Rooftop Unit Compressor Technologies

The need to have more energy efficient buildings and the knowledge of the potential energy savings with a building's mechanical equipment has inspired new higher efficiency compressor technologies for commercial building HVAC systems.

The HVAC industry has come a long way from open-type reciprocating compressors to the hermetic scroll compressors available today. Systems with scroll compressors have also evolved to provide more efficient system operation. The basic system included a single scroll compressor with on/off capacity control. The next step was to provide multiple on/off compressors; two equal capacity compressors giving 50% and 100% stages, uneven capacity compressors could provide more stages, but also became more complicated to control. Hot gas bypass was used to allow staged systems to operate variable air volume (VAV) systems, however, this resulted in wasted energy.

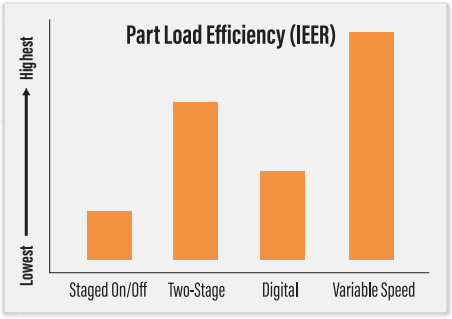
Scroll compressor technology has evolved into a two-stage compressor on a single circuit with 67% & 100% capacity stages. This allows more stages with simple control, even allowing for basic Single Zone VAV operation, without hot gas bypass.

Some applications, such as museums, hospitals, dedicated outdoor air systems, and VAV systems require very precise temperature and humidity control. This lead to variable capacity compressor technologies - the Digital scroll compressor with modulation from 10-100% and the variable speed compressor with modulation from ~15-100%, both achieve the results required. The Digital scroll compressor modulates using mechanical unloading and the variable speed compressor modulates using compressor motor speed control. These compressors allow for precise VAV and Single Zone VAV operation.

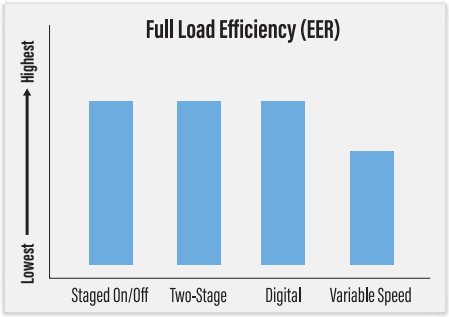
RN Series rooftop units are available with multiple different compressor technologies to meet application requirements.

Choosing a Compressor Technology

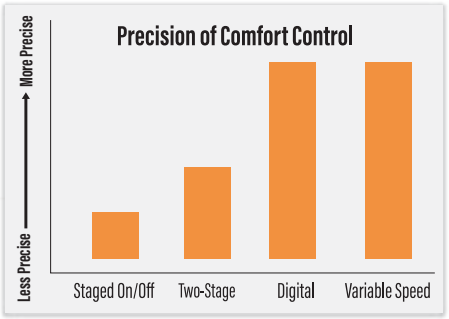
AAON recognizes there are many reasons for choosing a specific compressor technology and offers many different options to meet an application's needs. Efficiency, first cost, controls complexity, precise control and comfort are all considerations.



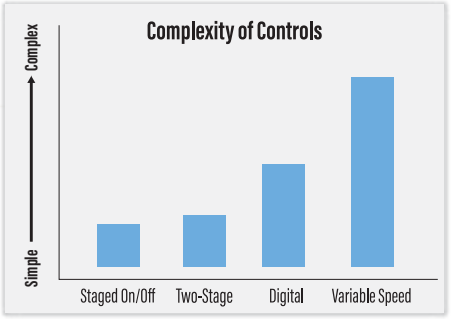
- Variable speed compressors have the best part load efficiency since a lower compressor speed at lower loads requires less energy to operate. To return oil to the compressor, flush cycles are necessary as capacity reduces, causing less stable operation.
- Digital scroll compressor motors run continuously even at low loads, between an unloaded state and loaded state. This cyclic operation allows for precise capacity control and energy saving variable airflow with stable supply air temperature control at all capacities.



