Absorption Chillers Use in America Today

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ABSTRACT

President Bush's National Energy Policy, Clear Skies and the Global Climate Change Initiatives form a comprehensive roadmap to a secure, clean, reliable, and affordable energy for the future. These far reaching policy proposals rely heavily on the development of distributed energy systems. Cooling, Heating and Power (CHP) systems will permit a substantial improvement energy efficiency use. Thermally Activated Technologies, in general, and absorption chillers, in particular, are increasingly being viewed as an important element to effectively apply CHP.

This paper will examine testing, demonstration projects and commercial applications of combining absorption chiller equipment with microturbines, engines, combustion turbines and thermal solar systems. Technical challenges of coupling absorption chillers to prime mover exhaust streams will be explored. Application specific integration of coincident power generation and thermal energy supply to satisfy building loads will yield economic metrics that will determine which combinations of prime mover and absorption chiller will succeed in the market place today and which combinations require more research and development.

KEY WORDS:

Absorption, Lithium Bromide, Double-Effect, Direct-Fired Absorption (DFA), Indirect-Fired Absorption (IFA), Exhaust-Gas-Fired Absorption (EGFA), Co-Fired Absorption (CFA), Cooling, Heating and Power (CHP), Distributed Generation (DG), Distributed Energy Resources (DER)

EVOLVING ENERGY MARKET IN AMERICA

Changes since the passage of Energy Policy Act of 1992 (EPACT) have been rapid and dramatic. Today utilities no longer build generation for their sales to their retail customers, but buy those supplies from the wholesale market. Some states have removed the restrictions that require retail monopolies, and allow their customers to pick their own generation suppliers. Other states have begun the process that will lead to dependence on competitive retail markets.

The transition to a competitive industry is well under way. However, not all has been smooth. The last few years have seen severe price spikes in the Midwest and South. There is a clear and pressing crisis in prices and supply in the West and particularly in California. The North American Electric Reliability Council reports that there may be problems with prices and supply in New York, New England and the Central South. The institutions on which the country now relies for delivery of affordable, dependable electricity service are showing the strain of adapting to the new market circumstances.

A broad portfolio aimed at increasing the efficiency of energy generation, delivery, and use coupled with conservation can boost economic productivity, and protect the environment. One of the areas in the energy portfolio in need of greater emphasis is distributed energy resources (DER). DER consists of a suite of clean, modular, and small-scale, energy generation and delivery technologies and techniques. These include, for example:

1. Distributed Generation (DG) - generally considered customer or third-party owned power generation for reliability, power quality and/or peak shaving purposes. Clean DG is produced by fuel cells, gas turbines and microturbines, reciprocating engines renewable sources like wind, solar, and biomass, and finally hybrid systems containing a mix of onsite solutions.

2. Thermally Activated Technologies (TAT) provides power, heating, cooling, and humidity control from onsite thermal sources including natural gas, propane, clean oil systems and recoverable energy from DG equipment.
3. Cooling, heat and power (CHP) systems which integrate DG and TAT equipment into packaged or modular systems designed to reliably and economically operate in single or multiple buildings.

The promise of DER is in having customers make their own energy choices – including an optimal mix utility and on-site generation - to customize and control the "can't do without" services energy provides the nation's factories, farms, commercial buildings, and homes. This offers, commercial and industrial customers a significant demand management tool today to deal with the transition to market based energy supply. The most interesting and practical technology examined hereafter is CHP. This is for three reasons. First, CHP offers an economically viable solution today for larger building installations (greater than 500 kW in the USA, second, CHP offers energy efficient consumption of fossil fuels and biomass and third, CHP actually has been in use for many decades throughout the world in district energy plants, on university campuses and in hospitals.

IMPLICATIONS FOR LIBR ABSORPTION TECHNOLOGY

Absorption technology has been applied to the space conditioning and process cooling/heating for 150 years. Today, absorption chiller/heaters are fuel flexible thermally activated systems utilizing clean fossil fuels, bio-fuels, steam, hot water, solar energy or exhaust gas to power the absorption cycle.

The second law of thermodynamics teaches us that during each energy conversion step energy is lost in the process. It is for this reason that global interest in distributed energy conversion technologies, like absorption chillers, chiller/heaters and CHP systems are attracting both public and private investment to offset current energy costs and provide research and development future energy efficiency gains, emission reductions and fuel productivity.

Direct-fired (DFA) chiller/heaters provide cooling, heating and hot water, without requiring more on-peak electric generation, transmission or distribution systems. Reducing peak electric grid requirements help all electric customers save money by reducing electric grid investment and improves grid load-factor providing better capital utilization. Reduced peak electric demand by using DFA chillers is good for the environment as electric grids are generally the largest atmospheric polluters in every country. Furthermore, absorption systems use naturally occurring fluids (water and lithium bromide) and avoid ozone depleting hydrogenated chlorofluorocarbons HCFCs.

As energy costs continue to raise, reliability requirements increase and regional and global environmental problems increase, new solutions are also emerging. Packaged and modular Cooling, Heating and Power (CHP) for buildings and industry systems are emerging which depend Indirect-Fired Absorption (IFA) chillers on absorption technology to capture waste heat.

