Four Seasons
CONTROLLED CLIMATES LTD.

PilotLight

A newsletter for the valued customers of Four Seasons Controlled Climates

Summer 2000

This Summer Natural Gas is COOL

SPECIAL REPORT

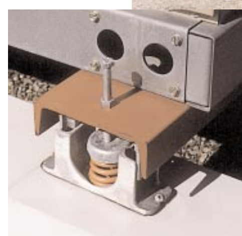
Building owners and managers are getting all fired up about GAS COOLING as the HVAC/R industry spawns a variety of natural gas powered equipment that promise lower operating costs than their electric counterparts.

CASE STUDY

COOLING THE MASSES

Perforated ductwork and levitating HVAC equipment are used to retrofit a local church.

The building that houses the Ethiopian Orthodox Tewahedo Church has rather unorthodox origins. Located in a commercial-industrial zone of North York, the church is a converted industrial building. In converting the secular structure to an ecclesiastical enclave the church required an entirely new HVAC system, which was installed by Four Seasons Controlled Climates. The new HVAC system is made up of rooftop heat/cool HVAC units and a completely new duct distribution system. On the surface this installation would seem rather unremarkable, but as famous architect Mies van der Rohe once said: God is in the details.



Curb-mounted isolation springs keep the HVAC units raised above the rooftop, minimizing the transference of noise and vibration to the church interior.

Holy Ductwork!

Installing the ductwork distribution system presented an interesting challenge. In a typical industrial building, ductwork is usually installed below the ceiling system to avoid run-ins with joists and piping. However, this building was not designed to take a duct distribution system, so a conventional installation would put the ductwork too low and that would unacceptably reduce the ceiling height. In order to keep the ductwork at a sufficient height the Four Seasons Controlled Climates team decided to integrate the ductwork right into the ceiling system. While the ducts were strategically located to avoid as many run-ins with pipes and joists as possible, the sheer length of the ducts made some run-ins inevitable. The solution was to let any interfering pipes and web members run right through the ducts. At some places where ducts cross piping, intersections occurred randomly. But where a duct runs through a series of open web steel joists, the duct had to be perforated at regular intervals where it crossed the web of each joist. In one particular location, a section of rectangular duct had to be "notched out" because it was not possible to run the existing piping through it. The overall result of this carefully contrived retrofit gives one the impression that transfixing the ductwork and the ceiling structure was simply part of the building's original design.

One of the many examples of pipe piercing duct; proving two objects can occupy the same space at the same time.

When you can't go through, you have to go around. Such was the case at this location where the position of the piping precluded going through the duct.

Levitating Equipment

Five heat/cool HVAC units supply the conditioned air that flows though the duct system. Here the low ceilings presented another challenge, namely the transfer of noise and vibration to the inside of the church. The sound of compressors working and fans blowing large volumes of air through metal ductwork could be distracting to the assembled congregation during services, so several steps were taken to ensure the HVAC units would remain as ubiquitous as possible.

The best way to reduce the transfer of noise and vibration from HVAC units to a rooftop is simply to keep the HVAC units off the roof. To accomplish this, each HVAC unit was mounted onto a spring isolation system in which the unit sits atop an array of spring supports that are specially designed to dampen noise and vibration. The spring isolators themselves are mounted to base curbs. With this system the HVAC units are, in effect, levitated above the rooftop and are never in direct contact with the building structure.

The initial length of ductwork that connects each HVAC unit to the building is exposed; therefore there was the potential for noise from the equipment and ambient outdoor noise to enter the building and travel through the distribution ducts. To minimize the transfer of noise and vibration the ductwork was acoustically isolated from the HVAC unit using flexible canvas duct connectors. As a final sound-reduction measure the exposed ducts were lined with acoustic insulation.

With a new quiet-running HVAC system and a space saving duct distribution system, the church can now offer it's congregation a place to maintain the comfort of the body while they tend to the well-being of the soul.

SPECIAL REPORT

Gas Cooling

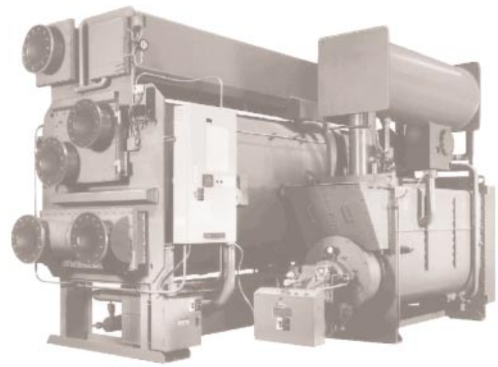
This summer we are once again flocking to the comfort of air conditioned spaces in order to escape the scorching heat. Cooling systems all around the country are being started up – or should we say “fired” up? While the operators of most cooling systems will hear the *whir* of an electric motor, more and more will be hearing the *phooomph* sound of gas burners igniting or internal combustion engines revving up. That’s because more cooling systems than ever are being powered by natural gas instead of electricity.

In many parts of the world natural gas is threatening electricity’s dominance as the energy source of choice for cooling systems. Here in North America gas cooling still only has about 8% of the space cooling market but experts predict that figure will rise sharply over the next several years.

In this special report we take a look at three types of gas cooling systems at the forefront of this growing trend and learn what is driving the market. From environmentally-friendly absorption technology to the performance of gas engine chillers and the precise humidity control of desiccant systems, ‘gas’ is definitely expanding as a fuel for cooling in the 21st century.

Absorption Chillers

An environmentally-friendlier alternative



Carrier 16DF Absorption Chiller-Heater

Absorption cooling is heating up around the world. Today in Japan, for example, more than half of total installed cooling tonnage is handled by absorption cooling equipment such as absorption chillers. While the growing use of absorption chillers may be a new trend, absorption cooling technology itself is not new; the first absorption chillers were developed in the 1800s. Despite the long history of absorption cooling, the 20th century had been dominated by electrically-powered, compressor-driven cooling systems. However, due to recent developments, absorption chillers are now considered viable alternatives to electric chillers for many applications.