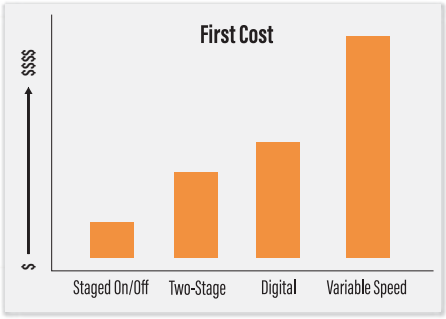
- For systems that operate at full load conditions most of the time, the staged on/off compressor might be the best option because it has high full load efficiency and the lowest first cost.
- Two-stage compressor systems have a high EER and also a high IEER, so if budget allows, the two-stage compressor is the better choice over a single staged on/off compressor.
- Variable speed compressor systems are optimized for higher efficiency performance at part load conditions.



- Variable speed and Digital scroll compressors offer very precise comfort control. Longer operating times, even at lower operating capacities provide some humidity reduction and precise sensible control. Precise capacity control allows for energy saving variable airflow application.
- Staged on/off compressors will have larger temperature swings within the space, and reduced comfort.

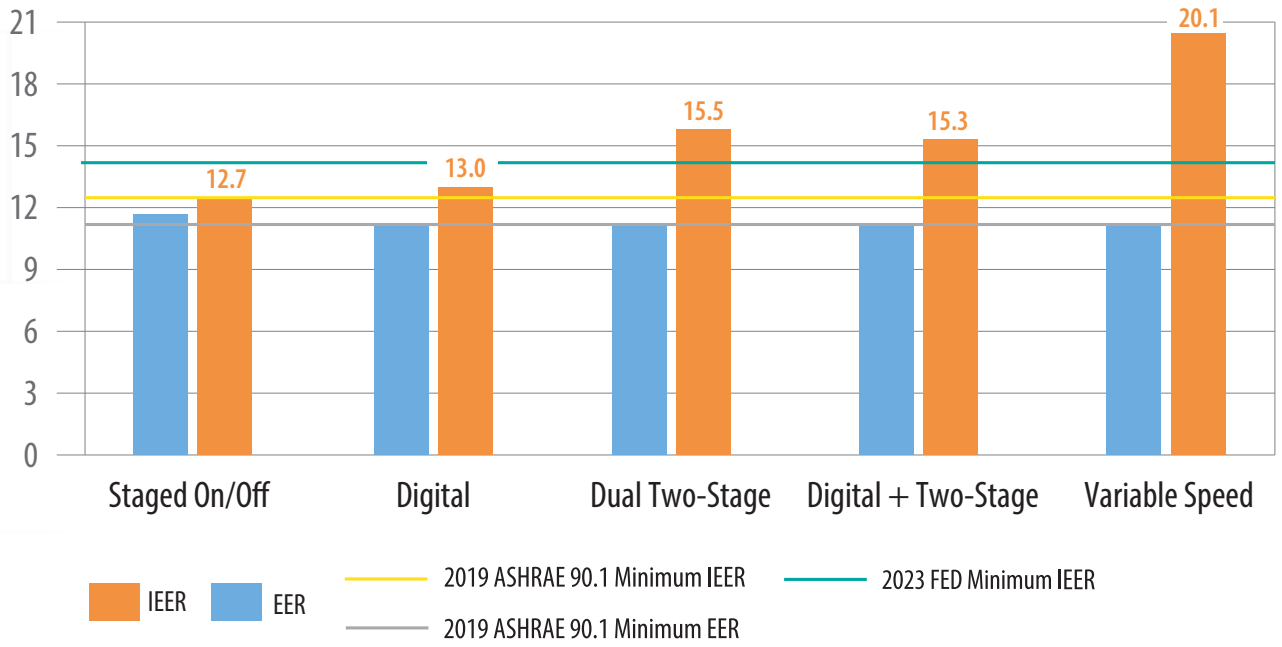


- Staged on/off compressors and two-stage compressors are the easiest systems to control. Units can typically be controlled using a standard thermostat.
- Digital scroll compressor requires a 1-5 VDC signal to control capacity.
- Variable speed compressor requires advanced refrigeration system controls to keep the compressor within a safe operating range, ensure oil return to the compressor, and to provide the precise control. The need to have flush cycles to return oil to the compressor at reduced capacity requires complex controls.



