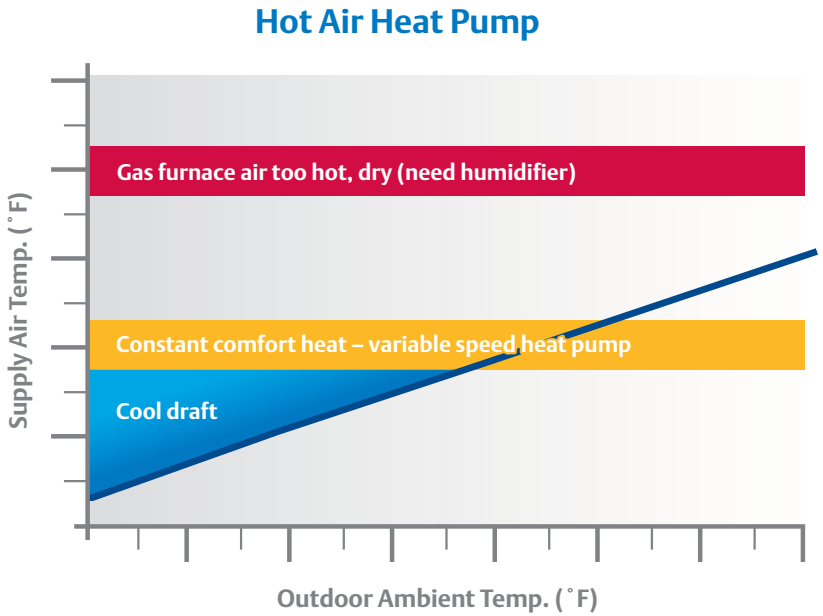


1,000-7,200 RPM speed range for 20-100% coverage

Benefits

Hot air supply

By increasing the speed of the compressor, systems with variable speed compressors maintain capacity to reduce strip heat usage and supply continuous hot air even at low outdoor ambient temperatures.



This unique compressor design enables heat pumps to supply hot air even during cold winter conditions

How it works

Variable speed systems modulate refrigerant flow by varying the speed of the compressor motor. This compressor motor speed variance determines the speed of the refrigerant flow. Therefore, by varying the motor frequency, capacity can be modulated. Capacity output increases and decreases with motor speed. Although this allows precise temperature and humidity control, oil management hardware and electronics are needed to ensure enough oil is in the compressor during slow motor conditions. This will ensure that excessive oil amounts do not get pushed out of the compressor during fast motor conditions.

Variable speed compressors are used in conjunction with a variable frequency drive, which dynamically adjusts compressor speed to ensure optimum efficiency. The drive also offers important compressor protection and diagnostic features.

Conclusion

Variable speed technology provides contractors with the opportunity to upsell homeowners and building owners to the most advanced technology. While fixed capacity and two-stage HVAC systems can be effective, variable speed technology delivers greater energy-saving potential and significantly improved summer and winter comfort. Other advantages of variable speed technology include:

Advantages of variable speed compressor modulation

Modulation Capability	Up to 7:1 turndown ratio achievable
Efficiency	High system efficiency is obtained by matching capacity with cooling/heating demand. Highest part-load efficiencies of any modulation technology
Reliability	Capable of superior reliability due to active protection provided by the motor control drive
Temperature & Humidity Control	Precise control is achieved

CHAPTER Five

Executive Summary

Another form of staged modulation technology applied in air conditioning applications is an approach that utilizes multiple compressors connected with a manifold, commonly known as multiples (also referred to as tandems or trios). Multiple compressors can be found in some residential applications and primarily in commercial air conditioning applications, such as larger commercial chiller systems.

With multiples, two or more compressors can operate individually or together, delivering several discrete capacity stages as needed while maintaining high Energy Efficiency Ratings (EER). Multiples offer improved part-load efficiencies, including Integrated Energy Efficiency Ratio (IEER) for rooftops and Integrated Part Load Value (IPLV) in chillers, while maximizing full-load efficiency.

Benefits

Like other forms of modulation, multiples deliver similar end-user benefits, including energy efficiency, comfort and reliability.

