OFFICIAL PROCEEDINGS
SIXTY-EIGHTH ANNUAL CONFERENCE

OF THE

INTERNATIONAL DISTRICT HEATING ASSOCIATION

HELD AT

PINEHURST HOTEL AND COUNTRY CLUB
PINEHURST, NORTH CAROLINA
JUNE 27, 28, 29, 1977

VOLUME LXVIII

Published by The
INTERNATIONAL DISTRICT HEATING ASSOCIATION
5940 BAUM SQUARE, PITTSBURGH, PENNSYLVANIA

Monday, June 27
2:00 PM

SECOND TECHNICAL SESSION

Norman R. Taylor, *Vice-President, Presiding*
Baltimore Gas and Electric Company, Baltimore, Md.

PRODUCTION COMMITTEE PROGRAM

George F. Urbancik, *Chairman*
Baltimore Gas and Electric Company, Baltimore, Md.

ECONOMICS, INSTALLATION, OPERATION AND MAINTENANCE OF HIGH-VOLTAGE ELECTRODE BOILERS

Peter M. Coates, *Vice-President, Marketing and Sales*
CAM Industries Inc., Kent, Wash.

INTRODUCTION

Pass an electric current through a high-resistance wire, and you get heat; that is how an electric range boils water. Pass a current through water, and the resistance of the liquid itself will convert the electric energy directly into hot water or steam; that is what happens in an electrode boiler.

Electrode boilers were developed before World War II, and have been built occasionally since then for special applications. Now, with energy suddenly a precious commodity, these sophisticated devices are beginning to sell as never before, and are going into commercial and industrial buildings in sizes that would have seemed gigantic just a few years ago.

In order to properly evaluate the possible use of an electrode boiler for specific applications, it is important to recognize the changes that have recently taken place in the relative status of various forms of "fuel" within the larger energy picture, and also to speculate on what further changes are likely to occur in the future. Electricity as an on-site fuel has always had several attractive features: safety, cleanliness, and efficiency. Unfortunately, it was also expensive, particularly when compared with plentiful natural gas or cheap fuel oil. Coal, and other solid fuels, were only considered for the very largest applications, because of the enormous capital cost of modern equipment and the pollution problems associated with burning solid fuels.

Today, in many areas of the country, industry is discovering that natural gas is no longer readily available, is subject to frequent and prolonged interruption, and is sometimes restricted, curtailed, or denied, particularly for new hook-ups. If the price of natural gas is eventually de-regulated (an increasingly likely possibility, especially for industry), it may also no longer be inexpensive. All over the country fuel oil prices have risen dramatically, availability has sometimes been a problem, and reliability of supply is open to question. Increasingly more stringent pollution control requirements, plant location, fuel-handling problems, rising capital costs and tight fuel supplies all tend to restrict the burning of coal or other solid fuels to only the largest industrial installations or to utility generating plants, and particularly to sites remote from large population centers. In those situations where it is more available than natural gas, more economical than fuel oil, and cleaner and easier to use than coal, electricity has become an increasingly realistic alternate fuel.

For the future, electricity enjoys one very important advantage over fossil fuels. There are many possible sources of electricity, including tidal, solar, geothermal, wind, and thermonuclear in addition to hydro, nuclear and fossil fuel. A great deal of time, effort and money is being devoted to the development of both new technologies and new sources. It is significant that electricity is a form of energy, a way of transmitting energy and making it available for use; it is not a source. Fossil fuels, on the other hand, are more properly a source. While much effort is being expended to find new reserves, very little can be expended to find new sources or create fuel; it is not a renewable resource. When supplies are exhausted, alternatives will have to take their place.

ECONOMICS

Quite naturally, since electricity is the fuel of an electrode boiler, the electric utility becomes the key to the feasibility of any electrode boiler installation. If the utility is short of generating capacity, availability of energy may be a problem. Capital shortages and siting problems have resulted in tight electricity supplies in some areas. If the utility generates extensively with oil, the cost of electricity may also be too high. The efficiencies of the generating process make it more attractive to burn oil on-site, rather than to first convert it to electricity for transmission and consumption. Electrode boilers merit the most serious consideration in those areas where the electric utilities have adequate or even excess generating capacity (both present and planned), and where generation is based extensively on the use of hydro, coal or nuclear power plants.

If the utility is in a favorable position, the relative cost and availability of alternate energy forms should be studied. Here, several unique characteristics of electricity must be considered. The economics of electrical generation dictate that utilities strive to maximize the use of these facilities (load factor). Unfortunately, electricity as such cannot be stored; if generated, and not used, it is gone forever. As a result, applications which avoid peaks, or which fill in valleys in a utility's seasonal or daily load pattern, are particularly attractive. Most utilities attach a cost to peak additions, demand charges, and many provide incentives to fill valleys in the form of lower "off-peak" rates. Rate incentives are often available for improvement in overall plant power factor. These special considerations can significantly alter the effective energy costs of any electrode boiler installation.

