DISTRICT HEATING
in the
UNION OF SOVIET SOCIALIST REPUBLICS

WITH BRIEFS ON
OTHER EUROPEAN COUNTRIES

A Report of
THE NATIONAL DISTRICT HEATING ASSOCIATION
Prepared by its
Educational Committee

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National District Heating Association
121 South Highland Avenue
Pittsburgh, Pennsylvania 15206
1967
FOREWORD

In 1958, 1959, and 1963, the Edison Electric Institute sponsored technical exchange missions to the U.S.S.R. to obtain first-hand information about electric power developments. In 1963, the mission leader, Mr. Walker L. Cisler, suggested to Mr. N. M. Chuprakov, Deputy Chairman, State Production Committee for Power and Electrification, U.S.S.R.*, that an exchange in the field of district heating merited consideration.

This suggestion was accepted by both the U.S.S.R. and the U.S.A., and was catalogued as Item 14 in Section III of the "Agreement Between the U.S.A. and the U.S.S.R. on Exchanges in the Scientific, Technical, Educational, Cultural, and Other Fields in 1964-65."

In March of 1964, the Executive Board of the National District Heating Association accepted the task of organizing a mission group of six engineers knowledgeable in the district heating art. The State Department negotiated an itinerary which provided that the mission should arrive in Moscow on November 15, 1964, should visit, in order, Leningrad, Minsk, Kiev, Kharkov, Rostov-on-Don, and Irkutsk, and should leave not later than December 5, 1964.

While the above arrangements were being finalized, independent arrangements were made to visit Sweden en route to Moscow, and Finland and Denmark after leaving the U.S.S.R. This was done in order to obtain frames of reference other than those available in the United States and so to provide for more knowledgeable evaluation of facilities to be observed in the U.S.S.R. As a result, November 12, 13, and 14 were spent with

*See Glossary
representatives of the Electricity Board in Stockholm, Sweden; December 3 and 4 with representatives of the Helsinki Electricity Works in Helsinki, Finland; and December 8 and 9 with representatives of the Copenhagen Electricity Works in Copenhagen, Denmark.

The route travelled is shown on Plate I. A visit to Irkutsk, included in the original itinerary, was cancelled at the request of the group because of adverse flying conditions resulting from bad weather.

A report of the Union Internationale Des Distributeurs Des Chaleurs (Unichal) was obtained in Helsinki, which gave the status of district heating in other countries including Austria, Belgium, France, The Netherlands, Switzerland and West Germany. Similar data later became available from a report issued by the Ministry of Mines and Power of Roumania. The latter included estimated 1975 peak requirements for both heating and power.

The roster of the mission group is presented in Table A. Each participant is a member of the National District Heating Association and of its Educational Committee. All are graduate engineers experienced in district heating or in activities closely allied thereto.

No mission of this scope could have been possible without assistance and guidance from many sources. Deep appreciation is felt and expressed for such help received from those agencies and individuals listed in Tables B, C and D. There were many others, too numerous to include in the list who did much to enhance the success of the mission. Gratitude is felt toward each of these persons.
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** From data in the 1962 report of UNICHAL.
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- Growth of Kiev Distribution.
- Heating risers in prefabricated partitions.
- Piping diagram - Venturi mixing - Open system hot water.
- Piping diagrams - Pumped mixing - Open system hot water.
- Piping diagram - Venturi mixing - Closed system hot water.
- Flow diagram - Hasselby Plant.

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- Contributors to the Mission from:
  - a. The U.S.A.
  - b. The U.S.S.R.
  - c. Other Countries.
- Labor Compliments
- Cost levels of Heat Generation.
- Basic Tariffs
- Rate adjustments.
- District Heating in UNICHAL countries
- District Heating in Roumania
Table A

Members of The Mission.

ALTHOUSE, James W. Philadelphia Electric Company.
Assistant Superintendent,
Meter Division.