- If the first cost of the equipment is the deciding factor, the on/off staged compressors are the least expensive.
- Variable speed compressors are the most expensive initially due to the advanced technology in the compressor, the VFD that drives the compressor, the controls, and oil management systems required.

RN 15 ton Unit - Compressor Technology Efficiency Comparison



This bar graph shows the different full load and part load efficiencies for each compressor technology available in the AAON RN 15 ton product. The lines represent the 2019 ASHRAE minimum IEER and EER requirements, and the Department of Energy's 2023 Federal Minimum IEER.

AAON Compressor Options

On/Off Scroll

Staged on/off compressors provide high full load efficiencies (EER), but cannot provide precise temperature or humidity control. Control of staged on/off compressors is simple and units with only a few compressors can use a thermostat. Larger capacity systems with multiple compressors can have multiple stages of capacity control.

Two-Stage Scroll

Two-stage scroll compressors provide the simplicity of the staged capacity control with similar high part load efficiencies to variable speed compressor systems. The use of dual two-stage compressors includes up to five stages of capacity control.

The two-stage compressor can switch between a part load and a full load capacity setting. Two internal bypass ports enable the compressor to run at the part-load capacity during times when only part-load heating or cooling is needed. When demand increases, a mechanical ring is pressure activated, sealing the bypass ports and instantly shifting capacity to 100%. Running a system for longer periods, even at part load capacity, can lower the humidity inside the building.

Two-Stage Scroll Compressors provide the simplicity of staged capacity control with high part load efficiency

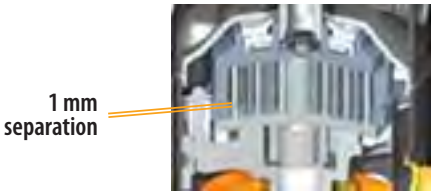
Unit Capacity Stages with Dual Two-stage Compressors					
	1	**2**	**3**	**4**	**5**
Compressor 1	67%	100%	67%	100%	100%
Compressor 2	0%	0%	67%	67%	100%
Total Unit	33.5%	50%	67%	83.5%	100%

Digital Scroll

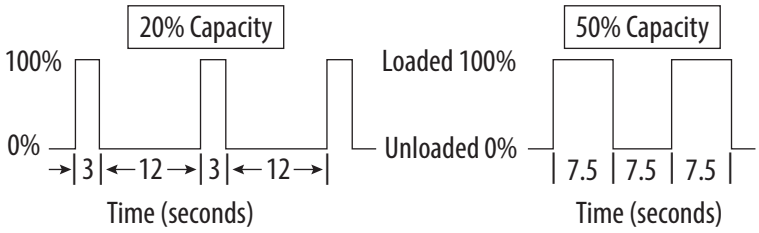
The Digital scroll, or 10–100% variable capacity scroll, compressors provide a wide range of precise modulation capabilities. This compressor technology is especially important in applications where precise temperature and humidity control are critical such as hospitals, museums, and data centers.

The Digital scroll compressor requires a 1–5 VDC control signal to control 10–100% compressor capacity modulation. The capacity is modulated by a solenoid unloader valve. The signal tells the solenoid how many seconds per cycle to unload the compressor. In the unloaded state, the scroll elements separate and thus create 0% capacity. There is minimum power draw as the compressor motor spins freely. In the 15 second cycle displayed below, the first scenario shows the compressor loaded for 3 seconds and unloaded for 12 seconds, providing a 20% capacity. The second scenario shows the compressor loaded for 7.5 seconds and unloaded for 7.5 seconds, providing a 50% capacity. The cyclical loading and unloading of the compressor via Pulse Width Modulation results in reduced capacity and energy savings. Oil return due to full flow of refrigerant during the loaded state is an advantage of the compressor.

Loaded Scroll Compressor



Unloaded Scroll Compressor



▲ Pulse Width Modulation of Compressor Capacity

Variable Speed Scroll

Variable speed scroll compressors operate with the highest part load efficiencies over any other compressor technology and they provide precise temperature and humidity control.

