Accelerated Growth Solutions

Consulting, Mechanical Systems, and Construction for the Cannabis Industry

Modulating Temperature and Humidity Control

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Temperature and humidity control are important to the quality of the indoor environment. On-off type control has been prevalent for many years; however, fluctuations in temperature and humidity are inherent with this type of control system. The technology of the on-off control system has evolved and superior modulating control systems are now available. The following discussion demonstrates the improvements the modulating compressor and modulating reheat systems provide to temperature and humidity control.

Temperature Control

Temperature and humidity fluctuations are common in buildings with an on-off compressor and on-off reheat air conditioning equipment. When the air conditioning unit's compressor turns on, it operates at full capacity. By providing cool air to the space, the unit begins to cool the area and the temperature drifts downward toward, and then past, the setpoint. When the temperature in the area drops below the lower limit of the dead band, the unit turns off. After the unit turns off, the sensible load in the space causes the temperature to drift up, past the setpoint, until the upper dead band is exceeded. When the upper limit of the temperature dead band is exceed, the unit's compressor will turn on and the process will repeat.

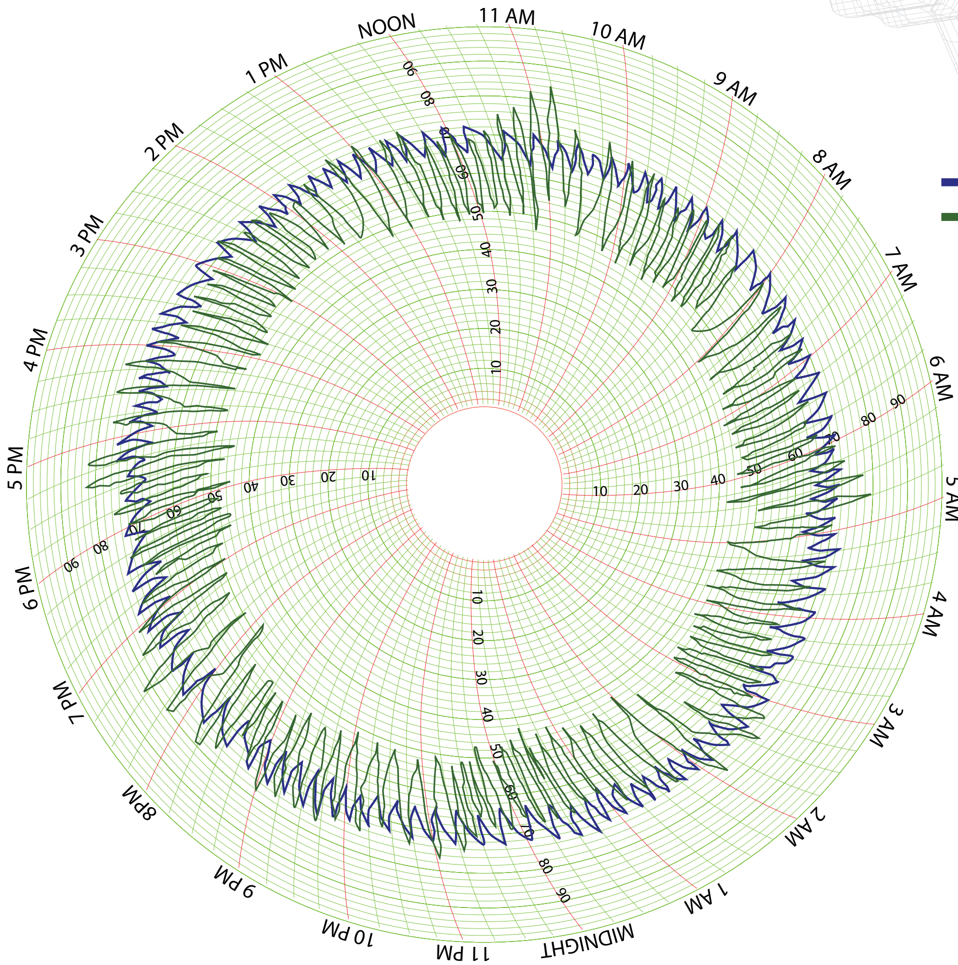
Humidity Control

When air is dehumidified, moisture is removed from the air. A common technique used to remove the moisture is to condense the moisture onto a cold surface. Anyone who has poured a cold beverage on a hot and humid day knows that moisture will condense on the glass. As air is cooled, it loses its ability to hold moisture; in the case of the cold glass, the moisture in the air condenses onto the glass. The moisture in a building's air is condensed in much the same way. A fan draws air from the space over the cooling coil of the unit to condense the moisture. At the same time moisture is condensed from the air, the temperature is being decreased. The moisture condensing from the air is known as latent cooling; the temperature change of the air is known as sensible cooling. To increase the amount of moisture condensed from the air, and further dehumidify the air, the temperature of the air must be decreased, sometimes past the desired setpoint (subcooled). To prevent overcooling the space, the air can be heated back up before it enters the space. This is done by passing the dry, cool air through a warm coil to reheat the air back up to its desired temperature before it is returned to the space.