Energy Efficiency
- Multiples provide high system efficiency at both full-load and part-load

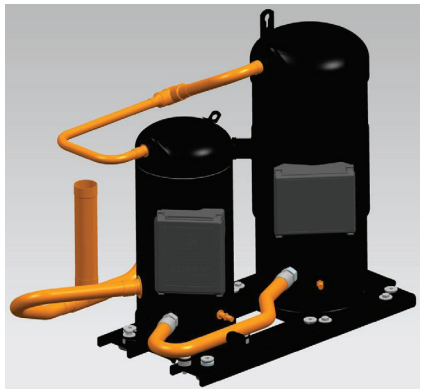
Comfort
- Through load matching and stepped capacity, multiples offer a variety of options to improve comfort levels

Flexibility
- Versatile compressor combinations offer a wide system lineup

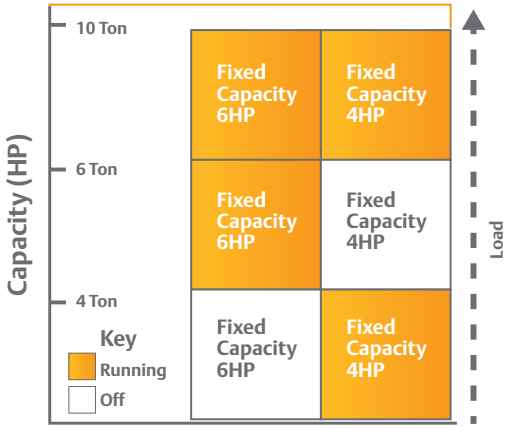
Reliability
- Multiples are designed for long life and qualified through extensive oil balance, strain gauge and life testing

How it works

Multiples can be used in packaged rooftop systems, split systems, or chillers to provide stepped modulation for optimal load matching. This type of modulation enables original equipment manufacturers to boost system part-load efficiency levels, as well as the ability to meet new energy standards and regulations. In the example below, the 10 HP uneven tandem delivers three stages of capacity modulation by turning compressors on and off to match the load as the demand increases.

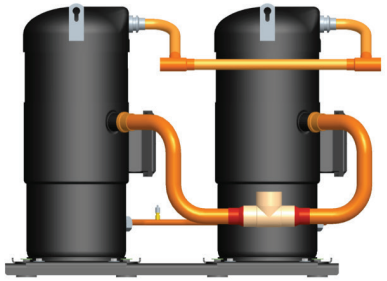


Uneven tandem compressor combination

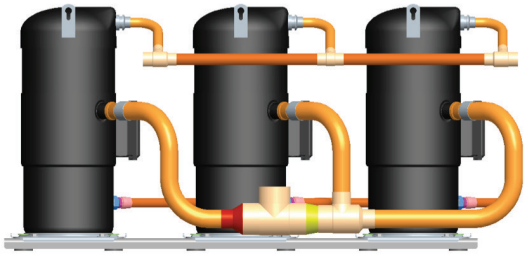


Uneven tandems can deliver three capacity stages to match the loads as the demand increases

Other Multiple Combinations Include:



Even tandem compressor combination



Trio combination

Conclusion

Multiples provide a viable solution to address the industry standard update to include IEER part-load efficiency requirements as part of the ASHRAE 90.1 standard for light commercial split, package and rooftop systems. It allows original equipment manufacturers (OEMs) to boost system part load efficiency levels to meet these new energy standards and aggressive Department of Energy (DOE) challenges.

Advantages of multiple compressor modulation

Modulation Capability	Staged capacity modulation for precision load matching
Efficiency	High system efficiency at both full-load and part-load
Flexibility	Versatile compressor combinations
Oil Management	No extra oil management hardware needed
Reliability	Designed and rigorously qualified for long life

CHAPTER Six

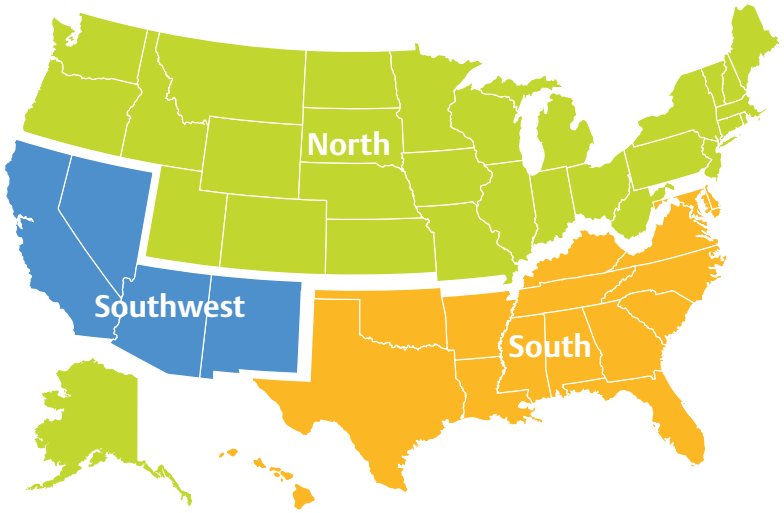
Executive Summary

The residential air conditioning market continues to face an increasing need for enhanced energy efficiency and improved comfort. The minimum SEER transition from 10 to 13 in 2006 combined with tax incentives and utility rebates helped make high efficiency systems more affordable for homeowners. In that year, the industry saw an increased adoption of high-efficiency systems, including geothermal systems, even through the economic downturn.