The variable speed scroll compressor modulates capacity using speed control. A Variable Frequency Drive (VFD) and controls are necessary to change the speed of the inverter-duty compressor. The VFD changes the frequency (Hz), which equates to a change of speed (rpm). Each variable speed compressor must also include specific controls, which protect the compressor by making sure it only operates within the safety of the compressor operating envelope. An electronic expansion valve must be used on the refrigerant circuit when variable speed scroll compressors are included because of the wide operating range of the compressor. To ensure oil return to the compressor, flush cycles are necessary as capacity reduces, causing less stable operation. Advanced refrigeration system controls are required to minimize these flush cycles and provide consistent control.

Digital Scroll + Two-Stage Scroll

This combined option takes advantage of the high part load efficiency of the two-stage compressor and the precise temperature and humidity control of the Digital scroll compressor. The Digital scroll modulates to precisely maintain supply air temperature, while the two-stage compressor stages on and off.

▲ Variable Speed Scroll Compressors provide the highest part load efficiency and precise temperature control.

Other High Efficiency Features

The efficiency of an HVAC system is more than just the compressors. AAON rooftop equipment is designed with energy saving features such as direct drive supply fans and low leakage, high thermal resistance cabinet construction. AAON offers several energy saving options, including modulating heating, energy recovery, and fully modulating economizer control.

Direct Drive Backward Curved Supply Fans

Direct drive backward curved plenum supply fans are standard on all units. A belt driven fan transfers energy through the belt and pulley system and can lose up to 15% of the applied power as heat due to belt slippage caused by normal bending and slipping of the belt. Direct drive supply fans are more energy efficient, quieter, and require less maintenance than belt driven fans. Backward curved plenum fans are more energy efficient than forward curved fans. Variable speed supply fans allow precise airflow control, reduced power consumption and reduced sound. In a Single Zone VAV system, variable speed fans operate only as fast as the space conditions require. Cutting the fan speed in half reduces the applied power to the fan motor by a factor of 8!

Modulating Gas Heating

Modulating gas heat provides consistent supply air temperature heating and improved occupancy comfort control, without overheating the space. AAON high turndown modulating gas heaters offer energy and fuel savings with up to 25:1 turndown.

Energy Recovery Wheel

Energy recovery wheels significantly reduce operating costs by transferring energy between the exhaust air and the entering outside air, reducing the amount of mechanical energy needed to cool the air from outside air conditions to supply air conditions. Energy recovery wheels remove moisture from the outside air during the summer to avoid excess moisture in the air and add moisture to the air during the winter to avoid over drying of the air. Energy recovery wheels help to maintain comfortable humidity levels year round. Up to 80% of the exhaust air energy is recovered by the wheel, significantly reducing energy usage during outside air ventilation.

AAON Energy Recovery Wheel produces significant energy savings while bringing fresh outside air inside the building.

Energy Saving Construction

Cabinet construction consists of two inch rigid polyurethane foam panels with G90 galvanized steel on both sides, a thermal break in between, and a closed cell polyurethane foam interior core. The inner wall protects the insulation from moisture damage, prevents microbial growth, and is easy to clean. This rigid cabinet design, with advanced sealing throughout, significantly reduces air leakage and infiltration and saves energy.

Two inch polyurethane foam insulated panels have a thermal resistance of R-value of 13 or greater, which exceeds the R-value of a cabinet with four inch thick fiberglass construction. They also make the cabinet more rigid and resistant to damage and provide increased sound damping.

Cutaway of double wall rigid polyurethane foam insulated cabinet panel increases thermal resistance, reduces air leakage, and attenuates radiated sound. Thermal break reduces heat transfer between interior and exterior metal cabinet walls.

