• Fuel Cells • Large Engines • Condensing Boilers •

SUMMER/17

VOLUME 30 / ISSUE 2

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Natural Gas Engines Power Commercial Greenhouses

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on the cover

Greenhouses in Europe and now in North America are increasingly turning to natural gas-powered reciprocating engines for electric power and use byproduct heat for heating and water heating. An additional bonus is capturing CO_2 from engine exhaust and using it to stimulate plant growth and increase production. Cover photo courtesy: General Electric

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Gas Technology is a trademark of Energy Solutions Center Inc. and is published in cooperation with CFE Media, LLC.

Gas Technology is an educational supplement from:
Energy Solutions Center Inc.
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Washington, DC 20001
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Printed in the USA

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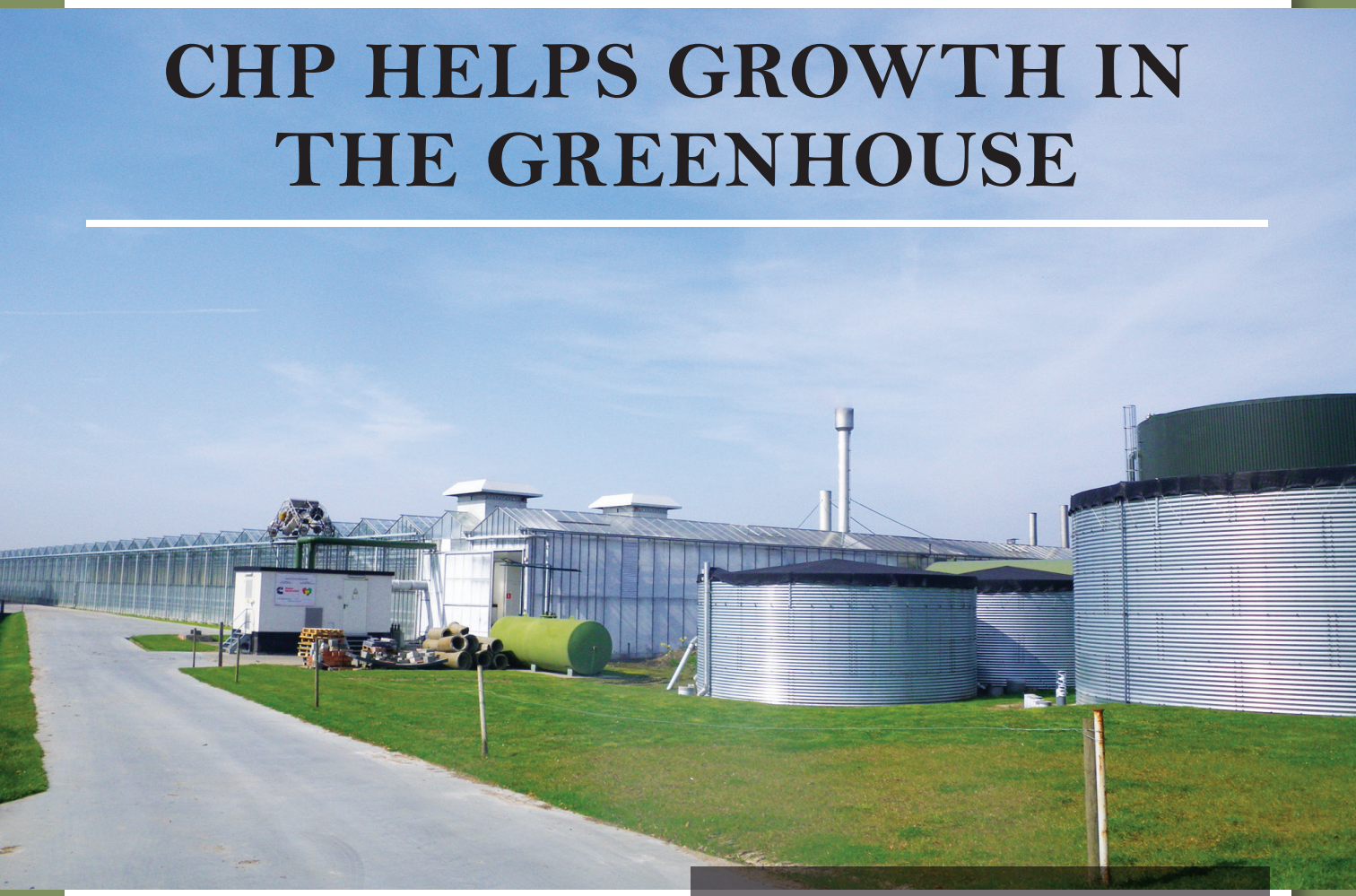
CHP HELPS GROWTH IN THE GREENHOUSE



Today's commercial greenhouses are increasingly turning to on-site electric generation. This greenhouse in Belgium produces peppers. Electric power and hot water is produced by two Cummins 1.4 MWe engine-generator sets with heat recovery and exhaust CO_2 recovery with use of SCR catalytic units. Tanks in the foreground collect tempered rainwater for irrigation. Photo courtesy: Cummins

IN THE SUPERMARKET PRODUCE AISLE, CUSTOMERS INCREASINGLY DEMAND GARDEN-FRESH VEGETABLES, REGARDLESS OF THE TIME OF YEAR. For much of the world away from the tropics, the demand for fresh produce is encouraging more commercial greenhouse development. Crops like tomatoes, peppers, eggplant, zucchini, cut flowers and many others are in demand year-round, and often can be economically produced in a modern greenhouse.

Energy-Intensive Business

Commercial greenhouse production requires energy for lighting, heating and ventilation. Often the best solution is combined heat and power (CHP) – on-site electric generation that also utilizes the byproduct heat for climate control in the greenhouse. And now there's a bonus: captured CO_2 from the engine or turbine exhaust stimulates plant growth, making crop yields bigger, plumper, and best of all, faster to market.

This triple-play energy solution was pioneered in northern Europe, where winter daylight hours are very short, and markets place a premium on product freshness. Hundreds of operators in Netherlands, Belgium, Denmark and other countries have embraced this technology. CHP with CO_2 fertilization is now being employed in commercial greenhouses in the U.S. and Canada. Companies including General Electric, Caterpillar and Cummins are actively developing this market in North America.

Large Operations the Norm

Generally, the greenhouses that are using CHP, possibly along with CO_2 enhancement, are large operations, sometimes covering 10 hectares (25 acres) or more. Often, they also collect rainwater for irrigation. For growers at this scale, CHP can also make operations both more efficient and greener.