Environmental Concerns

One main reason for the increased use of absorption chillers is that fluorocarbon-based refrigerants, which are used in electric chillers, can be harmful to the environment, particularly to the ozone layer.

The Montreal Protocol, established in 1987 and signed by forty-three countries, resulted in the phase-out of CFCs (Chlorofluorocarbons), thus accelerating the search for environmentally-safe alternatives. When they were first introduced, HCFCs (Hydrochlorofluorocarbons) were widely accepted as suitable replacements. However in 1990 HCFCs were added to the list of compounds to be phased out. Another alternative, HFCs (Hydrofluorocarbons) are considered benign with respect to ozone depletion but HFCs have been identified as 'green-house' gasses. Legislators have responded with more stringent regulations and harsher penalties for the improper use and disposal of fluorocarbon-based refrigerants.

The bottom line is that virtually all refrigerants used in electric cooling systems are either targeted for phase-out or face growing opposition. This casts a shadow of uncertainty on the long-term future of electric cooling systems if safe, affordable alternative refrigerants are not developed.

Absorption chillers, on the other hand, use no ozone-destroying substances and produce far less green-house gas emissions.

Electricity Costs

Electricity prices are the second main reason for the growing popularity of absorption cooling and for the growing use of gas cooling in general. First, the cost of electricity is rising, making all electric equipment generally more expensive to operate. Secondly, with the coming deregulation of Ontario's electricity market, forecasting electricity prices is difficult. Some experts predict that energy charges may go down but demand charges (the charge for drawing more than 50 kilowatts) will increase. Demand charges can have a great impact on overall electricity costs. Let's take a simple example using a 1000 ton electric chiller that runs 8 hours a day, 5 days a week. In one month the chiller will have run for 176 hours. If the chiller draws a constant 500 kilowatts (kW), the total energy used will be 88,000 kilowatt-hours (500 kW X 176 hours). At an average price of 6.4¢ per kWh the energy cost would be $5,632. However with a demand charge of $6.45 for every kW above 50kW that the chiller draws, the demand cost would be $2,902.50. In other words, the demand charge added more than 51% to the cost of the actual electrical energy used.

Direct-fired absorption chillers run primarily on natural gas. Prices for natural gas are also rising but they are generally much more stable and predictable than electricity prices and their are no time-of-use penalties or maximum load charges for natural gas. Furthermore, kilowatt for kilowatt, the cost of natural gas is far less than electricity – about 2.3¢ per kWh.

Disadvantages

While absorption cooling has some advantages over electric cooling it also has some pretty significant disadvantages. First of all absorption chillers can cost two and a half times more than electric chillers. Also, absorption cooling is inherently less efficient than electric cooling, making absorption cooling systems larger than electric systems of equal capacity. However, efficiency is improving. A recent innovation called the *two-stage absorption cycle* (see "How it Works", next page) has increased efficiency by up to 45% over older, single-stage systems.

Cooling and Heating in One

A major benefit of absorption chillers is their ability to supply both chilled and heated water. Thus, a properly sized absorption chiller can handle both a building's cooling and heating requirements, eliminating the need for a boiler. It is also possible to configure an absorption chiller to supply chilled and heated water *simultaneously* for process applications.

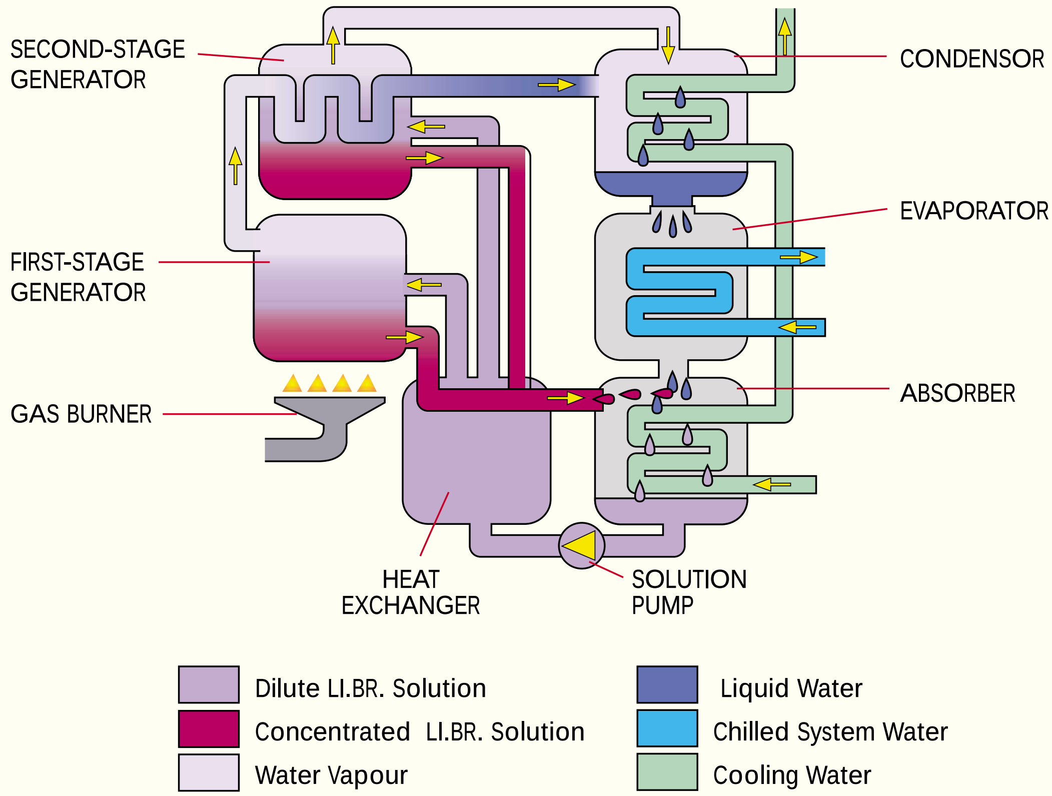
Electric-Absorption Hybrid Systems

In an electric-absorption hybrid system an electric chiller typically handles base load requirements and an absorption chiller handles peak loads. Hybrid systems take advantage of an electric chiller's higher efficiency while reducing or avoiding costly electricity demand charges. Having two chillers also adds redundancy, which can be a great benefit in the event of a breakdown.