Economizer

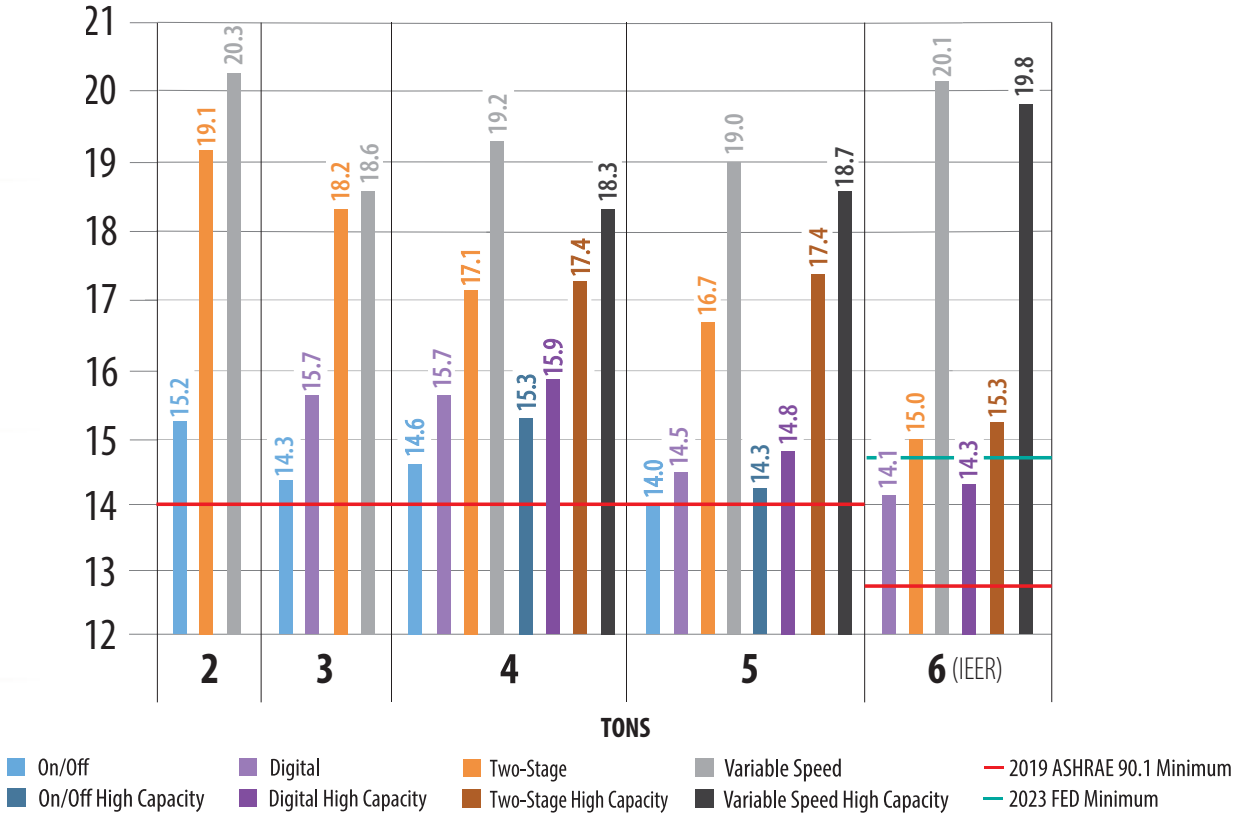
AAON standard low leakage economizer dampers are AMCA tested, certified, and labeled. They meet the stringent California Title 24 energy code damper air leakage and control requirements. Fully economizing dampers provide energy saving free cooling when ambient conditions are below setpoint values.

Aluminum gear driven economizer dampers eliminate the excess play and bind that occurs with linkage type economizers.

