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NEW Applications for Gas Cooling



By William Ryan, Ph.D, P.E.

At the beginning of 2002, new technologies for gas cooling and cogeneration systems were emerged from the laboratory and the minds of designers. Today, some of these systems have been installed and are being tested, including residential, light commercial, and central chiller plant systems. This article discusses why there is so much interest in these systems and some of the demonstrations that are currently underway.

Large Residential Applications

Since 1970, the average new home size has grown from less than 1,600 ft² (149 m²) to more than 2,200 ft² (204 m²). More than 10% of all new single-family detached homes built today are more than 4,000 ft² (372 m²).

These larger homes are at the high end of the luxury market, where "high comfort" heating and cooling options are required. In addition, these large homes face some of the same HVAC design issues as small commercial buildings.

Traditionally, homes have been treated as a single-zone system with heating and cooling operating on one thermostat. When a large home is designed in this way, uneven temperature distribution can become extreme. For this reason, many homes above 2,000 ft² (186 m²)

are designed with two independent single-zone systems, often one upstairs and another downstairs. However, by the time the home has increased to 4,000 ft² (372 m²), four or more zones may be required. At this point, the conventional design becomes complex and expensive with four or more independent condensing units decorating each wall of the home and operating noisily. Clearly, some other system that addresses the needs of these large homes is required.

Commercial HVAC systems provide some design and equipment direction. Novel residential systems that have come to market for larger homes include: air systems with power zoned air valves (similar to VAV systems), multi-zone, multiple evaporator refrigerant-based fan coil systems, and electric chilled water

systems with multiple fan coils. All of these systems are more expensive than single-zone systems, but provide greater comfort. Zoned hydronic heating systems, whether conventional or in-floor hydronic, provide multi-zone heating comfort but cannot handle cooling.

Gas Air Conditioners

Small gas air conditioners, produced in large numbers in the 1960s, operated on an ammonia water absorption cycle. By code, ammonia is not allowed within residences in any quantity. Therefore, these systems have always been outdoor air-cooled chillers that delivered chilled water to indoor cooling coils.

Such systems are at a distinct first-cost disadvantage relative to a simple direct expansion system for small 3-ton (10.5 kW_e) single-zone homes. Although these gas air-conditioning systems often were cheaper to operate, the savings were generally not enough to justify the added first cost and gas air conditioning fell from common usage.

The revival of interest in gas air conditioning is, in part, due to the benefits

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of chilled water. By providing cooling with chilled water, the systems can be zoned for the high-end residential market (*Figure 1*). Adding a heating boiler can provide a fully zoned hydronic heating and cooling solution. In many cases, this hydronic approach is close to the first cost of “high-end” zoned electric systems, while still maintaining operating cost advantages (see sidebar, “A California Test Case”).

Another Approach to Gas Cooling

Taking the technology to a more advanced stage, a field demonstration in Ohio is operating a “microcogeneration” system, teaming a microturbine with a gas air conditioner converted to run on the microturbine’s exhaust (*Figures 2, 3 and 4*).

One novel aspect of this particular chiller is that it can be driven by either the exhaust gas or by direct gas firing, or a combination of the two. This provides uninterrupted cooling even if the microturbine exhaust is not available.

This is an important feature. If the generator is down for maintenance, the electric load switches to the utility without interfering with building operation. However, owners expect continuous cooling operation. Providing two ways to fire the cooling system increases reliability.

Commercial Cooling

Systems for larger light commercial applications have been installed in

A California Test Case

A demonstration of a high-end zoned gas cooling system is being run in California. Data monitoring is under sponsorship from the Gas Technology Institute Cooling Solutions Collaborative Research Program. Its interest is in the potential for gas cooling to reduce peak summer electric demand on generating and transmission systems.

The California residence is a 6,000 ft² (557 m²), two-story home that has been split into four major zones. Separate zones were installed for 1) upstairs bedrooms, 2) a family room-kitchen area, 3) an office area, and 4) the bathroom areas. Each zone is controlled by a different air handler located in the attic space.

The air handlers are equipped with separate heating and cooling coils. Hot water is supplied by small water heating packages with hydronic heating circulating pumps, each located at the air handler. The chilled water system is supplied by two gas-fired absorption air conditioners located together outside the home.

Each air handler is controlled by the zone thermostat and set up with three-way valves on a bypass system. Controls lock the entire system into either heating or cooling. Three of the four zones are standard air-flow systems. The fourth system in the office area is a high-pressure air system with compact ductwork.

Four separate bathroom areas are each controlled by separate small fan/coil units, bringing the total air handlers to seven.

Outdoors, two 5-ton (17.5 kW_e) gas air-conditioning units are linked to act as one 10-ton (33 kW_e) chiller. At low load, only one of the air conditioners serves the entire chilled water system, while the other unit assists at higher loads.

Making the system even more responsive are the chiller’s air-cooled condenser cooling fans. Each unit has two fans, both capable of two-speed operation. Controlled by condenser pressure, the fans are cycled on and the speed controlled in sequence, allowing each condenser to have four different possible airflows.