ABSORPTION TECHNOLOGY DEVELOPMENT

Since the early 1990s, absorption chiller sales have increased modestly in the USA. Absorption chiller use in countries like Japan (see Figure 1), China and Korea has grown exponentially since the mid-1970s. The general underlying reasons for the disparate growth phenomena in Asia are complex, but it is clear that the economics are being evaluated differently between historical America and modern Asia when it comes to commercial water chiller technology.

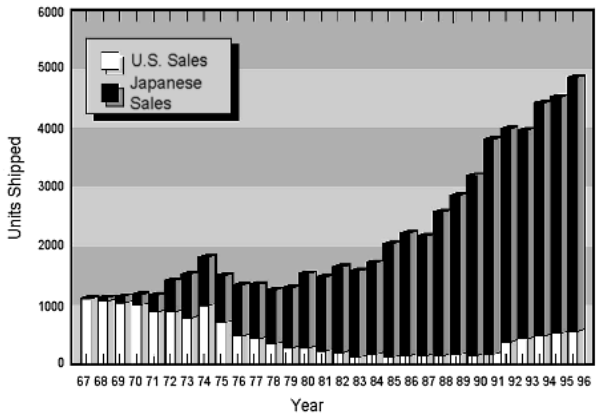

FIGURE 1
Latest Data on Japan versus U.S. Absorption Chiller Sales[1]

In many parts of Asia today, the siting of an electric water chiller, requires not only the usual economic capital of the chiller plant, piping, pumps and cooling tower, and boiler for heating, but also a portion of the electric transformer, wires and generating capacity needed to serve the chiller plant. Therefore, it is easy to see why an absorption chiller/heater plant is far more cost effective to install. Similar plant economics have been emerging as a result of electric utility restructuring whereby many new and retrofit electric customers are now required to purchase line extensions, and upgrades.

Today, Asian manufactures are making the innovations in the Distributed Energy Resources (DER) and Cooling, Heating and Power (CHP) markets, as the economic certainty of electric markets becomes clearer, it is only a matter of time before the US manufacturers join in.

PACKAGED AND MODULAR SYSTEMS

Energy efficiency and air emissions are a primary concern of government. However, energy consumers are primarily concerned with the price, reliability, and quality of energy supplied. CHP today consists of discretely developed technologies of power generation, thermal cooling and dehumidification, thermal transport and storage, thermal heating and hot water systems, and electric end-use equipment. These discrete components currently can be interrelated by building control systems. To improve reliability, reduce maintenance cost and decrease installation costs, the primary focus of engineering the next generation of CHP equipment is to develop packaged or modular systems.

The first step in the development of CHP systems is to understand the various power generation and thermally activated technologies that are potentially available and the current developmental status.

CHP Technologies

The next step in the development of CHP systems is to identify the appropriate near term technologies to apply to CHP systems. This task can be divided into two technology groups (onsite power generation and thermally activated technologies) and into two development levels.

ONSITE POWER GENERATION

Engines

Engine-driven generator sets use internal combustion engines to drive an electric generator in a single package. Typically, constant duty-cycle engines use spark ignition and burn natural gas as the primary fuel. Biofuels can also be used for fuel in place of petroleum and natural gas.

Current engine technology achieves efficiencies in the range of 30-40% lower heating value (LHV), and emissions of NOx approaching 1 gram per horsepower-hour without after treatment. While these emission levels are higher than most other distributed technologies, they have been reduced significantly in the last several years

[1] Courtesy of Oak Ridge National Laboratory

by exhaust catalysts and better design and control of the combustion process. Engines are generally low-cost, have proven reliability with proper maintenance, and have good load following characteristics and heat recovery potential. A public/private partnership is developing the next generation of engine equipment targeting 50% efficiency LHV and 0.1 gram per horsepower-hour without after treatment.

Historically engines have been used for standby generation because of problems with liquid fuels, today's natural gas engines are quite suitable for load following and CHP use.

Combustion Turbines

Combustion turbines range in size from about 800 kW to several hundred megawatts; however CHP type systems would typically encompass the range of 800 kW to 20 MW. Combustion turbines can burn a wide range of fuels and are capable of dual-fuel operation and have simple-cycle operating efficiencies in the range of 24-35% (LHV).

Gas-fired turbines require natural gas to be supplied at fairly high pressures therefore a fuel booster compressor is needed on most local distribution lines. Combustion turbines rapidly adjust to changes in load and produce high temperature recoverable energy ~ 538°C (~ 1,000°F).

Microturbines

Microturbines are small, high-speed (up to 100,000 rpm) electric generator systems that include a turbine, compressor, and generator on a single shaft or with a separate expander/generator shaft, and the power electronics for delivering AC power. Microturbines have only one or two moving parts and are air-cooled. Some systems use air bearings requiring no lubricating oil. Natural gas fueled microturbines require fuel pressures in the 65 to 100 psig range and these units may require on-board fuel gas compressors, which are available as a standard option.

Microturbines emit low levels of noise (approximately 70 dB at 10 feet), and noise can be further reduced through readily available, inexpensive control technologies.