In 2015 the residential market again faced new efficiency standards that included different standards for various parts of the country. A summary of these new regulations include:

- **Northern States** – Minimum 13 SEER air conditioning remains standard, but heat pumps increase to 14 SEER and 8.2 HSPF
- **Southern** (Southeastern States) – Minimum efficiency increases to 14 SEER for both air conditioning and heat pumps and 8.2 HSFP for heat pumps.
- **Southwestern States** – Minimum efficiency increases to 14 SEER for air conditioning, but there is also a new standard for EER that will call for 12.2 EER for systems less than 45,000 BTUH and 11.7 EER for systems over 45,000.

Regional Standard Zones



Homeowner Benefits

According to a survey conducted in 2011 by Emerson, only 12 percent of adults surveyed were willing to invest more than $2,000 in an energy-efficient home upgrade that would pay for itself in two years. This attitude leads to challenges for HVAC contractors to up-sell systems based on efficiency. The survey results show the primary reason for not investing in energy efficient upgrades (of any kind) to be that the high efficiency products are too expensive (31 percent) and confusion (20 percent) about all the high efficiency options available and the time required to research or install them.

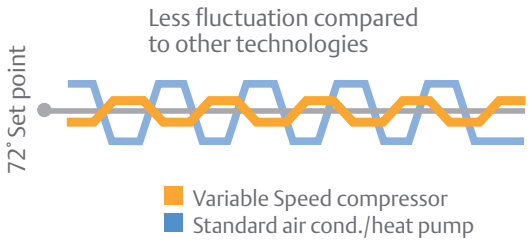
Armed with the right tools and information, contractors can help homeowners understand the benefits they can gain with higher efficiency systems, including enhanced comfort and energy savings.

Comfort

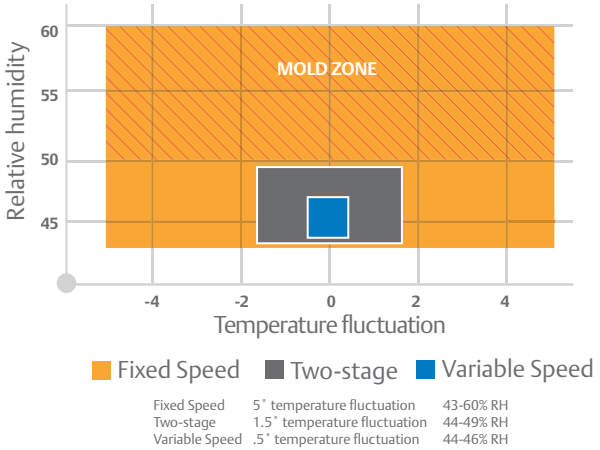
In areas of the country that experience high levels of humidity, such as Florida, managing both temperature and humidity can be a challenge for many homeowners. Tampa, for example, is among the nation's most humid spots during the summer months. The average relative humidity on mornings in July, August and September averages between 87 and 91 percent, says the Southeast Regional Climate Center at the University of North Carolina. In Phoenix, it hovers closer to 47 percent.

High efficiency systems not only help keep the air at the preferred temperature, but can more effectively remove moisture from the air. Modulated systems run longer cycles at lower pressures, helping to cool the air more evenly. Air that cools too fast without proper moisture removal can lead to mold and other airborne problems.