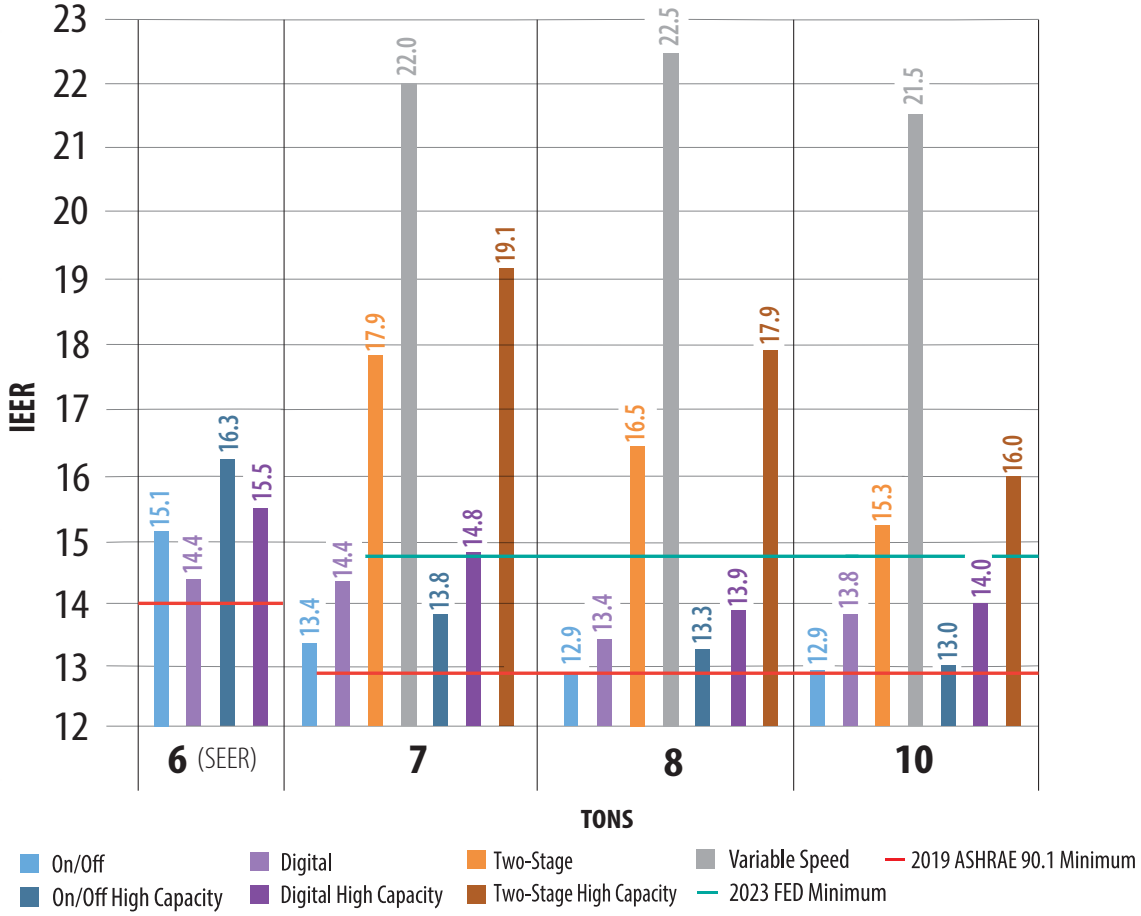
Part Load Efficiency Comparison

These bar graphs show the different part load efficiencies of different configurations of AAON rooftop units. The lines represent minimum efficiency requirements. High capacity configurations include six row high capacity evaporator coils.