ANGELEY, Henry W. Aerco Corporation.
President.

BOWMAN, Urban A. Carrier International, Ltd.
Technical Manager-Special
Projects.

COLLINS, Leo F. * The Detroit Edison Company.
General Superintendent,
Central Heating Department.

MARTIN, Robert D. Consolidated Edison Company
of New York.
General Manager, Wholesale,
Governmental and Steam Sales.

MEGLEY, James W. ** Boston Edison Company.
Assistant Director, Rate, Research
and Forecasting Department.

*Leader of the mission.

** Deputy Leader of The Mission.

Time schedule of the mission:

November 10 to 14th: Sweden
November 15 to
December 3rd: Russia.
December 3 and 4: Finland.
December 5 to 10th: Denmark.
Table B

Contributors to the mission from
The United States of America.

From government agencies.

<table>
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<th>Name</th>
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<tr>
<td>KOHLER, Floyd D.</td>
<td>United States Ambassador to Russia.</td>
</tr>
<tr>
<td>STOESSEL, W. J.</td>
<td>Consul General, U. S. Embassy, Moscow.</td>
</tr>
<tr>
<td>SCHWEITZER, Glen</td>
<td>Counselor for Scientific Affairs, U. S. Embassy, Moscow.</td>
</tr>
<tr>
<td>STOLTZ, R. F. Jr.</td>
<td>First Secretary, U. S. Embassy, Moscow.</td>
</tr>
<tr>
<td>BYRD, Pratt</td>
<td>EUR-SES, U. S. Department of State, Washington, D. C.</td>
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From Industry

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<th>Name</th>
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<tr>
<td>ANGELERY, H. W.</td>
<td>President, Aerco Corporation.</td>
</tr>
<tr>
<td>AVILA, C. F.</td>
<td>President and General Manager, Boston Edison Company.</td>
</tr>
<tr>
<td>BYNUM, William</td>
<td>President, Carrier Corporation.</td>
</tr>
<tr>
<td>CISLER, W. L.</td>
<td>Chairman, Board of Directors, The Detroit Edison Company.</td>
</tr>
<tr>
<td>EBLE, C. E.</td>
<td>President, Consolidated Edison Company of New York.</td>
</tr>
<tr>
<td>RINCLIFFE, R. G.</td>
<td>Chairman, Board of Directors, Philadelphia Electric Company.</td>
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From Technical Associations

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<th>Name</th>
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<tr>
<td>BUMGARDNER, H. E.</td>
<td>Secretary, World Power Conference.</td>
</tr>
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Table C

Contributors to the Mission from the USSR.

From the State Committee for Coordination of Scientific Research, RSFSR Council of Ministers.

<table>
<thead>
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<th>Name</th>
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<tr>
<td>PETRIKOVSKI, Boris S.</td>
<td>Chairman</td>
</tr>
<tr>
<td>POPOV, M. N.</td>
<td>Vice Chairman</td>
</tr>
<tr>
<td>FEODOROV, A. A.</td>
<td>Chief of Foreign Relations Department</td>
</tr>
<tr>
<td>FOOGENFICOV, E. M.</td>
<td>Assistant Chief of the Energetics Department</td>
</tr>
<tr>
<td>LIOHOVETSKY, G. E.</td>
<td>Senior Specialist of The Energetics Department</td>
</tr>
<tr>
<td>VOZNESENSKIY, Igor S.</td>
<td>Senior Expert, Foreign Relations Department</td>
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<tr>
<td>BOITSOVA, Sophia.</td>
<td>Guide and Interpreter, Foreign Relations</td>
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From the Moscow Power Administration-(Mosenergo)

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<tr>
<td>NEMOV, A. P.</td>
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<td>POZDNIAK, A. A.</td>
<td>Assistant Chief Engineer.</td>
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<tr>
<td>SHITSMAN, Semoon.</td>
<td>Assistant Chief Operating Engineer.</td>
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From the Lenengrad Power Administration.- (Leninergo).