Providing more consistent temperature control



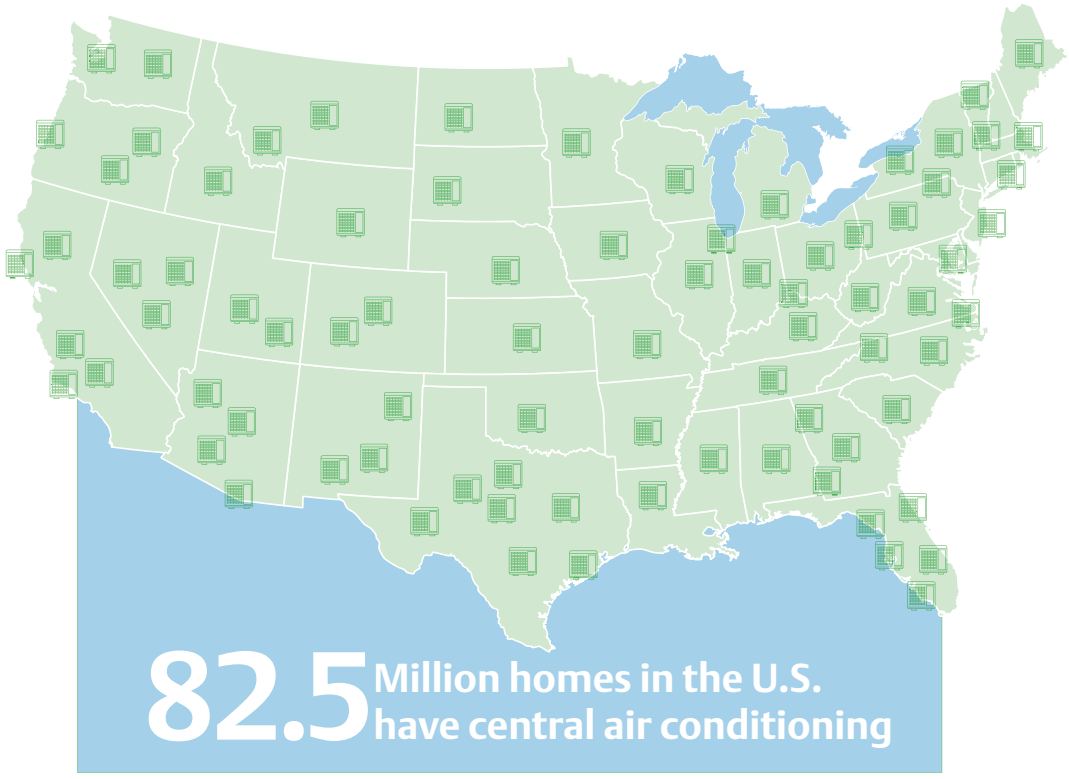
Temperature fluctuation vs. humidity control



Fixed Speed	5˚ temperature fluctuation	43-60% RH
Two-stage	1.5˚ temperature fluctuation	44-49% RH
Variable Speed	.5˚ temperature fluctuation	44-46% RH

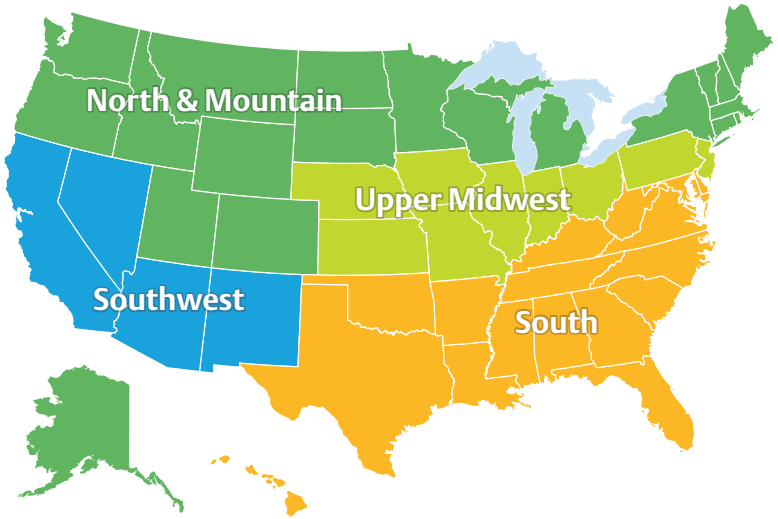
Energy savings

According to Energy.Gov, in an average air-conditioned home, air conditioning consumes more than 2,000 kilowatt-hours of electricity per year, causing power plants to emit about 3,500 pounds of carbon dioxide and 31 pounds of sulfur dioxide. With over 82.5 million homes in the U.S. that have central air conditioning, homeowners can help reduce their energy consumption by upgrading to higher efficiency systems. In fact, by upgrading to a variable speed heat pump, homeowners can save as much as 40 percent on energy costs.



Applications

When talking to customers about replacing their HVAC system, price is usually the biggest challenge to overcome. However, it is important to help homeowners look beyond initial costs of the system and more at the benefits the system will deliver based on their needs. Consider the following chart which outlines the best heating and cooling options based on geographic locations, cooling and heating seasons and utility costs.