Microturbines are currently developed in nominal 30 through 400 kW sizes and individual units can be linked together to serve larger loads. Microturbines are capable of producing power at 20-30% efficiency (LHV). Research and development efforts to use advanced ceramics technologies target 40% (LHV) efficiency for the next generation of products.

Current designs are offered for grid parallel, standalone (with or without black start capabilities) and can separate from the grid and restart in stand-alone mode when the grid goes down.

Fuel Cells

Fuel cells are an exciting technology that converts hydrogen-rich fuels, such as natural gas, propane, and methanol into electricity and heat through an extremely quiet and environmentally clean process. Fuel cells generate electricity through an electrochemical process in which the energy stored in the fuel is converted directly to electricity. There are three main components that govern the operation of fuel cell: Hydrogen Reformer that extracts hydrogen from a fuel source, Fuel Cell Stacks where the hydrogen fuel generates DC power in an electro-chemical reaction and Inverter that converts DC outputs to AC power.

Phosphoric acid fuel cells (PAFCs) have already entered the commercial marketplace with over 250 units sold worldwide; and molten carbonate fuel cells (MCFC) are undergoing demonstration; proton exchange membrane fuel cells (PEM) and solid oxide fuel cells (SOFC) are in various stages of development and testing. The most significant research and development activities are focused on PEM fuel cells for automotive and home use and SOFC for stationary applications. PEM and SOFC technologies are expected to enter the commercial building marketplace sometime this decade.

Absorption Chillers

The absorption cycle uses a condenser and evaporator just like vapor compression systems, but replaces the motor and compressor assembly with a thermal fluid compressor (absorber, generator and small fluid pump) to transfer low-temperature energy to high-temperature heat rejection. The absorption cycle uses thermal energy (natural gas, waste heat or solar energy), not electricity, to create chilled water.

The cooling cycle begins in the evaporator where the refrigerant (which is water) is sprayed over tubes containing chilled water that is circulated through the building as a cooling medium. The evaporator operates under a vacuum, which permits the refrigerant (water) to boil at a low temperature and remove heat from the chiller water. The refrigerant vapor migrates to the absorber where it is “compressed” by being absorbed into a concentrated aqueous solution of lithium bromide (LiBr). The combined LiBr/water solution is pumped to the generator where heat is added by natural gas combustion or another heat source to vaporize the refrigerant (water) from the absorbent (LiBr). The concentrated LiBr returns through intermediate heat exchangers to the absorber to repeat its cycle. The refrigerant enters the condenser where it is liquefied and returned to the evaporator to repeat the process.

Absorption systems are classified by single, double or triple “effect" referring to the number of generators in the given system and respective efficiency levels.

Single-effect absorption chillers ideally fit BCHP applications providing low cost chilled water using low quality heat (9 to 12 psig steam or 190 to 270 ºF hot water). Double-effect chillers increase efficiency using 70 - 125 psig steam, 300-370 ºF hot water or can be co-fired with hot air (e.g. direct microturbine exhaust).

Absorption chillers economically increase the capacity of combustion turbines by cooling turbine inlet air and using turbine exhaust to power the cycle. Combustion turbine output will typically increase by 10% to 18% for every 20°F of reduction in inlet air temperature.

INTEGRATION TECHNOLOGIES

Integration is the key to success for CHP systems. Integration will bring higher performance, lower installation costs and higher reliability. Integration can be divided into three distinct processes: equipment integration into a system, system integration with a building or buildings and integration with the grid. A word of caution is required. This paper deals with certain technological and policy aspects of CHP for buildings; it does not cover very important market and application aspects of the technology due to space limitations. This will be the subject of a future paper.

Equipment Integration

The first process for building a better CHP system is to examine potential onsite power generation technology recoverable energy quantity and quality together with common equipment that uses thermal energy input. The following are common CHP equipment and their temperature characteristics:

- Onsite Power Generation Recoverable Energy Available Temperatures
  - Microturbine exhaust temperature ranges between 232-260°C (450-500°F)
  - Engine jacket water temperature ranges between 82-93°C (180-200°F)
  - Engine exhaust temperature ranges between 427-649°C (800-1,200°F)
  - Gas turbine exhaust temperature ranges between 482-566°C (900-1,050°F)
  - Solar Thermal Collector
  - Low temperature PEM (under research) is projected to deliver temperature ranges between 60-71°C (140-160°F)
  - Solid oxide Fuel Cell (SOFC) (under research) is projected to deliver temperature ranges between 371-482°C (700-900°F)
  - Solar Thermal Power provides water temperatures between 148-188°C (300-370°F)
- Thermally Activated Technologies Temperature Requirements
  - Single-effect absorption chillers require a minimum temperature of 82°C (180°F)
  - Double-effect absorption chillers require a minimum temperature of 188°C (370°F)
  - Triple-effect absorption chillers require a minimum temperature of 316°C (600°F)

Table 1 serves as a guideline matching the thermal output from various technologies recognizing the recoverable energy quality (temperature) as well as recoverable energy quantity with lithium bromide absorption chillers.

