DISTRICT ENERGY

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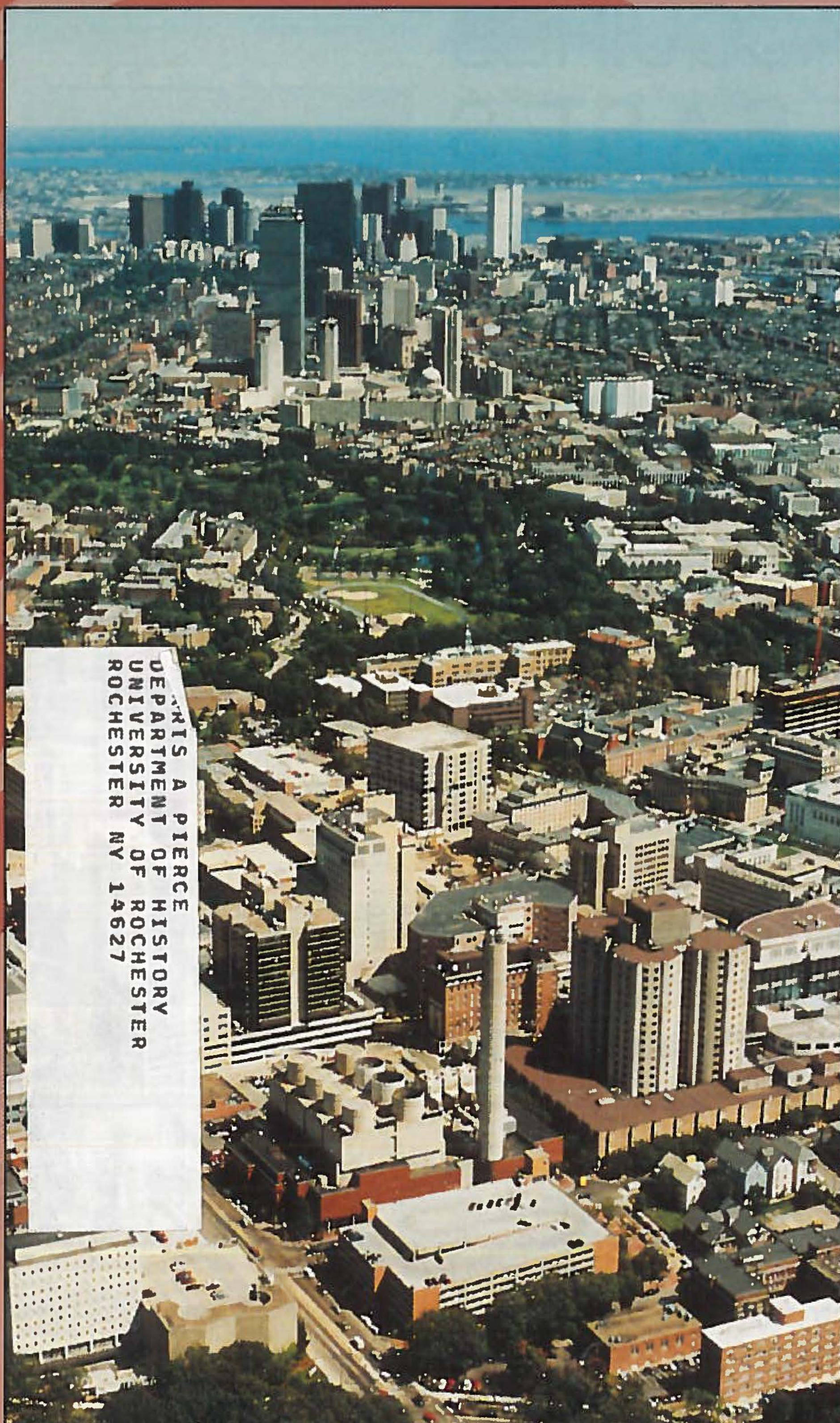

Medical Centers Operate on Energy from Central Source

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The General Services Administration at Work