				Natural Gas Costs Better Than Electric		Electricity Costs Better Than Natural Gas	
Region	Summer Cooling Season	Winter Heating Season	Climate	Heating	Cooling	Heating	Cooling
North & Mountain	Short, Mild	Long, Severe	Varies, Mostly Dry	High efficiency Gas Furnace 90% AFUE or Better	Basic 13 SEER Air Conditioning (with Capacity Modulation for Comfort)	Heat Pump with High Efficiency Gas Furnace for Coldest Days	Basic 13 SEER Air Conditioning (Capacity Modulation for Comfort)
Upper Midwest	Frequent Heat Waves	Frequent Periods of Severe Cold	Often Humid	Heat Pump with Basic Gas Furnace for Coldest Days	16 SEER or Better AC with Capacity Modulation	Heat Pump with Gas Furnace for Coldest Days (Dual Fuel)	16 SEER or Better AC with Capacity Modulation
South	Long, Hot	Short, Mild	Often Humid	Heat Pump or Gas Furnace	16 SEER or Better AC with Capacity Modulation	Heat Pump with Resistance Auxiliary Heat for Coldest Days	16 SEER or Better AC with Capacity Modulation
Southwest	Long, Hot	Short, Mild	Mostly Dry, Arid	Basic Gas Furnace	16 SEER or Better AC with High EER Rating (>12)	Heat Pump with Resistance Auxiliary Heat for Coldest Days	16 SEER or Better AC with High EER Rating (>12)

Two-stage modulation is widely used in air conditioning systems with higher 16+ SEER ratings, including both traditional air-to-air and water-to-air (geothermal) applications. Staged capacity scroll compressors are ideal for high SEER performance, and provide a simple, easy-to-apply affordable solution to enhance system efficiency for both air conditioners and heat pumps.

Though variable speed units tend to cost more than single- or two-stage equipment at the onset of installation, they can operate far more efficiently because their outputs vary according to the conditions of the home, rather than running at full or a single reduced capacity for the duration of a cycle. This can result in significant savings on monthly utility bills, reducing the payback period and offsetting the initial investment from the homeowner. In addition, variable speed compressors are ideal for areas of the U.S. that experience extreme weather conditions, including heat and humidity in the south and cold wintery conditions in the north.

Even though geothermal heat pump systems cost significantly more than conventional heating and cooling systems, many homeowners recognize the environmental benefits and lower operating costs. Federal tax credits and state and local incentives make these types of systems more attractive. Two-stage and variable capacity compressors are used in many geothermal systems to run at a lower capacity and maintain a consistent temperature and humidity level.

Conclusion

The following chart summarizes a comparison of the two types of modulation technologies for the residential market and which type best addresses specific needs, whether its part or full load efficiency requirements, comfort or costs.

Modulation Technology	Range	Ideal Application	Part Load Efficiency	Full Load Efficiency	Comfort	Applied Cost
Two-stage	2-5HP	16+ SEER	High	Medium	Medium	Best
Variable Speed	2-5HP	Premium residential A/C & heat pump, Geothermal applications	Highest	Low	Highest	Good

A Case for Commercial Modulation

CHAPTER Seven

Executive Summary

Modulating compressor technologies are also a good solution for the specific challenges facing the commercial air conditioning industry, including precisely managing varying temperature and humidity load requirements in the most efficient manner. As the main power consumer in rooftop systems, compressors account for over half of the system's total energy use, making them a primary target for improvements in efficiency. In fact, the commercial air conditioning market is facing upcoming efficiency regulations that will impact both part-load and full-load efficiency requirements. These new standards include:

- Part-load efficiency requirements for light commercial split, package and rooftop systems
  - IEER added to ASHRAE 90.1–2010 standard; part-load efficiency minimums increase 13-15 percent in 2016
  - Voluntary industry standards specify up to 23 percent part-load efficiency improvement
  - DOE rooftop challenge redefining high efficiency rooftop systems