Benefits of carbon dioxide supplementation on plant growth and production within the greenhouse environment have been well understood for many years. A factsheet published by the Ontario Ministry of Agriculture, Food and Rural Affairs describes the key role played by CO_2. "Carbon dioxide is an essential component of photosynthesis. Photosynthesis is a chemical process that uses light energy to convert CO_2 and water into sugars in green plants. These

sugars are then used for growth within the plant, through respiration."

Higher CO_2 Levels Frequently Beneficial

The factsheet goes on to explain that the normal atmospheric levels of CO_2 are about 340 ppm by volume. It notes that for many years, plant scientists have known that by increasing ambient levels of CO_2 in greenhouses to levels up to 1,000 ppm, plant growth and production can be dramatically increased for many, but not all, plant species. The publication points out that various methods have been used to increase CO_2 levels in commercial greenhouses.

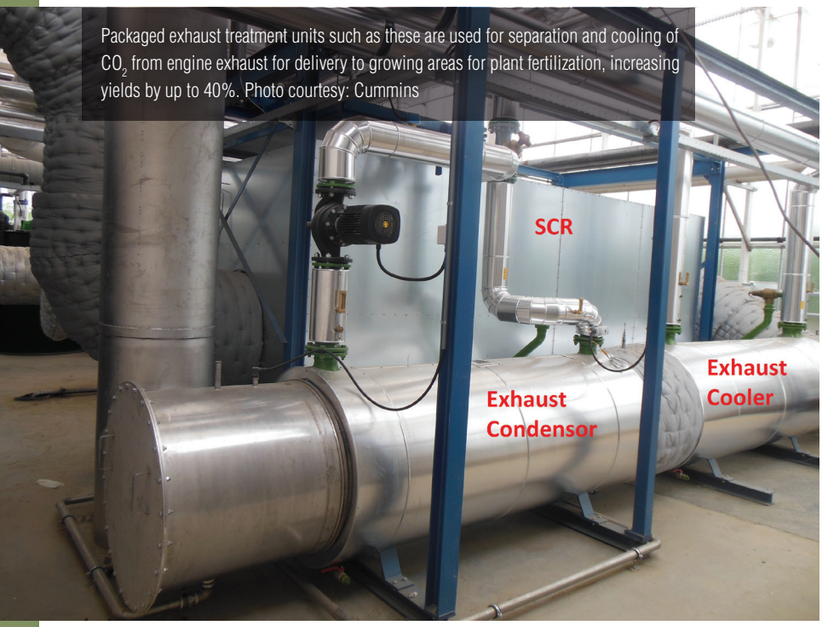
One of the most basic is to use tanks or cylinders of compressed CO_2 to release gas through a perforated tube network in the greenhouse. Another method is to maintain composting beds or bins in or near the greenhouse that will release CO_2 as vegetable material decays. A third method is to capture and treat the exhaust from dedicated burners or from natural gas-fired boilers that are also used for greenhouse heating as a source.

Newest Approach

The most recent innovation is to capture engine or turbine exhaust from on-site electric generation systems, separate the CO_2, and distribute it at appropriate levels in the greenhouse. Engine generation is widely used in combined heat and power (CHP) systems that also use byproduct heat on the same site. In commercial greenhouse operations, the byproduct heat is usually used for greenhouse heating.

The concept of using the CO_2 byproduct as a plant stimulant was pioneered in northern Europe. These CHP + CO_2 greenhouses produce tomatoes, peppers, cucumbers, lettuce, cut flowers, ornamental plants and other products. It is estimated that raising CO_2 levels will bring plants to maturity 10-15% faster and will increase crop yield and quality. According to Stefan De Wit from Cummins, operators in Europe are seeing total production increases of up to 40%. This more than justifies the additional capital expense of these sophisticated systems.

De Wit indicates that growers can get information on the suitability of various greenhouse crops for CO_2 enhancement from growers' associations, university horticultural departments and from specialty sites such as Cummins' greenhouse information website.



Packaged exhaust treatment units such as these are used for separation and cooling of CO_2 from engine exhaust for delivery to growing areas for plant fertilization, increasing yields by up to 40%. Photo courtesy: Cummins

North American Growers are Learning

This energy application is more established in Europe than in North America, but it is being pioneered here in several areas, ranging from Quebec to Southern California. In some cases, a key to success is being able to market surplus electric power to regional electric utilities. Daylight hours when the need for artificial lighting is minimal may coincide with periods of utility peak demand. Prices paid to operators for this energy vary from region to region, thus in planning such a facility, it is important to work with the electric utility.

Engine Exhaust Treatment Needed

When used as a CO_2 nutrient source for greenhouses, the engine exhaust must be treated. According to De Wit, a system that is commonly used in Europe is the COdiNOX™ system developed by the European firm Hug Engineering for scrubbing the exhaust gas using a selective catalytic reduction (SCR) system. These units are being used in many greenhouse operations, coupled with engines from various manufacturers. The COdiNOX system is sold as a package and is used in sized proportionate to engine output.

Applications Growing in Numbers

One of the leaders in promoting greenhouse CHP applications is GE-Jenbacher. According GE spokesperson Matt Falso, there is growing enthusiasm for this solution. "Today, more than 1,000 Jenbacher cogeneration units are deployed around the world, with a capacity of 2.3 gigawatts (GW). More than 60% have been installed with CO_2 fertilization." Falso adds, "Today's greenhouses can simultaneously increase crop production and effectively control CO_2 emissions."

Falso indicates that GE offers standard-sizes greenhouse cogeneration technology; the Jenbacher gas engine and generator, catalytic converter, heat exchanger and all balance-of-plant equipment and controls. He adds, "The compact, modular design of our CHP system creates a smaller footprint and can be scaled to fit unique requirements. The standardized package makes service easier since the generators and all other installations can be removed at the same time."

He notes that GE offers a digital solution, myPlant Asset Performance Management™, for Jenbacher gas engines which can help the greenhouse cogeneration plant run more efficiently to improve growing conditions and lower operating costs. He explains, "In North America, GE sales and services providers for Jenbacher gas engines are helping to engineer cogeneration plants to meet customer requirements. To accommodate our horticulture customers' changing business needs, GE provides flexible lease, loan and tax-exempt financing solutions for CHP operations for new installations, replacement and overhauls, and for implementation and maintenance."