Will absorption cooling ever supersede electric cooling?

Only time will tell, but with the uncertain future of fluorocarbon-based refrigerants, and rising, unstable electricity prices, demand for absorption cooling is definitely rising. How ironic that one of the dominant cooling technologies of the hi-tech 21st century may be one that utilizes an intrinsically low-tech process invented way back in the 19th century.

HOW IT WORKS



Following is a description of the cooling cycle in a direct-fired, two-stage, absorption liquid chiller-heater, powered by natural gas. Absorption cooling relies on three principles: 1) Liquids, such as water, boil (evaporate) at a lower temperature when under low pressure; 2) Lithium bromide has a strong affinity for water and readily absorbs it, and; 3) in a sealed (hermetic) system a vacuum is created when water in the system is absorbed by lithium bromide. While the description of the process is broken down into stages to make the process easier to understand, in actuality the process is continuous.

1. Solution Pump

A dilute solution of lithium bromide and water descends from the Absorber to the Solution Pump which moves the dilute solution to a Heat Exchanger (there are actually two Heat Exchangers, but for simplicity, only one is shown). The flow of dilute solution is split into two streams. One stream is pumped to the First-Stage Generator, the other is pumped to the Second-Stage Generator.

2. First-Stage Generator

The dilute solution in the First-Stage Generator is heated by a gas burner. Heating the dilute solution boils off much of the water, leaving a very concentrated lithium bromide solution. The concentrated solution is routed to the Heat Exchanger, while the hot water vapour goes to the Second-Stage Generator.

3. Second-Stage Generator

The dilute solution in the Second-Stage Generator is heated by the hot water vapour from the First-Stage Generator. As the water vapour gives up its heat it condenses to liquid. As in the First-Stage Generator, heating the dilute solution produces hot water vapour and concentrated solution. The concentrated solution goes to the heat exchanger while both the water vapour and the liquid water go to the Condenser.

4. Condenser

As it enters the Condenser, the liquid water vapourizes due to the low pressure inside the condenser. This water vapour combines with the water vapour coming from the Second-Stage Generator. The combined water vapour condenses to liquid as it is cooled by the condenser water. The liquid then flows down to the Evaporator.

5. Evaporator

The Evaporator is where the system water used for cooling the facility's supply air is chilled. The liquid water coming from the Condenser is sprayed over the Evaporator tubes which carry the system chilled water. Due to the extreme vacuum in the Evaporator some of the water vapourizes. As the water vapourizes it draws heat from the returning system water. The chilled water is then re-supplied to the system.

6. Absorber

The vacuum needed to vapourize the water in both the Condenser and the Evaporator is created by the absorption of water by the lithium bromide inside the Absorber. As the water liquid/vapour mix descends to the Absorber from the Evaporator, concentrated lithium bromide solution from the First and Second-Stage Generators is sprayed into the flow of the descending liquid/vapour mix and the water is absorbed by the lithium bromide. As the water is absorbed a vacuum is created. The water also gives off heat as it is absorbed, which is removed by the condenser water. The resulting dilute lithium bromide solution collects in the Absorber where it flows down to the Solution Pump to begin the cycle again.

Gas Engine Chillers

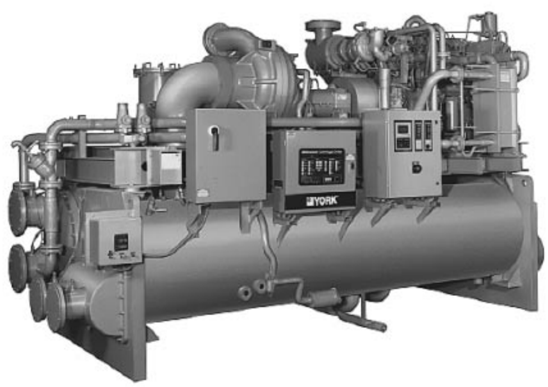
Turbocharge your cooling system

Ever thought of using a car engine to run your air conditioner? That's essentially the idea behind gas engine chillers. In a traditional compressor-driven chiller, the compressor is powered by an electric motor. In a gas engine chiller, the electric motor is replaced by a natural gas-powered internal combustion engine.

Gas engine chillers have been marketed in North America since 1960 but they have enjoyed only limited success – until now, that is. Over the fast few years the demand for gas engine chillers has increased and naturally so has the number of manufactures who are selling them.

What is driving this sudden increase in demand four decades after these systems first came to market? While environmental concerns may be a factor behind the growing popularity of other gas cooling technologies like absorption chillers, this is not the case with gas engine chillers. Unlike absorption cooling, which uses water as the refrigerant, compressor-driven chillers – whether they are powered by an electric motor or a gas engine– use HCFC or HFC refrigerants. Although not as harmful as CFCs, these compounds are certainly not benign, and have subsequently come under the watchful eye of environmental interests and legislators. Also, the internal combustion engine, with it's wide variety of harmful emissions has never been the paragon of environmental friendliness. To be fair, however, natural gas engines have lower emissions than gasoline-powered engines do.