TABLE 1

Electric and Thermal Matching Potential

Generator Type	Single-Effect Exhaust Gas Fired	Indirect-Fired Double Effect	Indirect-Fired Triple-Effect	Double-effect Co-fired
Microturbine	●	○	○	●
Engines	●	●	◒	◒
Advanced Engines	●	●	◒	◒
Gas Turbine	●	●	◒	●
Solar Thermal Collectors	●	●	◒	●
High Temp PEM Fuel Cells	●	○	○	◒
Solid-Oxide Fuel Cells	◒	●	●	●
	● Feasible – should be evaluated	◒ Feasible – should not be evaluated	○ Not Feasible	

DEVELOPMENT OF PACKAGED AND MODULAR SYSTEMS

Integration of CHP into commercially viable systems requires the development of a new approach. Current American path to market for building systems does not support field aggregation of CHP components. District energy and campus systems are viable today. Packaged system development is essential to penetrate the discrete building market and modularization of larger system components will provide increased market penetration of the district energy and campus marketplace.

Packaged System Development – Low Temperature Integration with Microturbine Exhaust Gas

A public/private partnership has established an integration test facility at a university with the objective of system optimization. The summer of 2001 saw the installation of the first integrated packages system test (Figure 2). This field erected system consists of a nominal 75 kW microturbine thermally coupled to a direct exhaust gas activated single-effect LiBr/Water chiller and a cooling tower to serve the absorption chiller. This initial installation also ducts the absorption chiller flue gas to the roof of the four story building to regenerate a solid desiccant dehumidifier; however this exhaust gas could also be used in conjunction with a flue gas recovery heat exchanger to make hot water.

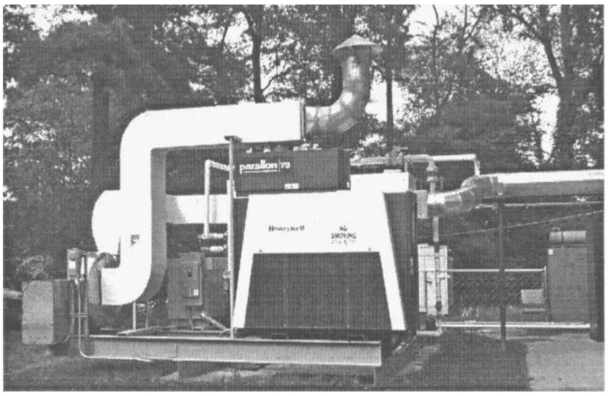

FIGURE 2
Integration of Microturbines and Direct "Exhaust Gas Fired" LiBr Absorption Chiller
(This is a first generation microturbine test)

The first 75 kW microturbine generation tested had a back pressure limit of 1 kPa (4 inches of water column) which is not enough to pass through the package test ductwork, absorption chiller, ductwork to the roof and the desiccant dehumidifier downstream. Therefore, a booster fan was installed between the microturbine and the absorption chiller.

The test program is designed to determine what steps are necessary to better integrate the equipment into a configuration that will provide optimal performance for the lowest installed cost, operate automatically and reliably and be simple to apply and operate. That is a tall order for essentially a more complex integrated system; however, the tools appear to be readily achieving these goals. The major goals of the testing are:

- Benchmark the system operation in a steady state mode capturing temperatures, pressures, flows, fuel consumption, power generated, and electric power consumed for the system and for critical components.
- Benchmark the systems performance of the system and components throughout the operating map mode capturing temperatures, pressures, flows, fuel consumption, power generated, and electric power consumed for the system and for critical components.
- Determine equipment changes necessary to optimize system performance while eliminating the need for microturbine exhaust fan.
- Optimize control systems of the equipment.
- Test heat recovery/hot water system with low fuel gas pressure drop.
- Design a "fit-for-purpose" skid.

The resulting system might look something like Figure 3 (right) where the packaging improvements could be quite noticeable when compared to Figure 3 (left). This is especially true with the potential addition of a hot water heat recovery system.

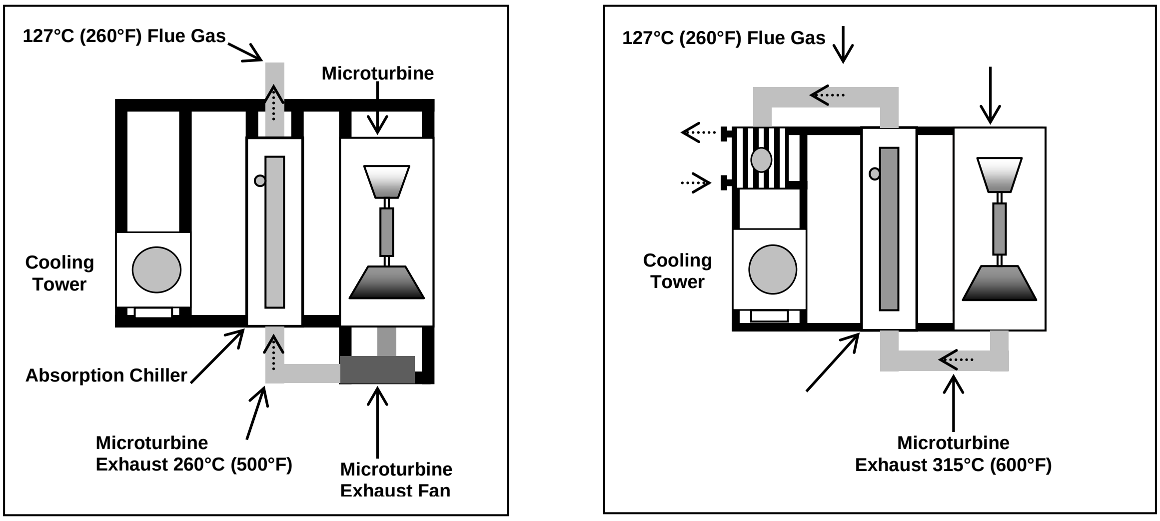

FIGURE 3
CHP Schmatic of Initial (left) and Future (right) - Microturbine and LiBr Absorption Chiller