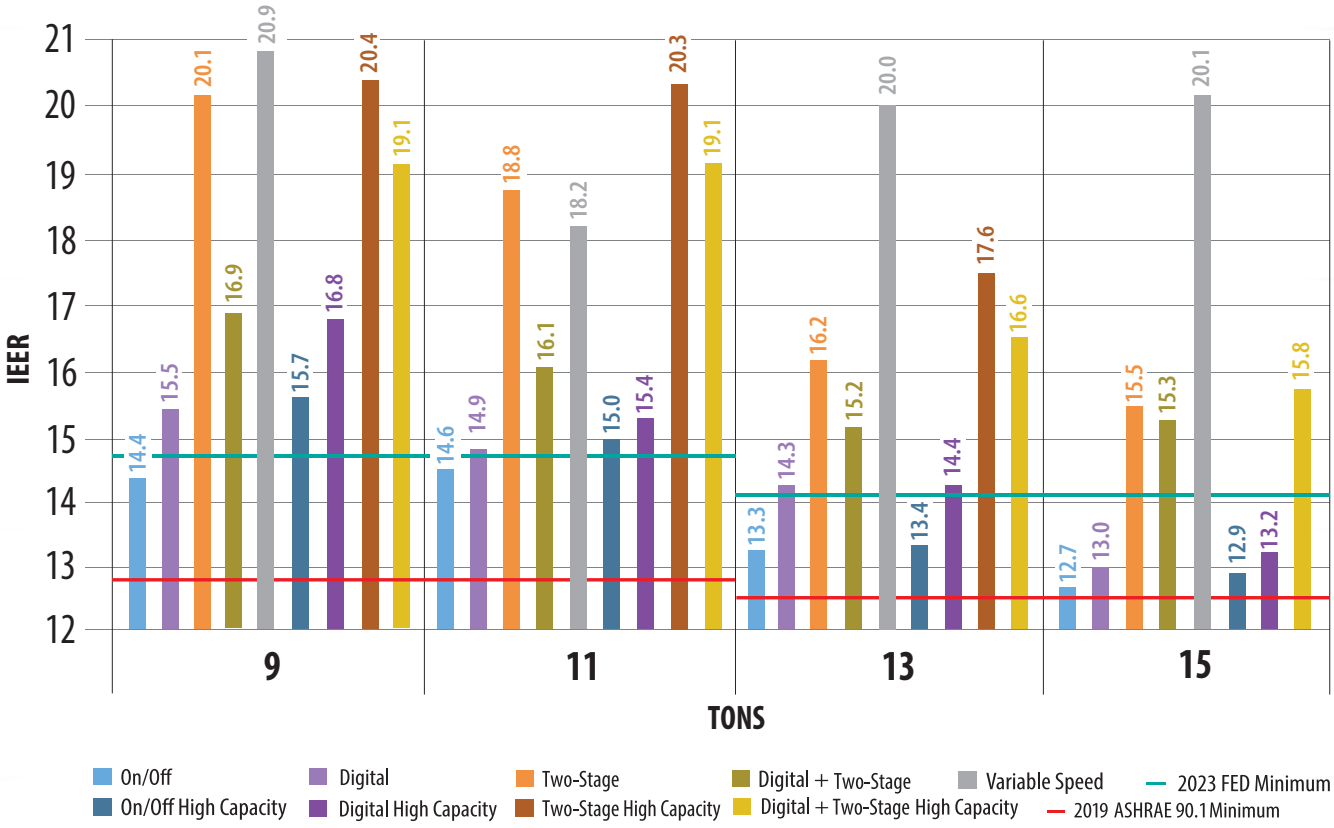
RQ Series Cabinet



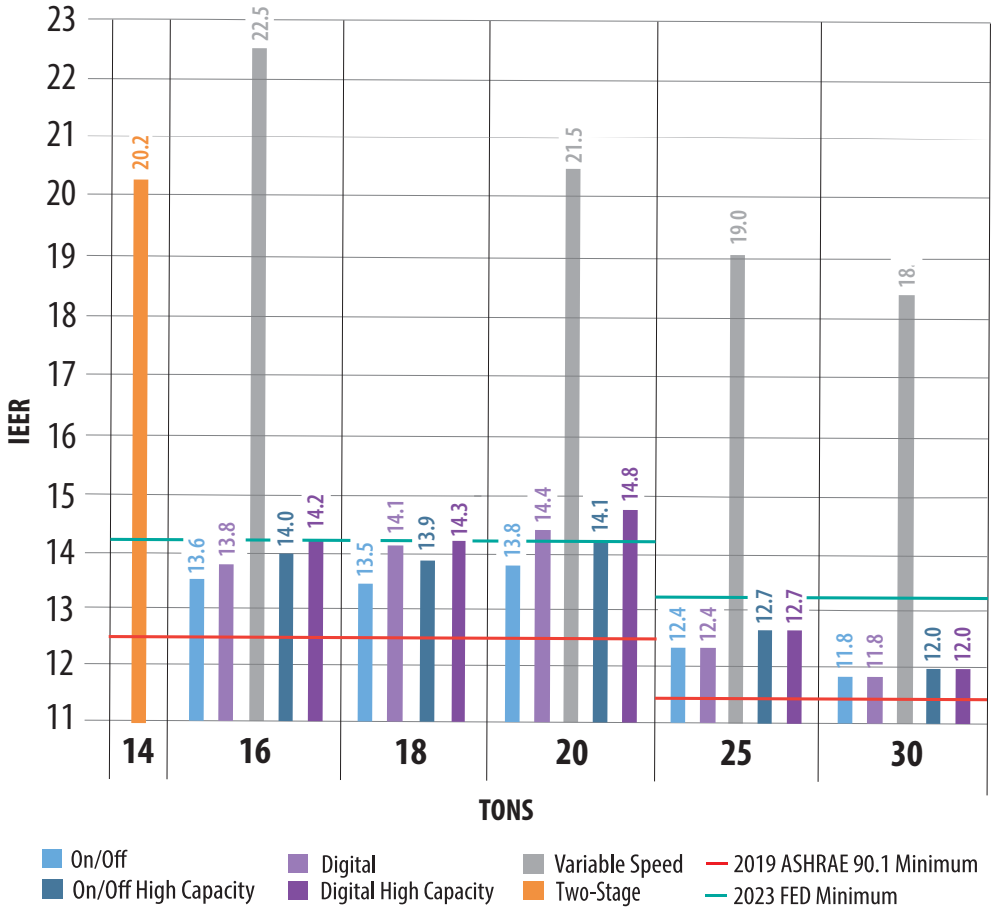
RN Series A Cabinet



RN Series B Cabinet

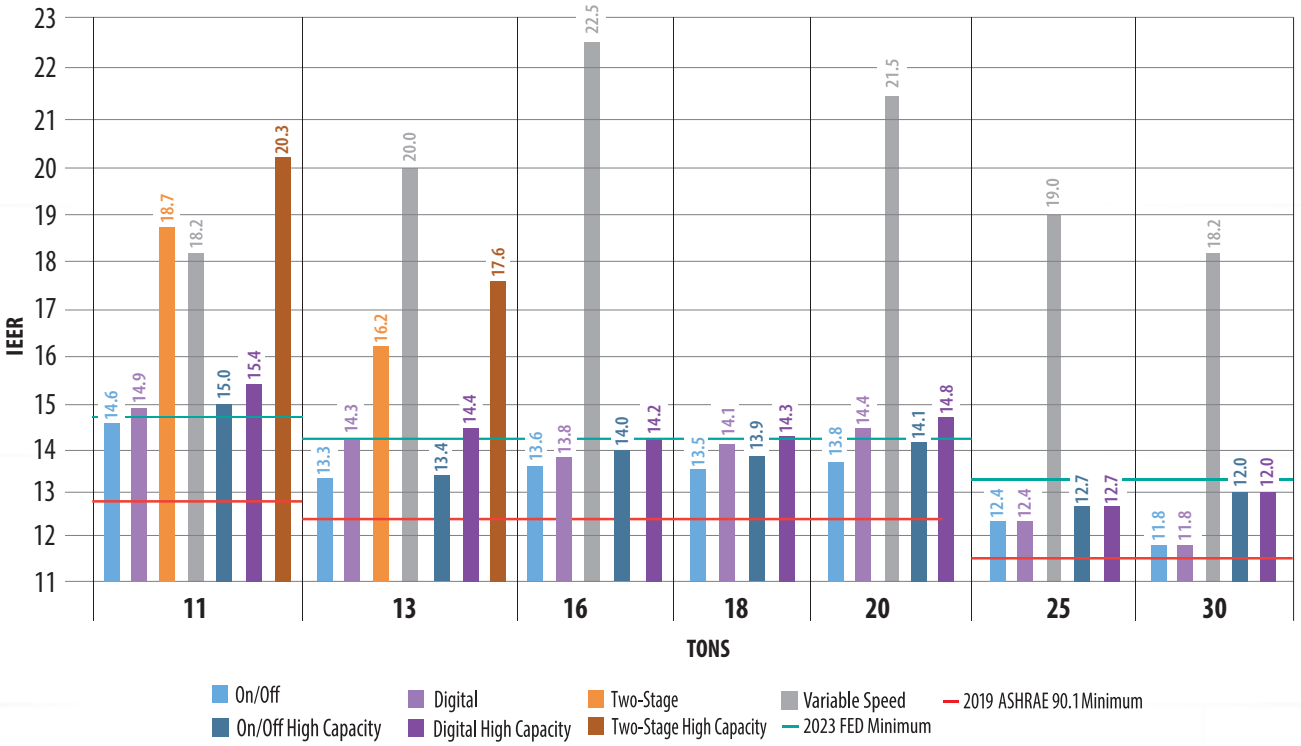


RN Series C Cabinet



Part Load Efficiency Comparison

RN Series C Cabinet - Horizontal Configuration



Summary

This compressor technologies guide gives an overview of the benefits and costs of different compressors configurations and the efficiencies possible with different configurations of AAON rooftop units. AAON recognizes there are many different reasons for choosing a specific compressor technology and offers many different options to meet a specific application's needs. To calculate detailed, application specific, unit efficiencies use the AAON selection software.

Contact your local AAON representative to find out more information about Rooftop Unit Compressor Technologies from AAON.

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