To understand how temperature and humidity are controlled using a dehumidifier and reheat system, it is important to realize the cooling coil, and corresponding compressor, affects both the temperature (sensible) and humidity (latent) control while the reheat coil affects only the temperature (sensible) control.

Note: *The temperature and humidity data shown in Figures 1-3 are taken from an actual job site installation in the central United States. The equipment was originally ordered with an on-off compressor and on-off reheat. The customer was not satisfied with the temperature and humidity swings associated with on-off control. Improvements were made to the system to include modulating humidity control and a modulating capacity compressor. The results of these enhancements can be seen graphically in the following illustrations.*

Figure 1: *On-Off Hot Gas Reheat, Standard On-Off Compressor*



Note: *The “turn-on” and “turn-off” temperatures are deliberately made to differ by a small amount, known as the dead band, to prevent the unit from frequently switching on and off when the temperature is near the setpoint.*

On-Off Reheat & Standard On-Off Compressor

Figure 1 displays the relationship of the on-off compressor and on-off reheat to the temperature and humidity values in the space. As the on-off compressor turns on, both the temperature and humidity decrease. To prevent the temperature of the dehumidified air from over-cooling the space, the reheat coil heats the air before it leaves the unit. With an on-off reheat coil, the leaving temperature cannot be modulated; instead, the temperature in the space will fluctuate up and down, as shown in the blue line of Figure 1, as the reheat coil cycles on and off. As the compressor turns on and off, the humidity will also fluctuate; while the compressor is on, the air is dehumidified and the space humidity drops. When the compressor is off, the latent load in the space causes the humidity to rise until the compressor turns on again and begins to dehumidify the air, as can be seen with the green line of data in Figure 1.

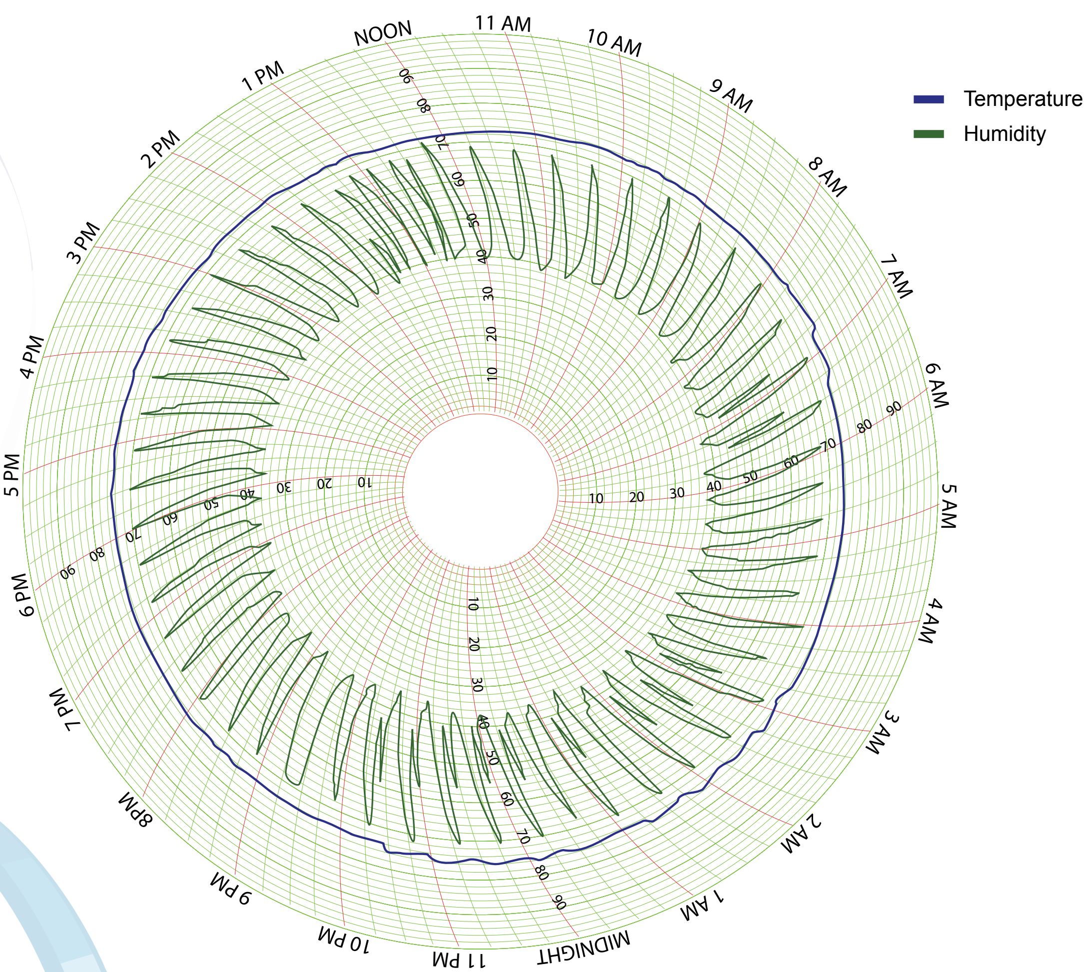
Modulating Reheat & Standard On-Off Compressor