The main reason the demand for gas engine chillers is growing is one of the main reasons that all gas cooling technology is becoming more popular – the cost of electricity. Rising, unstable electricity prices are making natural gas-powered chillers much more attractive from the standpoint of operating costs if not from the standpoint of purchase price.



This York Millennium gas engine chiller uses a turbocharged, 6-cylinder, liquid-cooled, four-cycle, 1800 RPM engine to drive a centrifugal compressor.

The Engine

A gas engine chiller has an internal combustion engine similar to the one you'd find in most cars, except it has been modified to run on natural gas. Some chillers employ purpose-designed industrial engines while others use engines that have been derived from mass-produced automobile engines. The automotive derivative engines typically cost far less due, at least in part, to the higher economies of scale in the automobile industry. Unlike electric motors which can reside inside the compressor housing, gas engines must be mounted external to the compressor in a open-drive configuration.

The Compressor

There are five types of compressors than can be used in compressor-driven chillers: *reciprocating, centrifugal. rotary, screw and scroll*. (For an explanation of how the different compressors work, see the article "Passing Gas")

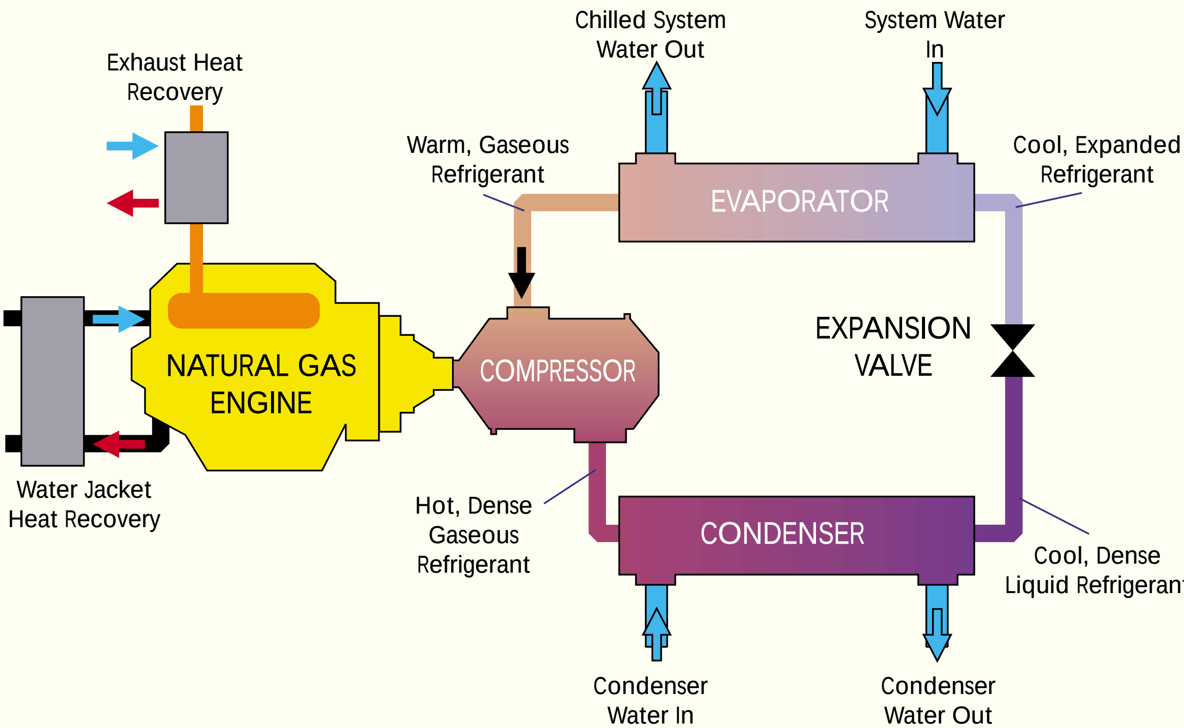
Gas Engine Chillers vs. Electric Chillers

- Wide range of operating speeds makes gas engine chillers more efficient than electric chillers at partial loads. On average, chillers operate at peak loads only about 1% of the time.
- Gas engines are capable of exceeding rated outputs for brief periods, sometimes allowing for the selection of a somewhat smaller unit that will still be able to handle peak loads.
- The engine itself generates heat which can be recovered and utilized for other purposes, such as for heating water.
- Gas engine chillers require more maintenance than electric chillers due to the mechanical complexity of the engine, although reports show natural gas engines need less maintenance than gasoline engines do.
- A study by the Georgia Institute of Technology shows that a gas engine chiller can have an equipment cost that is three times higher than that of an electric chiller of equal capacity but can have just over half the annual energy costs. A pay-back period of several years is typical.

Gas-Electric Hybrids

For those who want the best of both worlds, at least one manufacturer is offering a gas-electric hybrid chiller which comes equipped with both a natural gas engine *and* an electric motor. Hybrid chillers are capable of switching between the engine and the electric motor to drive the compressor. Hybrid systems enable operators to respond virtually instantly to changing electricity prices and also to avoid peak demand charges, therefore minimizing operating costs.

HOW IT WORKS



A gas engine chiller, as shown in the schematic above, mates a natural gas internal combustion engine to a compressor-driven chiller.

The Natural Gas Engine

Besides providing the energy needed to drive the compressor, the gas engine also generates heat which, if recovered, can be used for other purposes, such as water heating. The heat recovery feature is partly what makes gas engine chillers cost less to operate over electric chillers.

The Vapour Compression Cycle

The underlying process of any compressor-driven chiller is the vapour compression cycle. The vapour compression cycle relies on two principles.

