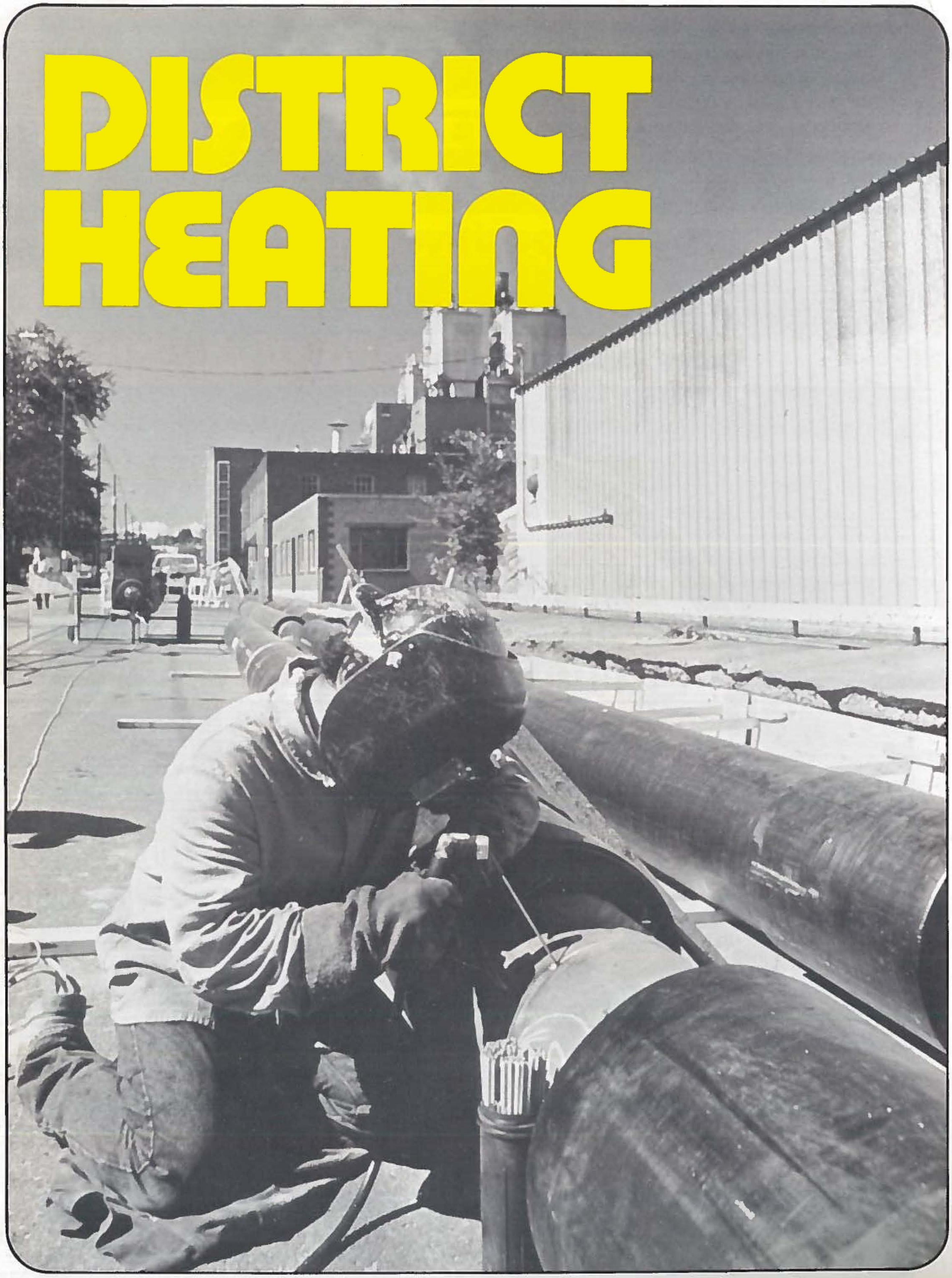
DISTRICT HEATING



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Construction of an Economic District Heating System in Jamestown, New York

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Introduction

The City of Jamestown, New York, and the New York State Energy Research Development Authority, in cooperation with the engineering firm of Burns and Roe, Inc., have developed a hot water district heating system for the City of Jamestown that could become the most economical in the United States. It has all the necessary prerequisites for a successful district heating system: a relatively high density thermal load in a small area, a highly efficient cogeneration heat source burning low-cost coal, and low-interest municipal financing. In addition it enjoys generally strong community and political support. To date, a pilot system with four customers and a peak thermal load of 2.6 MWt has been installed with construction slated to begin in early 1985 on a major expansion that should bring the peak load up to approximately 13 MWt.