Figure 2 displays the relationship of the on-off compressor and modulating reheat to the temperature and humidity values in the space. As the on-off compressor turns on, both the temperature and humidity decrease, however, by adding modulating control to the reheat coil, tight temperature control is achieved. This improved temperature control is accomplished by varying the amount of reheat applied to the dehumidified air so that temperature of the air leaving the air conditioning unit matches the desired setpoint. However, while the modulating reheat control improves the temperature variations, it does not affect the humidity swings. That is because the humidity oscillations are in response to the on-off operation of the compressor.

At part load operation, the compressor must cycle off because of low suction temperature. Even a unit equipped with hot gas bypass will cycle its compressor because the system will not bypass enough hot gas to operate continuously at low part load conditions.

To control precisely both temperature and humidity one must be able to vary both the cooling coil temperature and the reheat coil temperature. In a direct expansion refrigeration system, the most efficient way to modulate coil temperature is with a modulating capacity compressor. AGS utilizes a compressor that can modulate its capacity from 10% to 100%.

Figure 2: *Modulating Hot Gas Reheat, Standard On-Off Compressor*

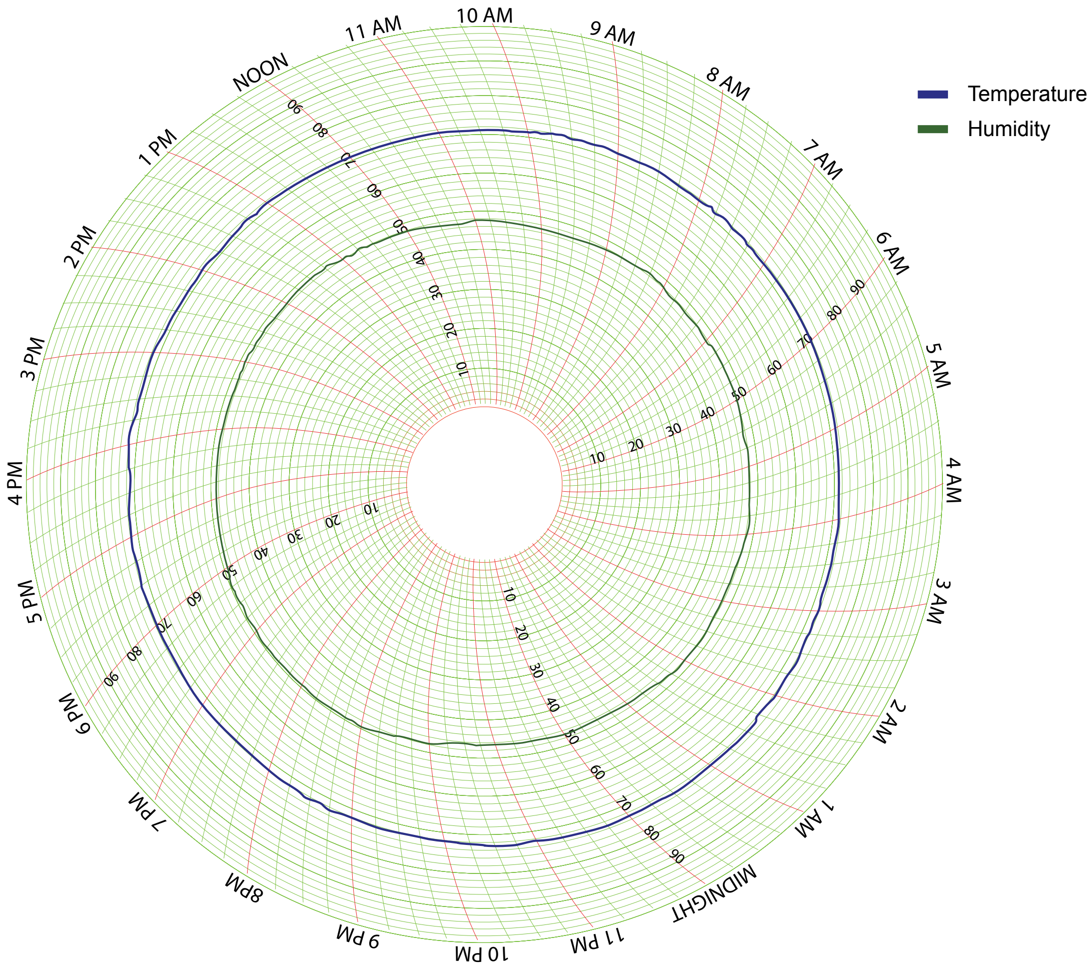


Modulating Reheat & Modulating Compressor