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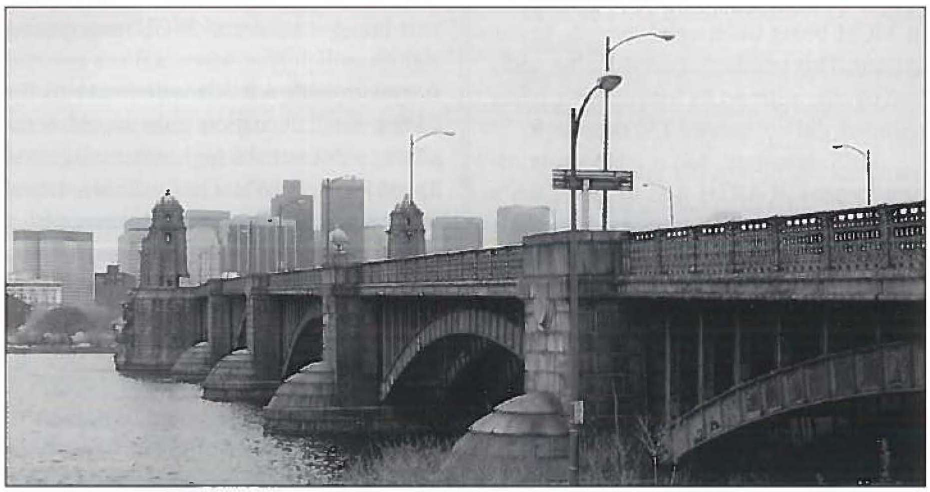
INTERNATIONAL DISTRICT ENERGY ASSOCIATION

District Heating and Massachusetts General Hospital — A Tale of Two Cities

A. Seth, Massachusetts General Hospital

Massachusetts General Hospital (MGH), a teaching hospital for Harvard University, is one of the world's premier institutions for teaching, research and patient care. The facility is located near Boston's Charles River and situated on approximately 11 acres of land. Since being founded almost 179 years ago, it has grown to approximately 2.5 million square feet on its main campus, while incorporating several other satellite campuses as well.

MGH uses steam for heating, sterilization, cooking and humidification. The hospital also uses several steam-absorption units. The laundry operations are conducted off-site.



The Longfellow Bridge connects Cambridge and Boston and serves as the carrier for district heating piping to Massachusetts General Hospital.
Courtesy of Massachusetts General Hospital

The three major reasons MGH decided to make the change were reliability; to facilitate the cogeneration of steam without the need for a cogeneration plant on its premises; and reduced operating costs.

Like most hospitals, MGH utilized an on-site boiler plant until it was connected to the Boston Edison Company's steam district heating system in the 1920s. Even at that time, MGH recognized the inherent value of being connected to a district heating system and getting away from on-site generation of its steam.

It was a successful decision that served the institution well. Boston Edison Company's steam division remained in business for almost 70 years and provided an excellent and reliable steam service to its downtown Boston customers.

The MGH campus was served by two connections at the Gray and Bartlett buildings from a 10-inch-diameter high-pressure steam line at two points from a line under the city street. Internally this steam piping was installed in a figure-eight arrangement, allowing any part of the campus to be fed from any connection point.

MGH initially explored the feasibility of installing an in-house steam/cogeneration plant. This study was first conducted independently and then later with the assistance of Boston Edison Company. In both studies the project proved to be marginally cost-effective. This finding, along with the lack of suitable space on MGH campus and the difficulty of permitting a fossil-fuel-burning plant inside downtown Boston, caused MGH to abandon this effort.

When Commonwealth Energy Company (CEC), the parent company of the Commonwealth Energy Steam Company (CES), contacted MGH in December 1984 with a proposal to sell cogeneration steam at cogeneration prices, the offer was given serious consideration.

Former Steam Supplier Problems

During the planning of MGH's renovation and construction of an inpatient buildings project to provide the steam required for this additional load, Boston Edison informed MGH that they could not even guarantee providing MGH's current needs for longer than one year.

In addition, the Boston Edison system lost pressure approximately six times in 1986. (Note: Boston Edison Company's steam system was purchased by Catalyst Energy in January 1987 and a subsidiary called Boston Thermal was formed to operate the system.) In contrast, CES's Kendall Station steam plant had an excellent record that showed it had not lost steam pressure in the previous 18 years. We carefully evaluated the differences in the systems.