Modular System Development – Mixed Temperature Integration with Microturbine Exhaust Gas

One of the limiting factors for commercialization of CHP systems is the relationship between waste heat available and the cooling or heating needs of the building. For most applications where electric generating systems are sized to meet part of the peak design demand the waste heat will not be sufficient to meet full cooling or heating load. Previous designs will often incorporate additional systems to combine the waste heat energy with additional heat input in a heat recovery steam generator (HRSG) to produce steam which will then be sent to an indirect fired absorber. In this way the additional heat input can be independently sized to produce enough energy to meet the cooling and heating needs of the building. While this approach resolves the problem it adds considerably to the space and equipment required, incorporates high pressure steam into the system and increases the cost making the system prohibitively complex and expensive. Other systems will utilize low temperature hot water which will remove the high pressure steam from the system but at a cost of lower overall efficiency.

One installation (Figure 4) has adapted a new approach which eliminates the conversion of waste heat to steam or hot water. This approach utilizes a direct fired absorber (DFA) where the waste heat is directed to the burner as preheated combustion air at over 250 °C (500 °F) reducing the energy required by the DFA. This "co-fired" approach works with well microturbines as the turbine exhaust contains enough oxygen (16% to 18%) to fully combust the DFA fuel such as natural gas or oil. The effect of using 250 °C (500 °F) combustion as compared to ambient temperature combustion air will be to reduce the fuel requirements by approximately 20%.

This particular installation results in the DFA utilizing ambient combustion air has the effect of increasing the integrated part load value (IPLV) from 1.3[3] COP to an IPLV COP of 1.6[1].

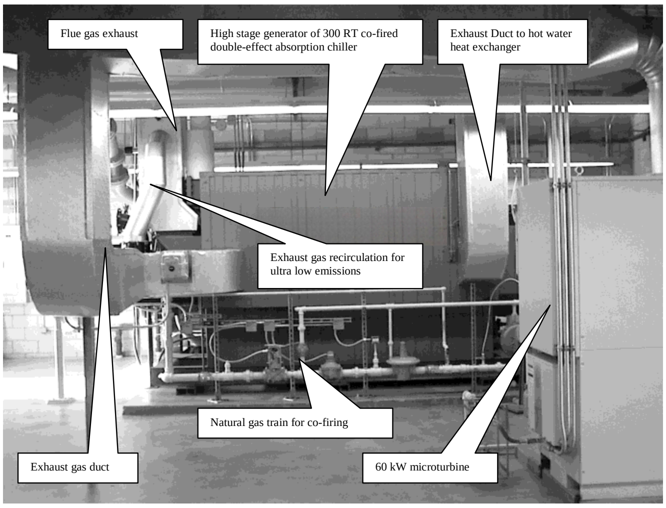

FIGURE 4

Installed CHP with 60 kW Microturbine and 300 RT Co-fired Double Effect Absorption Chiller

As an enhancement to the heat recovery an additional heat exchanger is added to the DFA which will use any excess exhaust not required as combustion air (see Figure 5). Combustion air requirements will to vary with loading on the chiller while exhaust production will vary independently with loading on the generators.

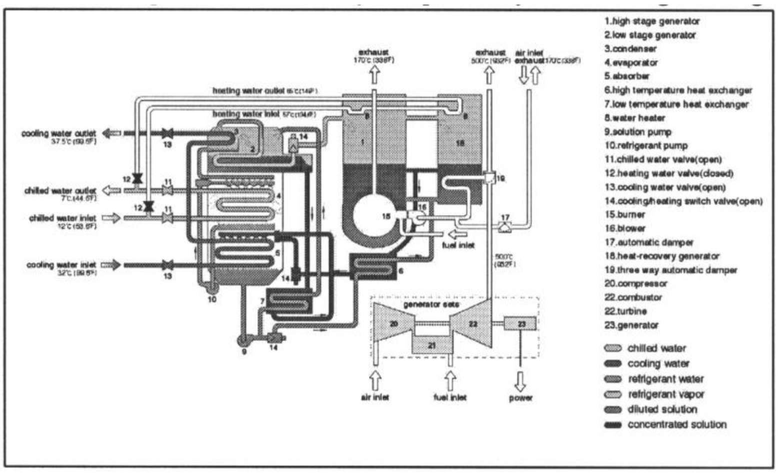

FIGURE 5

Co-Fired Absorption Chiller with Auxilliary Heat Exchanger Schematic

Modular System Development – Direct Industrial Gas Turbine Exhaust Gas Systems

Peak power, in America, is driven by air conditioning. Therefore, electric generating systems that can generate chilled water from waste heat (exhaust gas) portent to be valuable support for the electric grid of the future providing their owners with substantial economic return. One such system is currently being designed for a Texas installation that involves a 5.2 MW industrial gas turbine providing 486 °C (910 °F) exhaust gas to two 3.514 MW (1,000 RT) exhaust-gas-fried double effect water chillers that in turn provide flue gases to a 1.76 MW (500 RT) co-fired double effect water chiller (see schematic in Figure 6).