The first principle is that a fluid absorbs heat when changing from a liquid to a gas and releases heat when changing from a gas to a liquid. During this change in state, the temperature of the fluid does not change until all of the fluid is evaporated or condensed. The energy needed to change the state of a fluid is called latent energy or latent heat. A proportionately larger quantity of heat is needed to change state than to raise temperature. This is because when a fluid evaporates the molecular bonds that hold the fluid in a liquid state must be broken, and breaking molecular bonds requires a lot of energy.

The second principle is that the boiling point of a liquid changes with pressure. The lower the pressure, the lower the boiling point. In fact, it is possible to boil a liquid without adding heat, but simply by sufficiently lowering the pressure it is under. Following is an explanation of the vapour compression cycle.

1. The Compressor

Refrigerant enters the compressor as a gas. The compressor applies pressure to the gas, reducing its volume and raising its temperature. Compressing the refrigerant also raises the temperature at which the refrigerant will condense to liquid. After leaving the compressor the hot, compressed refrigerant gas travels to the condenser.

2. The Condenser

In the condenser, cold water is used to cool the refrigerant gas and condense it to liquid. While the temperature of the refrigerant changes, the pressure of the refrigerant is the same as it was when it left the compressor.

3. The Expansion Valve

After leaving the condenser, the high-pressure liquid refrigerant passes through an expansion valve that restricts the flow of refrigerant. The flow restriction reduces the pressure of the refrigerant. By reducing the pressure, the boiling point is lowered making the refrigerant more efficient at removing heat. As the pressure is reduced the refrigerant begins to expand and its temperature drops.

4. The Evaporator

After flowing through the expansion valve the refrigerant enters the evaporator. Due to the lower pressure in the evaporator, some of the refrigerant immediately evaporates and absorbs heat from the system water, thus chilling it. As the refrigerant flows through the evaporator, more and more of it evaporates as heat is absorbed. By the time the refrigerant leaves the evaporator it is entirely gaseous. It is then piped to the compressor where the cycle begins again.

Desiccant Wheel Dehumidification Systems

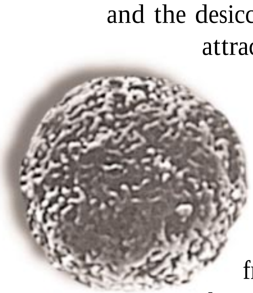
Powerful dehumidification on a roll

Dehumidification is one of the natural benefits of air conditioning. But sometimes the level of dehumidification provided by a building's cooling system is just not enough for certain environments. In cases where extra dehumidification power or precise humidity control is needed, desiccant dehumidification systems are often used. Desiccant dehumidification systems are used in applications where moisture levels of less than 40°F dew-point are required. (Dew point is the temperature at which water vapour will condense out of air. At a constant temperature, the higher the relative humidity level of the air is, the higher the dew point will be. For example, air with a dew point of 40°F contains less moisture than air with a dew point of 50° F).

Desiccant-based systems are the most economical choice to dehumidify air below 40°F dew-point, because condensate often freezes on the coils of conventional cooling systems at temperatures below 40°F, thereby reducing the coil moisture removal capability. If the dew-point requirement is between 40°F and 50°F, the choice to employ a desiccant-based system will depend on the site-specific conditions and requirements. If the dew-point requirement is greater than 50°F, dehumidification using a conventional air conditioning system is generally favoured.

What is a Desiccant?

A desiccant is a material that has a high affinity for water. Desiccants attract moisture by virtue of differences in vapour pressure. Desiccants naturally have a very low vapour pressure relative to air. The difference in vapour pressure between the air and the desiccant material causes moisture from the air to be attracted to the desiccant material.



Desiccants come in two basic categories: ***ab***sorbents which are liquids and ***ad***sorbents, which are granular solids. Absorbent desiccants attract and retain water molecules with chemical bonds, forming solutions. Lithium bromide is a common liquid desiccant (You may recall from the article on *absorption chillers* that lithium bromide is used in these systems).

Adsorbent desiccants attract and retain water molecules inside pores on their surface. Some common solid desiccant materials are *silica gel*, *titanium silicates* and *zeolite*. As shown by the photo of a magnified grain of silica gel at left, solid desiccants have a highly porous structure, which gives them a large surface area on which to capture moisture. Silica gel, for example, has a surface area of 750 square meters per gram! Most desiccant dehumidification systems use solid desiccants.

A desiccant will remove water vapour from the air until equilibrium is reached between the moisture level of the air and the moisture level of the desiccant. Once equilibrium has been reached the desiccant will no longer attract moisture. However the desiccant can be dried (regenerated) with heat, after which it can be used again. In general, temperatures between 180°F and 220°F are required for regeneration.

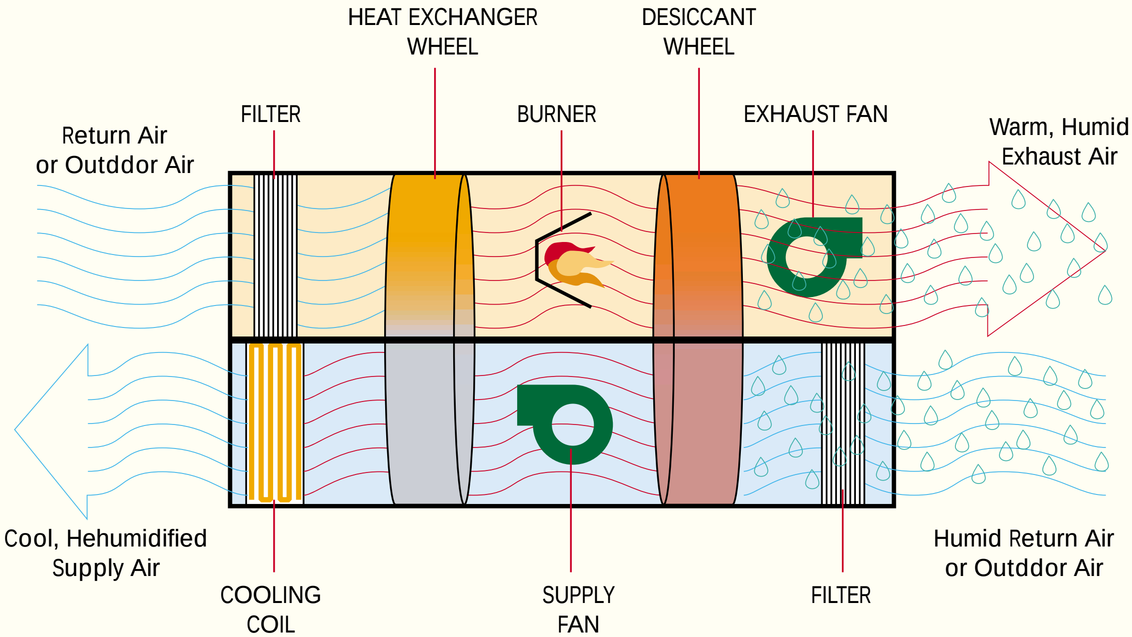
Applications for Desiccant Dehumidification

