The Hartford Story

The nation's first commercial district heating and cooling system was installed at Hartford some two years ago. This article tells why and how, and reports operating data and problems.

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DISTRICT HEATING systems operated by public utilities have been with us for many years, but the combination of district heating and cooling is so new that only one such system is now in operation. True, there have been a few installations of this type on land under one ownership; for example, at Kennedy International Airport, owned by the New York Port Authority, and at Rochdale Village on Long Island, owned by the United Housing Foundation. But the Hartford Gas Company's system in the center of Hartford, Connecticut is the first heating and cooling system to traverse land and serve buildings under multiple ownership.

Why at Hartford?

The first question that comes to mind perhaps is: Why hasn't this been done before and why Hartford? The best answer to this double barreled question is that exactly the right combination of circumstances hasn't arisen previously or elsewhere, or at least hasn't been recognized.

The idea of erecting a district heating and cooling system in Hartford came out of an urban redevelopment project, now called Constitution Plaza, to be built in the center of the city. This project would require air conditioning and would provide an immediate and substantial revenue for such a system. The Hartford Gas Co. was interested, of course, in supplying gas to all of the buildings, both for the improvement of its load curve, which was showing a winter gas use nearly three times as great as in summer, and for the additional revenue, which would come from what had been a slum area.

It was agreed early by all parties that a single central plant would be most logical for the plaza buildings. And when the large Travelers Insurance Co., which would provide a load greater than all of the plaza, indicated that it would give up its steam and chilled water plants and connect to the central plant, the gas company agreed to undertake the construction of the central plant on its own premises and the distribution system. Other nearby buildings followed this lead to provide added incentive.

Since the sale of steam and chilled water did not come under the jurisdiction of the Connecticut Public Utilities Commission, and also to facilitate financing, a subsidiary company called the Hartford Steam Company was formed to build and own the plant and another subsidiary called the Hartford Steam Service Company to operate it. On June 25, 1962, the first commercial district heating *and cooling* system owned by a public utility went into service.

To hold the cost of the undertaking down so that the service could be sold at rates competitive with the cost of operating private plants and yet yield a profit, it was essential to have from the start a substantial load and revenue concentrated in a limited area. This was provided by the following:

1) Constitution Plaza (*M* through *Q* in Fig. 1), consisting of two large office buildings, a 315 room hotel, two smaller commercial buildings, and a shopping center, with a total estimated demand for 2460 tons of refrigeration and 37,800 lb of steam per hr.

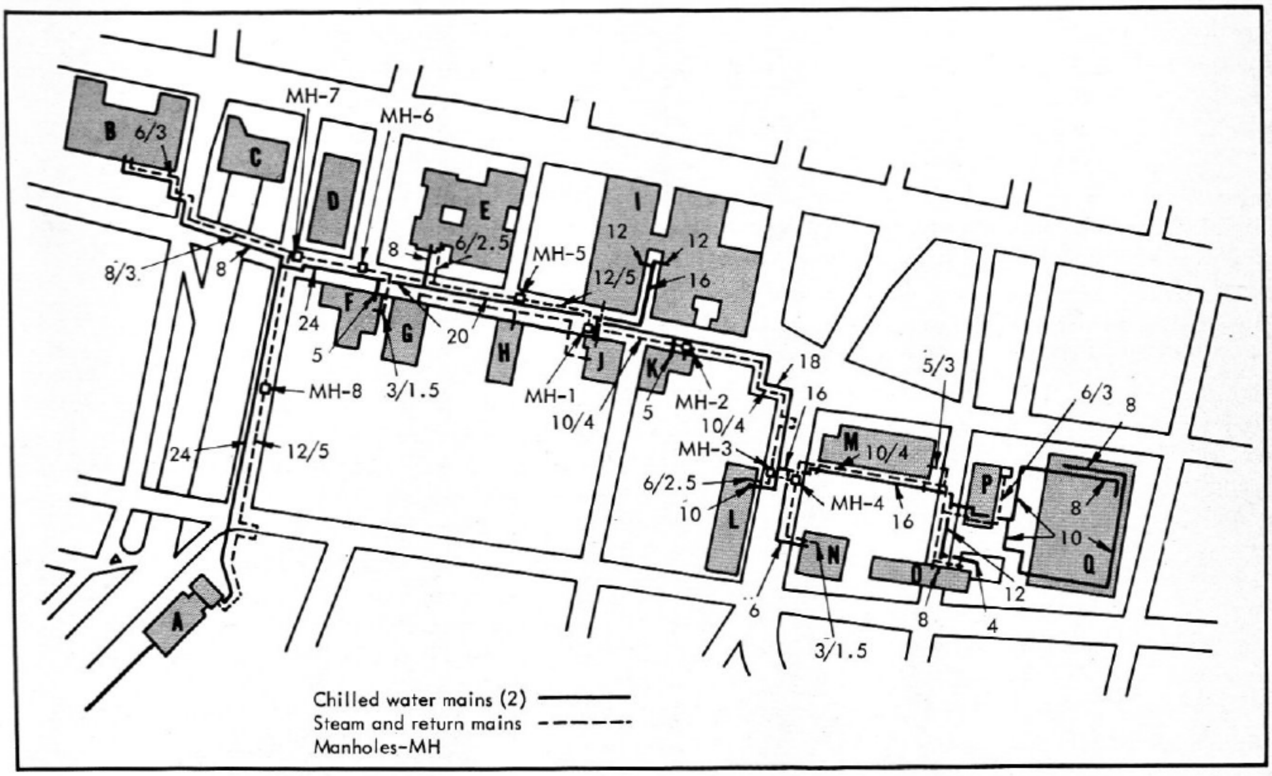
2) The Travelers Insurance Company group (*G* through *I* in Fig. 1) with estimated loads of 3240 tons of refrigeration and 56,900 lb of steam per hr.