Electrode Boilers Help Solve Energy Problems

The reasons for actually purchasing an electric boiler are as many and varied as the users themselves. In most cases, the choice involves some combination of energy cost and availability. For many, natural gas is restricted or unavailable and oil costs are too high. In some cases, on interruptible gas, electrode boilers are used as stand-by to gas/oil boilers to supply space and process heating loads on interruptible days. In other cases, where the amount of gas is restricted, an electrode boiler may be used to supply steam or hot water requirements, while the gas is reserved or used where alternate fuels are less suitable, such as heat treating. In many areas, natural gas is not available for new facilities, or even expansion of existing ones.

Electrode boilers have been base-loaded as the sole source, or are backed up with oil stand-by. In still other areas, gas is short, but oil is more reasonably priced; electrode boilers may be used to satisfy a desire for an alternate fuel. Today, it often makes as much sense to have a stand-by fuel capability as it does to have stand-by equipment.

Often there is a seasonal relationship between gas and electricity that makes a combination of gas/oil and electrode boilers attractive. Many utilities have a "summer peak" and consequently have excess capacity in the winter months. Conversely, most gas shortages occur during the winter. In this situation, the use of an electrode boiler to satisfy winter space or process heating loads will not only improve the utility's load factor, but also relieve pressure on gas supplies. During the summer, the relationship is reversed. Since natural gas storage is often difficult and expensive, this seasonal relationship is especially important.

Electrode boilers can also be used to take advantage of the daily peaks in a utility's system, whenever attractive off-peak rates or significant demand penalties exist. With an appropriate demand control, an electrode boiler can easily be set up to cut back or shut off during periods of peak electrical consumption. Where there is a night-time demand for space or process heat, the electrode boiler can operate on lower off-peak rates, while a gas/oil boiler provides day-time requirements; or the electrode boiler may be base-loaded, while an oil-fired unit is used for peaking requirement. With this arrangement more atttractive, electricity is used to supply the bulk of the plant requirements, and oil is used to supply the peaks and hold electric demand charges down. In some situations, electricity may be consumed at low off-peak rates and stored, usually in the form of hot water, in accumulators for use during some or all of the peak hours of the day. This approach is being used very effectively in several district heating projects in Canada.

An even more attractive application of the load leveling concept is possible, at those plants which are able to purchase their electric requirements as "block" power. In this case, the customer pays a fixed amount for his power requirements, provided that they do not exceed a maximum demand. Whenever the plant electrical load drops below this maximum, there is "free" energy available. An electrode boiler controlled by a master demand controller can be used to convert this "free," or excess, electricity into heat for use by the plant while other fuel-fired boilers are cut back and fuel is saved for later use. The resultant uniform power consumption results in maximum utilization of the power distribution equipment, and enables the company to benefit from all of the energy for which it is paying. Several large pulp and paper mills are using this concept successfully with electrode boilers as large as 30,000 kw, with capacities in excess of 100,000 lb of steam/hr.

Electrode boilers are especially well suited to take advantage of the way electricity is sold—a must in many areas if electricity is to be competitive. The units always start at zero load. The load increases gradually so that no sudden peaks are created. Yet, the load can be varied rapidly to respond to changes in the system's demand for heat or electricity. Start-up and shut-down are also rapid, so that a boiler operating on demand-control can take advantage of dips in plant demand, without the danger of establishing new peaks. Output and/or consumption is infinitely variable, enabling the boiler to closely follow either the plant load, or electric demand patterns. The opportunity for both local and remote control adds additional flexibility to the operation of an electrode boiler. With a unity power factor, both power factor penalties and the need for compensory capacitors may also be reduced or eliminated.

At times, pollution also becomes an important criterion. Many oil burning and most coal or solid fuel burning installations are faced with emission control problems. The cost of equipment to enable facilities to meet ever more stringent air quality standards can be substantial. Maintaining and operating this equipment effectively can also add to this problem. This is especially true where older, less efficient equipment must be upgraded or replaced in order to conform to new standards. Electrode boilers, on the other hand, avoid these on-site problems. With electricity as a fuel, there are no emissions or other products of combustion, and no need for unsightly stacks or noisy air-handling equipment. Pollution control was of prime consideration for one forest products company which uses electrode boilers to help grow trees in two large seedling nurseries. This ability to meet strict on-site air quality standards and avoid additional capital expenditures, may help to overcome operating cost disadvantages in some situations.