- supermarkets, food preparation plants and restaurants
- hospital operating rooms
- schools
- ice arenas
- unheated warehouses and storage areas
- environmental chambers
- chemical processing plants and water treatment plants
- electronic instrument manufacturing plants
- pharmaceutical manufacturing plants and laboratories
- in conjunction with conventional air conditioning where the air conditioning system cannot provide adequate dehumidification.

Benefits of Desiccant Dehumidification

- Reduction in the size of an existing air conditioning system is often possible because the dehumidification load is shifted to the desiccant system.
- Independent control of temperature and humidity. In conventional cooling systems, only temperature is controlled directly. Dehumidification is a secondary effect.
- Can reduce moisture much below 40°F, while conventional cooling systems can only dehumidify the air to temperatures above 40°F.
- Can improve indoor air quality because humidity levels can be precisely controlled as desired.
- Can utilize an existing boiler to supply the heat needed to regenerate the desiccant.
- Do not use ozone-depleting substances.
- Can reduce electricity costs, especially in humid regions, due to the reduced load on the air conditioning system.
- Reduced chance of microbial growth because there is typically very little water on a post-desiccant cooling coil or, subsequently, in the drain pan and the air distribution ducts.

HOW IT WORKS



The schematic above shows a Two-Wheel Desiccant Dehumidification System (TWDDS). A typical TWDDS consists of a desiccant wheel, heat exchanger wheel, supply fan, exhaust fan, a heat source for regenerating the desiccant and an optional cooling coil. The TWDDS is divided into two sides, the process side (blue) where air is dehumidified and cooled, and the regeneration side (orange) where the desiccant wheel is regenerated.

Both the desiccant wheel and the heat exchanger wheel are constantly rotating so that half of each wheel is always in the process side and half is in the regeneration side of the TWDDS. As it rotates, the desiccant wheel continuously picks up moisture in the process side and releases that moisture in the regeneration side. Similarly, the heat exchanger wheel continuously picks up heat on the process side and releases that heat in the regeneration side.

The desiccant is a finely divided material, usually silica gel, titanium silicates, or some type of zeolite. The desiccant material is impregnated into a fibrous support structure that has been rolled into the shape of a wheel or into a wheel-shaped rotor with a lightweight structural honeycomb core of man-made, fire-retardant material. The heat exchanger wheel resembles the desiccant wheel in appearance and design.

1. Dehumidifying the Process Air

The process airstream is made up of either outside air, return air from the conditioned space or a mixture of both, depending on the specific application. As the process air passes through the desiccant wheel, the desiccant adsorbs the moisture it holds. As the moisture is adsorbed it condenses and gives off heat. The heat remains in the process air stream, increasing the air stream's temperature. The process air is now dry and hot. It must be cooled before it can be supplied to the conditioned space.

2. Cooling The Dehumidified Air

In a system with a supplemental cooling coil, as shown, cooling the dehumidified air takes place in two stages. First the dehumidified air passes through the heat exchanger wheel where much of the heat is removed. After passing through the heat exchanger wheel, the dehumidified air passes through the cooling coil to further lower the air temperature, making it cool enough to be introduced into the conditioned space.

3. Regenerating the Desiccant

The saturated desiccant must be dried (regenerated) before it can pick up more moisture. The desiccant is regenerated by the regeneration air stream. The regeneration air stream is made up of outdoor air, return air or a mixture of both and it must be at 180º F or higher to regenerate the desiccant.

The regeneration air stream is heated in two stages. First, the regeneration air stream passes through the heat exchanger wheel where it picks up the heat that the heat exchanger wheel recovered from the dehumidified air. Next the regeneration air is further heated by a direct-fired natural gas burner or other heat source.

A TWDDS can be configured in several modes for different applications. In Recirculation Mode the TWDDS is used to dehumidify and recirculate conditioned inside air. In Ventilation Mode the TWDDS can be used to introduce cool, dry outdoor air into a building space. In Makeup Air Mode it supplies cool, dry air to replace air that is exhausted from a process application.

Passing Gas

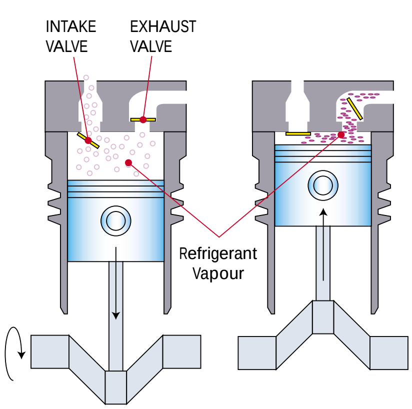
A quick look at how different compressors work

Most cooling systems, from residential air conditioners to large commercial and industrial chillers, employ the refrigeration process known as the *vapour compression cycle*. At the heart of the vapour compression cycle is the mechanical compressor. A compressor has two main functions: 1) to pump refrigerant through the cooling system and 2) to compress gaseous refrigerant in the system so that it can be condensed to liquid and absorb heat from the air or water that is being cooled or chilled (See the "How it Works" section of the article “Gas Engine Chillers” for an explanation of the vapour compression cycle).