Engine generation, heat recovery and CO_2 recovery equipment in a commercial greenhouse in the Netherlands. Often the equipment is placed in an indoor mechanical space. Photo courtesy Cummins.

Bringing More Production to Market

Because greenhouse horticulture is a capital-intensive business, it is important to maximize plant production and to shorten growth cycles. Growers have learned to optimize lighting, greenhouse temperature and CO_2 levels. Thus, at certain times of day and seasons of the year, surplus generating capacity is available. Falso points out that in some situations, a useful option is to sell surplus electric energy to local or regional utilities, particularly at time when renewable sources such as solar or wind generation are not available or adequate. In this way, cogeneration units can continue to operate at optimum levels. He notes that GE Jenbacher engines are well suited to load-following or frequent start-stop operations, allowing them to be gainfully used in commercial greenhouses or other applications.

Advanced Horticulture Opportunities

For optimal greenhouse plant growth and production, there are numerous variables, including plant species, air temperature, moisture supply, light levels and duration, soils or hydroponic nutrient levels, and CO_2 levels. Temperature, light levels and duration and CO_2 levels can all be controlled by a CHP-CO_2 system. Individual owners must consider the cost of optimizing growing conditions, but today many are including these systems in their evaluations. It may be your time to look into investing for a more productive greenhouse. **GT**

MORE info

CATERPILLAR SITE FOR GREENHOUSES
www.catgaspower.com/greenhouses.aspx

CUMMINS SITE FOR GREENHOUSES
http://power.cummins.com/greenhouse-growers

GE-JENBACHER INFORMATION ON CO2 FERTILIZATION
https://powergen.gepower.com/applications/co2-fertilization.html

ONTARIO FACTSHEET ON CO2 ENRICHMENT
www.omafra.gov.on.ca/english/crops/facts/00-077.htm

Many of today's commercial greenhouses are very large, covering 20 acres or more. Combined heat and power, together with CO_2 capture, makes them highly productive. Photo courtesy: General Electric

Fuel Cells Find New Applications

Generating Clean and Reliable Electricity

A FUEL CELL CREATES ELECTRICITY FROM HYDROGEN, OR HYDROGEN-RICH FUEL, AND OXYGEN. If pure hydrogen is used, fuel cells emit only electricity, heat, and water. Fuel cells can be used in a wide range of applications including transportation, stationary, portable, and backup power applications.

Grid support applications provide utilities with an economical, practical, and scalable way to enhance resiliency. An example of a grid support application is a 14.9 MW installation for Dominion Energy in Bridgeport, Connecticut. Photo courtesy: FuelCell Energy

A fuel cell consists of two electrodes—a negative electrode (or anode) and a positive electrode (or cathode)—sandwiched around an electrolyte. A fuel, such as hydrogen, is fed to the anode, and air is fed to the cathode. If a hydrogen source is not available, a fuel processor converts natural gas to hydrogen. In a hydrogen fuel cell, a catalyst at the anode separates hydrogen molecules into protons and electrons, which take different paths to the cathode. The electrons go through an external circuit, creating a flow of electricity. The protons migrate through the electrolyte to the cathode, where they unite with oxygen and the electrons to produce water and heat.

Fuel cells have come a long way since they were used only to power spacecraft. However, the promise of fuel-cell-powered cars fueled by hydrogen seems to be running on empty.

Whereas the use of fuel cells in the transportation sector has fallen short of what was expected a decade ago, things are different in the power sector. Fuel cells represent a tiny, but growing, share of total generation with the largest fuel-cell power plants approaching 40 MWe. The primary difference between the transportation and power sectors is fuel. Instead of using hydrogen as do fuel cells for vehicles, power sector fuel cells use natural gas.

Kurt Goddard, Vice President, Investor Relations for FuelCell Energy sees growth in the fuel cell industry: "The size of the applications continues to increase, the adoption by leading utilities and global companies is advancing, the awareness and appreciation of the attributes of fuel cells continues to expand globally, and the types of applications continues to grow," he said.

Fuel cells provide stable predictable power. At Pfizer's research and development headquarters in Groton, Connecticut, two fuel cell plants generate 5.6 MW of power to increase the energy resiliency of the 160-acre campus. Photo courtesy: FuelCell Energy

Fuel Cells Support Utility Grids

Grid support applications, where power is supplied to electrical grid or utility substations, provide utilities with an economical, practical, and scalable way to enhance grid resiliency. An example of a grid support application is the 14.9 MWe installation for Dominion Energy in Bridgeport, Connecticut. Comprised of five SureSource 3000 plants from FuelCell Energy, each of which generates 2.8 MWe, this fuel cell park is utility-owned and located on a remediated brownfield property occupying only 1.5 acres. The project enhances the resiliency of the electrical grid by generating predictable and clean power for three substations. "The city benefits by returning an unused and difficult to develop brownfield back to the property tax rolls as well as benefitting from infrastructure enhancements and environmental remediation of the city-owned land that was paid for by the project," said Goddard.

In another grid support application, Delmarva Power in Newark, Delaware has deployed 30 MWe—enough to power about 22,000 homes—generated by fuel cells from Bloom Energy. "The project provides price stability and predictability over the term of the project," said Asim Hussain, Vice President of Marketing and Customer Experience at Bloom Energy. "It also provides environmental benefits far superior to conventional electricity generation."

Fuel Cells Stabilize On-site power

While utility applications for fuel cells are growing, so are onsite or "behind-the-meter" applications, where power is generated at the point of use, providing end users with improved power reliability and energy security by reducing reliance on the electrical grid.

The Coca-Cola Bottling plant in Elmsford, New York installed a pair of fuel cells to deliver reliable power, reduce water consumption, and benefit the environment. The two units have been providing 35% of the electricity and heat required to operate the facility since 2010. Photo courtesy: Doosan Fuel Cell America Inc.

At Pfizer's research and development headquarters in Groton, Connecticut, two FuelCell Energy SureSource 3000 plants generate 5.6 MWe of power to increase the energy resiliency of the 160-acre campus. The on-site fuel cell plant ensures continual power even in the event of a grid disturbance. This aspect of predictable power is critical to avoid disruption of pharmaceutical research and testing.

The Owens Corning Roofing and Asphalt Plant in Compton, California was dealing with several power outages per week due to an overloaded local infrastructure. To mitigate this issue, the company installed two 200 kW fuel cells from Bloom Energy to provide approximately 65% of the plant's power.