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<tr>
<td>SIDOROV, M. M.</td>
<td>Chief Engineer</td>
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<tr>
<td>GLOTOV, A. V.</td>
<td>Assistant Manager</td>
</tr>
<tr>
<td>MAISAK, E. Z.</td>
<td>Chief of Technical Department</td>
</tr>
<tr>
<td>KHORDORKOV, L. A.</td>
<td>Director, Heating Systems.</td>
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<tr>
<td>KOSTENKO, L. T.</td>
<td>Chief Engineer, Heating Systems.</td>
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<td>YEVELEVA, K. A.</td>
<td>Director of the Laboratory.</td>
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From the Kiev Power Administration, -(Kievenergo).

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<tr>
<td>ZUBANOV, K. V.</td>
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<tr>
<td>PODGAJEVSKY, V. L.</td>
<td>Chief Engineer</td>
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<tr>
<td>BLANKMAN, V. D.</td>
<td>Chief Engineer, Heating Systems</td>
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<tr>
<td>ISHENKO, A. I.</td>
<td>Senior Engineer, Technical Department</td>
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From the Kharkov Power Administration, -(Kharkovenergo)

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<td>BRUSENTSOV, P. F.</td>
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<td>BELOKHVOSTIKOV, F. L.</td>
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<td>ZAJETS, I. S.</td>
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From the Main Board for Energetics, Council of Ministers, Republic of Byelorussia.

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<td>RUTSEVICH, V. C.</td>
<td>Chief Engineer</td>
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<td>STOLOV, N. A.</td>
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<td>BARBASHEVICH, I. A.</td>
<td>Chief, Heating Systems</td>
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From the Rostov Power Administration, -(Rostovenergo).

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<td>BUSOKINA, A. V.</td>
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<td>BUNTSEV, V. J.</td>
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PART I

DISTRICT HEATING IN THE U.S.S.R.
INTRODUCTION

District heating* in the U.S.S.R.* is an extensive and rapidly expanding "enterprise." The current level of energy supplied annually to the heat distributing systems, expressed in terms of equivalent steam*, exceeds 1500 billion pounds. Its growth rate is of the order of 7 percent per year.

More than 60 percent of such energy is supplied via systems operated by regional administrations of the State Production Committee for Power and Electrification. The balance is supplied either from municipally operated plants serving medium sized communities or from plants associated with industrial enterprises. The latter, in addition to providing the steam requirements of the industry also supply heat to the nearby community.

The systems operated by the regional administrations are analagous to the concept of district heating as accepted in the U.S.A., with the exception that more than 70 percent of their output is supplied as industrial process steam. Of the total regional output, 670 billion pounds are used for industrial purposes and 290 billion pounds are supplied for space and water heating in commercial and residential structures.

In concept, district heating for all buildings supplied from combination "Thermal Electric Stations" (Tets*) generating both electric and heat energies is the ultimate goal, and this is so because it is profitable. Inquiry reveals that such profitability is credited to (a) improved hygienic conditions resulting from the elimination of individual building stacks, (b) reduction in the amounts of fuel and ferrous resources that must be committed to the production and distribution of heat and electric energy, and (c) reductions in manpower requirements.

*See Glossary for definition.
PLATE II
TYPICAL APARTMENT STRUCTURES
Among other facets is the capability to control the load characteristics by locating the Tets close to industrial plants having year-round process steam requirements. The greatest single factor contributing to the implementation of the district heating concept has been the extensive program of apartment house construction carried on since the late Forties. (see Plate II) The glimpses that one gets of the remaining pre-war housing accommodations give dramatic evidence of the tremendous need that must have existed for housing. It emphasizes what must have been a very practical necessity for giving quantity a higher priority than either quality or appearance.