3) The new office building of the Phoenix Mutual Life Insurance Company (*L* in Fig. 1), located close to the proposed mains and adding another 920 tons of refrigeration and 12,800 lb of steam per hr.

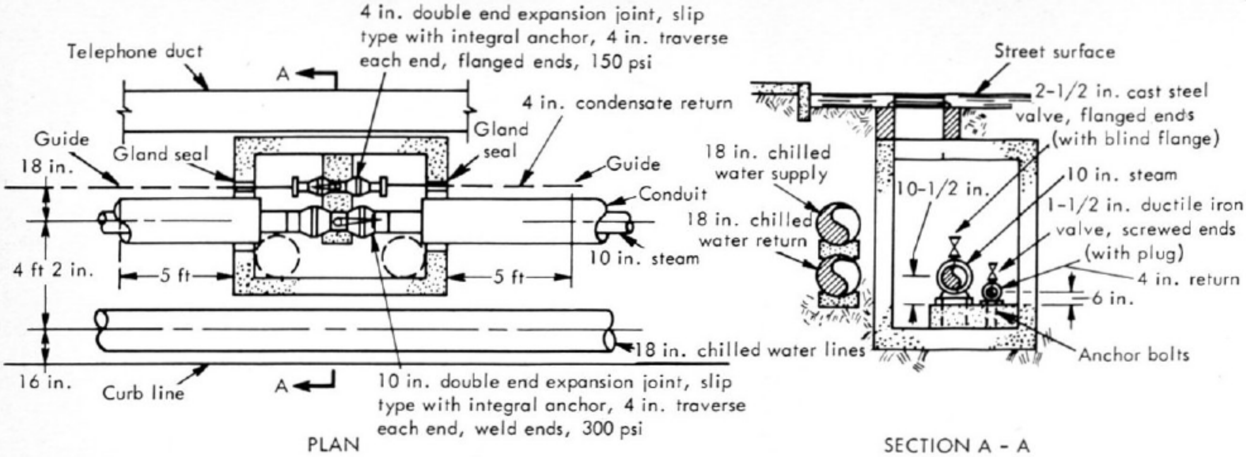
Other considerations included the availability of a suitable site for the new boiler plant and the source of condenser water. The utility had such a site only a short distance from the first customer. And by running 1900 ft of 36 in. concrete pipe, water could be pumped from the Connecticut River, using an existing screen house that otherwise would have been abandoned. Moreover, the water could be discharged into a covered creek only 70 ft away. With an unlimited quantity of water available, at 33 to 85 F depending on season, a major cost item—for cooling towers or spray ponds—was eliminated.

HTW or Steam? Two-, Three-, or Four-Pipe System?