[1] Using the Air-conditioning and Refrigeration Institute's Standard ARI 560-92 IPLV COP calculation

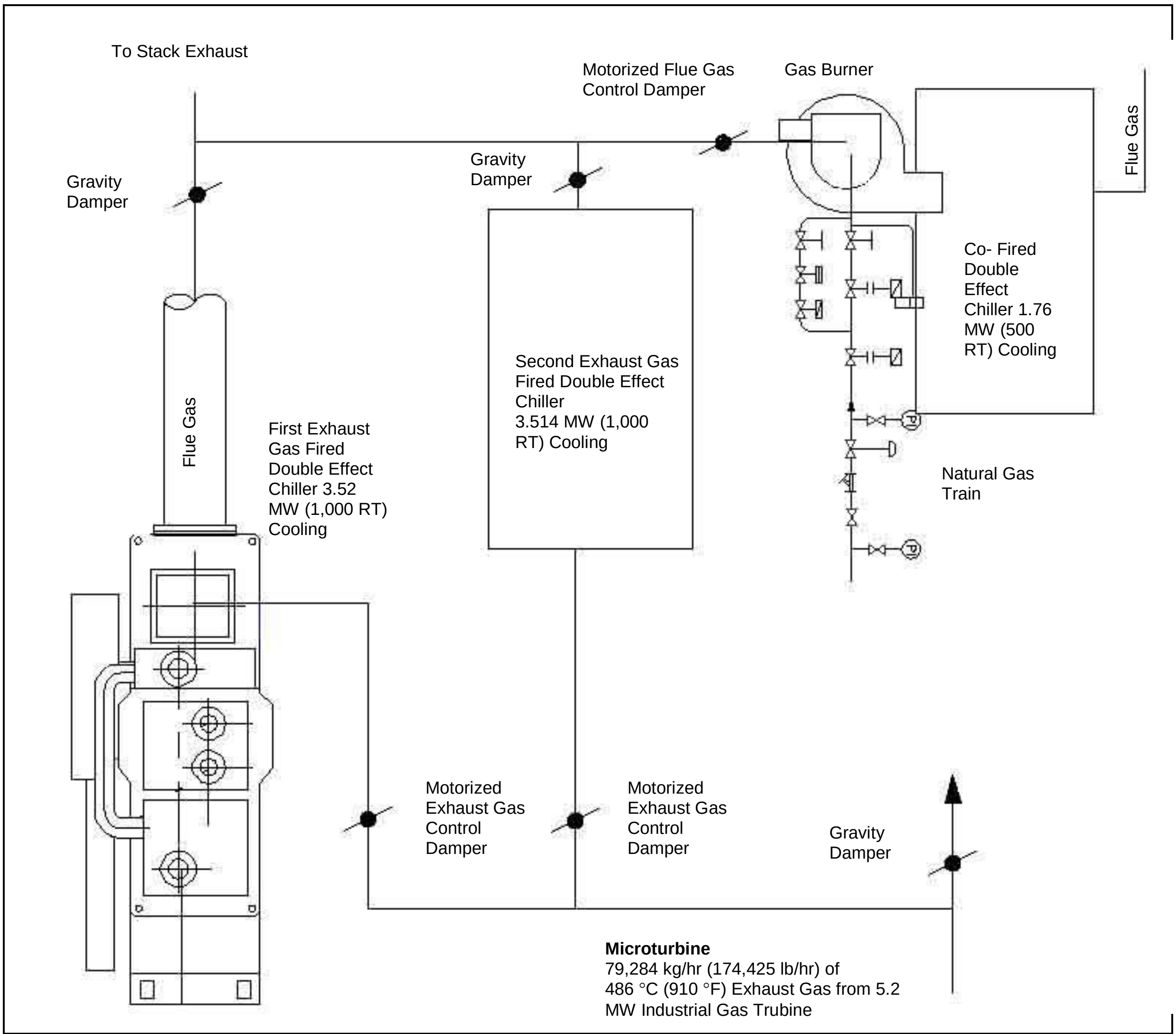

FIGURE 6
Industrial Turbine Exhaust Fired Absorption System Schematic

The reason to provide such bottoming cycle systems is simple. The American electric grid showed significant signs of stress in 1999 and 2000. The recession during summer of 2001 combined with mild temperatures largely relieved systems stresses. However, projected economic growth, aging electric distributions systems, increasing transmission congestion and the need for higher quality power combined with more stringent environmental regulations will lead to significant grid problems and rising mid-range and peak pricing in the future.