Just as these urgent needs for dwelling units took advantage of the high quantitative capabilities afforded by totally prefabricated construction practices, the selection of the methods for providing energy requirements was predicated upon obtaining the most effective and efficient use of available resources and capabilities.

Thus most new construction in urban areas obtains its heating services from a district heating system. Except where industrial steam is supplied, heating service is distributed using medium temperature water (300 F). Heat input to such systems is obtained from district boiler plants* and/or from Tets.

The district boiler plants (see Plate III) are located within the immediate area served and generate medium temperature water directly. Such plants serve relatively localized areas. The trend is towards the interconnection of these plants, with the ultimate goal being to supply all heating service from Tets.

*See Glossary for definition.
FIGURE 1

HEAT ENERGY PRODUCTION IN U.S.S.R.

HEAT ENERGY PRODUCTION IN THE USSR
IN TERMS OF
EQUIVALENT POUNDS OF STEAM

LEGEND
CURVE A = TOTAL
CURVE B = REGIONAL
CURVE C = INDUSTRIAL & MUNICIPAL

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Ø ESTIMATED OR PLANNED

PLATE III

DISTRICT BOILER PLANT
Figure 1 reflects the growth of district heating in the U.S.S.R. between 1950 and 1965. The leveling off of expansion in industrial and municipal plant growth is obvious from Curve C, while the increase in the growth rate of Tets is equally obvious from Curve B.

Very little variation was noted in plant and system characteristics from one city to another. Steam is supplied at distribution pressures ranging from 60 to 240 psi so as to satisfy the needs of the particular utilization process.

Medium temperature water distribution may be direct from the stations to groups of buildings or through intermediate heat exchanger substations from which secondary mains transport the heat to the buildings.

A substantial degree of control of building temperatures is obtained by varying the temperature of the water leaving the heating plants.

Domestic hot water, in most cases, is obtained via a heat exchanger arrangement. In some areas, where the quality of the make-up water permits, the domestic water is drawn from the heating system.

The prevalent method of allocating costs to the tenant is an assessment based on the area of the apartment (sometimes excluding kitchen, bath, and closet areas) and upon the total number of occupants thereof.

A typical apartment occupant pays the equivalent of about $33.60 per year for heat and, with an occupancy of four, $21.12 per year for domestic hot water. These prices reflect the arbitrary exchange rate of $1.10 per ruble. When referenced to an index of relative income, they are not as low as the dollar quantities seem to indicate.

The regional administrative organization is sharply functional, pyramiding downward from the top echelon committees through the state and
local level committees to the staffs of the individual systems and plants. The staff organization follows normal departmental lines.

Financial control and expansion policy appear vested in the Financial Ministry of each republic. This State Committee sets the allocation to be made between the State treasury and the local Power administration, of the revenues received for the electric and heating services. About forty percent accrues to the local administration thus becoming available for operational expense and for expansion funds.

Expansion may be instigated by proposals from the local administration. In the event the local administration is directed to carry out expansions beyond that which their funds can support, financial aid is forthcoming from higher authority.

The Financial Ministry also controls the rates to be charged to consumers. These are adjusted from time to time so as to insure that the operation will be on a profitable basis.

Although the winter climate is relatively more severe in the U.S.S.R. than in the U.S.A., the annual load factors of the heating operations are basically similar. Leningrad was the most northern city visited. The annual load factor of Tets No. 3 in that city was about 23 percent.

Direct degree day comparisons are not fully realistic. The buildings in the U.S.S.R. are heated to a maximum temperature of 64 F. Because of the temperature control method, the assumption that this temperature is continuously and uniformly maintained is probably optimistic.

One interesting feature of the U.S.S.R. weather pattern is that as one goes eastward the isothermal lines* become longitudinally oriented in contrast to the lattitudinal orientation familiar in the U.S.A.

More detailed descriptions, technological detail, and appraisals of interest are presented in subsequent sections of this report.