The Coca-Cola Bottling plant in Elmsford, New York installed a pair of PureCell Model 400 fuel cells from Doosan Fuel Cell America Inc. to deliver reliable power, reduce water consumption, and benefit the environment. At the Elmsford plant, the third largest Coca-Cola bottler in the world, the two units have been providing 35% of the electricity and heat required to operate the facility since 2010. The units are capable of operating independent of the local electric utility, so if there's a power outage, the fuel cells will continue to provide power to the facility until grid power is restored. The Doosan on-site power plants provide continuous power for electrical needs, heat for process loads and space heating, and grid-independent backup power.

Using Heat from Fuel Cells

Combined heat and power (CHP) is the useful application of byproduct heat from on-site electrical generation. CHP is an important strategy for reducing greenhouse gas (GHG) emissions. "For industrial applications, fuel cell plants are typically configured for CHP so end users benefit from a continuous and predictable supply of clean electricity and the high-quality heat, steam, or hot water to support processes and facility needs," Goddard said.

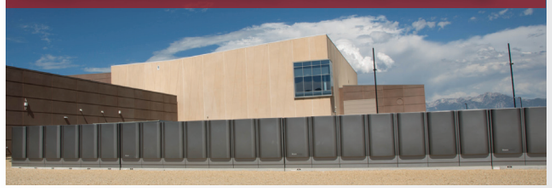
St. Helena Hospital, a 181-bed full service community hospital in Napa Valley, California, installed a Doosan fuel cell to provide clean, reliable energy to the 350,000 sq ft facility. In addition to providing 63% of the hospital's electricity needs, the fuel cell also provides 50% of the facility's space heating and hot water requirements through on-site distributed generation.

The Pepperidge Farm bakery in Bloomfield, Connecticut has two SureSource power plants configured for CHP. The fuel cells meet the majority of the plant's power needs along with a solar array that supports peak power needs. The high temperature heat generated by the fuel cells is supplied to the facility to support the baking process. The CHP configuration enhances efficiency while reducing CO_2 emissions and pollutants by lessening Pepperidge Farm's reliance on a combustion-based boiler.

Fuel Cells Generate Clean Power

Not only do fuel cells produce electricity, heat, and water, they do it cleanly and efficiently. Fuel cells do not operate using combustion. Therefore, they are virtually pollution free. Because the fuel is converted directly to electricity and heat, the total system efficiency of fuel cells can be much higher than internal combustion engines, extracting more energy from the same amount of fuel.

The eBay Inc. data center in Salt Lake City has integrated 30 fuel cell plants, providing 6 MW of power, into the data center's architecture. The electric utility grid will be used only as backup. Photo courtesy: Bloom Energy



"The main issue is being able to produce energy that costs less than the grid," said David Giordano, Federal and State Government Relations at Doosan. "Other issues deal with the fact that [fuel cells] are the cleanest way to use natural gas; [they] can provide power to critical facilities when the grid goes down because [they] run 24/7—and they lowere GHG emissions and criteria air pollutants."

In September of 2013, eBay Inc. opened its data center in Salt Lake City—the first in the world to use Bloom Energy fuel cells as primary, on-site power. The state-of-the-art facility incorporates 30 Bloom Energy Servers, providing 6 MWe of power into the mission critical data center's energy architecture. The electric utility grid will be used only as backup. By using Bloom Energy fuel cells—which generate on-site power 24 hours a day, 365 days a year—eBay replaced large expensive backup generators and UPS components, and will drastically reduce the carbon footprint of its new facility.

Fuel cells provide grid support for utilities, and on-site power stabilization and process heat for end users. To decide if a fuel cell is appropriate for your operation, you should understand your power usage and costs. Is high electrical efficiency or high thermal efficiency of value? Is an environmentally "green" power source important to you? Can you make use of the heat byproduct for your facility? If so, a fuel cell can be the right choice. GT

MORE info

BLOOM ENERGY
www.bloomenergy.com

DOOSAN FUEL CELL AMERICA INC.
www.doosanfuelcell.com/en/main.do

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ENGINE-GENERATOR SETS COME IN ALL SIZES, FROM THE TINY BOXED UNIT YOU TAKE ON CAMPING TRIPS TO THE ENORMOUS UNITS THAT MOVE CONTAINER SHIPS OR SUPPLY POWER TO UTILITY GRIDS. It's a technology that has been tested by time and is well understood. Yet the reciprocating engine continues to improve in reliability, efficiency and control. Large stationary units are especially attractive for many electric power applications.

Multiple Engine Types

Reciprocating engines operate on various types of cycles. The most common are the Diesel cycle, the Otto cycle and the Miller cycle. The Diesel and Otto cycles date to the 19th century, but have somewhat different operating characteristics. The Miller cycle is an enhanced development from the Otto cycle.

Diesel cycle engines use compression ignition with a liquid fuel, typically light oil, that is injected into the cylinder and explodes with power as the piston compresses the fuel-air mixture. The Otto and Miller cycles also uses a compressed mixture of fuel and air, but the mixture is ignited by a spark source. Otto cycle engines have historically been fueled with gasoline but are increasingly also using gaseous fuels. Miller cycle engines can also use a wider variety of fuels.

Today's large gas-fired reciprocating engines have efficiencies as high as 50% and are increasingly the choice for institutions and even electric utilities. With heat recovery, total fuel utilizations can be as high as 90%. Photo courtesy: Wartsila

Growing Interest in Natural Gas

With today's abundance and availability of natural gas, and the long-term outlook for attractive pricing for this as fuel, we have seen a growing interest in engines burning this economically attractive and very clean fuel. Whether for powering automobiles or generators, natural gas engines are growing in popularity.

Natural gas can be used in both diesel and spark-ignition engines. When used in the diesel cycle, it is normally mixed with a "pilot" amount of diesel fuel to allow compression ignition. This pilot fuel might represent as little as 5% of the total fuel.

With spark ignition engines, natural gas can be used as the only fuel.

Choosing the Largest Practical Size

As the size of a stationary generator increases, the engine efficiency usually increases as well. For this reason, industrial and institutional energy users benefit by choosing the largest-size engines suitable for their needs. Of course, this efficiency goal must be tempered with a need for reliability with redundant engines. Modern reciprocating engines are very reliable. Most owners are better off with two large engines rather than six smaller units.