INSTALLATION

A major factor in any equipment decision is capital investment. The high cost of capital, measured either by interest rate or rate of return, often adds significantly to the effective operating cost of a boiler installation. The installed cost of a new electrode boiler will usually be less than 10% of the cost of a new coal-fired facility, and can be as little as 25% of a new oil-fired facility. A large part of these differences can be found in the support facilities required by fuel-fired boilers. Certain items such as deaerators, blowdown systems, and water treatment equipment, are as appropriate to electrode boilers as they are to coal and oil-fired ones. Electrode boilers also require a significant investment in electrical switchgear. They do, however, eliminate the need for special boiler rooms and fire walls, fuel handling and storage equipment, air handling equipment, preheaters or economizers, stacks and emission control equipment, ash-handling and disposal facilities, combustion safety systems, noise abatement equipment, and of course, the space and installation costs associated with this equipment. The use of a high-voltage electrode boiler will also eliminate the cost of step-down transformers and reduce the cost of power supply feeders. The electrode boiler, itself, will generally cost more than a good fire-tube boiler; but less than the better water-tube boilers, depending on size, and may require as little as 25% of the floor space. Actual installed cost comparisons will vary, depending on the amount of existing equipment which can be utilized versus the new equipment required.

Additionally, electrode boilers are often adaptable to existing boiler rooms with minimal modifications to previously installed equipment being required. This becomes an especially attractive feature when the electrode boiler is being installed to provide stand-by or peak load capacity. A relatively simple valving arrangement can integrate steam from the electrode boiler when needed, with steam being generated by fuel-fired boilers.

OPERATION AND MAINTENANCE

Maintenance and safety are issues which usually merit considerable review. The simplicity of the electrode concept reduces the number and complexity of operating controls and safety devices. Hazards associated with combustion are eliminated, as is maintenance to remove combustion residue. Since heat is generated directly in the water itself, no part of the boiler is at a temperature higher than the steam or water. This lack of elevated temperatures reduces the tendency for scale to form, and eliminates the problem of thermal shock. While scaling is to be avoided, and its presence will increase maintenance, there will be no loss in boiler efficiency or danger to personnel or equipment. The use of the boiler water to conduct electricity, and generate heat, also means that electrode boilers are fail-safe on low water. Without water, the circuit is open, no current can flow and no heat can be generated. There are no tubes to foul or burn out. The absence of these common boiler problems means not only less frequent and less costly repairs, but safer operation as well. When maintenance is required, an electrode boiler both cools down and restarts faster for reduced downtime. With fewer moving parts and less instrumentation, reliability is increased and requirements for spare parts and maintenance personnel are lowered substantially.

Reduced Personnel Requirements

The absence of combustion often reduces the need for operating personnel as well. Electrode boilers are designed for unattended operation. There is no need for routine cleaning operations for such components as oil guns or strainers. Most controls are automatic and few require manual reset. Without danger from low water conditions, frequent inspection is unnecessary. Automatic controls are available for power supply, pressure or temperature, water level, conductivity, electrical demand, component failure and start-up or shut-down sequence. In many instances, these parameters are monitored or controlled from remote locations. Usually, one inspection visit per shift is sufficient to observe boiler operation and check parameters. Periodic checks of the water treatment system are also mandatory.

Proper Water Treatment Required

The importance of proper water treatment for an electrode boiler cannot be emphasized too strongly. As with all boilers of any size, feedwater should be thoroughly softened, sludge should be conditioned, phase (ph) should be controlled, and oxygen should be removed or scavenged. Unlike fuel-fired boilers, however, boiler water conductivity must be monitored and controlled.

The electrode principle requires that the boiler water be capable of conducting electricity. The higher the conductivity, the greater the amount of current a given cross-sectional area of water can carry a constant voltage. Thus, boiler water conductivity determines, to a certain extent, the amount of heat that a particular electrode boiler can produce. If too low, capacity will be restricted and chemicals must be added to enable greater output. As conductivity rises, more current will be carried by less water. If conductivity gets too high, current concentrations (amp density) may reach levels where erosion of components, such as electrodes, may occur; or, conductivity may reach a point where the associated total dissolved solids (TDS) is sufficient to cause foaming in the boiler. Foaming may also be caused by use of improper chemicals or amounts. Foaming will provide electrical paths across the spaces between the electrodes and ground (shorts) and will result in current surges which may take the boiler off the line on either ground fault or overcurrent. Consequently, the effect of all water treatment chemicals on both conductivity and foaming must be carefully considered.

The most common means of controlling high conductivity in an electrode steam boiler is with a continuous surface blowdown. The amount of surface blowdown required is a function of the conductivity of the raw feedwater and the amount of raw feedwater required. In general, the more condensate that is returned, the less surface blowdown is required. Automatic conductivity controls are frequently used to initiate surface blowdown on high alarm and chemical feed or low alarm. With either sufficient condensate, or, rather pure feedwater, conductivity may also be controlled by periodic bottom blowdown.