There are many ways to compress a gas. As such, many different types of compressors have been invented over the years. Each type utilizes a specific and sometimes downright ingenious method to pressurize refrigerant vapour. The five types of compressors used in vapour compression systems are *Reciprocating*, *Rotary*, *Centrifugal*, *Screw* and *Scroll*.

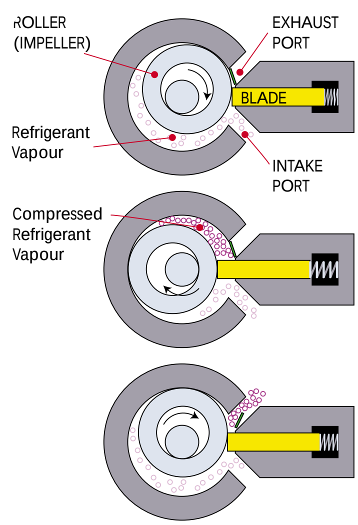
Reciprocating Compressors

A reciprocating compressor uses the reciprocating action of a piston inside a cylinder to compress refrigerant. As the piston moves downward, a vacuum is created inside the cylinder. Because the pressure above the intake valve is greater than the pressure below it, the intake valve is forced open and refrigerant is sucked into the cylinder. After the piston reaches its bottom position it begins to move upward. The intake valve closes, trapping the refrigerant inside the cylinder. As the piston continues to move upward it compresses the refrigerant, increasing its pressure. At a certain point the pressure exerted by the refrigerant forces the exhaust valve to open and the compressed refrigerant flows out of the cylinder. Once the piston reaches it top-most position, it starts moving downward again and the cycle is repeated.



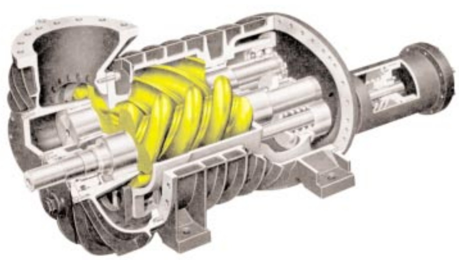
Rotary Compressors

In a rotary compressor the refrigerant is compressed by the rotating action of a roller inside a cylinder. The roller rotates eccentrically (off-centre) around a shaft so that part of the roller is always in contact with the inside wall of the cylinder. A spring-mounted blade is always rubbing against the roller. The two points of contact create two sealed areas of continuously variable volume inside the cylinder. At a certain point in the rotation of the roller, the intake port is exposed and a quantity of refrigerant is sucked into the cylinder, filling one of the sealed areas. As the roller continues to rotate the volume of the area the refrigerant occupies is reduced and the refrigerant is compressed. When the exhaust valve is exposed, the high-pressure refrigerant forces the exhaust valve to open and the refrigerant is released. Rotary compressors are very efficient because the actions of taking in refrigerant and compressing refrigerant occur simultaneously.



Screw Compressors

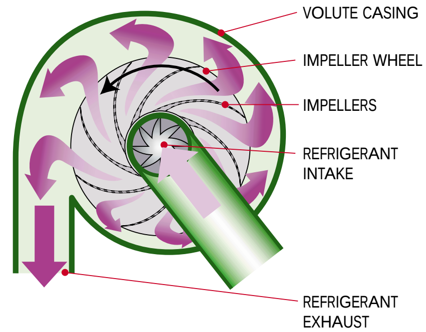
Screw compressors use a pair of helical rotors (male and female) inside a sealed chamber. As the rotors rotate they intermesh, alternately exposing and closing off interlobe spaces at the ends of the rotors. When an interlobe space at the intake end opens up, refrigerant is sucked into it. As the rotors continue to rotate the refrigerant becomes trapped inside the interlobe space and is forced along the length of the rotors. The volume of the interlobe space decreases and the refrigerant is compressed. The compressed refrigerant exists when the interlobe space reaches the other end.



Centrifugal Compressors

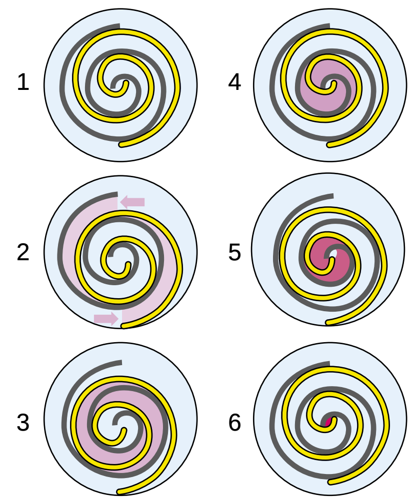
Centrifugal compressors use the rotating action of an impeller wheel to exert centrifugal force on refrigerant inside a round chamber (volute). Refrigerant is sucked into the impeller wheel through a large circular intake and flows between the impellers. The impellers force the refrigerant outward, exerting centrifugal force on the refrigerant. The refrigerant is pressurized as it is forced against the sides of the volute. Centrifugal compressors are well suited to compressing large volumes of refrigerant to relatively low pressures. The compressive force generated by an impeller wheel is small, so chillers that use centrifugal compressors usually employ more than one impeller wheel, arranged in series. Centrifugal compressors are desirable for their simple design and few moving parts.