A substantial part of the cost of any district system lies in the underground piping, and a decision must be made as to the type before cost estimates can be undertaken. One obvious question is: High temperature water or steam? At Hartford, the choice of steam was almost automatic because of the need for steam at the plant for compressor turbine drive and because of special circumstances. The latter re-



1 DISTRICT HEATING AND COOLING distribution system is traced here. Numerals along solid line indicate size, in inches, of two chilled water mains and branches. Numerals along broken line divided by slashes indicate sizes, in inches, respectively, of steam and condensate return mains. Alphabetically labeled buildings are identified as follows; A, central air conditioning plant with condenser water line extending to Connecticut River; B, Federal Building; C, Library (not served); D, Municipal Building (not served); E, Wadsworth Atheneum; F, Hartford Times; G, Travelers Printing Building; H, Travelers Education Center; I, Travelers Insurance Building; J, Travelers Annex; K, Hartford Steam Boiler Inspection and Insurance Co.; L, Phoenix Insurance Building; M, 20 story Connecticut Bank; N, TV studio; O, 315 room Hotel America; P, 18 story office building; Q, office building.



2 PLAN AND SECTION at Manhole No. 2 indicate typical treatment of four-pipe distribution system.

lated to the provision of steam service to the new broadcasting building in Constitution Plaza and to the older group of buildings owned by Travelers.

Another decision was whether the distribution should be a two-, three-, or four-pipe system. This was resolved more or less automatically in favor of a four-pipe system on the basis of end use. At Rochdale Village, referred to above, the end use is primarily for heating and cooling apartment buildings and secondarily for stores in two shopping centers. Apartments may not demand simultaneous heating and cooling as do commercial buildings where heavy lighting, severe sun effect, and machinery (especially computer rooms in banks and office buildings) make it essential to have chilled water available year 'round. Therefore, a two-pipe system such as the one employed at Rochdale could be eliminated at once for Hartford's almost completely commercial end use.

A three-pipe distribution system was rejected because it would mean that all customers would have to use three-pipe systems, which was considered a somewhat absurd restriction. There was no escaping the conclusion that a four-pipe system would have to be used, as was the case at Kennedy International Airport where simultaneous heating and cooling were also a must. This greatly increased project cost, for, of course, two-, three-, and four-pipe systems cost progressively more than does a single steam main, which is all that is needed for heating (if condensate is wasted). At Hartford, the cost of the distribution system was estimated at $200 per lin ft, and this proved to be nearly correct.* The cost of distribution amounted to approximately 27½ percent of the total cost including the plant.

Conditions Met; Work Begun

It was estimated that the entire project to serve the original group of customers would cost $4.5 million. Rate schedules were prepared on this basis and included demand and consumption charges estimated to bring in nearly equal revenues. The demand charge was calculated to cover amortization of investment and other fixed charges, the consumption charge to cover all operating costs. To secure financing for the project, it was necessary to have 30 year contracts, to which the original customers agreed.

Almost immediately after work had started, other customers signed up, principally the General Services Administration of the federal government, which added 760 tons of refrigeration and 15,600 lb of steam per hr to the 6600 tons and 107,500 lb contracted for by the original group. The service was for the GSA's new building, to be erected close to the new mains.

Nearly Four Miles of Mains

Construction began with the digging of approximately 5200 ft of trench, 3400 ft of this through city streets and the rest through Constitution Plaza where the chilled water mains were in part run under the garage floor. This meant a total of approximately 20,800 ft of mains.

While steam is generated at 250 psi and the distribution system is designed for that pressure, the pressure is currently reduced to 125 psi for distribution. It is further reduced by customers to 10 psi for most building services. The steam mains are dripped through the customers' service connections into condensate pumps that return the water to the boiler plant. All mains are cathodically protected against corrosion.

As shown in Fig. 1, the chilled water main starts out at 24 in. in diameter and reduces to 8 in. at the far ends. The steam main leaves the boiler plant at 12 in. and reduces to 6 in at the far ends while the condensate return main starts at 3 in. and increases to 5 in. before reaching the boiler plant.