Figure 3 displays the relationship of the modulating compressor and modulating reheat to the temperature and humidity values in the space. This figure reveals the improvements that are obtained by including a modulating capacity compressor and modulating reheat into air conditioning equipment design.

The improved temperature control accomplished by varying the amount of reheat applied to the dehumidified air is still present; in addition, it is now shown that the humidity level is precisely controlled as well. Because the modulating compressor can adjust its capacity to match the required load of sensible or latent cooling, the modulating compressor is not required to cycle on and off as a standard compressor would to match the load. The modulating compressor can therefore maintain much longer run times with much tighter humidity and temperature control. The combination of the modulating reheat and the modulating compressor have completely eliminated the temperature and humidity fluctuations seen in Figure 1 and Figure 2, associated with on-off reheat and on-off compressor control.

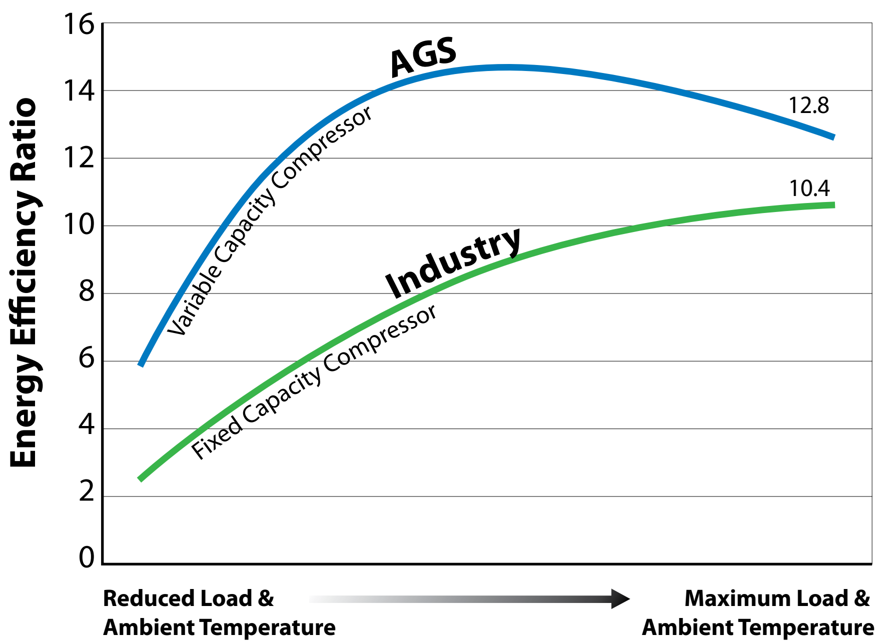
Figure 3: *Modulating Hot Gas Reheat, Modulating Compressor*



Energy Savings with Modulating Compressor

In addition to stable temperature and humidity values, energy savings are also gained, as can be seen in Figure 4. The part load efficiency of equipment with a modulating compressor can be up to 35% more efficient than equipment with a standard on-off compressor and hot gas bypass. Most air conditioning equipment spends 95% or more time operating at less than full load, therefore, there are significant energy savings throughout the year with a system containing a modulating compressor.