Typical impeller wheel of a centrifugal compressor

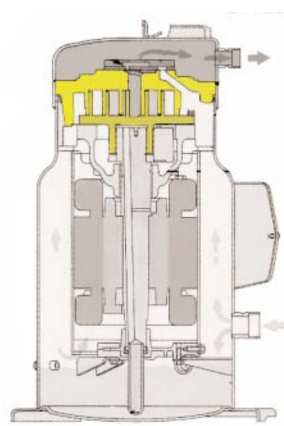


Scroll Compressors

In a scroll compressor refrigerant is compressed by two offset spiral disks that are nested together. The upper disk is stationary while the lower disk moves in orbital fashion. The orbiting action of the lower disk inside the stationary disk creates sealed spaces of varying volume. Refrigerant is sucked in through inlet ports at the perimeter of the scroll. A quantity of refrigerant becomes trapped in one of the sealed spaces. As the disk orbits the enclosed space containing the refrigerant is transferred toward the centre of the disk and its volume decreases. As the volume decreases, the refrigerant is compressed. The compressed refrigerant is discharged through a port at the centre of the upper disk.



Scroll compressors are quiet, smooth-operating units with the highest efficiency ratio of all compressor types. They are commonly used in automobile air conditioning systems and commercial chillers.



Willy spent many a lazy summer day cruising the Mississippi on a big old river boat with his friend Mark Twain – 'course back then they called him Sam. Willy remembers how much Twain liked to opine (with such sharp wit) on just about any subject. Here are some of Willy's favourite 'Twainisms'.

"All you need in life is ignorance and confidence and then success is assured."

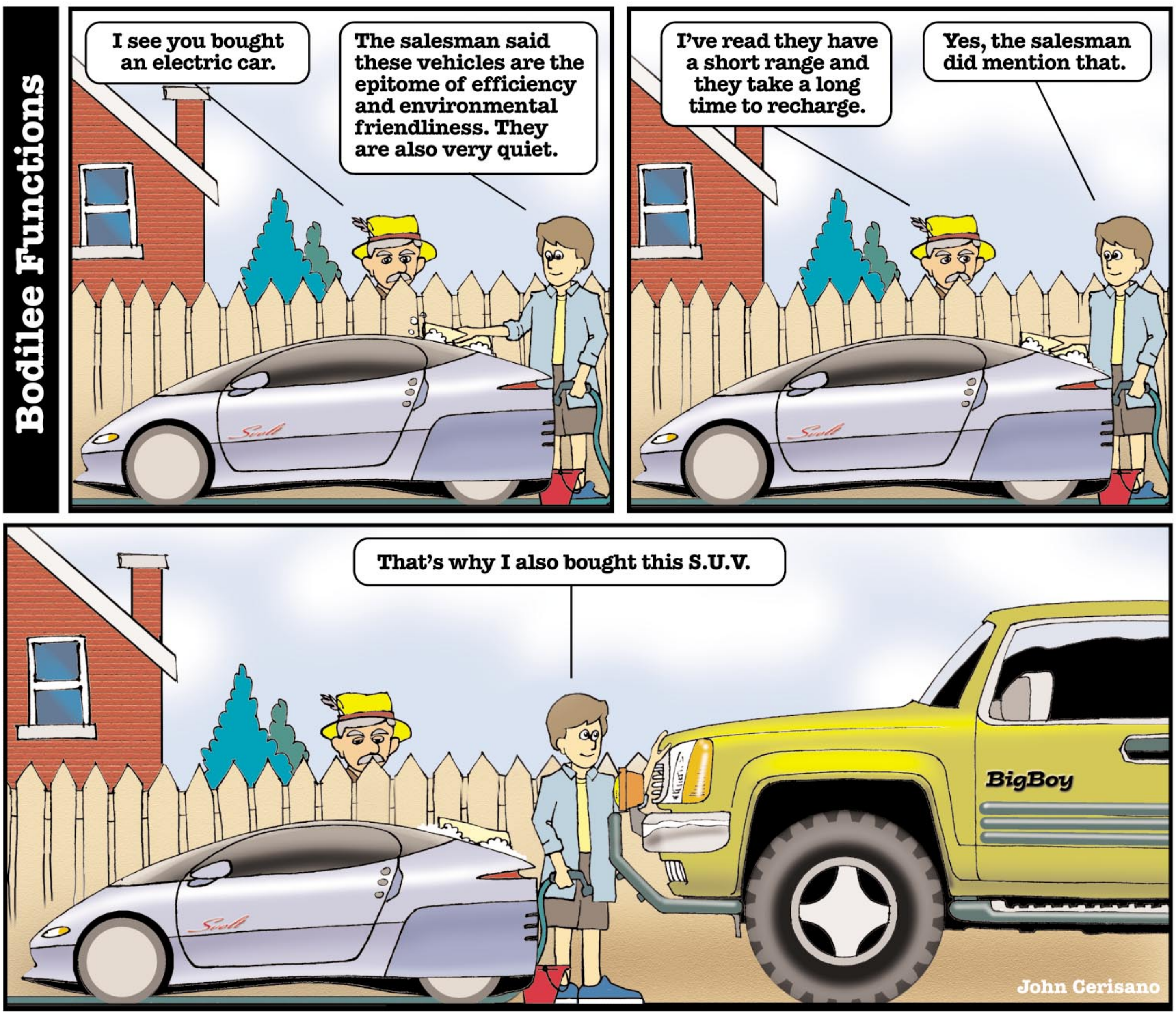
"The lack of money is the root of all evil."

"There are two times in a man's life when he should not speculate: when he can afford to and when he can't."

"Thousands of geniuses live and die undiscovered – either by themselves or by others."

"Why shouldn't truth be stranger than fiction? Fiction, after all, has to stick to possibilities."

"If we had less statesmanship, we would get along with fewer battleships."



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