**As reported in the August issue of HPAC, the actual cost was $225 per ft.*

The chilled water mains were sized for a head loss of 120 ft. This plus 60 ft inside the plant results in a total pumping head of 180 ft when the maximum flow of 16,000 gpm is handled. This is based on a load of 10,500 tons of refrigeration and a temperature difference of 15 F. The design tonnage has not yet been attained but soon will be.

Choose Stainless for Condensate Return

Chilled water mains are in the same trench as the steam and condensate return mains. Wherever possible, however, 4 ft 2 in. is maintained between center lines as shown in Fig. 2.

The steam main is Schedule 40 steel pipe and is run in prefabricated conduit. The condensate return main is Schedule 10 stainless steel, laid in the trench and provided with loose-fill insulation. Stainless steel was selected because of its resistance to corrosion, which is especially problematic in condensate return lines. Because of the low operating pressure of approximately 25 psi, the wall thickness of Schedule 10 was deemed adequate, and, of course, it was much less expensive than Schedule 40.

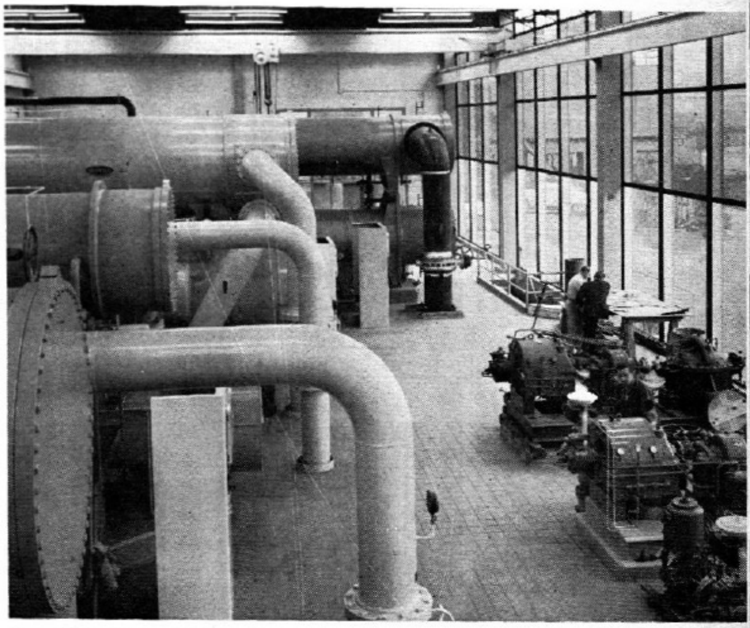
The chilled water flow main is insulated with 1 in. thick expanded polystyrene foam. The return main, however, being so close to the ground temperature, is not insulated. As a rule, the flow main is on top of the return main. No expansion joints were needed for the chilled water mains because chilled water is circulated year 'round at nearly the same temperature. What little contraction there was initially was too small to require expansion joints.

Chilled water supply and return mains do not pass through the manholes. The steam mains and return lines have slip type expansion joints at each manhole, except in the few cases where loops or offsets could be used.