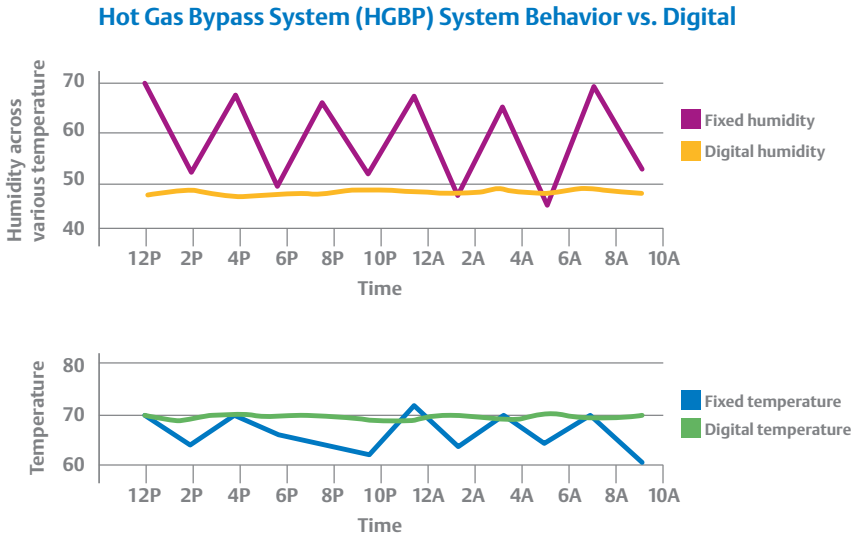
- 2015 chiller standards include both full-load & part-load efficiencies
  - Air-cooled chillers: 1-6 percent more efficient at full-load and 10-26 percent more efficient at part-load than ASHRAE 90.1–2010 standard
  - Water-cooled chillers: 3-5 percent more efficient at full-load and 16-19 percent more efficient part-load than ASHRAE 90.1 -2010 standard

End-User Benefits

Today's commercial air conditioning applications are varied, each one having its own set of challenges and demands. Building owners and facility managers are looking for equipment that not only operates efficiently, but is reliable, easy to install and easy to maintain. In addition, commercial environments experience a wide range of cooling requirements based on the time of day, occupancy, location and season. Systems with modulation technology are best suited to address these key areas for commercial applications.

Tighter temperature and humidity control

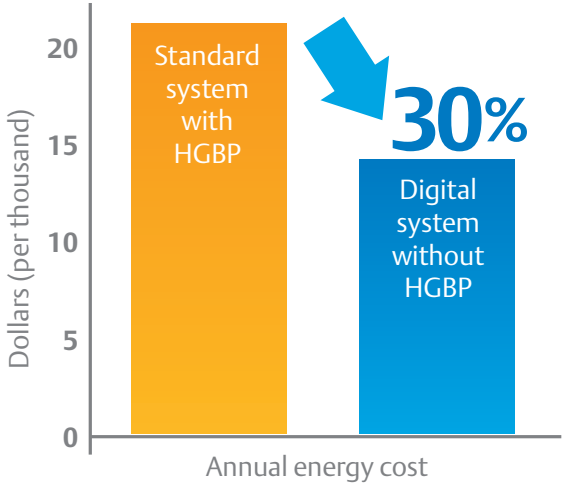
In applications that require tighter temperature and humidity controls, like museums, hospitals or data centers, HVAC systems using continuous modulation or variable speed technology are ideal because of their ability to maintain precise temperature set points as well as control humidity levels.



Efficiency

According to Energy Star, commercial buildings account for nearly half of all energy consumption in the United States at a cost of over $200 billion per year. And, often up to 30 percent or more is wasted through inefficiencies, which has led to new technologies and improved building practices to improve energy efficiency. In fact, building energy codes and standards are being mandated to help set minimum efficiency requirements for new and renovated buildings, ensuring energy reduction over the life of the building. With more stringent building codes and energy regulations, facility owners and managers are increasingly looking for ways to save energy and cut costs. Systems with modulation technologies have proven to be the most efficient systems, saving thousands of dollars in operating costs.

Energy costs wasted through inefficiencies



Load variation

For environments that experience wide daily shifts in loads, such as restaurants, schools, conference rooms or movie theaters, it is important for the HVAC system to be able to adjust to meet those varying loads. Technologies like variable speed, continuous modulation and multiple compressors are able to adjust capacity to meet changing cooling and heating load demands.

Applications

Today, a robust combination of regulatory requirements and customer preferences is driving manufacturers to achieve unprecedented levels of compressor efficiency without sacrificing reliability and comfort. From office buildings to big-box retailers, HVAC systems with modulation technology help ensure the comfort, efficiency and reliability needed to keep businesses up and running.

For small light commercial split and package applications, two-stage and continuous modulation technologies are viable options. Two-stage modulation achieves high SEER performance, and provides a simple, easy-to-apply solution to enhance system efficiency for both air conditioners and heat pumps.