The Jamestown district heating project began in October 1981 as a preliminary feasibility study funded by The New York State Energy Research and Development Authority. The goal of the study was to determine if a hot water district heating system could be designed to economically supply the downtown area of Jamestown with thermal energy from the municipal electric plant. The results of the study were that district heating was technically feasible and economically attractive in Jamestown. In light of the favorable results, a comprehensive second phase study was contracted to bring the City to the final decision point as to whether or not to proceed with final design, financing and construction of the system. The objectives of the second phase study were to: Perform an engineering reference design to serve as the basis for financial analysis, marketing, final design and engineering and final bid specifications; market district heating to potential customers and negotiate energy purchase agreements; prepare the basis for the financial instruments for project financing; and develop a project business plan. Seventy five percent of the study was financed by The New York State Energy Research and Development Authority and 25% by the City of Jamestown. Based on the favorable results of the first stage of this study, Jamestown committed to building a pilot system during the summer of 1984 and the downtown core area system in the spring of 1985.

Pilot Project

The purpose of the pilot project was to let the local district heating officials gain valuable construction and operating experience before implementing a large scale system and to allow prospective customers a chance to visit and inspect a facility retrofitted to district heating. The pilot project was a success on both accounts, especially the latter. Potential customers witnessed the construction, talked to pilot project building staff and even requested that the scope of the pilot project be expanded so that their buildings could be included.

Official authorization to proceed with the Pilot Project came in late June of 1984 and at that time only the heat load and a preliminary heat source design existed. Scheduled completion date for the project was October 1984 to coincide with the start of the heating season. It was realized that close cooperation and much hard work would be required by all parties including the City, Burns and Roe and the equipment vendors if the schedule was to be met. Work began immediately. The design of the pilot project was finalized and equipment specifications were released. Contract awards were made on July 27. Equipment delivery and system construction began on August 20. Testing of the system began October 23 and system start-up was October 29. The formal dedication of the project took place on November 2, 1984.

Expansion

The expansion for 1985 should bring the total system load up to peak of 13 MWt with annual sales of 117,000 MBtu's. This is the Phase I construction or the minimum economically feasible system and includes mostly large-scale commercial buildings with paybacks of less than five years. Much more load is available in the area, and the system's expansion to accommodate this load will occur in well-planned phases to keep capital expenditures from having an adverse impact upon the rate structure. The expected loads for the various expansion phases are shown below:

Phase I –Core Area—13 MWt
Phase II –Saturated Core Area—17 MWt
Phase III –Saturated Core + Industrial Corridor—31 MWt
Phase IV –Saturated Core + Industrial Corridor + Outlying Areas—76MWt

Power Plant Retrofit

The Steele Street Power Station consists of two coal-fired units. Both have General Electric non-reheat turbines. Cooling water for the station is taken from the Chadokin River and passed through cooling towers before being returned to the river.

Preliminary investigation determined that the heat obtainable from the Unit 5 turbine is small compared to that from the Unit 6 turbine. Therefore, only schemes involving the modifications of Unit 6 were considered in detail. Unit 6, a 25,000 kW, 3600 rpm, 15-stage single-flow condensing unit, is designed to operate at 850 psig steam pressure and 900°F temperature at 3.5 inches Hg. condenser pressure; it has a rated throttle flow of 238,072 lb/hr. Extraction steam for regenerative feedwater heating is taken from four extraction points. The turbine has one blanked-off extraction point at the 11th stage. The feedwater heating cycle consists of four closed and one open feedwater heater with makeup to the cycle through the condenser hotwell. Steam is extracted from the blanked-off 11th stage of the turbine for use in a new district heat exchanger for loads up to 7 MWt. For loads above 7 MWt, additional steam is taken from the auxiliary steam header and used in the existing auxiliary heat exchanger that is arranged in series with the new district heat exchanger.

During peak heat load operation, the return water temperature is 160°F with a district heating water supply temperature of 250°F. The district heating water flow rate corresponding to peak load is 498,000 lb/hr. The maximum extraction flow available from the 11th stage extraction allows heating of 379,000 lb/hr of district circulating water to 223°F. At the maximum heat load conditions, 119,000 lb/hr of district heating water bypasses the district heat exchanger and the auxiliary heat exchanger. The 379,000 lb/hr of 223° effluent water from the district heat exchanger is passed through the auxiliary heat exchanger where it is increased in temperature above the design temperature of 250°F such that when mixed with the bypassed water the final temperature is 250°F.

The district heat exchanger operates throughout the year, providing both space heating and domestic hot water needs. The auxiliary heat exchanger operates about one-third of the year. The maximum operating pressure of the district heat exchanger is about 20 psia; the maximum operating pressure of the auxiliary heat exchanger is 60 psia during district heating operation with a maximum steam flow of 18,900 lb/hr during district heating operation.

When the heat load is equal to or less than 7 MWt, the auxiliary heat exchanger is out of service and the maximum extraction steam flow to the district heat exchanger is 23,813 lb/hr at an extraction stage pressure of 21.8 psia. The maximum electrical load reduction from the Unit 6 turbine-generator is about 1.24 MWe during district heating operation. Drains from the district heat exchanger are cascaded to the condenser through an internal drain cooler.