Applying exhaust-gas-fired absorption (EGFA) chillers and co-fired absorption (CFA) chillers to industrial gas turbines in the 1 to 20 MW_e size range, under today's regulated rate tariffs makes economic sense. For example, the systems being designed or Texas (Figure 8) will see the cost of producing electricity and supplying chilled water reduced from 7 ¢/kWh to an effective rate of 5.5 ¢/kWh by using the waste heat to produce chilled water (Table 2). It is clear that absorption chiller technology applied to industrial gas turbines makes economic sense at 5.5 ¢/kWh.

TABLE 2
Texas Industrial CHP Simplified Economic Analysis

Industrial Gas Turbine	5.2 MW_e	5.2 MW_e
Two Exhaust-Gas-Fired Absorbers (each)	3.514 MW_{th}	1,000 RT
One Co-Fired Absorber	1.76 MW_{th}	500 RT

Gas Turbine Exhaust Gas System:		
Gas Turbine Exhaust Outlet	486 °C	910 °F
Exhaust-Gas-Fired Absorber Flue Outlet	200 °C	392 °F
Exhaust Gas Flow	79,284 kg/hr	174,425 lb/hr
Recovered Energy (in the form of chilled water)	7.47 MW_{th}	**2,125 RT**
Absorption Chiller Parameters: # Stages	2	
Chiller COP	1.3	
Chiller Capacity %	100	
Chilled Water Output Including Co-Firing (Tons)	**8.788 MW_{th}**	**2,500 RT**
Economics – Impact of CHP on Cost of Generation:		
Electric Chiller	0.6 kW/ton	
Equivalent Electricity Needed (plus 10% on-peak line losses)	1,417 kW_e	
Generator Output	5,200 kW_e	
Generating Cost per kWh Including Cost of Capital and Maintenance	**7 ¢/kWh**	
CHP System		
Chiller Effective kW	1,417 kW_e	
Total Effective kW	6,617 kW_e	
ffective Cost per kWh	**5.5 ¢/kWh**	

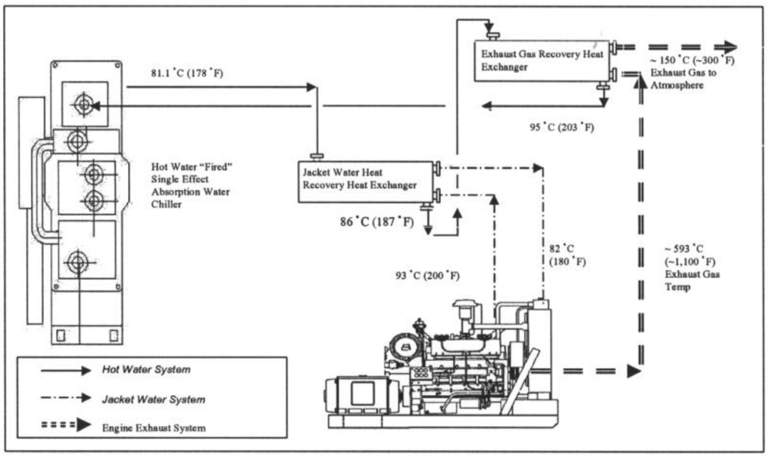

FIGURE 7

Recip Engine with Jacket Water and Exhaust Recovery and Single-Effect Absorption Chiller

Modular System Development – Reciprocating Engine Jacket Water and Exhaust Gas Integration

Reciprocating engines provide almost all of the standby power service in America today. These, largely diesel fueled engines, are being looked at for future replacement. The replacement strategy often being considered is not just the equipment but also moving from just providing standby to providing standby plus power quality, reliability, and energy savings. This generally requires natural gas or a renewable fuel (bio-diesel, digester gas or land fill gas) and effectively using the waste heat. This is where absorption chillers come in.

Reciprocating engines reject heat differently that gas turbines. Generally you can view recoverable energy from a medium sized reciprocating engine for absorption chiller activation in the following manner: 33% of the fuel input energy provides electrical output, 12% is recoverable from the jacket water, 15% is unrecoverable from the jacket water, 20% is recoverable from the exhaust, 15% is unrecoverable from the exhaust and 5% is lost in radiant heating the air. Systems using booth engine jacket water and exhaust gas recovery (see Figure 7) can expect to yield about 0.3 refrigeration tons (RT) for each kW of generator capacity. For example a 400 kW generator should yield 120 RT of cooling.

Modular System Development – Solar Thermal Systems

Technology innovation is bringing a new class of solar/thermal CHP systems to market. Integrated Compound Parabolic Concentrator (ICPC) evacuated tube solar thermal collectors combined with double-effect absorption chillers. The conversion efficiency for space cooling is almost 60%, four times better than solar thermal systems with single-effect chillers. The new ICPC solar thermal collector efficiency is approximately double the efficiency of other collectors at operating temperatures of 1,815 °C (3,300 °F). The preferred heat transfer fluid is water because of its good thermodynamic properties and low cost. However, at these high operating temperatures, the high system pressure works against using the conventional thermal storage tanks for solar HVAC systems. This leads to hybrid solar/fossil fuel installations using hot water/natural gas co-fired absorption chillers with small high pressure buffer tanks for the solar/thermal working fluid.

