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DISTRICT HEATING AND TOTAL ENERGY

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The association of district heating, per se, with the discipline now called "total energy" is of as long standing as district heating itself. In fact, many of today's large district heating enterprises had their genesis in the form of a small combination heat-electric operation.

Throughout Europe and Russia the vast majority of district heating energy is obtained from the operation of heat-electric stations. Although such operations could not be called prevalent in the Western Hemisphere, a number of systems derive their steam from extraction and/or back pressure operation associated with large power stations.

Concern over pollution, as well as interest in economy, are inducing renewed attention on the potential of heat-electric operations, some of which is directed towards the concepts of "on-site" total energy projects.

The latter may be defined as projects which are sited at the point of utilization and which are fundamentally self-contained within a finite complex. The feasibility of such projects becomes a function of the levels of annual load factor and of the balance between heat and electric energy load characteristics. Where such load factors and heat balances are high, the feasibility of on-site operation may be attractive to the consumer.

The principal thrust of this paper is to present the broad results of a comprehensive analysis of a situation where such a project was seriously considered, and where the utility was interested in owning and operating the plant.

Criteria

The client who was considering such a plant comprised a medical school complex and several surrounding major hospitals all of which were geographically contiguous. Collectively, the group was planning a better than two-to-one expansion of facilities over an eight to ten-year period.

Precedence for the individual members of the group to consider an on-site total energy operation existed through their historical association in the joint ownership of an existing plant supplying steam and other utility services. At one time this plant supplied direct current power, but almost all power is now alternating current and is purchased individually by each group member from the local utility.

Under the concept of the on-site plant, electric power, steam and chilled water would be supplied. In addition, there was a requirement for incineration of biological waste, some of which would be radioactive, and for a supply of energy power.

The magnitude of the project is illustrated in the following Schedule of Requirements.

Schedule of Requirements

	1966	*1971*	*1975*
Gross Steam—lb/hr	208,000	368,000	640,000
Net Steam—lb/hr	160,000	243,000	424,000
Gross Power—kVa	11,300	17,820	28,375
Coincident dem—kVa	—	15,500	24,670
Chilled water—tons	—	5,765	18,355
*Local stm. abs.—tons	1,326	1,676	3,051

* The local steam absorption plant served one of the hospitals and was to be expanded rather than to provide chilled water service from the proposed central chiller plant.

Preliminary Considerations

In considering the question of ultimate source of services, three options were available and were explored in varying degrees.

1. The first was the purchase of electric and steam services from the local utility with the provision of chilled water from one or more consumer-owned plants. This option was negated by the fact that steam supply from the utility district heating system was economically unfeasible due primarily to geographical circumstances.
2. The second was the purchase of electricity and provisions of steam and chilled water from a central plant, owned and operated jointly by the consumer group. A cursory examination of the economics indicated that, in view of the known high levels of load factor and heat balance associated with the energy requirements of such a group, the attractiveness of this option would be less than that of a combined heat-electric generation operation.
3. The third and final option was an on-site energy plant, which for reasons indicated above, appeared to offer the most attractive possibilities.

The consumer group through its own engineering staff had retained a consultant to develop preliminary load data and plant concepts, and to prepare related feasibility studies.

The magnitude of the plant constituted a major undertaking for the consumer group. Conversely, from the viewpoint of the local utility, it was an extremely small plant. Nevertheless, the utility management took the attitude that they should consider anything within reason in this situation.

The offer of the utility to consider building, owning, and operating the total energy plant was accepted and arrangements made for the utility to become a party to the feasibility study already underway.

Plant Concepts

The consultant was oriented towards a steam turbine generating plant. The utility considered and analyzed both a steam plant and a gas engine waste heat boiler plant. Preliminary study results indicated that the owning and operating costs of a gas engine plant would be more favorable from the utility's position than those of a steam plant.

The versions of plant design developed by the consultant and the utility were quite compatible. Brief descriptions of the utility versions are given in the following.

1. Steam Plant

	1971	*1975*
Number of boilers	3	5
Total output capability, lb/hr	525,000	875,000
Number of turbines	2	4
Total capability (kw)	18,750	37,500
Cooling tower sections	1	2

The three boilers in the 1971 schedule were required to provide firm boiler capacity. Electric back-up was available via a tie to the utility's distribution.

Package-type boilers of 175,000 lb per hr capacity, equipped with economizers for further heat recovery were specified. Steam conditions were 900 psi and 825 F, with feedwater entering at 361 F. Although pollution considerations had not then reached their current level of concern, the fuels considered were No. 6 low sulphur oil and natural gas.

The turbo generators were 9,375 kw units for steam conditions at 810 psig, 800 F and 4 in. of mercury absolute back pressure for condensing operation. Extraction at 150 psig would provide steam for all uses, including the supply to steam-driven refrigeration compressors.

Since no source of condenser water was available, the plant design included cooling towers which would serve both the generating plant and the chiller plant. Demineralizers were sized for ten per cent make-up.