Figure 4: *Equipment Part Load Efficiency*



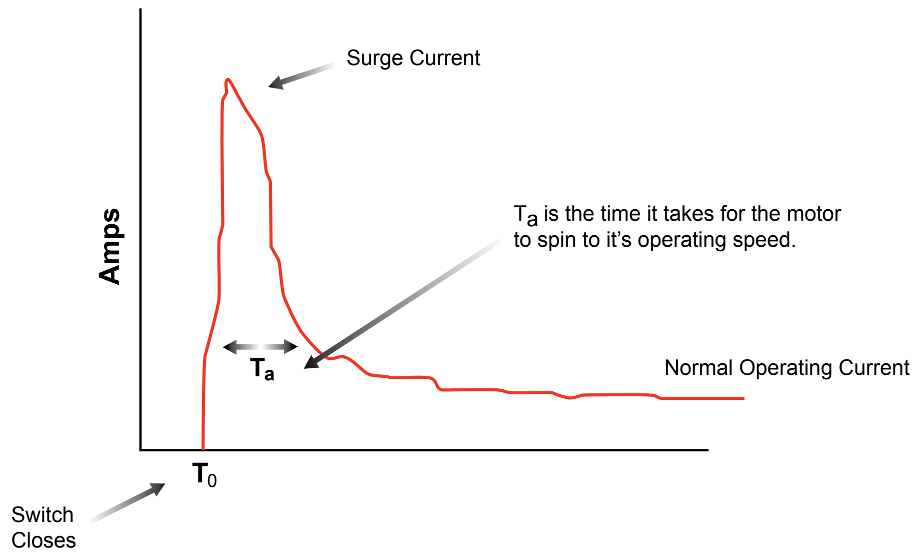
There are a number of factors that contribute to the modulating compressors increased part load efficiency:

Reduced Cycling Losses

To match the required cooling capacity of a given load, traditionally compressors are switched on and off as necessary to meet the load requirements. When an electrical motor starts, such as the motor that drives a compressor, there is an inrush of current (amperage). When an electrical motor is at rest, there is very little inductive resistance to current flow through the windings. As the motor starts to turn, this inductive resistance increases with the increase in RPM. This means that as power is applied to a stopped motor, there is a spike of electrical current far greater in amplitude than the design amp draw of the motor. (Figure 5) This temporarily increases the amp draw, each time the motor starts, and leads to decreased efficiency at part load operation when the compressor cycles on and off because the increased amp draw requires increased power consumption but does not provide an increase in cooling capacity.

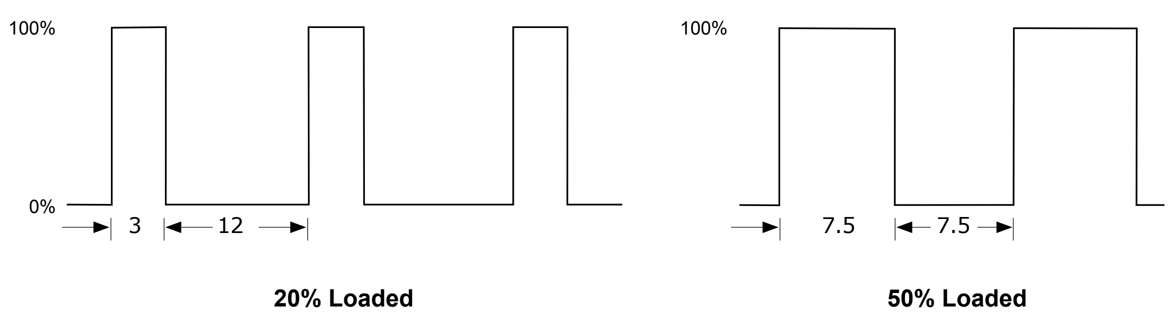
Instead of turning on and off the motor, the capacity of the modulating compressor is controlled through a pulse width modulated signal to a solenoid valve. The compressor motor operates continuously; however, the pumping output of the compressor operates in two stages - the "loaded state" and the "unloaded state". During the loaded state, the compressor operates like a standard scroll compressor and delivers full capacity and mass flow. However, during the unloaded state, there is no capacity and no mass flow from the compressor.