Boston Edison's system was steam-supply only, with the condensate generated at MGH being discharged into the sewer system. This required cooling by the addition of city water so its temperature, when dumped, did not exceed 130 degrees F.

CES, however, had a condensate return system. If MGH was to take CES's offer, MGH would require modifications and additions to the existing condensate piping system in its internal distribution. Yet as a result, MGH would receive a credit for all condensate returned to Kendall Station and be able to lower its present sewer costs related to the current practice of condensate discharge.

MGH concluded that construction of a service connection with CES's Kendall Station Plant would be very advantageous to MGH, both economically and in terms of quality and reliability of service.

The three major reasons MGH decided to make the change were

a. Reliability;
b. To facilitate the cogeneration of steam without the need for a cogeneration plant on its premises; and
c. Reduced operating costs.

The goals of the new steam system, therefore, were to have:

a. High reliability;
b. Low maintenance; and
c. The earliest in-service date possible.

Preliminary Considerations for Design

A preliminary engineering feasibility was undertaken by Commonwealth Energy Co. (CEC) to determine the appropriate location and size of steam and condensate line sizes to bring steam from Cambridge to Boston. The decision was governed by two key factors:

- That the line be sized sufficiently large enough to serve present and future capacity; and
- That the system be cost-effective and reliable.

Boston Edison's former district steam distribution system did not have the capacity to collect and return condensate to its steam-generating stations. Due to the high temperature of condensate, the Boston Water and Sewer Commission would not allow direct introduction of hot condensate into its sewers; the condensate instead had to be cooled with cold water before disposal. The most common way to cool condensate was through the injection of city water, a procedure which was both costly and inefficient. Not only the condensate, but cooling water was being wasted and MGH was paying significantly higher water and sewer costs. A system with a condensate return to the CES's Kendall Station plant would completely eliminate the high water usage and its consequent waste. The final line selected for steam was 14 inches in diameter with a 6-inch diameter condensate line running from Boston to Cambridge.

General Description of Piping System

The piping system was designed to deliver approximately 150,000 lb per hour of 400 degree F, 200 psi steam to the hospital complex. Steam is be supplied by a 14-inch schedule 40 steel pipe. Condensate is returned to Kendall Station via a 6-inch Schedule 160 steel pipe. The piping is entirely welded. Sufficient insulation (minimum 8 inches) is provided to maintain a maximum surface temperature of 105 degrees F. At each end of the line, isolation valves are provided. Piping is routed so as to be inaccessible to either pedestrian or vehicular traffic.

Having identified that a steam pipeline from the Kendall Station plant could significantly improve MGH's steam supply, MGH proceeded to analyze several routings:

- Expansion and extension of CES pipelines presently supplying the Museum of Science from Kendall Station;
- Piping submerged in the river; and
- Piping suspended from the underside of the Longfellow Bridge.

After investigating the costs, environmental impacts, and possible operational difficulties associated with each of these routes, it was decided that location of the piping suspended from the Longfellow Bridge would provide the most desirable installation.

The steamline projects were designed by Stone and Webster Engineering Corporation of Boston, an internationally known firm with extensive experience in all phases of mechanical and electrical projects.

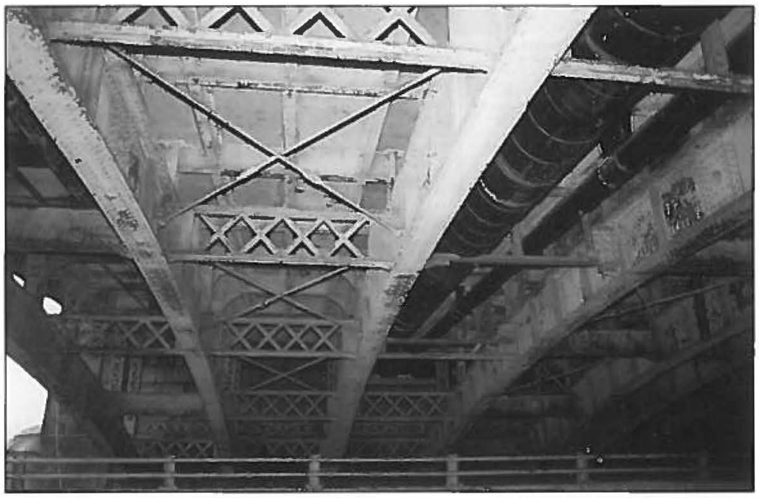
. . . as part of the contract with CES, the escalation of the rate portion of the steam cost would be capped according to gross national product indices.