2. *Gas Engine Plant*

The main components of the gas engine plant were the following:

	1971	*1975*
No. gas turbine-waste heat units	2	3
Electric capacity, kw	30,000	45,000
Steam capability, lb/hr	400,000	600,000
Peaking kw available (to utility)	14,500	20,320

This plant was designed with a standby gas turbine-waste heat boiler for relay purposes. Continuous operation was envisioned as a means of achieving maximum efficiency and the use of the excess kilowatt-hours so generated being absorbed by the utility system. The waste heat boilers were to be equipped with supplementary firing in order to meet steam requirements in excess of the gas turbine exhaust heat. The generating pressure was 150 psi.

Gas was to be used as a fuel when available, and when not, jet fuel would be burned in the gas turbines and low sulphur domestic No. 6 oil in the waste heat boiler. This plant required no cooling towers.

3. *Chiller Plant*

A brief summary of the refrigeration plant equipment is shown below:

	1971	*1975*
Number of machines	3	6
Capability, tons	7,500	21,000
Number of cooling tower sections	2	6

The chiller plant employed turbine-driven centrifugal compressors operating at steam conditions of 150 psi to four in. of mercury. Chilled water was to be delivered at 38 F and returned at 53 F.

Cooling towers were designed to accommodate a maximum entry temperature of 103 F with a leaving temperature of 85 F. As a matter of passing interest, the ultimate cooling tower installation would comprise six sections plus two more in the case of the steam generation plant. The eight sections would have occupied an area 260 ft by 71 ft, with a height of 53 ft.

4. *Distribution Facilities*

In order to utilize the existing distribution facilities as much as possible, a distribution center for steam and chilled water was to be located as near as practicable to the existing power plant. The distance from there to the site of the new plant approximated ¼ mile.

All metering would be provided at this distribution center. Each taker assumed responsibility for return of both condensate and chilled water to the center, from whence they would be pumped back to the plant.

Facilities for handling steam consisted of two 24-in. supply and one 10-in. return. Supply and return lines for chilled water consisted of two 24-in. lines each.

Electric distribution would be via the utility's 13,800 volt system to which a tie to the new plant would be added.

Owning and Operating Costs

With the foregoing description of facilities for reference, the next matter of interest is the level of annual owning and operating costs relating to the supply of total energy requirements. The latter were established as follows:

	Power	*Steam*	*Chilled Water*
Maximum demands*	29,259 kVa	604,500 lb/hr	23,929 tons
Annual energy	175,000,000 kWh	2,315,000 M/lb	33,840,000 ton hr
Charges	$2,100,000	$3,000,000	$2,600,000

* undiversified

The total of all charges, ($7,700,000) represents the net estimated owning and operating cost for utility operation (Table I). Charges for power were obtained by application of the utility's schedule of rates as appropriate for each customer.

Table I—Approximation of Utility's Owning and Operating Costs

Investment		
Electric Plant	$ 9,630,000	
Electric Distribution	330,000	
Steam Plant and Distribution	9,810,000	
Chiller Plant and Distribution	6,930,000	
Direct Engineering	180,000	
Interest During Construction	1,420,000	
Land	900,000	
Total Investment	$29,200,000	
Owning Costs		
Depreciation	$ 850,000	
Local Taxes	1,600,000	
Interest	1,140,000	
Earnings	710,000	
Income Tax	830,000	
Total	$ 5,130,000	
Credit Peaking Cap	300,000	
Net Owning Costs		$4,830,000
Operating Costs		
Fuel	$ 2,160,000	
Labor	410,000	
Maintenance	560,000	
Total	$ 3,130,000	
Credit for kWh to system	260,000	
Net Operating Costs		2,870,000
Total Owning and Operating Costs		$7,700,000

The balance was allocated between steam and chilled water on the combined basis of relative investment, heat energy requirements and maintenance. Rates for the latter two services were established as indicated in Tables II and III. Escalation provisions were contained in the text of the proposed agreement.

Results

The ultimate comparison of owning and operating costs indicated a differential of slightly over $2,000,000 per yr in favor of a consumer-group plant. A major portion of this difference can be accounted for by the difference in tax status between the consumer group and the utility. Inspection of Table I will show that for the utility, local taxes alone amounted to $1,600,000.

To complete the analysis, had conventional utility steam and electric services been available, the approximate cost level would have been $11,500,000. Hence, relative costs may be summarized as follows:

Conventional utility services	$11,500,000
Utility owned on-site plant	7,700,000
Customer owned on-site plant	5,700,000

Table II—Schedule of Charges

Steam Service Rate

Demand Charge

$250 per month per M lb per hr for the first 3 M lb per hr of demand*
$200 per month per M lb per hr for the next 7 M lb per hr of demand*
$170 per month per M lb per hr for all over 10 M lb per hr of demand*

Consumption Charge

For the first	500 M lb of steam per month	$.98 per M lb
For the next	2,500 M lb of steam per month	.89 per M lb
For the next	7,000 M lb of steam per month	.83 per M lb
For all over	10,000 M lb of steam per month	.80 per M lb

Condensate Credit

For all acceptable condensate returned 2.8 cents per M lb plus 4.8 cents per therm[1] for the heat in the water above 52 F[2].