*See Glossary for definition.
HEAT PRODUCTION

Over four hundred Tets are in operation and many more are planned. Approximately one hundred and fifty are operated under the regional administrations of the State Committee for Power and Electrification. The remainder are operated by municipalities or by local industrial enterprises.

In the district boiler plants, package type* hot water boilers are used exclusively. Usually they are gas and/or oil fired, are automated and float on the line. Their cost is said to be about one-half that for steam generators of equivalent heat output.

Development of Tets

Starting in 1948, boilers designed for 350 psi* and 932 F were put into operation. Turbo-generators of 25 megawatt (MW) capacity, with extraction at 15 to 25 psi for heating water for space heating and extraction at 120 to 195 psi to provide steam for industrial uses, were standard during the early 1950's.

After 1955, a new series of steam turbines appeared with design steam conditions of 1,350 psi and 1,000 F, and/or of 1,950 psi and 1,050 F. These units have capacities of 50 MW. When hydrogen cooled, they can be operated at capacities up to 60 MW. They are installed in many of the large Tets built at petroleum refineries, suburbs of large cities, and other places needing larger amounts of heat and power.

In 1963, the first models of a series of 100 MW thermal were placed in operation at Moscow Tets No. 20 and Minsk Tets No. 3, operating at 2,100 psi and 1,065 F.

Such units will be standard throughout the sixties for new installations in very large Tets. Thermal units with a capacity of 250 MW are being developed but may not be in operation for several years. Units within the range of 500 to 800 MW were reported to be in the design stage.

*See Glossary for definition.
Facilities Visited

A total of eight regional Tets and three local boiler plants were visited. Architecturally, all conformed closely to Tets 16, operated by the Mosenergo.* (See Plate IV) The grounds were securely fenced, the roadways narrow and of macadam or gravel construction.

The general appearance of the structures and of the mechanical equipment indicates that priority is given to "make do" functionality and performance, to low manufacturing and installation costs, rather than to external appearance.

Laydown areas* for major maintenance are limited. Lighting, heating and ventilation facilities are equivalent to U.S.A. practices circa 1930.

In contrast, virtually all of the technological refinements common to American power plants of the same vintage are in evidence. Instrumentation is plentiful. Safety devices (ladders, guard rails, etc.) appeared ample. Most boilers are equipped to burn locally available fuels which are predominantly low grade coal and/or natural gas. Housekeeping compares favorably with that found in the U.S.A.

Operating efficiencies for summer, when running as a condensing plant were 28 to 30 percent. However, in the winter when most of the extracted or exhaust heat from the turbo-generators was used for district heating purposes, the overall thermal utilization efficiencies were reported to be in the order of 80 to 90 percent. The annual average was considered to be in the 45 percent area.

Personnel

Sampling in Leningrad and in Kiev, relative to plant personnel, gave the data shown in Table E.

*See Glossary for definition.
Table E

Labor Complements for Tets Plants

<table>
<thead>
<tr>
<th></th>
<th>Leningrad Station #2</th>
<th>Kiev Station #4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Installed capacity - megawatts</td>
<td>96</td>
<td>250</td>
</tr>
<tr>
<td>Number of boilers</td>
<td>6</td>
<td>9</td>
</tr>
<tr>
<td>Operating and Maintenance personnel</td>
<td>400</td>
<td>450</td>
</tr>
<tr>
<td>Supervision and Clerical</td>
<td>60</td>
<td>90</td>
</tr>
<tr>
<td>Technical (Engineers)</td>
<td>-</td>
<td>110</td>
</tr>
</tbody>
</table>

Compared to U.S.A. practice these complements are high. The number of women employed and the tasks performed by them seemed amazing. They were performing duties such as those of firemen, crane operators, turbine operators, insulation applicators, etc.

In discussing these complements, it was indicated that in Tets:

1. The ratio of operators to maintenance workers is normally about one to one.

2. Little on-the-job training is done. Most workers become qualified through technical school training supplemented by limited in-plant experience.