Modifications to the turbine are not required since the redistribution of extraction flows are relatively minimal, and all existing feedwater heaters remain in service without modification. The completed Phase I retrofit has a rated capacity of approximately 26.0 MWt due mostly to the large capacity of the auxiliary heater. However, this is limited by a pumping capacity of approximately 19 MWt.

Figure 1 shows the operation of Unit 6 during district heating operation, and Figure 2 shows the system arrangement.

The second phase of heat source development builds on the first by incorporating the Unit 5 auxiliary heater into the district heating cycle in parallel with the Unit 6 auxiliary heater. This addition does not increase the rated capacity of the heat source but does increase the operating flexibility of the plant. The second phase development also involves the installation of additional pumping capacity that allows the full heat generation capacity of 26 MWt to be utilized if required. The first phase pumping capacity is limited to approximately 19 MWt.

The third phase of heat source develoment involves the installation of a new cogeneration steam turbine cycle to the Steele Street Plant. This development phase is based on the assumption that the utility will be installing new electric capacity at the plant. The new thermal capacity associated with the cogeneration cycle could have a thermal capacity as high as 80 MW. This new capacity would be used to supply the heat load of the industrial corridor and other outlying districts. The new cycle would be run at partial load in parallel with the initial heat source retrofits or at full load in place of the initial heat source retrofits. The heat source development phases are summarized below:

	Phase I	Phase II	Phase III
Rated Thermal Capacity, MWt	19.0	26.0	80.0
Estimated Installed Cost (1984 Dollars × 10^3)	633	157	2,473

Transmission and Distribution System

The transmission and distribution system developed to deliver hot water to the Jamestown district heating customers is a two-pipe closed system installed below sidewalks wherever possible. It has a peak load supply temperature of 250°F and a peak load return temperature of 160°F. The design operating pressure of the system is 200 psi. The pipe design used is a prefabricated insulated conduit consisting of a carbon steel carrier pipe, polyurethane insulation, a polyethylene casing and incorporates a leak detection system. The initial phases of development are designed with excess capacity to facilitate expansion. The piping system development is summarized below:

	Phase I	Phase II	Phase III	Phase IV
Transmission Piping (Mi)	3.34	0.21	2.18	5.63
Distribution Piping (Mi)	0.96	0.94	0.12	4.08
Total Piping (Mi)	4.30	1.15	2.30	9.71
Installed Costs (1984 Dollars)	2,558,000	394,000	1,789,000	5,330,000

Ownership and Regulatory Considerations

In New York State, as with most other states, there exist constraints to the operation of a disrict heating