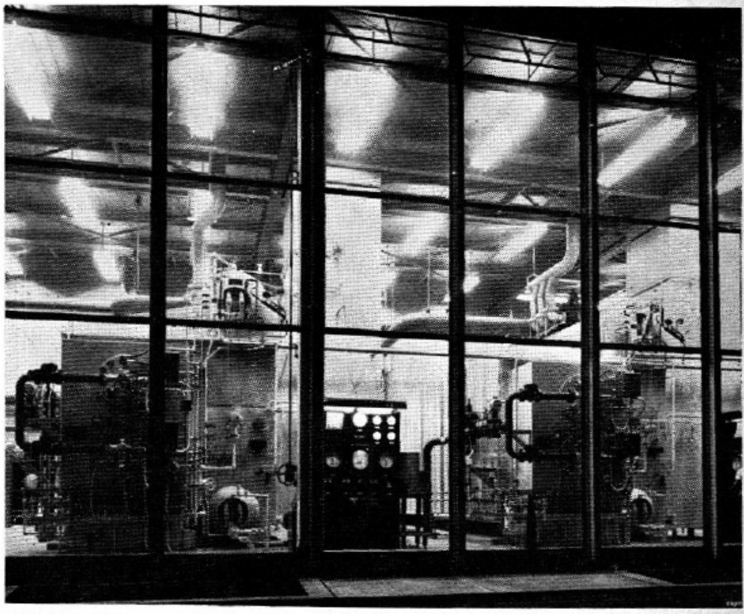
Handling Necessary Pressures

The pressure on the chilled water mains is presently determined by the height of the Travelers Insurance Co.'s tower building, a prominent feature of the Hartford skyline. This results in a static pressure at the circulating pumps in the boiler plant of 130 psi. The pumping head when the present maximum of 11,000 gpm is handled is approximately 45 psi, but with the design maximum of 16,000 gpm, it may reach 80 psi. Thus, the total pressure will slightly exceed 200 psi. All customers are advised of this and are asked to prepare for it by selecting equipment suitable for this pressure or installing heat exchangers.

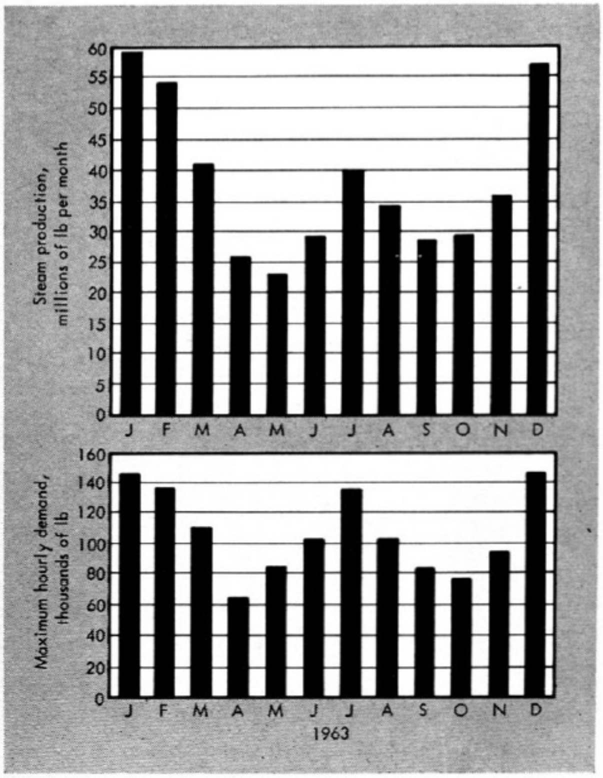
At first it was considered that it might be better to install heat exchangers for the upper floors of the Travelers building, but this was found to be more



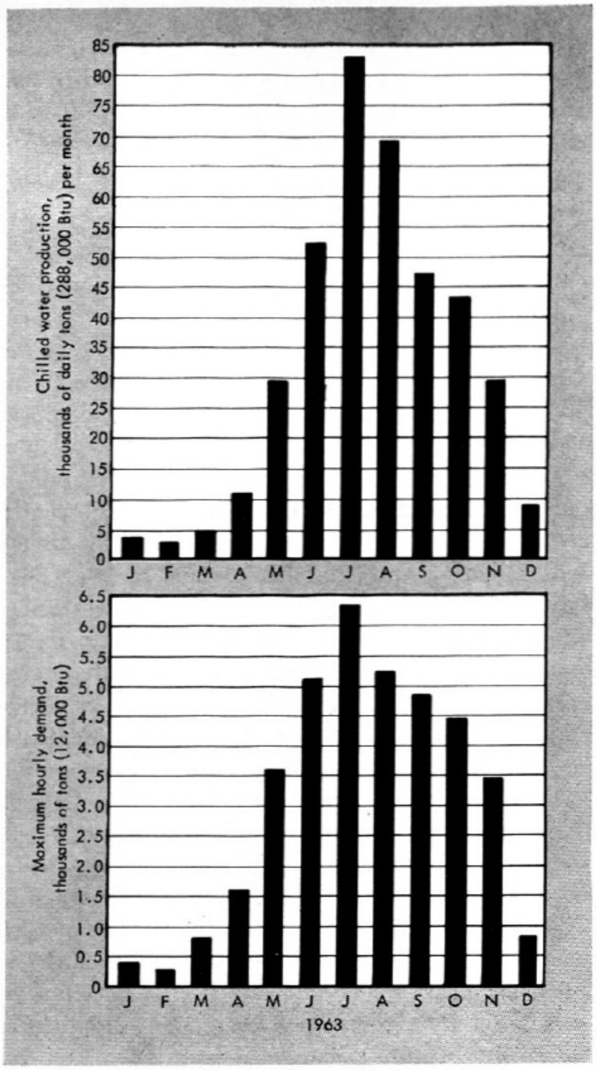
3 INTERIOR VIEW of central plant shows 4500 ton chiller in background, chilled water circulating pumps in lower right foreground.