Kendall Station Plant

Commonwealth Energy Steam Company (CES) is a subsidiary of the Commonwealth Energy Company and was formed in 1981 as a result of the reorganization of Cambridge Steam Corporation. CES provides heating and process steam to customers in the city of Cambridge through a distribution system consisting of approximately four miles of buried steam supply and condensate return piping. Steam is supplied from the Kendall Station Plant that began operation in 1949 and is located on the Cambridge bank of the Charles River, adjacent to the Longfellow Bridge.

Kendall Station, located 2,600 feet from the Massachusetts General Hospital on the opposite bank of the Charles River, is a cogeneration plant that generates electricity for the Cambridge Electric Light Company, another subsidiary of the Commonwealth Energy Company, in conjunction with its steam production for CES. Using five boilers, three steam turbines and two gas turbines, the plant can produce up to 900,000 lb per hour of steam and 110 MW of electric power. The plant is presently fueled by No. 6 oil, or natural gas when available. Due to a decline in the number of industrial customers in Cambridge, Kendall Station had additional steam capacity available for sale to MGH.

A desuperheater was installed in the plant in order to reduce the 200 psig, 450 degrees F superheated steam to 400 degrees



Steam and condensate piping can be seen in the right half of this photo taken from under the Longfellow Bridge.
Courtesy of Massachusetts General Hospital

F. The design condition of the steam supply leaving the Kendall Station is 150,000 lb per hour @ 225 psig and 500 degrees F.

Economic Considerations

In 1985, when the switch to steam was conceived, MGH was paying Boston Edison $12.85 per thousand Mlb. At that time, MGH projected a yearly operating cost savings of $1,200,756 if Commonwealth Energy Steam Company became our steam supplier. During MGH's next fiscal year (1986), Boston Edison provided a lower rate structure to MGH, and the yearly operating cost savings compared to CES decreased to $1,023,770.

Furthermore, as part of the contract with CES, the escalation of the rate portion of the steam cost would be capped according to gross national product indices. The fuel portion would remain a pass-through cost. Since steam is an unregulated utility, Boston Thermal (formerly Boston Edison), on the other hand, could have conceivably inflated its rates without restriction.

Permitting

In the state of Massachusetts, district steam is not considered a "utility," and therefore is not regulated. As a result, this project's regulating procedure became somewhat easier, since we did not have to go through the Department of Public Utilities. Nevertheless, we still encountered a rigorous and careful review by various other state and local agencies.

The hospital decided to conduct the permitting process internally, without the help of outside consultants. In every case, we made preliminary contact with the agency, showing them the schematic diagrams of what we were trying to accomplish. In all cases, we stressed that we would be careful not to disturb the architectural integrity of the bridge while being sensitive to environmental concerns. The pipeline design and the proposed route had to minimize impact on the historical structures of the area and be aesthetically pleasing. We also explained in detail the precautions that we were planning to take to ensure that all areas affected during construction would be reverted back to normal. We pledged that all work underneath the bridge would be done in an environmentally sensitive manner. We also agreed to install several amenities at the request of state and local agencies.

Project Description

The resulting project consisted of steam supply and condensate return systems that are approximately 5,000 feet in length. The system starts in Cambridge at the Kendall Station, runs underground, crosses a canal under a bridge, continues under the Longfellow Bridge abutment — traversing the historical bridge under the steel work, exits the bridge on the Boston side through the abutment, goes underground through a parking lot, continues under a road, and finishes in the Warren Building of MGH.

The Warren Building is one of the MGH buildings closest to the Charles River. This connection location was selected to minimize the length of external pipe lines. The lines were designed to enter a basement machine room of Warren Building.