According to the Department of Energy (DOE), nearly half of the cooling-conditioned commercial floor space in the U.S. features rooftop units. Businesses nationwide would save roughly $1 billion each year collectively in energy costs if they replaced their 10- to 20-ton commercial units with units that meet the new High Performance Rooftop Unit Specification. Tandems are one cost effective way for OEMs to address the industry standard update to include IEER part-load efficiency requirements as part of the ASHRAE 90.1 standard for light commercial split, package and rooftop systems. Other options to meet the industry standard are outlined in the Conclusion section of this chapter.

Businesses could save $1 billion/year by replacing their 10- to 20-ton commercial air conditioning units

In addition to rooftops, a large consumer of energy in the commercial space is chillers. As stated by the DOE, chillers consume more than 50 percent of electrical energy during seasonal periods of building use. And, more than 120,000 chillers in the U.S. are expending more than 30 percent in additional energy costs through operational inefficiencies. Compressor suppliers are providing innovative products that can help chiller manufacturers improve system efficiency through variable capacity technologies or operating point optimization. Modulation makes it possible to tailor compressor performance to changes in ambient conditions improving comfort and part-load efficiencies.

Conclusion

The following chart summarizes a comparison of the three types of modulation technologies for the commercial market and which type best addresses specific needs, concerning part or full load efficiency requirements, comfort and costs.

Modulation Technology	Range	Ideal Applications	Part Load Efficiency	Full Load Efficiency	Comfort	Applied Cost
Two-stage	2-5HP	Light commercial split & package applications	High	High	Medium	Best
Continuous	3-15HP	Light commercial split, package and chiller applications	Low	High	High	Better
Variable Speed	3-10HP	Light commercial rooftop and chiller applications	Highest	Medium	Highest	Good
Multiples	3-120HP	Commercial split, rooftop and chiller applications	High	High	High	Best

Tools to Help You Sell Higher Efficiency Systems

CHAPTER Eight

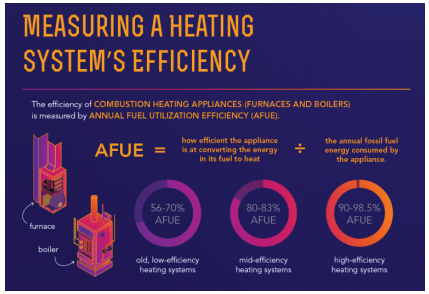
Executive Summary

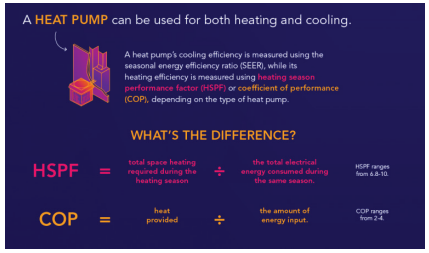
Now that you have a better handle on the different types of modulation technologies available and the types of applications they are best suited for, we will explore some of the tools available to help as you discuss options with your customers when it comes to decisions about their HVAC systems.

Many of these are online tools that you can access via your smartphone or tablet while on the job. Others are sites your customers can reference to help understand HVAC and make more informed decisions. From websites to mobile apps, there are a number of sites that can aide in moving the customer in the right direction to meet their needs.

Energy.gov site

The **Energy.gov** site can be a great place to send customers for information about energy as it relates to their home. This website has helpful **Energy Saver 101 infographics** that provide homeowners information on everything they need to know about home heating and cooling – from how systems work and the different types available in the market to what to look for when replacing their system as well as proper maintenance. These infographics provide homeowners with ways to cut costs (with programmable thermostats) as well as increasing energy efficiency through better systems.





There is also a tips section for heating and cooling providing a list of things homeowners can do in order to help cut down on their utility bills. Finally, homeowners can submit questions via social media using **#AskEnergySaver**, where Energy Department experts will answer questions about saving energy at home.

DsireUSA.org site

DsireUSA.org is the most comprehensive source of information on incentives and policies that support renewable and energy efficiency in the United States. Established in 1995, DSIRE is currently operated by the N.C. Solar Center at N.C. State University, with support from the Interstate Renewable Energy Council, Inc. DSIRE is funded by the U.S. Department of Energy. The website provides summaries of renewable energy and energy efficiency incentives and policies established by the federal government, state governments and U.S. territories, local governments, and larger electric and gas utilities in the United States. The site also features summary maps and tables, and a search tool to help users determine which incentives and policies apply based on their particular project and can help with purchasing decisions.