4 EXTERIOR VIEW of central plant shows two of three 75,000 lb per hour steam boilers. They can be fired with either gas or oil.



5 STEAM PRODUCTION and maximum hourly demand are shown by months for 1963.



6 CHILLED WATER PRODUCTION and maximum hourly demand are shown by months for 1963.

expensive than adapting the mains for the 200 psi. As the load continues to grow and the pumping head increases, however, this may have to be done.

Solve Water Flow Problem

There are five chilled water circulating pumps (one for standby), rated at 4500 gpm each at 80 psi pumping head. The pumps are driven by steam turbines of the condensing type, operating at 250 psi and 26 in. Hg vacuum. As mentioned, chilled water is circulated all winter because the insurance companies and banks have computer rooms and interior spaces that need cooling year 'round. The water flow in winter is low, however, and can easily be handled by one circulating pump.

Originally, an outdoor thermostat was installed to adjust the speed of the circulating pumps, and hence the flow, in relation to the outdoor temperature. This alone did not always provide the proper amount of water, and manual adjustments were necessary. In spite of close attention, however, there were occasions during periods of low cooling loads when the water on the far ends of the mains was too warm as a result of the temperature rise of the chilled water in the mains.

To correct this, an instrument was attached to an orifice at the far end of the main to indicate and record on a chart via a leased telephone line to the plant the rate of water flow at the remote point. The plant operator is thus able to anticipate the necessary adjustments and maintain the flow that is necessary to offset the temperature pickup in the mains at all times.

15,000 Tons of Refrigeration by 1965

The original design was to send out a maximum of 16,000 gpm at 38 to 40 F with the water returning to the plant at 55 F, and the first installation of refrigeration equipment consisted of two 1500 ton units and one 3000 ton unit. These are of the centrifugal

TABLE 1 — STEAM AND CHILLED WATER total and peak hour send-out (SO) by Hartford Steam Service Co. are tabulated by months for 1963 and first quarter of 1964.

Month	Steam SO, 1000's of lb		Chilled water SO	
	Total[1]	Peak hour	Total, daily tons[2]	Peak hour, tons[3]
1963				
Jan.	59,215	142	3,304	375
Feb.	53,877	140	2,501	300
Mar.	41,131	112	5,039	735
Apr.	25,383	68	11,566	1,545
May	23,857	83	29,579	3,585
June	29,193	105	52,223	5,065
July	40,622	133	82,533	6,345
Aug.	34,550	105	69,320	5,280
Sept.	28,542	86	47,143	4,890
Oct.	29,184	79	43,223	4,440
Nov.	36,745	94	29,417	3,435
Dec.	57,016	146	7,876	750
Total	459,135		383,724	
1964				
Jan.	65,635	162	11,695	705
Feb.	62,147	142	11,056	660
Mar.	43,831	128	9,893	2,715

[1]Monthly send-out for steam includes that for circulating and boiler feed pumps and other station auxiliaries.
[2]288,000 Btu
[3]12,000 Btuh

type with steam turbine drive for the compressors operating at 250 psi steam pressure and 26 in. Hg vacuum. Based on a 6600 ton connected load and a load factor (the ratio of actual peak demand to connected load) of 75 percent (experience shows that 85 percent is a better factor), the maximum hourly demand would be approximately 5000 tons.

Enough new load was quickly added, however, so that a 4500 ton unit, Fig. 3, was installed in June 1963. In July, the peak demand reached 6345 tons with a new peak of 8000 tons anticipated for 1964. With more to come, a second 4500 ton unit has been ordered to assure adequate capacity for the summer of 1965. This will bring the total installed capacity to 15,000 tons. The 4500 ton units are said to be the largest ever built. The compressors are driven by direct connected 5210 hp turbines running at 4900 rpm.