Figure 8 is a simplified schematic of a typical 50-ton solar/ double-effect hot water/natural gas co-fired absorption chiller IES. Not shown is a buffer high-pressure thermal storage tank sized at approximately 30 gallons per peak ton of cooling positioned between the ICPC collector array and the hot water boiler. A low temperature, low pressure thermal storage tank for space heating and domestic hot water is usually included and sized at 2 gallons for every square foot of collector array aperture area. A chilled water thermal storage tank can also be included to better handle transients in the building cooling load and to reduce the cycling rate for the chiller.

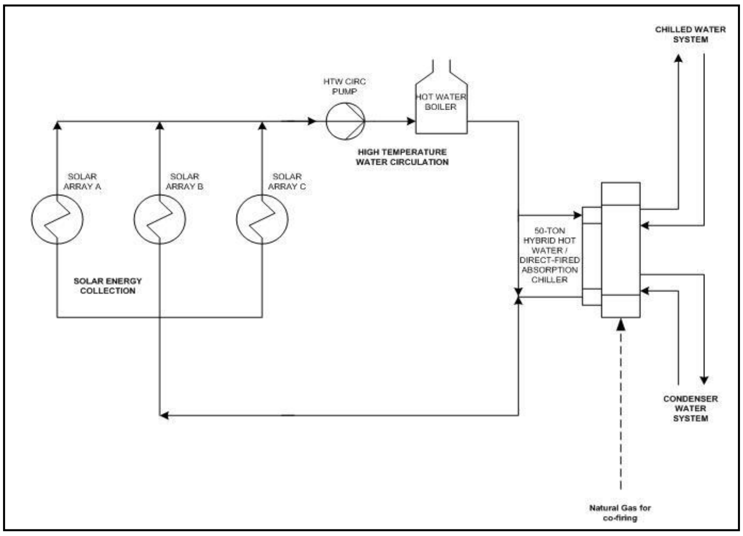

FIGURE 8

Thermal Solar / Double Effect Hot Water-Fired Absorption Chiller

GAS TURBINE INLET COOLING

Absorption chillers also provide significant economic return when applied to gas turbines for the purpose of gas turbine inlet cooling. Combustion turbines are mass-flow engines. Power output increases within limits, in inverse proportion to the temperature of the inlet air. Cooler air is denser and consequently provides more mass flow. Output will typically increase by 10% to 18% for every 20°F of reduction in inlet air temperature.

Historically evaporative cooling was used where the air temperature is reduced as a percentage of the difference between dry bulb and wet bulb temperatures. This means that in relatively humid areas, this method is not effective. However, even in hot and relatively dry climates, the temperature drop may be as little as 25 degrees. This is far higher than the standard ISO rating condition of 59 degrees F. For example, cooling the inlet air to the gas turbine system to 50ºF from 110ºF, and increases the turbine output power in the up to 60%, depending on the turbine performance. Refrigeration Inlet Cooling: Refrigeration Inlet cooling is used to provide power enhancement for base load operation. Since the cooling is to be provided on a continuous basis a chiller (Absorption or Mechanical) or direct refrigeration system is used. Refrigeration Inlet cooling provides constant power output regardless of weather and constant moisture content of inlet air to facilitate NOx control.

Gas turbine power plants are ideal for providing certain midrange and peaking electric power to the grid on for onsite power generation as they provide a clean source of energy. Gas turbines are responsive to load and are very cost effective; however, they have one drawback. Gas turbine power performance falls off rapidly with ambient air temperature. Economically reducing inlet air is highly beneficial. Combustion turbine output will typically increase by 10% to 18% for every 20°F of reduction in inlet air temperature.

CONCLUSIONS

The electric power industry is in transition with the intended outcome leading to competition in a formerly restricted and regulated environment. In time, numerous benefits can be expected from a competitive electricity market; however, the transition will require rethinking electric delivery system design to accommodate the nation's future economic, environmental and reliability needs.

Absorption technology will play an important role in the transition of American energy delivery systems as ultimately they transition toward market-based systems. This is particularly true if one considers the potential from the point of view of thermodynamics. The American energy delivery system has essential optimized First Law principles in providing today's energy to consumers. If we are to move to the next level of savings (essentially doubling the useful output from a Joule (BTU) of fuel input, we must move on to optimizing Second Law principles. Hence the need to find good coincident electrical and thermal loads and a great reason the think of LiBr absorption technology.

CHP systems have the potential to eliminate costly transmission and distribution bottlenecks, reduce electric peak demand, improve power reliability and power quality. Technology exists today that can be integrated into successful CHP systems, particularly in sizes above 500 kW. Smaller sized and advanced CHP systems are on the horizon.

District energy, campus and other large CHP systems are a significant factor in system design and operation today. There remain a number of technical and regulatory issues that require resolution, especially for smaller systems under one MW in size. These impediments to successful CHP – no standardized or fair grid interconnection, inequitable capital depreciation schedules, no appropriate output based emission standards, barrier based utility tariffs and standby charges, and no integrated modular or packages CHP systems – are currently the primary focus of a public/private partnership.

In America, there is a new and compelling reason to consider CHP systems. September 11, 2001 has changed our way of life. Even to the consideration that increased use of onsite power generation will improve our homeland defense, in that buildings so equipped can continue to provide goods and services if the grid is shut down by weather, expected load growth and even terrorist attack.