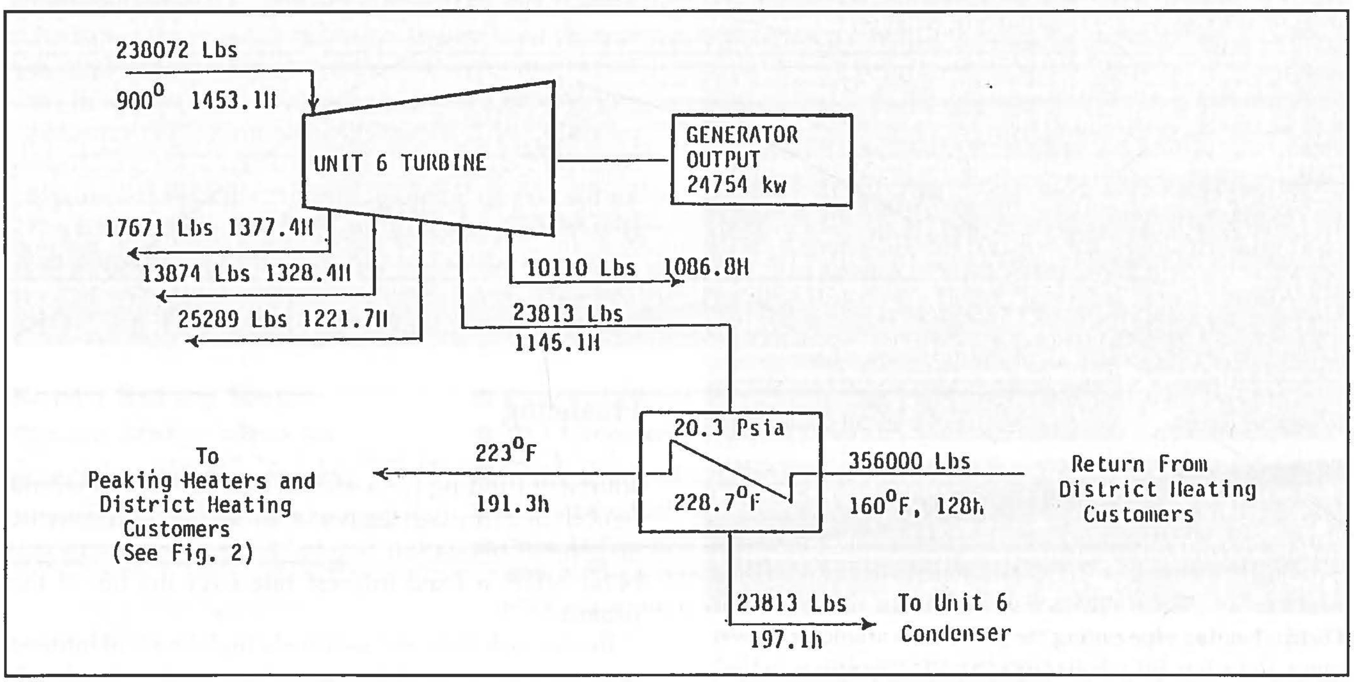


Figure 1
Steele Street Generating Station Unit 6—Cogeneration Operation

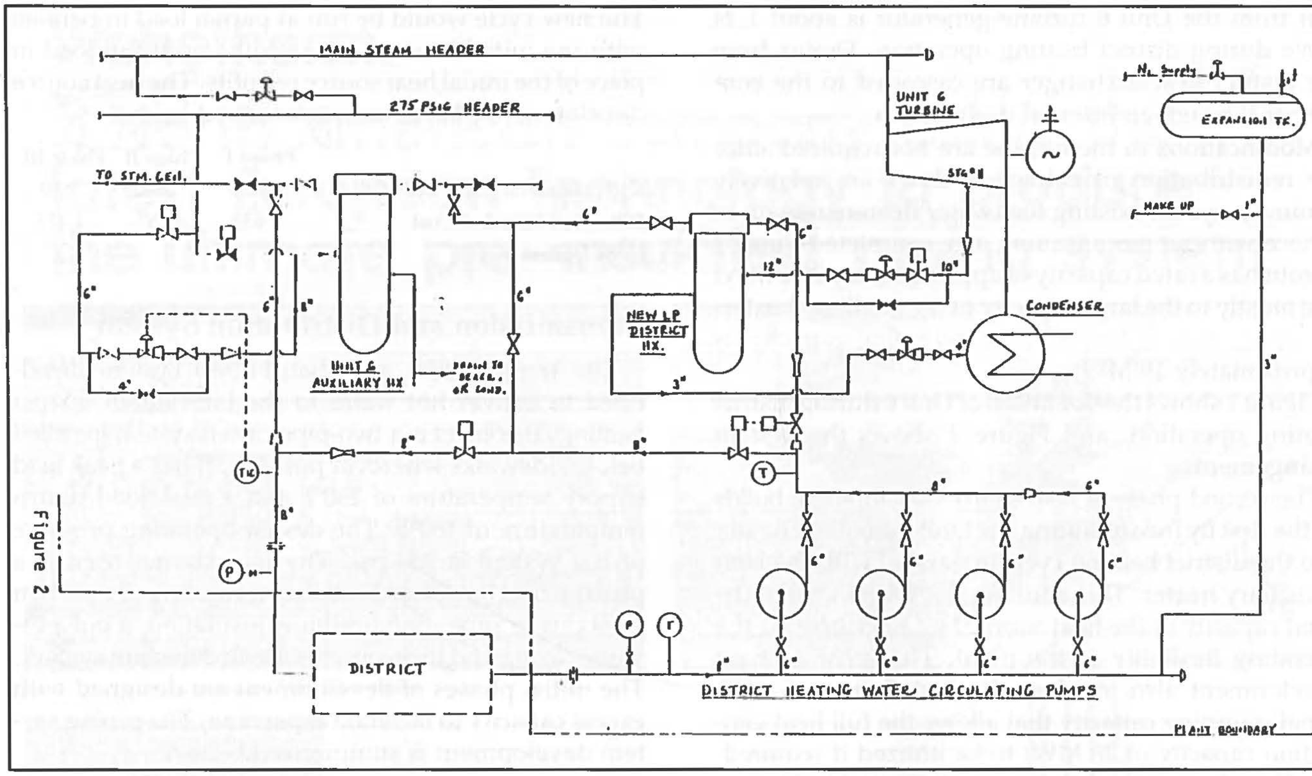
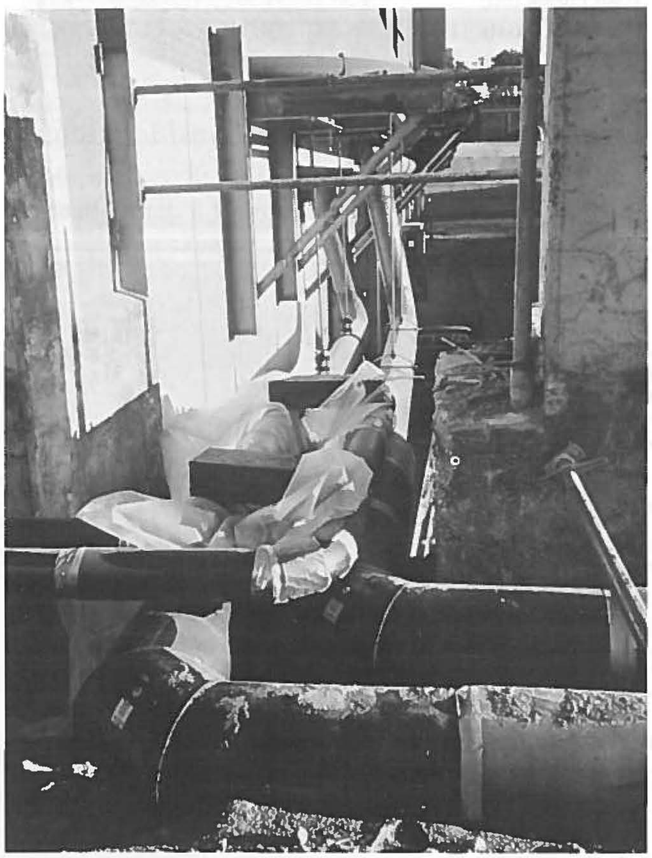