Determination of Demand

The maximum 60-minute demand will be determined each month in M lb of steam per hr by instruments installed by the Company.
The demand billed each month shall be the highest monthly demand recorded within 12 months immediately preceding the date to which the bill is rendered, provided, however, it shall not be less than the estimated demand of service specified elsewhere in this Agreement for Steam Service.

Condensate Return

Condensate return shall conform to provisions set forth elsewhere in this Agreement for Steam Service.

[1] A Therm = 100,000 Btu
[2] Weighted Average Temperature MDC Water
* An M lb of steam being 1,000 lb of water evaporated into steam or 1,000 lb of steam condensed into water.

Table III—Schedule of Charges

Chilled Water Service Rate

Demand Charge

$11.00 per month per ton of refrigeration effect* per hr for the first 300 tons per hr of demand

9.10 per month per ton of refrigeration effect* per hr for the next 700 tons per hr of demand

6.60 per month per ton of refrigeration effect* per hr for all over 1000 tons per hr of demand

Consumption Charge

For the first 500 C ton hr of refrigeration effect per month $2.50 per C ton hr**

For the next 2,500 C ton hr of refrigeration effect per month 1.95 per C ton hr**

For the next 7,000 C ton hr of refrigeration effect per month 1.50 per C ton hr**

For all over 10,000 C ton hr of refrigeration effect per month 1.10 per C ton hr**

Determination of Refrigeration Effect

The Company will install meters to measure (1) the water flow of the chilled water service to the customers' utilization devices and (2) the difference in heat content between the water as it enters and as it leaves such devices. The refrigeration effect shall be that quantity of heat content so measured or that quantity of heat content equivalent to 15 Btu per lb of measured water flow, whichever is the greater.

Determination of Demand

The demand billed each month shall be the highest 60-minute refrigeration effect determined as above, recorded within 12 months immediately preceding the date to which the bill is rendered, provided, however, it shall not be less than the estimated demand of service specified elsewhere in this Agreement for Chilled Water Service.

* A ton of refrigeration effect being the removal of 12,000 Btu from the structure or the addition of 12,000 Btu to the chilled water system.

** A CTH being a hundred ton hr (1,200,000 Btu).

Conclusions

It would appear that under such favorable conditions of load factor and heat balance as existed in this case, supply of conventional utility services (if available) may not be in a favorable competitive position with on-site operations. However, great care must be taken in analyzing the load factor-heat balance levels.

It would further appear, that without the tax free advantage accruing in the above case, the position of the utility owned on-site plant would have been within the competitive range.

Thus, district heating, per se, may play a meaningful role in the on-site total energy picture, affording advantage to one concept or the other as the vaguaries of each individual set of circumstances dictate.

Discussion of Mr. Megley's Paper By

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I was the engineer who prepared the master plan for the hospital group and who developed the feasibility of a combination of the generation of all required utilities in a single plant, which Mr. Megley's paper describes. Our first concept was that it be built and operated by the public utility.

However, we knocked at the utility company's door for quite some time before we aroused their interest.

We had another experience two years ago with another large utility company concerning a mixed development of commercial and residential space requiring approximately 1,500,000 lb of steam per hour with high temperature water distribution, 80,000 tons of refrigeration and 120,000 kw of electric power.

In this case the utility company's attitude was as follows: "We will sell you the electric energy. It is questionable whether we want to extend our steam system to sell you the steam. We do not want to get involved in chilled water. We are definitely not interested in building a small, on site generating plant; 300 megawatts is the smallest that we would consider. But we will do everything in our power to stop you or anyone else from constructing such a plant."

This is the wrong attitude on the part of companies that have received a monopoly on the basis that they would serve the public. It is shortsighted too, for Mr. Megley's paper shows that money can be made when the generation of utilities can be combined.

Moreover, conservation of our natural resources and protection of our environment must influence our thinking henceforth. Air pollution of our cities has reached unbearable limits. We must, therefore, have more large central boiler plants with the most sophisticated pollution control devices and operate district heat distribution systems. We must shut down the individual small boiler plants.

From district heat distribution to district chilled water distribution is only a short step and, believe me, it is an economic one. I have learned this from a number of economic analyses which we prepared on large central chilled water plants and distribution systems. Here too we will be improving our environment. Elimination of noise, vibration and spray nuisance is one improvement. Elimination of the cooling tower space from the top of our buildings is another.

Where we can combine heating and cooling with power generation, we will, by the improvement of the thermal efficiency of the process, reduce the burning of fuel and therefore conserve natural resources and reduce air pollution.

This presents a challenge to our public utilities and to us all to abandon our complacent ways, to make our cities more livable, to espouse the cause of service to the public.