Jamie Fox from Caterpillar notes, "It is important that the customer thoroughly compares apples to apples, as high efficiency comes at the price of higher capital cost and less operational flexibility. A good engine dealer should provide the customer with a manufacturer's data sheet calculated at the exact site altitude conditions, with a graph or data to describe the power and efficiency derates of the engine at 77°F all the way up to the maximum temperature the engine can handle at a stated altitude."

Fox also points out that one reason that larger engines are more efficient is they generally use the Miller combustion cycle rather that the traditional Otto cycle. "This is due to economic and standby response capabilities. The Otto cycle is inherently less efficient than the Miller cycle." However, she adds that Otto cycle engines are unmatched in terms of quicker response to sudden load changes, tolerance to fuel contamination, and ability to operate independently of the utility.

Best Results with a Matched System

Fox indicates that a successful CHP project needs to be specified as a system and not as a collection of independent hardware. This means, she says, "Probably the best option for the end-customer is to purchase a turn-key CHP project from a power systems dealer or a very capable CHP packager. There are superb companies out there doing engineering, sourcing and integration of CHP projects. Good definition of scope and responsibilities is a must."

Wartsila is another world leader in very large reciprocating engine-generator sets. The company is headquartered in Finland and is a respected manufacturer of both marine reciprocating engines and large stationary engine-generator sets. Joseph Ferrari is the Business Development Manager for Wartsila North America, headquartered in Annapolis, Maryland.

Slower Engine Speeds

Ferrari notes that there are good reasons why larger engines are generally more efficient. "Larger engines have less combustion surface area relative to volume, leading to lower thermal losses (heat transfer to the cooling system) which in turn means more energy is available to push down the piston. So, the larger the cylinder, the more efficient the combustion process." In addition, he says, "Theoretical engine efficiency is related to combustion length (in time) relative to degrees of crank shaft rotation. Therefore, slower speed engines tend to have higher efficiency."

Wartsila medium speed (514-720 rpm) engines use very lean air-fuel mixtures and fast combustion as the key elements for lower emissions and high output per cylinder, therefore clean, high-efficiency combustion. Ferrari says this leads to Wartsila engine efficiencies being greater than any other simple-cycle gas-fired technology in the market. In some cases, engine efficiencies greater than 50% are achieved.

MORE info

CATERPILLAR ENGINE GENERATORS
www.cat.com/en_US/products/new/power-systems/electric-power-generation.html

GE JENBACHER AND WAUKESHA ENGINE GENERATORS
https://powergen.gepower.com/products/reciprocating-engines.html

SIEMENS DRESSER RAND ENGINE GENERATORS
www.dresser-rand.com/products-solutions

WARTSILA STATIONARY POWER PLANTS
www.wartsila.com/energy/solutions/gas-power-plants

Total Efficiency Can Exceed 90%

Ferrari adds that in situations where the heat from engine jacket water and exhaust are collected using heat exchangers, total plant efficiency of more than 90% can be achieved. The Wartsila SG engine-generator sets that operate on gaseous fuel only are available in sizes from 5.3MWe to 19 MWe (60 Hz). In addition to these gas-only sets, Wartsila offers dual fuel diesel generators that use as little as 5% of their input as light fuel oil.

One example of the growing attractiveness of large generator sets is the installation of multiple Caterpillar units in Markham, Ontario. Markham is a satellite community near Toronto that has seen significant growth in the past two decades. Community planners place emphasis on planned community density rather than urban sprawl. This makes Markham an ideal candidate for district energy, where local generation plants can also provide thermal energy for heating or other purposes. Markham District Energy (MDE) is the organization established to plan, maintain and operate the energy facilities.

Often large engine-generator sets are skid-mounted for rapid installation and startup. Photo courtesy: Caterpillar

Ice Storm Experience Influences Selection

The decision by Markham planners to localize electric generation was in part influenced by a major ice storm that struck Eastern Canada in 1998, causing large and long-term electric outages. One benefit of district energy is that the lights would stay on, even if there was a regional grid failure.

MDE selected natural gas-fired reciprocating engine generators as the method of choice. In 2007, they designated Toromont Power Systems, the local Caterpillar dealer, to design, deliver and commission a 5.0 MWe plant at Warden Energy Centre, which went into operation in 2008. Gas-fired boilers can supplement the hot water supplied by the engines as a thermal byproduct. Hot water is used for space heating and other applications throughout the district.

Continue Choosing Large Engines

As MDE continued to expand its service area, in 2012 it added a 3.0 MWe Caterpillar engine-generator at its Birchmount Energy Centre and a 4.0 MWe Caterpillar unit at its new Burr Oak Energy Centre. MDE also operates a diesel standby energy plant at Markham Stouffville Hospitals for this anchor power and thermal energy customer.

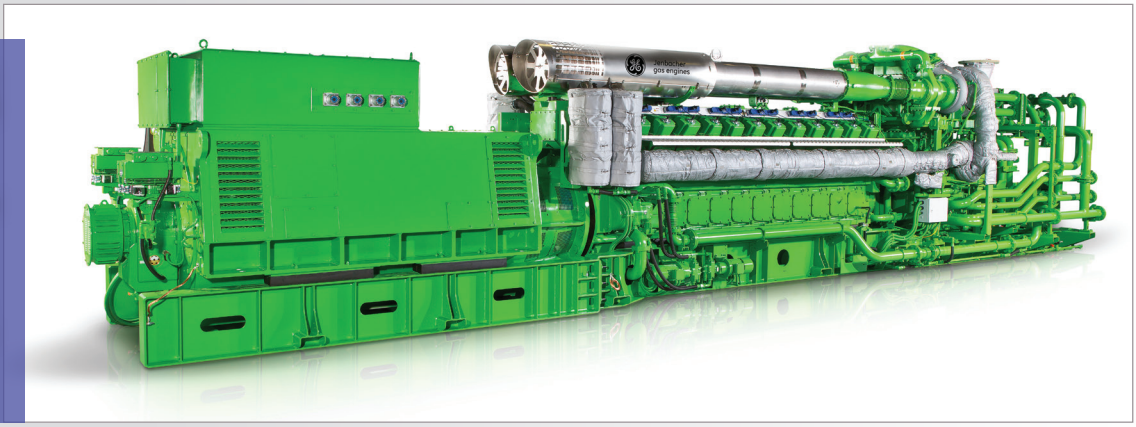
Bruce Ander is the president and CEO of Markham District Energy. Regarding the importance of reliability, he states, "First and foremost, our core business is to create thermal energy, and reliability is our first priority. Whether the Cat® fleet is providing emergency power to our customers, or grid power, or thermal energy for our heating system, high reliability is the goal for MDE and our suppliers."