Where electrode hot water boilers are used in closed systems, the use of de-mineralized, or de-ionized, water will be required to lower system conductivity. This relationship between the amount of condensate and the conductivity of raw feedwater should be reviewed carefully. In extreme cases, blowdown requirements may be high enough to significantly reduce efficiency and create disposal problems. Under such circumstances, part, or all of, the raw feedwater may have to be de-ionized.

This impact of blowdown on electrode boiler efficiency is important. In an electrode boiler, 100% of the electrical energy consumed by the boiler is converted to heat in the water. There are no stack losses and no energy is expended handling fuel or air. Even the horsepower used to run internal circulating pumps (if required) goes into the pumped water as heat. Only two sources of heat loss remain; radiant loss to the boiler room and blowdown losses. A well insulated electrode boiler may have a radiant loss of less than 5%. Operating efficiency runs from 99.5% at full load to 95% at only 10% of full load; far higher than the best fuel-fired boilers, particularly at the lower loads. These efficiencies will then be reduced further by actual blowdown losses. The interaction of this efficiency characteristic with system load patterns will yield the actual operating energy cost. Electrode boilers are available in both hot water and steam versions. Water temperatures may range from 70 F to over 400 F, while steam pressures are available from 12 psi to over 500 psi. High-voltage electrode steam boilers are available for operation at distribution voltages from 4.16 to 15 kv in capacities from 1000 kw (3000 lb/hr) to 50,000 kw, or over 150,000 lb/hr.

High voltage electrode hot water boilers are available in capacities from 2000 kw, or 6.8 million Btu's to 20,000 kw, or over 68 million Btu's.

The savings realized in the operation and maintenance of an electrode boiler, vis-a-vis a fuel-fired boiler, are frequently great enough to offset the higher cost of electricity.

HEATING APPLICATIONS

While electrode boilers have unique and sometimes "different" characteristics, they are flexible enough to have found a place in an ever widening range of applications. The list includes food processing, pulp and paper, forest products, chemical, manufacturing, shipbuilding, automotive, warehousing, commercial buildings, hospitals and schools, power generation, district heating, sewage treatment, plating, mining, and many more.

The following installations are typical examples of the application of high-voltage electrode boilers to satisfy diverse space heating requirements.

Lane Community College

Two electric boilers furnish hot water to heat the 14 buildings of the Lane Community College in Eugene, Oregon. Rated 3000 kw at 4160 volts each, the boilers operate on the principle of the familiar electric vaporizer. That is, they generate hot water as long as electrodes remain immersed in water, which acts as the electrolyte. Shields are raised or lowered by motorized gears to obtain greater or less exposure of electrodes to the water as the heating demands fluctuate. The heated water is then pumped through a closed-loop piping system to heating units located throughout the buildings.

Because the system is totally closed, dissipation of water due to evaporation is prevented, and make-up requirements are negligible. Moreover, the closed loops exclude external contaminants, and electrodes can remain immersed indefinitely without becoming corroded. Motorized load controllers in each

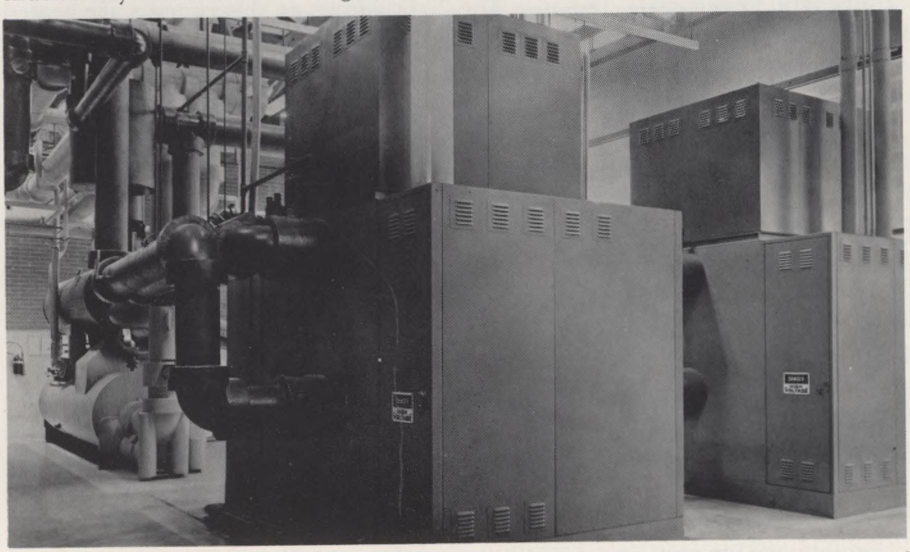

Fig. 1—Lane Community College. Two Coates electrode high-voltage boilers, capable of producing over 20 million Btu's/hr for the 30-70 psi hydronic system, supply heat and service hot water to the campus buildings.

boiler can regulate unit outputs between 25% and 120% of rated capacities, and the two boilers can operate singly, together, or alternately as required.