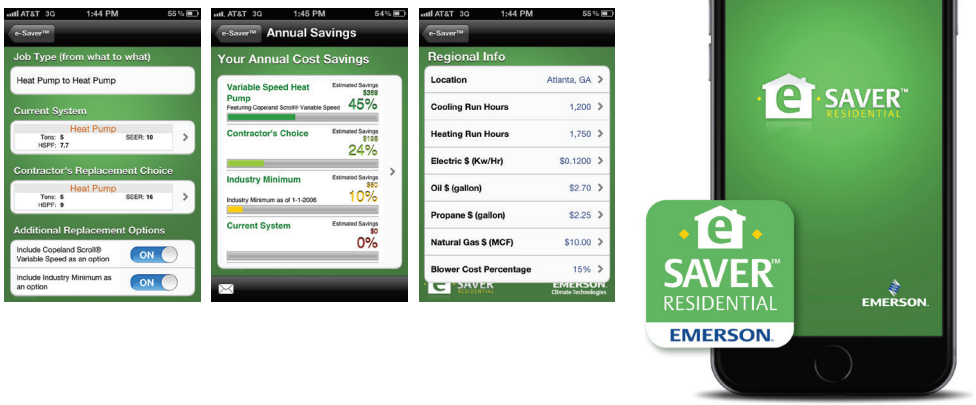
Mobile apps

According to research from Eric Mower + Associates, contractor use of smartphones has jumped 35 percent from last year. While the use of tablets (i.e., iPad) rose nearly 54 percent over last year (overall, 22 percent of contractors are using tablets), most contractors (68 percent) said they use smartphones as part of their workday. The survey also indicates that a key driver for this increased usage is convenience and the importance for the ability to communicate to coworkers, check specifications, and compare products and prices on the jobsite.

Emerson provides a wide range of helpful **mobile apps** designed to help contractors while on the job site. For example, the **Emerson e-Saver app** was specifically developed as an important tool to help contractors grow business and deliver outstanding customer service. By simply inputting basic information like current system, geographic location and your recommended system upgrade, one can generate a report detailing annual cost savings to share with your customers. This app gives contractors a way to use real numbers to show customers the benefits and value of system upgrades.

The Emerson e-Saver app allows contractors to:

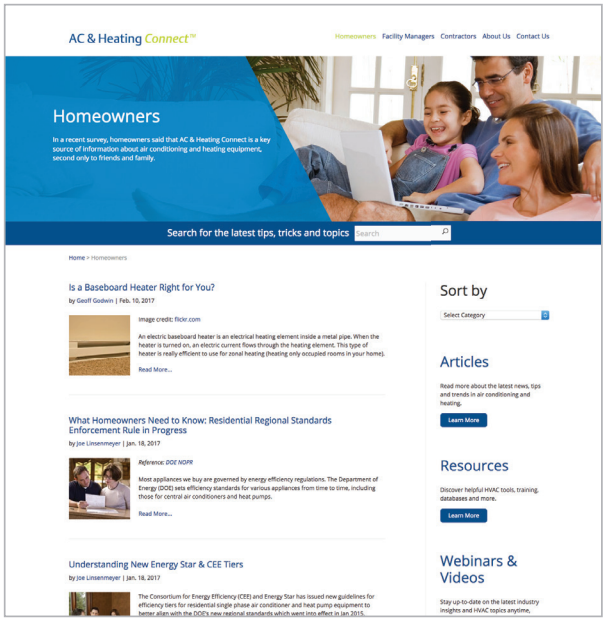
- Download the **FREE** easy-to-use application on your iPhone, iPad, iPod touch and Android device
- Input current system settings to provide up to three replacement estimates for cost comparison
- Generate a customized .pdf to email to homeowners for review



AC & Heating Connect site

AC & Heating Connect is a new website dedicated to contractors, facility managers and consumers that provides useful tools for improving business and communications with customers. The website offers industry insights as contractors get ready for 2015 regulations, as well as point-of-sale tools to share with customers such as an HVAC glossary, the benefits of high efficiency systems and diagrams of how their HVAC systems work.

The website also features the HVAC Pro's Toolkit that has downloadable documents to help aid in conversations with homeowners on topics like new efficiency regulations and refrigerants. The goal of the site is to help increase client satisfaction by providing homeowner-friendly information contractors can share with customers when they are faced with important HVAC purchase decisions.



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