Figure 2
Steele Street Plant District Heating Retrofit System Arrangement



District heating pipe exiting the Jamestown municipal power plant. Branch to the left services two city buildings. Branch to the right services Jamestown General Hospital and Jamestown Plywood. The branch to the right will be extended to service the downtown area in 1985.

system imposed by the public utility regulatory framework and the franchise authority of the local municipality. The degree of such constraints varies substantially with the form of ownership chosen.

Municipal ownership is the alternative least impacted by regulatory constraints. The City of Jamestown has a distinct advantage over most other localities which have instituted district heating systems because it already has in place a municipal electric utility capable and experienced in dealing with all regulatory requirements as well as being attuned to the City's needs and procedures. The existing structure of the Jamestown Board of Public Utilities presents a unique opportunity for the City to institute a system which is fully responsive to the interest of the City with only limited additional procedural, administrative and managerial cost. The Jamestown Board of Public Utilities has existing authority to use public right-of-ways.

Financing

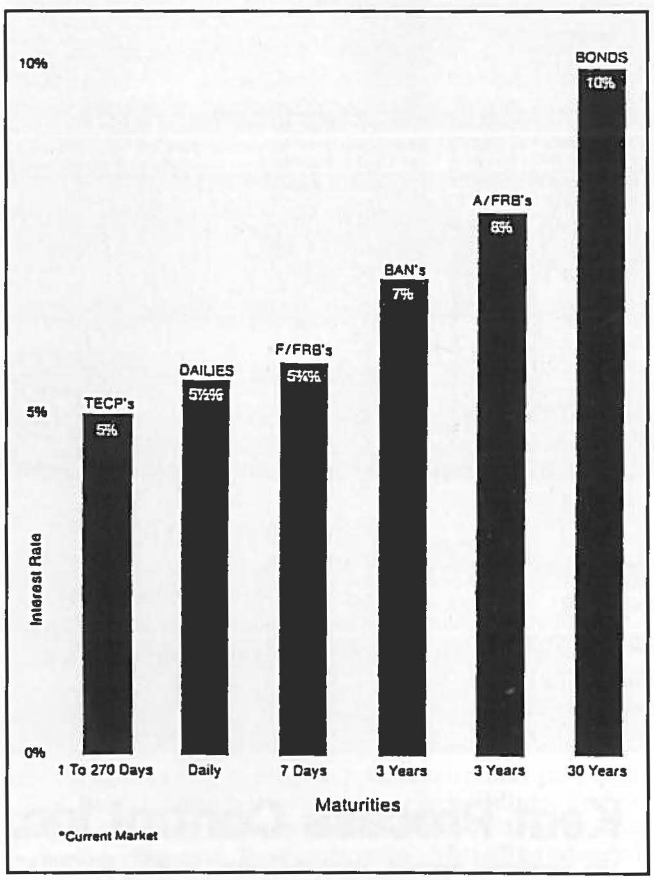
In the context of municipal ownership, the normal source of funding for a district heating project would be obtained through the issuance of long-term revenue or general obligation bonds. A long-term municipal bond offers a fixed interest rate over the life of the project.

Recent volatility and relatively high levels of interest rates on long-term obligations, have lead to the development of a broader spectrum of tax-exempt alternatives, including short-term, as well as floating-rate,

Pipe entering Jamestown General Hospital boiler building.

longer-term instruments. Short-term tax-exempt alternatives present opportunitites for taking advantage of substantially lower interest rates, particularly during the construction period. Generally speaking, however, short-term tax-exempt alternatives are only available if long-term bonds are intended to be the ultimate debt. A short-term debt is considered to be any debt having a maturity of less than one year. Municipal short-term debt instruments include Tax-Exempt Commercial Paper (TECP) and Bond Anticipation Notes (BAN'S).