Boiler efficiency is 98% when output is 25% of rated capacity, climbing to 99.27% when loadings reach 75%. This indicates excellent power/heat conversion economy. Yet, economy is enhanced even further through savings obtained by the elimination of stack and fuel problems, conserving space and reducing maintenance of equipment.

Because the closed-loop distribution system holds considerable residual heat, it is possible to build up water temperatures prior to planned shutdown periods and then capitalize on stored residual heat while boilers are deactivated for reasonably brief periods to allow for inspection, maintenance or repair. This feature also makes it feasible to restrict the college's electrical demand during short periods when demands in other parts of the power utility's service territory are high. By granting this option to the utility, the college obtained an attractive power rate reduction.

Such periods of power curtailment have been infrequent, occurring (when they do) generally during a 90-minute noontime period or between 5:00 and 6:30 in the evening. In all cases, these periods have been anticipated by the utility sufficiently far in advance to advise the college of the possibility; therefore, ample time has been provided to build up stored heat in the system. Actual boiler shutdowns are then initiated directly from the power company's midtown remote-control center, and no further load balancing is required.

De Pauw University

"At today's prices, it's more economical for us to let the utility company burn fuel for electricity and use that power to generate steam in our own plant," according to Director of Physical Plant, Robert Gaston. He is referring to the installation of two high-voltage electrode boilers recently installed at DePauw University, Greencastle, Indiana. The 27 buildings on this campus are heated with steam previously supplied by three fuel-fired boilers.

With the price of oil and coal increasing at a rapid rate over the past year or so, and the scarcity of gas already a reality, the *electro-efficiency* of electrode steam boilers became apparent. After getting all facts and figures together, Mr. Gaston made the following comparison in the cost of energy to produce steam at this plant:

Energy Source	Cost/Million Btu
Coal	$3.77
Oil	3.73
Electric	3.60

In addition to the operating costs, estimates showed that the necessary boiler house and boiler renovation would amount to $2-1/2 million for coal (new plant with controls), $1 million for oil and only $225,000 for electrode steam boilers.

An advantage in the use of high-voltage boilers, which would be true in any industrial installation as well, is that the cost of power transformation to a lower operating voltage is eliminated. Another favorable point at DePauw was time. The electrode boilers could be delivered in six months, whereas the others took ten months to a year for delivery. The electrode boilers arrived on time, to the day.

Safety, another important feature of the electrode boilers, is assured with automatic controls protecting against undervoltage, overvoltage, high and low water levels, low conductivity, phase unbalance, and ground faults. In addition, in order to do any work on or in the boilers, interlocks make sure the vacuum circuit breakers are open for worker safety.

The boilers are insulated so there is only about .6% heat lost to the boiler room. Virtually all of the energy goes into steam. The steam is 99.7% free of solids also, assuring that there will be no clogged steam lines and, at the end of each shift, the boilers are put through a blowdown to remove sediment. At other times, blowdown is automatic and will activate whenever the conductivity of the water is too high.

Operation of the old fuel-fired boilers required a staff of nine men operating three shifts to maintain the system. Now, only four men operate the two steam boilers, while the others have been reassigned to other maintenance duties. One of the old boilers is being dismantled, another will soon be removed and there is a possibility the old stack, a landmark for many years, will be removed, too.

Hamilton Place Project

[Excerpted from an article by Dan R. Tyrrell (Quist, Tyrrell, Palmers, Ltd., Hamilton, Ontario, Canada) printed in the 1976 Energy Management Guidebook published by POWER Magazine. We thank the publisher of POWER for granting the International District Heating Association permission to reprint the excerpt in this 1977 Proceedings. Editor.]

Off-peak electricity will heat, ultimately, eight buildings without polluting the air, at Hamilton Place Project, a central-city development in Hamilton, Ontario. These buildings include the City Hall, Hamilton Place Theatre-Auditorium, a new art gallery, an underground parking garage and, when completed, the Trade and Convention Centre, the Provincial Office Tower, a new public library, and a proposed sports arena. Service will be provided at a cost substantially equal to that of a comparable gas and/or oil-fired system.