High Reliability

Reliability comes from several sources. Modern reciprocating engines take advantage of metallurgical advances and improved designs that minimize unexpected failures and extend times between necessary engine services. Because natural gas is a very clean fuel, this service interval time is further extended. Planned maintenance can be done at times of year when electric and thermal demand is lowest. And many of the larger engine sets have on-board diagnostic tools that alert operators of changing engine conditions so that maintenance can be scheduled rather than on an emergency basis.

Engines Can Be the Best Choice

Whether your operation is a school or university, an industrial campus, a healthcare facility, or something else, on-site electric generation with natural gas allows you to get more out of your energy dollar. Today's large reciprocating engine technology is reliable and surprisingly energy-efficient. To get started, ask your natural gas supplier and your consulting engineer to help you consider this important option. **GT**

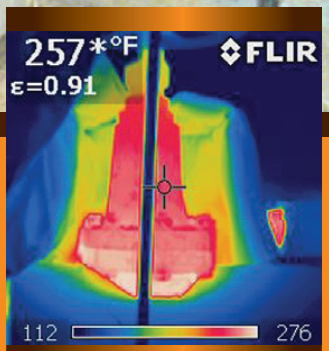


Large engines such as this unit from GE Jenbacher can be matched with heat recovery equipment and used for a wide range of electric generation applications. Photo courtesy: General Electric

HELP STOP RADIANT HEAT LOSS AT THE SOURCE

Energy Savings

MAIN STEAM STOP VALVES & GATE VALVES ON A BOILER ARE PRIME CANDIDATES FOR TREATMENT.



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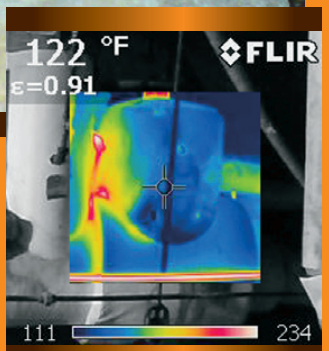

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Condensing Boilers

The same strategy is increasingly being deployed in commercial and industrial hydronic boilers. Manufacturers today offer fully condensing hydronic boilers, often used for space or process heating. These use advanced heat exchangers, usually in series, to reduce the temperature of boiler exhaust below the condensing point, typically around 130°F (55°C). The cooler the return water, the higher will be the unit efficiency.

With cool return water temperatures, condensing hydronic boilers such as these Cleaver Brooks units offer efficiencies of 90% and higher. Photo courtesy: Cleaver Brooks

The U.S. Department of Energy's National Renewable Energy Laboratory (NREL) performed an evaluation of condensing boiler installations for guidance for the General Services Administration (GSA) Rocky Mountain Region. The report concluded that condensing boilers in space heating applications can increase the steady-state heating efficiency from 6% to 18% over standard boiler systems. The report indicated that the level of efficiency improvement will depend on how the condensing boilers are designed and operated, and on the temperature of the return water.

Return Water Temperature is Important

A condensing boiler will be most attractive in certain hydronic applications with relatively low return water temperatures, such as with under-floor heating, cast iron radiator systems, process heating applications, or any application where there is a significant amount of cool makeup water added. The cooler the return water is when entering the boiler, the higher the potential efficiency. In a situation where the water is 100°F (38°C) and the unit is sized appropriately, unit efficiencies may range from 95 to 98%.

Kyle Bottorff is a product manager for Fulton Heating Solutions, a major manufacturer of condensing boilers and related equipment. Regarding potential markets for condensing boilers, he explains, "The largest fuel saving benefits occur when boiler return water temperatures are under approximately 135°F. However, even when in higher temperature operation, a condensing boiler is generally more efficient by several percentage points over a non-condensing alternative. Retrofit applications with 160-180°F water temperatures can still reap the efficiency benefits of a condensing boiler by implementing an outdoor reset schedule. The highest heating water temperatures are only required on the coldest days of the year, so return water temperatures are automatically lowered (into fully condensing) during the mild weather shoulder loads which make up the majority of the season."

Thriving at Part-Load

Non-condensing boilers tend to be at their greatest efficiency when at 80% to 90% of full load. However, condensing boilers tend to be at their most efficient at lower part-load levels. Because many boilers operate at these lower levels, this contributes to their having overall higher annual efficiency.

Bottorff notes that in addition to space heating, certain other applications make sense for condensing boilers. This might include food processing, dairy plants, or other industrial applications where the boiler water is consumed. He adds, "Many closed-loop applications using water or a water/glycol solution as the heat transfer fluid operating between 40°F and 200°F can also be great fits."

Many Candidates for Condensing Systems

Bottorff adds, "Payback on a condensing boiler will be quicker as water temperature requirements decrease. Some areas where condensing boilers are growing in popularity include automotive and aerospace painting facilities, indirect pool heating, indirect domestic hot water, and wastewater treatment plants."

According to Bottorff, Fulton manufactures four condensing boiler lines – Endura, Endura+, Vantage and Pulse. These range in size from 750,000 Btu/Hr to 6,000,000 Btu/Hr. All are firetube heat exchangers built with Duplex stainless steel, a robust alloy for long-term service and reliability. The Fulton products are designed to save on installation costs by eliminating the requirement for dedicated boiler pumps and primary-secondary piping arrangements.

Unique Design Elements

Exhaust condensate from a natural gas-fired condensing boiler typically has a pH ranging from 3.0 to 5.0, or mildly acidic. This acidity would be damaging to a cast iron or mild steel heat exchanger, so in a condensing boiler, heat exchangers are usually either an aluminum alloy, or stainless steel. Units are equipped with drains that collect condensate for transfer to a floor drain or sump. In some locations, the condensate also needs to be neutralized, which can be accomplished with a collector filled with limestone chips or magnesium oxide.

Owners should check with local wastewater treatment specifications for possible pH limitations. In a pure condensing boiler, the combustion exhaust temperature is low enough that an exhaust blower is needed. Low temperature exhaust means the exhaust stack can be PVC construction, although an existing non-corrosive flue is entirely satisfactory.