Figure 3
Municipal Tax Exempt Financing Alternatives



In certain cases, financing combining both long-term and short-term characteristics may be applicable. Such an approach was used for the St. Paul, MN, bond financing which permitted a 30-year maturity, but at a temporary floating rate, resulting in discounts of over 200 basis points from an equivalent fixed rate facility. Examples of such facilities are floating/fixed-rate bonds (F/FRB's) and adjustable/fixed bonds (A/FRB's).

Floating fixed-rate bonds, alternatively known as "lower floaters," are instruments which "float" for a specified period, and then at the initiation of the sponsor "fix" for the remaining life of the bonds. During the floating period, the sponsor would benefit from short-term interest rates (about ¼% to 1% above TECP rates). F/FRB's or "lower floaters" always require some form of third-party liquidity support, normally a commercial bank letter of credit during the floating period. The advantage of F/FRB's over other instruments is that F/FRB's are long-term bonds which reduce the risk that the obligations cannot be refinanced at maturity.

Another combined long-term, short-term financing technique is adjustable/fixed rate bonds (A/FRB's). A/FRB's are long-term bonds which bear a fixed of interest for defined period (usually 1, 3 or 5 years) with a new interest rate to be established at the conclusion of each period based upon the interest rates prevailing in the market for securities with comparable ratings and maturities. In effect, 30-year A/FRB's could be structured as a series of shorter term maturities, for example 10 periods of 3 years each. A/FRB's, like F/FRB's, have mechanisms for fixing the rate if long-term rates become favorable.

St. Paul was able to save approximately 200 basis points in the 30-year tax-exempt revenue bond financing for the district heating project through the employment of a "lower floater" type of instrument. Under present interest rates (see Figure 3), savings on F/FRB's or "lower floater" type instruments compared to fixed-rate long-term bonds could be as significant as 400 basis points. However, the requirement for a letter of credit during the floating period of the bonds reduces such savings by at least 100–150 basis points. On balance, the approach of a floating fixed-rate instrument appears the most favorable and is being considered during the initial financial planning for the district heating project.

Economic Analysis

The economic analysis of hot water district heating in Jamestown was performed from the viewpoint of ownership by the City of Jamestown. The analysis determined the annual carrying charges for the system and the unit cost of district heat.

The required revenue approach was used to determine the necessary charges for district heating. The