The heating system, when completed, will comprise two 5500 kw electrode-type high-temperature boilers, four 45,000 gallon hot water storage tanks, and two heat exchangers to hold the distribution system water at 200 F. The boilers will take service at 13.8 kv from the project's supply substation to raise 400 gal/min of 180 F water to 395 F for storage in the four tanks. These tanks, insulated with four in. of glass fiber and pressurized to 250 psi by nitrogen in a separate expansion tank to prevent steaming, will hold 160,000 gal of water at an average of 385 F. The heat exchangers will use 385 F water from the storage tanks to raise 2800 gal/min of 180 F returned water to 200 F for building heating.

The proposed public library may require additional boiler and storage tank facilities, but they will be served by the same electrical supply and control system.

The system is sized to store sufficient heat during 14 off-peak hours, when electrical consumption of buildings in the complex is down, to supply heat for 10 hours during the coldest (-10 F) weather. The control system will hold off recharging the storage system until it will not add to the project's electrical billing demand during much of the heating season. Winter ambient temperatures average 20 F to 25 F, so most of the operating cost for heating will be only for the energy component of the electricity it consumes.

The decision to build the Central Utilities Plant evolved over several years. As early as 1970, United Gas Company had received electorate approval to supply heating and cooling service to the downtown core of the city; but closer economic evaluation of the proposed system, along with delay in securing customers for the service (probably because of minimal potential savings over the cost of operating individual plants at the low energy costs existing at the time), defeated the project. Meanwhile, however, the City government favored district supply and the Hamilton Place Theatre-Auditorium was designed to use it. Temporary heating and cooling facilities had to be installed to permit use of the building.

Thereupon, the City ordered its study extended to evaluate the capital and operating costs of all possible fuel systems for the Central Utilities Plant against those of the gas/oil proposal. This extension was to be based on the estimated need for 950 boiler horsepower (bhp) of heating, 1600 ton/hr of cooling, and 6000 kva of electric service. Three alternatives were considered:

1. Gas or oil heating, with electric cooling and building services.
2. Conventional electric heating, with electric cooling and building services.
3. Electric heating with storage to limit peaks, plus electric cooling and building services.

The third alternative, total-electric with storage, was found to require the lowest owning cost over the amortization life of the plant, as well as the lowest operating costs by the time all projected buildings had been completed. Additional advantages were that the total electric plant, requiring no venting to the atmosphere, could be installed in the first section of the underground parking garage in time to serve other proposed buildings, and it would not add to air pollution in the area.

At that point, the Ministry of Government Services, a major participant in the project because of the projected Provincial Office Tower, requested further study of the all-electric alternate. It was to evaluate: high-voltage electrode-type boilers supplied at 13.8 kv; resistance-type boilers supplied at 600 v; and heat pumps.

This report, issued in January 1974, determined that heat pumps would use less energy, but would add to the project's peak billing demand. Between the two boiler alternates, the electrode-type could be modulated easily, should be extremely reliable, and would cost less than the resistance-type in the sizes required.

The 1974 report also evaluated three types of heat storage to cover ten hours of building operation. It found that storage in the form of 200 F water would require more space than the garage could provide, and it discarded the use of steam accumulators in favor of 385 F water. The installed cost of such a system was found to be substantially comparable to that of a gas- or oil-fired heating system.

In addition to heat, the Central Utilities Plant will include up to 2100 tons/hr of refrigeration for chilling water to the 42-52 F range. For this function, the existing 500 ton/hr chiller at the Hamilton Place Theatre-Auditorium will be moved to the central plant and augmented with two new 800 ton/hr units. The chilled water will be circulated through air coolers in all the buildings of the complex.

Heat extracted by the refrigerant from water passing through the chillers will be dissipated in a below-grade cooling tower, whose fans will also remove upwards of 300,000 cu ft/min of air and exhaust fumes from the garage area.

Control for the entire system will be provided by Energy Conservation Computer Optimization (ECCO), which continuously records electrical peaks. If building electrical usage starts to rise, ECCO will cut back on boiler power to limit total demand, replacing boiler output with 385 F water from the storage tanks. ECCO also will monitor and control equipment in the City Hall and other connected buildings. In addition, the computer system will handle fire control, monitor carbon monoxide, log maintenance, and start or stop ventilating fans.

Centralized control permits operation of the entire system by only five men, located in the Central Utilities Plant. These five, in fact, will be the same crew that formerly operated heating, cooling, and electric services in the City Hall.

Comparison Shows Savings for Stored-Heat Electric System

	Gas/Oil	All Electric	All Electric With Storage
Capital cost	$2 891 000	$2 693 000	$2 871 000
Annual operating cost	604 000	679 000	616 000
Annual 1973 owning/operating cost	991 000	1 040 000	1 000 000
Annual 1983 owning/operating cost	1 927 000	2 126 000	1 876 000

Iowa Public Service Company

Iowa Public Service of Sioux City, Iowa is a joint gas-electric utility, which serves the Sioux City area. In addition, they operate a 150,000 lb/hr plant to provide steam for heating to 250 downtown customers. In 1976, it became apparent that it was no longer feasible to continue to operate this steam plant and existing distribution service, due to the rapidly rising cost of operating an old and inefficient facility. The cost of fuel oil appeared prohibitive and the old plant, built in the 1920's, was in need of considerable repair and required licensed operators around the clock. Water treatment was also a consideration. Since the system returns no condensate and local water has considerable impurities, blowdown losses were high and treatment was costly.