Opportunity for Major Savings

Cleaver Brooks is another manufacturer of a range of boilers and related products that offers its ClearFire® line of condensing boilers. Catie VanWormer, PE, is a product manager with the ClearFire line who offers her views on condensing boiler potential. "For the majority of new construction projects, it makes sense to use condensing boilers for a number of reasons; operating efficiency gains, controls, reduced footprint, and a modular design approach with efficiency." However, they require the right situation.

VanWormer explains, "When evaluating a retrofit project to convert from non-condensing to condensing there are items that must be researched before determining the best solution; system operating temperatures, the ability to reduce those temperatures to reach condensing performance, project budget, existing system piping design, venting, and combustion air routing." She offers, "Cleaver Brooks representatives have the ability to help potential customers in their areas -- engineers, contractors, or end users – to determine the best solution for their specific system."

In this hospital installation, three skid-mounted Fulton Vantage™ condensing boilers are installed in a hospital hot water system. Multiple units allow matching to seasonal and daily hot water demand patterns. Natural gas-fired units respond quickly. Photo courtesy: Fulton

Hybrid Systems

In some situations, the condensing boiler may be combined with new or existing conventional non-condensing boilers. Because a non-condensing boiler is typically less expensive, this approach allows an owner to take advantage of condensing technology without the expense of an entire fleet of condensing boilers. In this situation, the initial cool return/makeup water is routed first through the condensing boiler, then through the non-condensing boiler/s once the water temperature is well above the condensing point.

Van Wormer points out that this can be the best solution where there are legacy non-condensing boilers that are still in good operating condition. "Adding a condensing boiler and controls in an appropriate piping arrangement can drastically improve the overall plant efficiency without replacing all the equipment."

The Cleaver Brooks ClearFire condensing boilers feature the AluFer® tube which greatly increases heat transfer and the effective heating surface. The AluFer tube has an aluminum internal heat exchange surface within an outer stainless shell. These boilers feature a true counterflow heat exchanger with dual return connections to maximize boiler efficiency. They also feature a highly efficient pre-mix burner and outside air reset capabilities.

Condensing Economizer Another Approach

If your application is not suitable for a condensing boiler because of space considerations, another alternative is to add a condensing economizer in the boiler exhaust stream. These can be used with cool boiler makeup water streams or possibly domestic hot water streams to achieve the benefits of condensing heat recovery.

When you are using a condensing boiler or a condensing economizer, you are maximizing the efficiency of your heating plant. Ask for help from your engineer or a manufacturer's representative in evaluating your savings potential. **GT**

MORE info

CLEAVER BROOKS
www.cleaverbrooks.com

FULTON HEATING SOLUTIONS
www.fulton.com/product-profile.php?ptc=&uid=16

GSA REPORT ON CONDENSING BOILER EFFICIENCY
www.gsa.gov/portal/getMediaData?mediaId=197387

NEW BOILER LIFE WITH A NEW BURNER

Advanced Controls Technology

PERHAPS YOU'VE BEEN UNHAPPY WITH THE PERFORMANCE OF YOUR BOILER PLANT. It seems to be operating inefficiently, especially at part load. The controls may be sluggish, or your exhaust stack monitoring indicates incomplete combustion or excessive emissions. Is it time for a boiler replacement? Maybe a controls and burner replacement will solve the problem.

Is the Boiler the Problem?

In certain cases, boiler replacement is warranted. If you've had a lot of tube leaks or major corrosion problems, it's probably time to replace. Or perhaps the boiler no longer meets your steam or hot water requirements. It might be too large or too small for current needs. It may be supplying steam at the wrong temperature or pressure. There's not much you can do about that except replace it with the right equipment.

But boiler design is a mature technology and most boilers have a potential life of many decades if properly maintained. However there have been many recent advances in boiler burners and controls. By replacing an obsolete or deteriorated burner or burner control system, the life of a sound boiler can be extended by many years.

Today's widespread replacement of coal-fired equipment requires burner replacement. Here a previously coal-fired boiler has received efficient new gas burners and controls. Photo courtesy: Cleaver Brooks

Achieving Ideal Fuel Mixture

A report by the U.S. DOE describes the role of the burner. "A power burner mechanically mixes fuel and combustion air and injects the mixture into the combustion chamber. All power burners essentially provide complete combustion while maintaining flame stabilization over a range of firing rates. Different burners, however, require different amounts of excess air and have different turndown ratios."

The report adds that an efficient natural gas burner requires only 10% to 15% excess air in the flue gas to burn fuel without forming excessive carbon monoxide. It states that most modern gas burners today exhibit turndown ratios of 10:1 or 12:1 with little or no loss in combustion efficiency. This is important because a higher turndown ratio reduces the number of burner starts and provides better boiler load control. It also reduces stresses on the boiler and burner and provides significant energy savings. New burners and controls can help you achieve that high turndown characteristic.

Certain Cases are Obvious

In some cases, older boilers that have been converted from oil firing to natural gas are still using features such as rotary cup burners. These are inefficient and often have emission levels that are unacceptable by modern standards. If the boiler has significant remaining life, these burners should almost always be replaced.

Another common situation is where the boiler burner is modulated using a mechanical linkage control. In some cases, there are also additional linkages for an oil valve (for dual fuel boilers) and for dampers for flue gas recirculation (FGR).

Linkage Controls are Sloppy

Mechanical linkage controls are problematical because they are difficult to keep in calibration, and under the best conditions inevitably have some slip. Even changing ambient temperatures can take the control out of calibration. In some cases, it's practical to keep an existing burner and simply replace the linkage control with a modern parallel positioning control system, where individual servo motors precisely modulate the valves and dampers to maintain optimum fire conditions. In other cases, replacement of both the burner and control may be needed.

Roger Perstein is Vice President of Sales and Marketing for the Burner Systems Group of Cleaver Brooks, a major provider of boilers and burners. He points out, "Burner replacements frequently offer opportunities to improve the efficiency and/or reduce emissions." He explains that modern controls technology allows far more precise combustion ratio control and greater responsiveness to season or operational variability in steam or hot water demand. "Modern burners can deliver as much as 5% to 10% in energy savings and up to an 80% reduction in emissions."

Features of New Systems

Perlstein describes the several features of modern burner and control systems that improve efficiency and reduce emission. "The big ones are parallel positioning [using servomotor drives], flue gas recirculation, [increased] turndown and staged combustion. The government refers to this group of features as Maximum Achievable Control Technology (MACT) and they enable higher efficiency. These advances can also have a positive impact on emissions. And they have the potential to pay for the burner upgrade purely from fuel and energy cost reductions."