A double two-step pressure-reducing valve (PRV) station was designed to reduce 200 psig to 60 to 65 psig, the MGH internal steam distribution system pressure.

In general, the line was constructed without any expansion joints — the sole exception being an area where one was used due to the lack of space for an expansion loop. The expansion loops were installed to ensure that minimum maintenance would be needed underneath the bridge.

Special Design Features and Considerations

The project had several special design features and considerations.

- Telephone cables were located under the bridge in the area that was needed for the steam line, and wherever possible the cables were moved.
- Since the Longfellow Bridge also contains electrified rail lines for the Metropolitan Boston Transport Authority (MBTA), a concern was raised regarding possible stray current and its effect on the piping. Therefore, a Stray Current Survey and Soil Resistivity Testing was undertaken by Stone and Webster to determine the existence of any DC "stray currents."
- As a further concern, it was noted that whenever MBTA trains cross the bridge, it is clear even to the casual observer that vibrations are induced in the structure. This raised questions of what the design criteria would have to be for the pipe and its pipe supports in order to assure the integrity of the steam supply system when subjected to these vibrations. Thus, Stone and Webster also had to perform a Vibration Survey and Analysis of the Longfellow Bridge.

Once the design was completed and the project was bid, the bid prices reviewed were significantly apart. Therefore, the three low bidders were interviewed at length to determine their approach to the project, their construction methodology and their estimating process. Two of the contractors assumed that installing catwalks or walkways underneath the entire bridge would be necessary for access. The selected contractor had a novel idea: it proposed using barges in the Charles River to bring piping and construction materials to the individual piers, where they could be hoisted underneath the bridge. The approach appeared reasonable, and the contractor was selected on the merits of its construction methodology and lower cost estimate.

To ensure the quality of pipe welding underneath the bridge, a thorough process which called for X-rays of the welds was undertaken. Such careful attention to detail was extremely helpful since, from the inception of the project, there have not been any pipe-leaking problems reported underneath the bridge or in any of the bridge abutments.

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MGH Condensate Return System

Since the MGH main campus was not previously returning condensate to the Boston Edison system, no condensate collection or return system existed. In almost all the buildings, the existing receivers deposited condensate into the sewer using the above-mentioned cooling system. Therefore, a full condensate pumping and return system had to be installed. The new condensate piping system discharges into a large condensate receiver in the Warren Building, where the steam line initially enters into the facility. This condensate tank is controlled by a level controller. These pumps operate depending upon the level switches to pump the condensate back.

Startup

In general, the startup on December 16, 1988 (one of the coldest days of the year), was uneventful. The whole line had been previously hydrostatically tested for leakage. The line was slowly warmed up with all blow-down valves fully open. All traps were operational. When full pressure was achieved at the MGH entrance, the main valve was slowly opened to warm up all internal piping at the steam PRV station. Once that was achieved, both systems (Boston Thermal and Cambridge Steam) were at equilibrium. Gradually the pressure setting at two existing PRV Stations at Boston Thermal connections was reduced. The pressure setup at Warren Building, entrance of the new connection, was increased until the full flow condition was achieved. Because of the extreme cold ambient temperature, Commonwealth Energy Steam Company engineers were concerned about the likelihood of ice formation inside this pipe. As the pipe heated up, a lot of condensate was generated. The concern was that unless the line heating process was not accomplished and established rapidly, some of this condensate might freeze. Although we experienced problems from a water main break, no condensate freezing has ever occurred.

Conclusion

MGH continues to benefit from the reliability and reduced operating and capital costs of district heating service. We also appreciate the fact that valuable space on our premises is not consumed by a boiler or cogeneration plant.

We still purchase some steam from Trigen-Boston Energy (Boston Thermal's new name following a merger between their present company and Trigen Energy Corporation). Their work on the Boston system has been commendable. It was unfortunate timing for them with respect to our decision.

Commonwealth Energy Steam Company has provided an exceptionally reliable service. They have proved to be an excellent energy supplier to a modern healthcare facility.

Acknowledgments

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Robert Pierce – Director of Energy Supplies, Commonwealth Energy Company.

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