At present there are three boilers, two of which are shown in Fig. 4. (A fourth had been ordered and was to be installed this summer.) They are of the water tube type with water jacketed combustion chambers, each rated at 75,000 lb of steam per hr at 250 psi. Either gas or heavy oil can be burned. In summer they supply steam for the turbines plus a small amount needed by customers for domestic water heating. In winter they supply steam for heating. In fall and spring, steam is used for both heating and cooling.

Boiler water is treated by conventional means. Protection of chilled water equipment and underground mains is achieved by injecting a sodium nitrite-borax mixture plus a copper inhibitor into the water to maintain a solution of 2000 ppm minimum. Samples are analyzed regularly, and the only difficulty encountered in maintaining this mixture has resulted from some customer drawing down the water in his system for repairs or alterations. There has been no observable corrosion to date.

Steam Production in 1963

The data on steam generation per month and maximum demand, graphed in Fig. 5 and tabulated in Table 1, are quite interesting. Considerably more steam is used for space and domestic water heating than for cooling although the cooling and heating cycle maximum demands are very nearly alike. It should be pointed out that the refrigeration compressors are shut down from mid December to the first of March because the temperature of the river water used for the condensers does not exceed 35 F during that time, and up to 1000 tons of cooling can be produced by direct exchange from this water. The peak demand for cooling during this interval does not exceed 750 tons. Thus, the only steam used during this time for cooling service is that by the circulating pumps.

Originally, a peak demand of 109,000 lb of steam per hr was visualized, but this has already been substantially exceeded. To assure firm capacity to meet the peak loads even if one boiler should be out of service, the installation of the fourth boiler is being made earlier than was originally anticipated.

Burn Oil for 40 Percent of Total Steam Production

The Hartford Gas Co. buys natural gas (with a heating value of 1035 Btu per cu ft) from a pipeline

DEMAND CHARGES for district cooling are made according to the following schedule. One ton is defined as 12,000 Btuh, and an hour is defined as any 60 consecutive minutes.

$340.00 per month for the first 100 tons of demand or any portion thereof.
2.90 per month for each of the next 400 tons of demand.
2.80 per month for each of the next 1500 tons of demand.
2.70 per month for each ton of demand in excess of 2000.

CONSUMPTION CHARGES for district cooling are made according to the following schedule, with appropriate adjustments for variations in fuel, labor, and tax costs. A daily ton is defined as 288,000 Btu.

$1.15 for each of the first 1000 daily tons per month.
1.05 for each of the next 3000 daily tons per month.
1.00 for each of the next 6000 daily tons per month.
0.95 for each of the next 10,000 daily tons per month.
0.90 for each daily ton per month in excess of 20,000.

company for practically all of its send-out requirements. The Hartford Steam Service Co., which operates the district heating and cooling system, buys gas from the parent company for boiler fuel. Like most purchase contracts for gas for industrial boiler fuel, theirs is for interruptible supply at times of peak demand by other customers. Consequently, to retain the advantage of the low cost interruptible gas supply, the Service Co. uses oil for approximately 40 percent of the total annual steam production. For this purpose, the company maintains a reserve supply of approximately 2 million gal of oil.

Very little gas is fired in the boilers in winter, the time of peak use by the gas company's firm customers so that gas is not available for industrial boiler fuel. In January 1963, for example, the gas consumption in the boiler plant was only 3087 M cu ft, or less than ½ percent of the total gas sent out by the gas company. In July, however, 50,510 M cu ft of gas was used in the boiler plant, or 14 percent of the gas company's total send-out.

Chilled Water Production in 1963

The 4500 ton chiller was designed to use from 13 to 14 lb of steam per ton of refrigeration, but with the wide variation in condenser water temperature, this rate is less than 10 lb at times. The chilled water send-out is graphed in Fig. 6 and tabulated in Table 1. Of interest here is the fact that the ratio of maximum to minimum consumption is twice as great as the ratio of maximum to minimum demand. It must be remembered that the compressors are shut down during mid winter.

One of the reasons for going into the heating and cooling business from a district plant was to fill the summer valley in gas consumption. By using gas for practically all of the cooling and oil for heating in the coldest weather, this can be accomplished. To date, however, the steam plant load has been too small a part of the gas company's operation to have any great effect on the load curve (only 14 percent in July 1963). Of course, the project is a step toward the company's goal, and the steady increase in cooling load will move it closer.