Burner and control replacement is usually done at a time of low steam or hot water demand and can take from a little as 2-3 days to as long as several weeks. If it is a plant with multiple boilers, having one out of service may be no problem. In some cases, it may be necessary to rent a skid-mounted or trailer-mounted temporary boiler while the regular boiler is out of service.

Remote Monitoring and Alarming

Another feature that is available in new burners and control is remote monitoring, including internet access technology. Controls can monitor for "out of tune" conditions and can send alerts for undesirable conditions. They can also provide logging for flue gas monitoring, boiler demand history, high flue temperature or many other conditions.

Smaller Boilers Can Benefit Too

The advantages of updating boiler burners and controls are not limited to large industrial or institutional boilers: Smaller boilers –1,000 bhp and less – can also benefit. Companies like Carlin Combustion Technology offer solutions for these smaller boilers. Carlin specializes in replacement burners for residential, commercial and light industrial boilers. Facilities like clinics, retail stores, schools, bakeries, churches and many others need a reliable and efficient source of steam or hot water. If properly maintained, their older boilers may be great candidates for burner replacement.

According to Carlin spokesperson Jim Jones, burners for smaller boilers have made great strides since 2000. Improvements have included linkageless controls, step-firing options and much more precise fuel metering and air damper management. Jones indicates the first step is an assessment of the current boiler and controls. "If that boiler has been maintained well, it may have a long life into the future."

He explains that many older boilers – both cast iron and steel -- were very stout machines, with rugged designs that give them a long life. "This is where burner replacement makes a lot of sense." Jones suggests getting help from a local or regional boiler specialist first to do the assessment, and if appropriate, to recommend type and size of the replacement burner. "Size is important. Too often the burner is oversized, which leads to a lot of stop-and start-operations. Correct burner sizing and step-firing can eliminate much of this."

Evaluate the Potential

Regardless of the size of the boiler, if your unit has older controls, particularly if it is an oil conversion or has mechanical linkages, now is a good time to consider a burner or control upgrade. Perlstein from Cleaver Brooks agrees that the evaluation of the boiler and burner be done by conducting an operating efficiency and emissions audit.

He notes, "This should be done by a qualified service company that has access to emissions gas analysis equipment. They must take fuel savings and energy savings into account in determining return on investment. Also, carbon taxes should be factored in since lowering emissions can also reduce operating costs." Every application is different and it is impossible to project potential savings without this kind of analysis. But these are steps worth investigating for any operator of older boiler equipment. **GT**

MORE info

CARLIN COMBUSTION TECHNOLOGY
http://carlincombustion.com

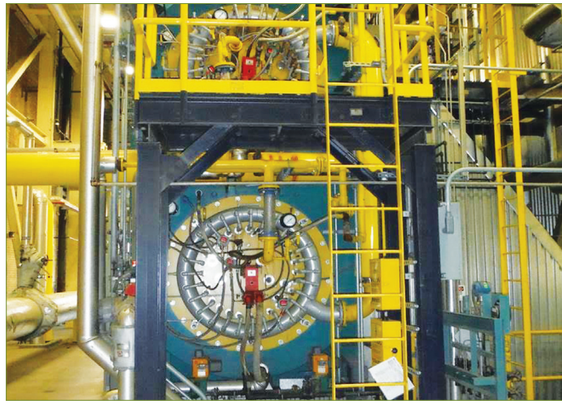
CLEAVER BROOKS BURNERS
www.cleaverbrooks.com/products-and-solutions/burners/index.aspx

COEN BURNERS
www.coen.com

DOE INFORMATION ON BURNER REPLACEMENT/UPGRADE
https://energy.gov/sites/prod/files/2014/05/f16/steam24_burners.pdf

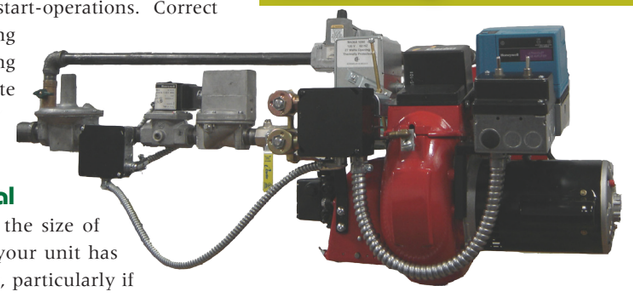
SIEMENS BURNERS AND CONTROLS
http://boilersburnersandcontrols.com/products/controls/siemens-combustion-controls

U.S. EPA RULES ON EMISSIONS
www.epa.gov/stationary-sources-air-pollution



New burners extend the life of a dual fuel (natural gas & oil) boiler at the University of Wisconsin. Photo courtesy: Cleaver Brooks

Photo shows typical arrangement of a replacement burner, together with piping and control configurations. Photo courtesy: Carlin Combustion Technology



Before You Dig...

One-call underground utility location is mandatory

EVERY YEAR, UNDERGROUND UTILITIES BECOME MORE WIDESPREAD. Natural gas, electric transmission and distribution, cable television, private data services, municipal water, telephone and other utilities are placing services underground. That's why any underground digging, drilling or landscaping projects cannot take place until the utilities are properly located and avoided. It is dangerous, professionally embarrassing, and potentially very costly to disturb or damage any of these services.

Just a Phone Call

Fortunately, it's easy to avoid trouble. Anywhere in the U.S., a phone call to 811 or a visit to the 811 website gives you a one-stop opportunity to have all utilities located and marked before you put a shovel, drill or backhoe into the ground. In Canada, all provinces have a one-call underground utility location service as well. With today's one-call services, the number of dig-in accidents is diminishing, despite more utilities going underground every year.

Before you begin digging, drilling or landscaping, make the appropriate phone call or internet communication. This is a requirement.

MORE info

811 in Your State Details
http://call811.com

DigSafe Canada
http://digsafecanada.ca

Both owners and contractors are responsible for safe digging practices. If as an owner you hire a contractor, it is also wise to assure the proper procedures are followed. Most one-call services will locate and mark all utilities within 72 hours and will notify you when the process is complete. Your action will demonstrate your good faith effort to avoid conflicts. Typically, the location and marking service is valid for about two weeks, but it may vary from state to state, province to province. If your project comes close to any indicated service, communicate with that utility to look for resolution. Don't take a chance – make the call before you start. **GT**