A decision was made to convert individual buildings from central steam to steam supplied from high-voltage electrode steam boilers. These boilers were to be purchased and operated by IPS; but, located either in the buildings or in transformer vaults located adjacent to the buildings. In this way, IPS

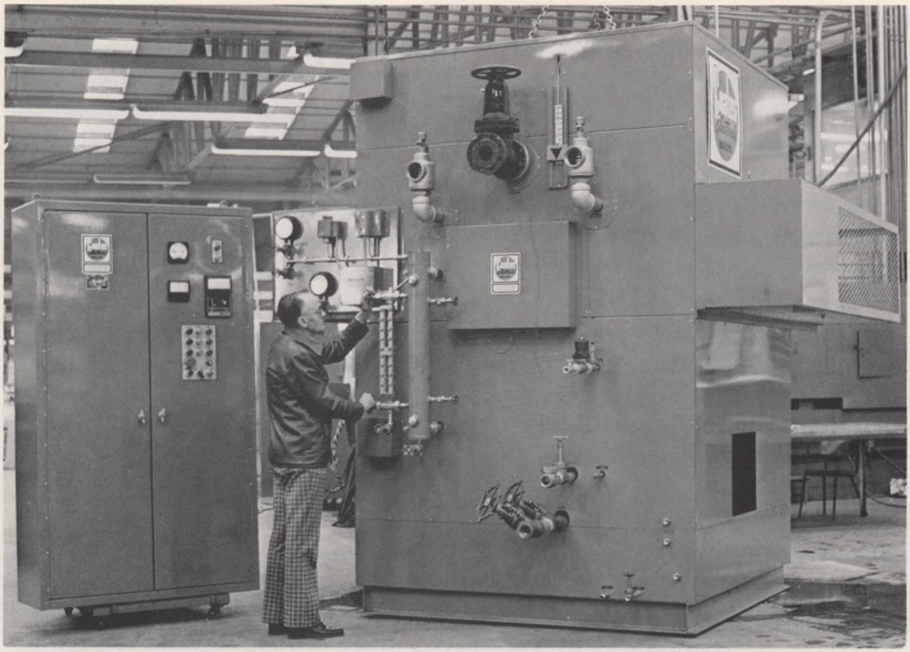

Fig. 2—Iowa Public Service Company. Model CSHS-1 boiler used as basis for the Company's conversion plan. Sizes used: 2000-6000 kw; 6000-20,000 lb/hr.

could continue to serve its customers with steam, without having to upgrade their old central steam plant.

To date, the Company has purchased nine boilers in sizes ranging from 3 to 6 mw, for a total of 47 mw, or 155,000 lb/hr. Additional purchases of six boilers, totaling 27 mw, will add 89 lb/hr to this system in the next year, bringing the total for this unique system to 15 boilers, totaling 74 mw or 244,000 lb/hr.

Seattle Steam Corporation

Seattle Steam Corporation is a privately owned central steam utility, serving customers in downtown Seattle from a one million lb/hr steam plant. Until 1976, all of the steam required by this system was produced by burning fossil fuels, primarily natural gas.

In the summer of 1976, Seattle Steam installed a 30,000 kw Coates electrode high-voltage steam boiler, capable of producing in excess of 100,000 lb of steam/hr at 180 psig. This boiler operates at 13.8 kv, supplied directly from a utility substation located close-by. With careful planning. Seattle Steam was able to install the boiler and integrate into their system for less than $3/lb, including boiler, instrumentations, and electrical switchgear, compared with $8/lb or more for fuel-fired boilers.

Since September 1976, the boiler has operated as a base load at 30 mw, producing 100,000 lb of steam/hr, 24 hr/day, seven days/week. The boiler operates in conjunction with one or more of the company's fuel-fired units and produces 180 psi steam at greater than 99.5% steam quality, while operating at better than 99.7% efficiency. By base-loading the electric boiler, the