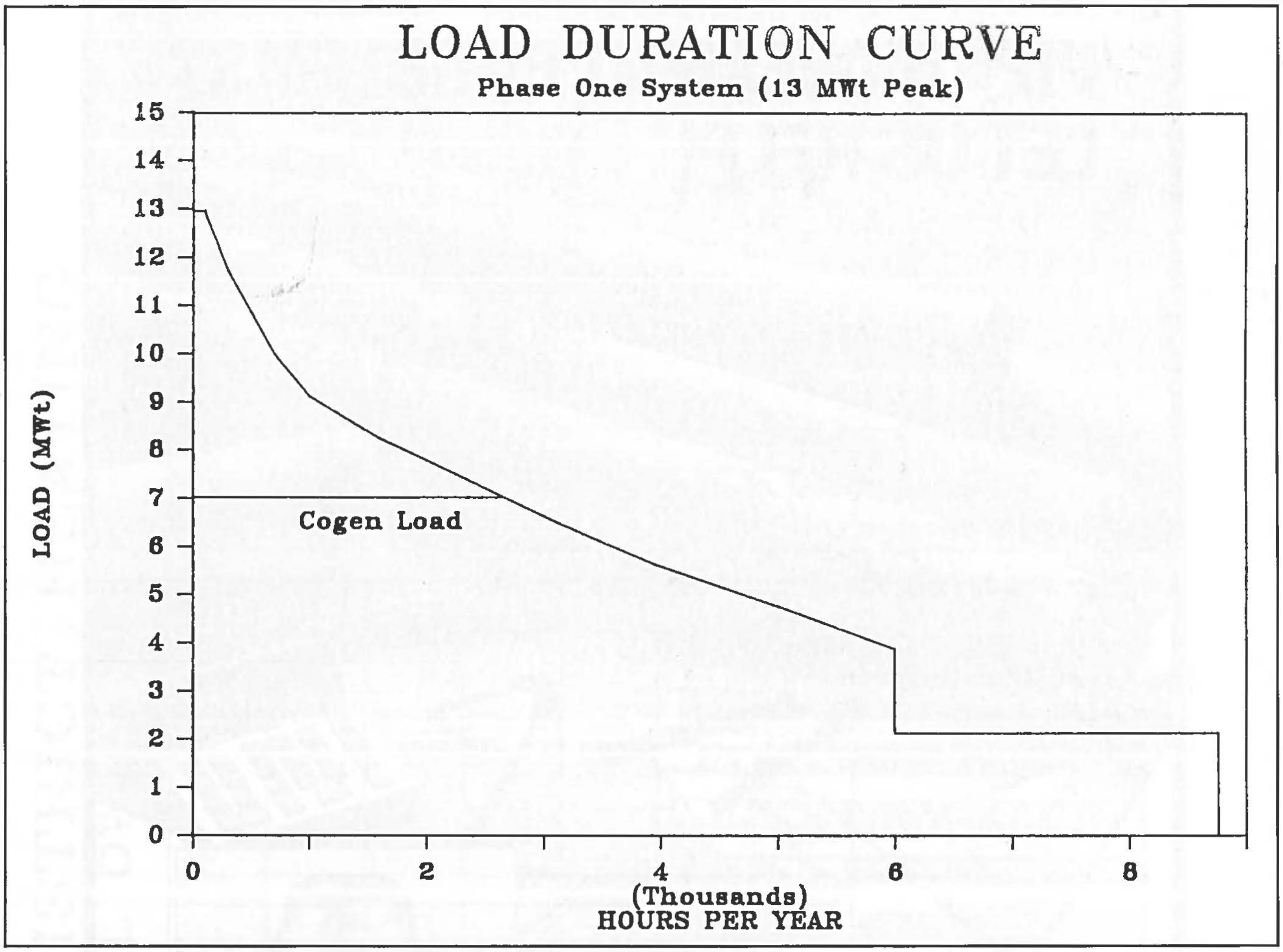


Figure 4

Chairman William D. Cotter (seated left) and Mayor Steven B. Carlson (seated center) discussing future expansion of the district heating system with (standing) Fred Strnisa, Marion Panzarella, James Pullan, Ishai Oliker, Douglas Champ and James Gronquist.

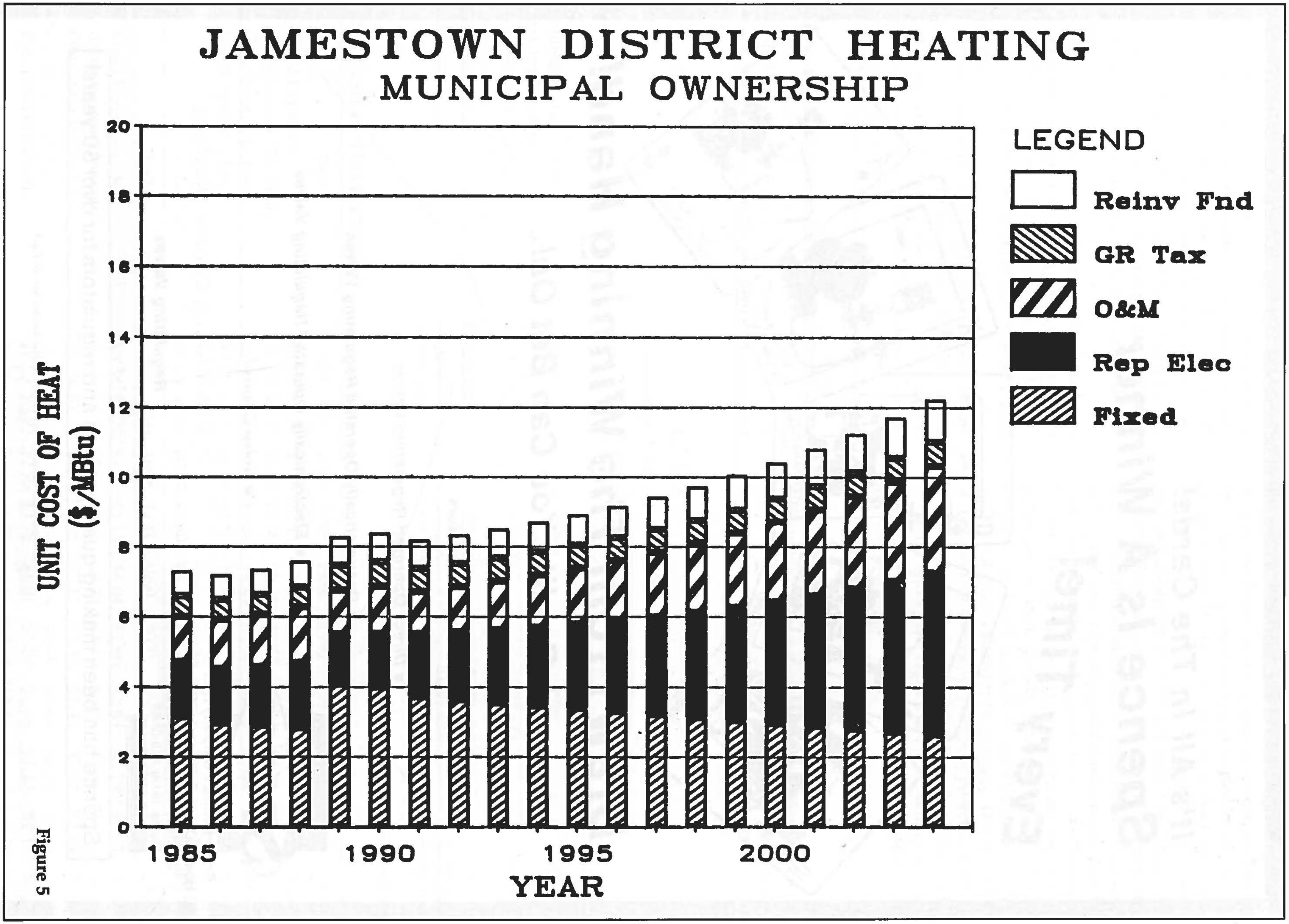

JAMESTOWN DISTRICT HEATING
MUNICIPAL OWNERSHIP
UNIT COST OF HEAT ($/MBtu)
YEAR
1985
1990
1995
2000
0
2
4
6
8
10
12
14
16
18
20
LEGEND
Reinv Fnd
GR Tax
O&M
Rep Elec
Fixed