Figure 5: *Example of Motor Inrush Current*



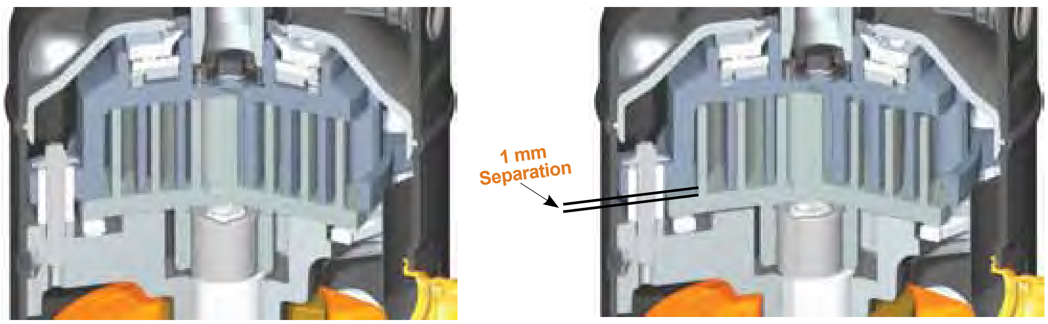
The loaded and unloaded states are created by varying the width of the pulse to a solenoid valve that controls the pumping output of the compressor. This concept can be seen graphically in Figure 6. The solenoid valve allows the scrolls inside the compressor to separate, which results in no compression of the gas in the scrolls. When the solenoid valve reengages the scrolls, compression is resumed. The separation of the top scroll is very small (1.0 mm) and consequently the amount of energy required to reposition the scroll, and vary the pumping output, is very little (Figure 7).

Figure 6: *Concept of Modulating Compressor Cycle Time*



The combination of the loaded and unloaded states, over a period of time, determine the capacity modulation of the compressor. Example: In a 20-second cycle time, if the loaded state time is 4 seconds and the unloaded state time is 16 seconds, the compressor modulation is (4 seconds x 100% + 16 seconds x 0%)/ 20 second = 20%. If for the same cycle time, the loaded state time is 10 seconds and the unloaded state time is 10 seconds, the compressor modulation is 50%. The capacity is a time-averaged summation of the loaded state and unloaded state. By varying the loaded state time and unloaded state time, any capacity (10%-100%) can be delivered by the compressor.

Figure 7: *Loaded and Unloaded Stages of Modulating Compressor*



Loaded Compressor   Unloaded Compressor

This wide capacity output is continuous and seamless and is an improvement over other modulation techniques, where capacity outputs can only be achieved in steps, or the capacity modulation is energy intensive. The seamless delivery of capacity by the modulating compressor ensures that there is a very tight control on room air temperature. The wide capacity output also contributes to the high energy efficiency of the system. Frequent start-stops of the compressor consume more energy. The wider capacity output of the modulating compressor reduces the number of start-stops and saves energy.

Extended Operating Life

The benefit of starting up the motor fewer times not only allows greater operating efficiency; it also can lead to longer motor life. The inrush current (Figure 5), which occurs during the initial start up, can have a harmful effect on motors. The initial inrush current forces the motor to spin to its operating speed immediately and abruptly. This places a great deal of stress on the motor, thereby shortening the useful operating life of the motor. By stopping and starting less, the motor of the modulating compressor has less strain on it and can provide for a longer motor life and reduced maintenance costs for the owner.

Improved Humidity Control

Optimum efficiency and effectiveness of an air conditioning system is achieved at continuous running of the compressor; air conditioners are very inefficient when they first start operation. It is far better for the air conditioner to run steadily for a period than to cycle for many shorter periods. The efficiency of the typical air conditioner increases, the longer it runs, until it reaches a steady operating point.

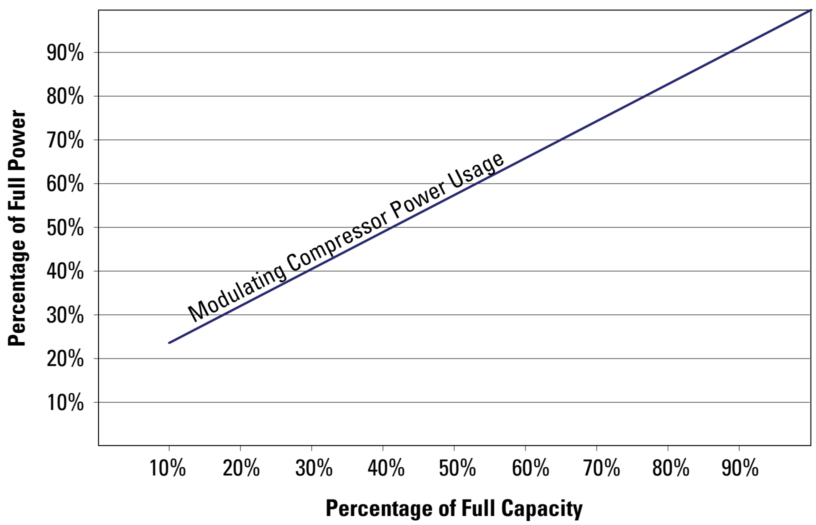
The ability of the air conditioner to remove moisture (latent capacity) is lowest when the compressor first begins to operate. The moisture removed from the indoor air is dependent upon the indoor coil temperature being below the dew point temperature of the air. At startup, the unit's indoor coil has not operated long enough to cool the air to its dew point temperature; therefore, no dehumidification will occur. In addition, for short cycles, the coil does not have time to operate at the dew point temperature for an extended period and when the unit stops, the moisture on the coil evaporates back into the indoor air. Thus, in humid climates, a unit with continuous operation will do a far better job of removing moisture from the air than a unit that turns on and off continuously.