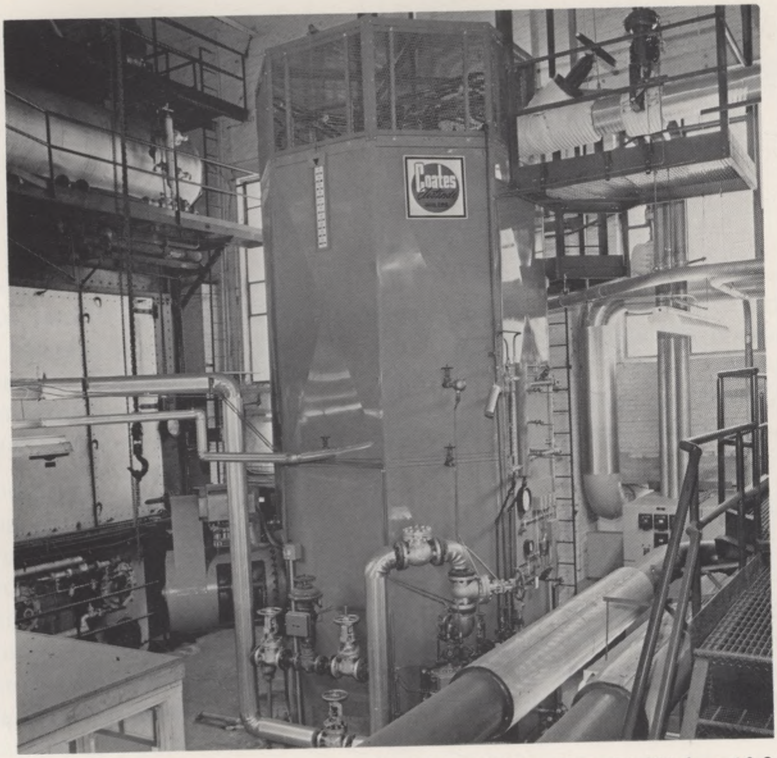

Fig. 3—Seattle Steam Corporation. Model BAHS-5 boiler: 30,000 kw; 13.2 kv; 180 psi; 100,000 lb/hr.

electric demand charge is spread over the maximum number of kilowatt hours and results in the lowest possible effective electric energy cost; so low, in fact, that the cost per million Btu's using interruptible natural gas is nearly twice that of the electric boiler.

One of the keys to this very successful installation was careful planning. The other was proper water treatment. Since this system returns no condensate, 100% raw water must be treated properly to insure minimum maintenance and maximum efficiency in the operation of the fuel-fired boilers as well as the electrode boiler. In addition to the usual concern with the hardness, ph, oxygen, and the like, Seattle Steam must also contend with high alkalinity and silica in all of the boilers. They must also control the conductivity in the electrode boiler by means of a continuous surface blowdown. With careful design of the water treatment program and attention to its implementation, the Company has found that the electrode boiler was unattended with only minimal inspection and maintenance.

Actually, the boiler runs so reliably and so quietly, that without an ammeter, kw meter, or flow meter, a visitor would not even notice that the boiler was operating.

HOW AN ELECTRODE BOILER OPERATES

The high-voltage Model BAHS Coates electrode steam boiler operates on 13,800 volts, and can develop operating temperatures and pressure in about 10 minutes.

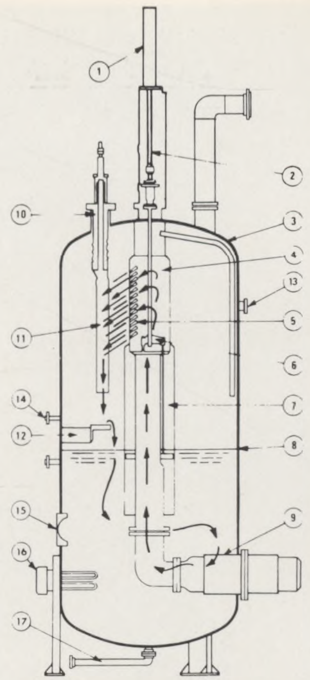

Fig. 4—Schematic of the electric boiler shows direction of water flow. Water pumped through jets to electrodes enables current to flow, generating heat in the water.

When the boiler is in operation, water is sprayed through jets onto electrodes suspended in the steam space within the boiler. The water acts as a conductor, enabling current to flow, thereby generating heat in the water to produce steam instantly.

Boiler output is regulated by raising or lowering a control sleeve hydraulically. This action intercepts and diverts the streams of water from some or all of the jets, preventing the water from striking the electrodes. A lift cylinder moves the control sleeve. It is positioned by the boiler pressure and load-control system to hold the steam pressure contant or to limit output to a predetermined level.

The system is virtually 100% efficient. Solid-state control provides stepless operation over the entire output range of the boiler. If there should be a water failure, the unit would cease to operate. Without water, current cannot flow and the boiler cannot function. There would be no possibility of overheating or danger to equipment or personnel.

Maintenance of the boiler should be minimal, since there are few operating parts and no fuel residues. Electrodes should last for years. At any time maintenance should be required, the boiler will cool down fast and can be quickly started up again.