Pumps for the chilled water system are



California home is split into 4 zones.

located outdoors, and the system is controlled to provide 55°F (13°C) chilled water return water temperature, and 45°F (7°C) supply water to the building. The 45°F (7°C) water provides coil temperatures significantly below those in most residential systems, leading to improved dehumidification.

The chilled water used in these systems is a combination of water and glycol that is left in the system at all times, providing freeze protection. Such systems have been run in much colder climates such as Chicago or Boston.

The ammonia-water absorption units used in this application have no crystallization issues. These particular chillers are designed for minimal capacity deterioration at higher temperatures, with only a 6% decrease in listed capacity at 105°F (41°C) and 10% at 115°F (46°C), albeit with an increase in chilled water supply temperature. This is less of a capacity reduction at high temperatures than standard electric units, and should allow less oversizing in hot desert climates, a concern in much of California.

One interesting feature of the installation was that the home was completed before the air conditioning was installed. The chilled water connections from the outdoor units to the copper piping system in the attic were done with a flexible plastic piping. This allowed the chilled water lines to be “snaked” through existing walls without demolition.

Although this particular application is in an unusually large home, such showcase applications may pave the way for applications of this system in the 3.2 million homes in the United States that are more than 4,000 ft² (372 m²).

Mexico, New York, and Boston. These systems deliver chilled water from multiple chillers all operating in sequence to meet varying building loads.

Larger Applications

A larger California cooling plant is taking an entirely different approach to gas cooling. California has some of the highest electric prices in the country and is still facing a tight electric supply situation during hot weather.

Gas chillers remove the chiller load from the electric grid. Eliminating both the cooling system and the attendant accessories from the electric grid, and tying these systems together for greater efficiency improves the situation further. This is just what has been done in one smaller central plant in California. The system is shown in *Figure 5*.

Inside the cooling plant, a microturbine generates just enough electricity to operate the plant's chilled water pump, chiller solution pump and controls, and cooling tower pump and fan. The exhaust heat from the microturbine passes to a double effect direct fired absorption chiller.

This chiller, unlike units discussed previously, is of the more typical lithium bromide solution water-cooled variety. The unit used in this plant is a customized version of a direct-fired double effect absorber. The modifications allow the chiller to, once again, use a combination of microturbine exhaust heat and direct gas firing. However, this is a much larger capacity unit at 300 tons (1,050 kW). The chiller is also a "chiller/heater" system, producing hot water when cooling is not needed. This makes the plant a self-contained, self-powered heating and cooling package.

The exhaust from the 60 kW microturbine is in the 550°F (288°F) range and carries enough unburned oxygen to serve as preheated combustion air for the chiller.

This layout resembles a cogeneration system. However, unlike most cogeneration schemes, the electric load and the thermal load are coincident as both follow the cooling load. As the microturbine exhaust heat is well below the overall heat requirements for this chiller, and the operation of the turbine and chiller are coincident, the useful heat recovery can be well

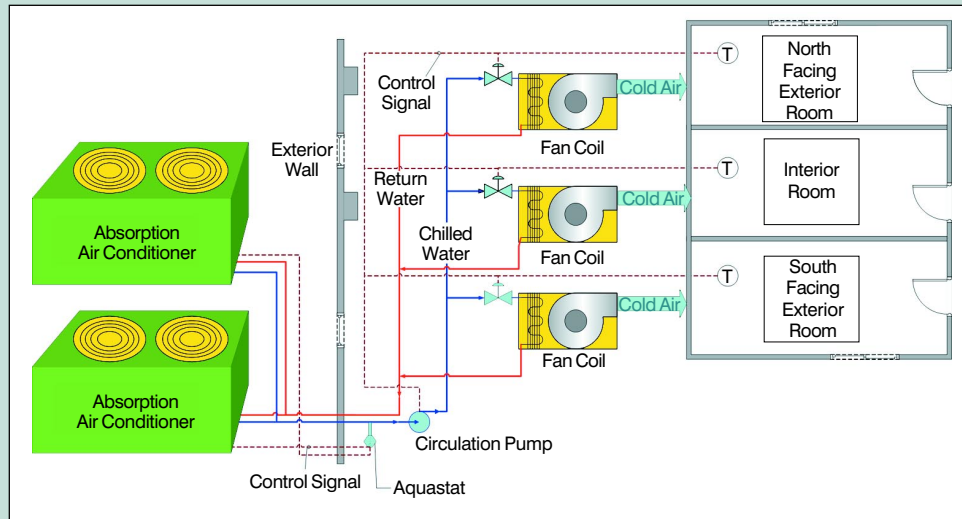


Figure 1: Typical layout for a gas air conditioner in a zoned system.