Figure 5

annual carrying charges for the district heating investment were calculated based on 100% debt financing with bond rates of 7%. The method used was to develop the total system costs and compare these costs with the total quantity of heat sold to determine the minimum required charges for district heat. The total system costs are comprised of fixed expenses, operating expenses, replacement electricity and gross receipt taxes.

The capital costs were derived in 1984 dollars and then escalated to the year of expenditure at a rate of 6.5%. The capital costs include all direct and indirect costs associated with the power retrofit and the piping systems.

The annual carrying charges were based on the assumption that the entire system would be owned by the city and that the project would be financed using municipal bonds. The income and property tax rates for the utility are 0% and the insurance rate is 0.5%. The analysis was conducted for a 30-year book life.

The operating expenses for the district heating system are comprised of replacement electricity costs, pumping costs, operating and maintenance manpower, operating and maintenance materials, and steam costs. The replacement electricity costs are charged against the district heating system to compensate for the reduction in electrical output caused by the district heating retrofit. The replacement electricity and pumping costs are calculated using $30/MWh. Power costs are escalated at 7.5% per year. Operating and maintenance manpower for the system is estimated to cost $30,000 per man-year in 1984 dollars, escalated at 7.5% per year. Operating and maintenance material costs are estimated to be equal to 3% of the capital costs of the heat source and 1% of the capital costs of piping on an annual basis, escalated at 7.5%. Steam costs are calculated using $2.07 per thousand pounds in 1984 dollars, escalated at 1% per year. The quantities of replacement electricity, pumping power and steam are determined from a load duration curve (Figure 4).

Table 1 shows the results of the economic analysis and Figure 5 shows graphically the cost of district heat for a 7% bond rate.

Acknowledgements

We would like to acknowledge Andy Farmer, Robert Tom, Bashir Shaikh, William Major and Frank Silaghy for their help in preparing the original report.

Table 1
Economics Analysis Results
Bond Rate 7%

	Phase I	Phase II	Phase III	Phase IV
Implementation Date	1985	1986	1989	1991
Peak load (MWt)	12.96	16.50	30.70	76.20
Annual Sales (MBtu)	117,309	114,929	253,614	508,917
Investments (1984 Dollars)				
Power Plant	$ 633,000	157,000	2,473,000	0
Piping	2,558,000	394,000	1,789,000	5,330,000
Total	$3,191,000	551,000	4,262,000	5,330,000

UNIT COST OF HEAT ($/MBtu)

Year	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994
1. Fixed Expenses	$3.15	$2.96	$2.89	$2.83	$4.08	$3.99	$3.71	$3.63	$3.54	$3.46
2. Replacement Electricity	$1.59	$1.58	$1.69	$1.88	$1.44	$1.55	$1.82	$1.96	$2.10	2.26
3. Operating Expenses	$1.27	$1.39	$1.48	$1.57	$1.24	$1.33	$1.19	$1.28	$1.38	$1.48
4. Gross Receipts Tax	$0.59	$0.57	$0.56	$0.57	$0.71	$0.70	$0.67	$0.67	$0.66	$0.66
5. Reinvestment Fund	$0.73	$0.72	$0.74	$0.76	$0.83	$0.84	$0.82	$0.84	$0.85	$0.87
	$7.33	$7.22	$7.37	$7.60	$8.30	$8.42	$8.21	$8.37	$8.54	$8.73

Year	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
1. Fixed Expenses	$3.38	$3.29	$3.21	$3.13	$3.04	$2.96	$2.88	$2.79	$2.71	$2.63
2. Replacement Electricity	$2.43	$2.61	$2.81	$3.02	$3.25	$3.49	$3.75	$4.03	$4.34	$4.66
3. Operating Expenses	$1.59	$1.71	$1.84	$1.98	$2.12	$2.28	$2.45	$2.64	$2.84	$3.05
4. Gross Receipts Tax	$0.66	$0.66	$0.66	$0.66	$0.66	$0.66	$0.67	$0.68	$0.69	$0.70
5. Reinvestment Fund	$0.89	$0.92	$0.95	$0.98	$1.01	$1.04	$1.08	$1.13	$1.17	$1.23
	$8.95	$9.19	$9.46	$9.75	$10.08	$10.44	$10.83	$11.27	$11.74	$12.26