Even at reduced capacity, the modulating compressor provides very good dehumidification because it operates at a lower suction pressure than other modulation techniques. As mentioned before, given any modulation output, the compressor operates at full capacity during the loaded part of the cycle. This full capacity operation results in a lower average suction pressure that leads to a lower coil temperature and greater dehumidification.

Enhanced Compressor to Coil Surface Area Correlation

The efficiency of an air conditioning unit is the ratio of the amount of cooling produced divided by the amount of power used - the higher the number, the greater the efficiency. The capacity of an air conditioner is dependent not only on the outdoor conditions, but also on indoor conditions such as temperature, humidity and airflow.

Modulating Compressor Power Usage Versus Capacity Range



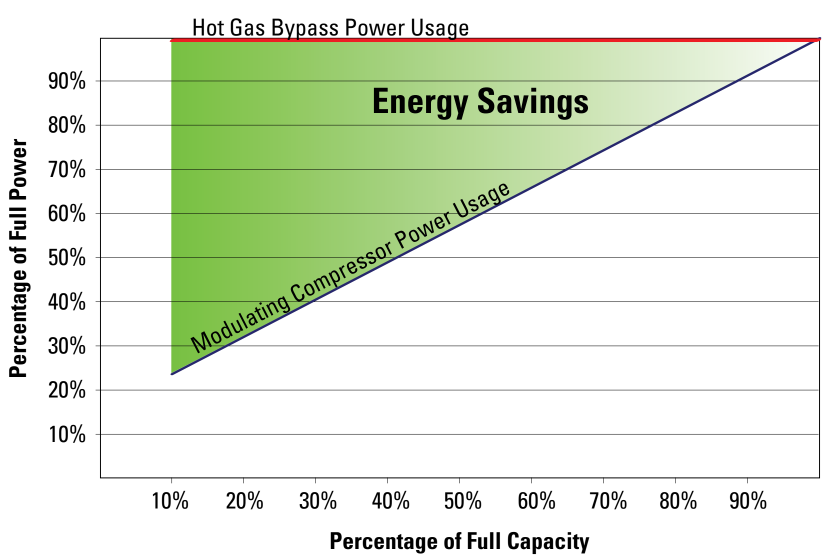
For a fixed capacity, on-off compressor it has been shown that over sizing the indoor coil, in relation to the compressor, generally reduces latent capacity (humidity removal), increases sensible capacity (temperature decrease), and improves overall efficiency. This relationship implies that, assuming all other aspects of the system remain constant, as the surface area of the coil increases in relation to the capacity of the compressor the efficiency of the unit will increase because the area available for heat transfer has increased while the amount of power used by the compressor has not.

The modulating capacity compressor takes advantages of this relationship without the added cost of additional material for larger coils. As the capacity of the compressor is modulated downward, the amount of power consumed by the compressor also decreases (Figure 8). Therefore, in an air conditioning unit with coils of a fixed area and a modulating capacity compressor, the reduced amount of power used by the compressor at part load conditions will lead to increased overall system efficiency, as shown previously in the Equipment Part Load Efficiency of Figure 4.

Modulating Compressor versus Hot Gas Bypass

A common method for modulating system capacity, until the arrival of the modulating compressor, was a technique referred to as, hot gas bypass (HGBP). Hot gas bypass works by diverting hot, high-pressure refrigerant vapor from the discharge line directly to the low-pressure side of the system. This keeps the compressor fully loaded for a greater period while the cooling coil satisfies the part load condition. HGBP greatly reduces operating efficiency because the bypassed vapor does no useful cooling and increases compressor energy usage. In fact, on-off systems equipped with HGBP consume MORE energy than an equivalent on-off system without HGBP. The load created by diverting a portion of hot gas away from the condenser and to the cooling coil requires a longer runtime of the compressor and hence greater energy usage. A standard on-off system would actually use less power than the "modulating" HGBP system because the compressor would turn on and off to match the load.

Figure 9: *Modulating Compressor Energy Savings Verses Hot Gas Bypass Energy Usage*



Why Use a Digital Scroll Compressor?