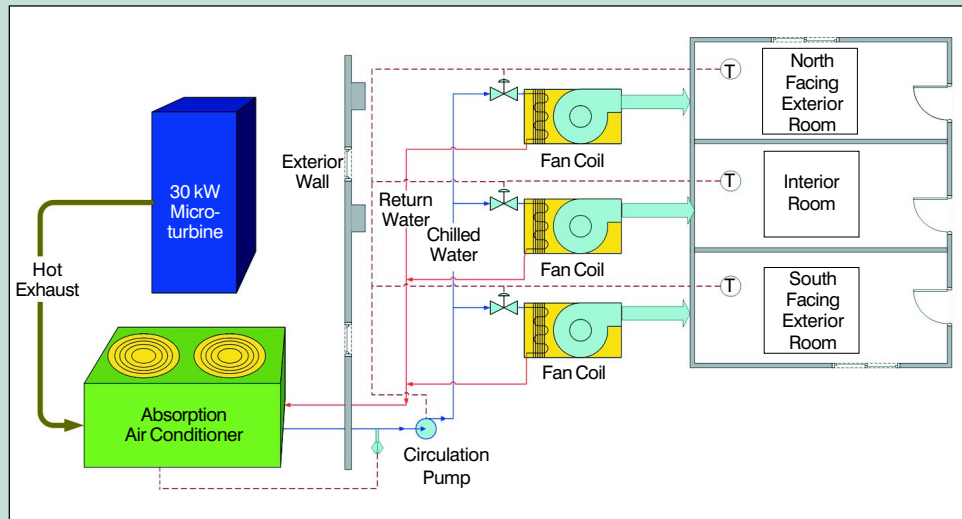


Figure 2: A microturbine produces enough exhaust to provide 8 to 10 tons of cooling.

above that seen in most cogeneration arrangements.

Looking at this system from the outside, this plant is a self-contained gas cooling "system." Gas goes in — chilled water comes out. The system is installed as a freestanding central plant, feeding chilled water to other buildings.

The high-efficiency and self-contained nature of this system may be attractive for third-party owner or leasing arrangements. The system can also be viewed as a cogeneration option that requires none of the complexities or expense of grid interconnection.

The chiller/microturbine plant began operation late November 2001 (*Figure 6*). In this particular application, the microturbine can also send power to other buildings when cooling is not required, allowing the microturbine to operate full time. After some initial compatibility problems with other controls systems at the site were settled, the turbine reached 5,400 hours of operation last July without incident.

The chiller, which operates only as the cooling load occurs,



Figure 3: Test site for microturbine exhaust-driven cooling.

operated for fewer hours. It has experienced no mechanical problems though controls required some fine adjustment in midsummer.

The task of defining an overall efficiency for this plant is unusual — the outputs can be both cooling and power. However, to focus on the cooling operation, the waste heat introduced even by this comparatively small gas turbine contributed significantly enough to allow the gas only COP of the direct fired absorber to frequently exceed 1.2 in actual run-of-plant operation.

Conclusions

New gas cooling technologies and system arrangements are finding their way into new applications such as high comfort residential systems, small cogeneration systems, and even using a “cogeneration approach” to produce a higher efficiency central cooling plant. The common message is the need to take new technologies to the market in novel cooling system designs that can truly capture their benefits.

In the long run, these systems demonstrate new thinking for thermally activated cooling, ready for a future where the most desirable heat source may be a gas burner, the generator in a cogeneration system, or solar.

Will these systems find wider application? There is no way to know which direction the market will take, but in changing times the greatest risk is the risk not taken. With changes continuing in the energy industry, believing that the current, often “cookie cutter” approach, to HVAC design can continue in the future may be the biggest risk of all.

Acknowledgments

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Figure 4: Microturbine and exhaust-driven air conditioner.

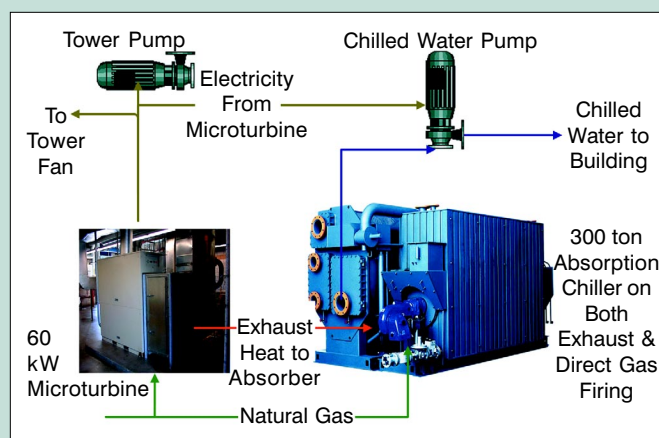


Figure 5: A self-contained gas cooling system. Power from microturbine drives chilled water pump, tower pump and fans. Microturbine exhaust heat aids in driving chiller.



Figure 6: Inside the chiller/microturbine plant. View shows the absorber (center) and microturbine (right).

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Figures 1, 2 and 5 are courtesy of UIC. Figures 3 and 4 are courtesy of Cooling Technologies. Figure 6 is courtesy of the Southern California Gas Company. ●