What Rates? No Precedent

Steam for customers is metered through flow meters. Steam has been sold for many years, and the National District Heating Association is able to provide its members—The Hartford Steam Service Company is one—with complete information for the establishment of proper rates, so this entails nothing new. The schedule adopted provides for a demand charge and a consumption charge with adjustments applicable to the latter for variations in the cost of oil, labor, and taxes.

The sale of chilled water, on the other hand, is entirely new, and there was no background for establishing rates. Hence, the Hartford Steam Service Co. had to pioneer this field.

For the purpose of determining the amount of refrigeration used and the maximum hourly demand, a ring balance flow meter with automatic compensation for temperature difference is installed at each customer's service connection. This involves an instrument to measure the pressure drop across an orifice; two temperature elements, one in the supply line and the other in the return from the building; a multiplying linkage; a graphic chart showing the demand in tons; and a totalizer. For small customers not using more than the minimum demand, the chart is omitted.

The charts have a uniform scale for all customers and read from 0 to 100 percent, with a constant or multiplier for each installation.

Demand and consumption rate schedules are shown in the box. Appropriate adjustments are made in the consumption charge for changes in costs of fuel, labor, and taxes. The reason for using the term *daily tons* is simply to deal in units larger than the customary ton of refrigeration capacity of 12,000 Btuh.

Demand is defined as "the largest number of tons of cooling demand in any of the twelve (12) months ending with the month next preceding the month in which the bill is stated or, in case there is in existence a contract with the customer containing a minimum demand, the greater of the two." The minimum monthly charge will be the demand charge.

Contracts with customers specify that the water will be supplied at 40 to 41 F at the building entrance and that each customer must arrange and operate his equipment so that the water is returned to the distribution system at no lower than 54 F. The meters are equipped with pens to record both the flow rate and temperature rise of the water.

The established rate must be about right because the company showed a profit for 1963.

The architect for the boiler plant building was Charles DuBose of Hartford. Seelye, Stevenson, Value & Knecht of New York were engineers. F. H. McGraw & Co. of Hartford was the general contractor; C. N. Flagg & Co. of Meriden, Conn. was the mechanical contractor.

Future Tied Up With Urban Renewal

The future of district heating and cooling systems owned by gas companies is closely tied to urban renewal projects. This is because most such projects are in or very near the centers of larger cities where buildings will not only be of the type that are always air conditioned today (office buildings, apartment buildings, stores, etc.), but they will also be of considerable size and relatively closely spaced. They therefore provide a basic, concentrated, and substantial revenue producing load. If these projects alone are not of sufficient size to justify a district system, additional customers can very likely be found not too far from the mains. If a suitable location can be found for a boiler plant and if condenser water is readily available, as from the river at Hartford, then the undertaking becomes attractive. This combination of favorable circumstances may occur more frequently in the future.

Pipe sizes also play a part in determing the feasibility of district heating and cooling systems. With a chilled water temperature rise limited to a maximum of 16 F, the mains can become large enough to kill a project unless the central plant can be located at the load center.

Rundown on a Similar System

Several similar projects are now under consideration, but the only one that is firm is that to be built by Equitable Gas Co. at Pittsburgh. This will be based on the urban redevelopment project called Allegheny Center, located on 62 acres on the north side of the Allegheny River, opposite downtown Pittsburgh. Here there will be office buildings, apartment houses for 1200 families, and a shopping area with a covered and air conditioned mall. The feature that distinguishes this project from Hartford is that 220 private residences will be supplied with hot and chilled water. The mechanical design is being executed by Ford, Bacon and Davis, Inc., of New York.

Plans and specifications are not yet available, but it is expected that the central plant will contain two steam boilers, each rated at 70,000 lb per hr at 250 psi, and three chillers, each rated at 2000 tons and supplying 10,000 gpm. Although the river is not too distant, conditions are more favorable for using a cooling tower alongside the plant. Distribution will be by a four-pipe system, with steam for heat exchangers in all buildings. The so-called townhouses, which are groups of two story, single family residences with party walls, will be located in four areas. Each area will contain an equipment room with a heat exchanger to provide hot water and the necessary circulating pumps for both hot and chilled water. Local distribution for each area will be by means of a four-pipe system, thus providing simultaneous heating and cooling if required. ⧺