Sequence of Operation

As the space temperature increases or decreases, the controller modulates the compressor's capacity to maintain the space temperature setpoint.

As the space humidity rises, the controller modulates the compressors capacity to maintain a low evaporator coil temperature to maximize dehumidification and meet the space latent load.

There four common ways to modulate the refrigerant capacity of a cooling system: hot gas bypass, multiple compressors, an inverter driven compressor and a Digital Scroll compressor.

A **hot gas bypass system** mixes hot refrigerant gas from the compressor with cool refrigerant liquid at the evaporator to control the cooling capacity. Hot gas bypass is an inefficient modulation technique because it is adding a false load that the system must satisfy.

A **multiple compressor system** stages the compressors on and off to control the cooling capacity. The problem with this system is that it has a finite number of capacity steps for modulation and will have inefficient operation at many part load conditions. Another issue is at smaller tonnages multiple compressors are often not available.

An **inverter driven compressor system** varies the speed of the compressor motor to control the cooling capacity. This system, however, has oil return issues and the modulation range is limited by the motor speed range.

A **Digital Scroll compressor system** modulates the volume of refrigerant that flows through the cooling system to control the cooling capacity. It is a simple, reliable, energy efficient system with wide modulation capability.

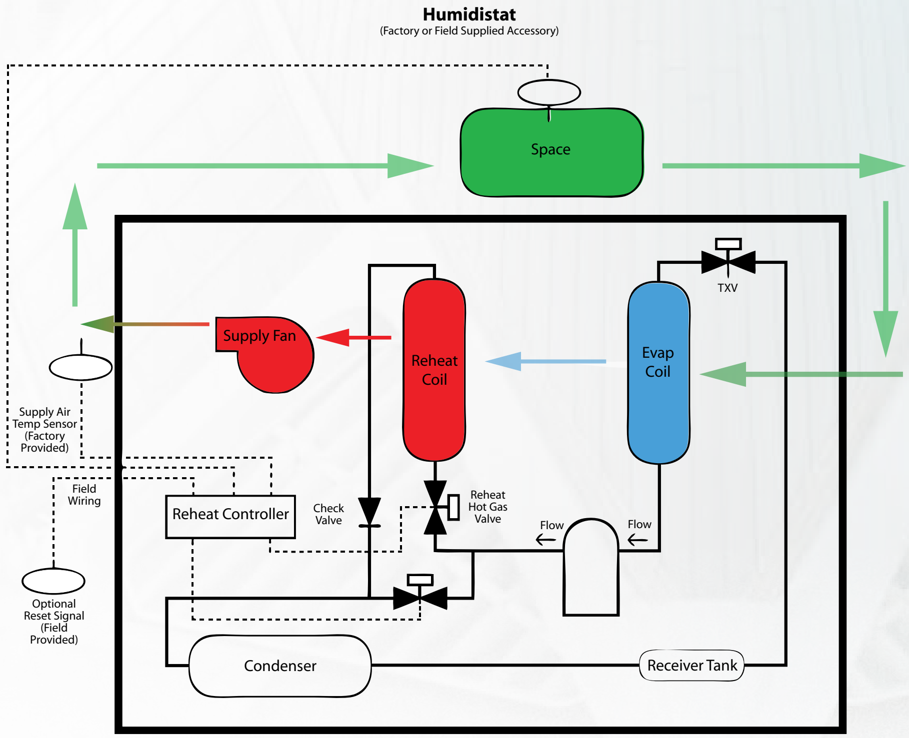


Figure 5: **Modulating Hot Gas Reheat**

Accelerated Growth Solutions

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Precision Enviromental Control Products

AGS Environmentally Friendly HVAC Product Family

Custom & Cataloged Air Handling Units
(800-200,000+ cfm)

Condensers & Condensing Units
(2-230 tons)

Chillers (Air-Cooled, Evaporative-Cooled, Heat Pumps)
(4-5,000+ tons)

Rooftop Units
(2-240 tons)

Outdoor Equipment Rooms
(Chillers, Boilers & Pumps)

Self-Contained Units
(3-70 tons)

Residential Systems
(2-5 tons)

Geothermal & WSHP Units
(2-230 tons)

Air-Source Heat Pumps
(2-230 tons)

Heating and Cooling Coils
(Booster, Hydronic, & DX)

Fluid Coolers
(50-450 tons)

Providing unparalleled temperature and relative humidity control for the indoor agricultural enviroment. We provide products and solutions for the serious home cultivator and the large scale commercial producer alike. AGS can assist in designing facilities as well in the construction process. Contact us for project assistance and pricing.

Defining Quality. Building Comfort.