3. Supervisory and professional people are selected principally on the basis of their scholastic records.

In the Kievenergo, it was indicated that district heating enterprises employ about 7,500 people. Of the total, some 800 are college trained and 1,000 are technicians.

In Kharkov, it was indicated that the wages of plant operating supervisors vary between $165 and $190 per month; that the average wage for operators is about $140 per month; and that it is possible to earn bonuses of up to 40 percent of base wages through exceptional performance. However, the basis for determining the levels of such bonuses was not obtained.
Production Costs

Production cost data are catalogued in Table F.

Table F

Cost Levels for Heat Generation

<table>
<thead>
<tr>
<th>System Location</th>
<th>Total Cost*</th>
<th>1960**</th>
<th>1963***</th>
</tr>
</thead>
<tbody>
<tr>
<td>Minsk</td>
<td>$1.13</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>Kiev</td>
<td>0.84</td>
<td>$1.08</td>
<td></td>
</tr>
<tr>
<td>Kharkov</td>
<td>0.81</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>Leningrad</td>
<td>1.39</td>
<td>1.18</td>
<td></td>
</tr>
<tr>
<td>Moscow</td>
<td>1.08</td>
<td>0.96</td>
<td></td>
</tr>
</tbody>
</table>

*Dollars per 1000 pounds of steam or equivalent, based on $1.10 per ruble exchange rate.

**Published data.

***Quoted to the mission.

Mosenergo - Moscow Power Administration

The Mosenergo embraces eight districts. In addition to a number of district boiler plants ten Tets are in operation. Tets No. 16 (Plate IV) is the oldest, its first stage having been put in operation in 1955 with a second stage operating in 1960. A third stage is under construction.

Coal from the Donets Basin is the predominant fuel burned during the cold weather. The warm weather fuel is natural gas.

Coal is delivered by rail in trains comprising 32 to 38 cars. A complete train must be unloaded with a 6-hour period to avoid penalties. When the coal is frozen, a novel device, consisting of four augers driven by two 55-horsepower motors, is used to supplement car shakers. With this system six men can unload a car in approximately five minutes. All unloading and coal storage facilities are under roof in order to minimize the detrimental effect of dust on the hygienic conditions of the adjacent areas.
Tets No. 20 is a more modern station and ultimately will be the largest of the Mosenergo stations. Three of its present boilers deliver 375,000 pounds per hour. Three others have a capability of 500,000 pounds per hour. In all boilers steam conditions are 1650 psi and 950 F.

Four 25 MW and one 50 MW turbo-generators deliver up to 1,000,000 pounds of exhaust steam at about 30 psi to the district heating system hot water boilers. This plant is being expanded to a capacity of 550 MW, at an estimated cost of $120.00 per KW.

The first 100 MW turbine of the extraction type to be used in the U.S.S.R. went into operation in October 1963. Steam conditions are 1950 psi and 1050 F. A similar unit is under construction, and two more are planned. When the second unit is completed, the station is expected to have a heat send-out capability equivalent to about 6.5 million pounds per hour of steam.

Lenenergo - Leningrad Power Administration

The electrical capability of the Lenenergo region is in the order of 700 MW. There are 110 KV interconnections with a northwest power grid which covers Latvia, Estonia, White Russia and parts of Finland. Interconnection with the Moscow area is available via a railroad electrification system. Planning provides for future interconnections with the Russian-Central European system.

About eighty percent of the generated power is derived from thermal operations, the remaining twenty percent being hydro. About thirty-five percent of all space heating in Leningrad is currently supplied via district heating facilities. The area so supplied is essentially in the central part of the city. The total maximum demand is the equivalent of about 9,000,000 pounds of steam per hour. Approximately one-half of this heat is obtained from turbine exhaust. The balance is supplied directly from low pressure steam or hot water boilers. Typical inside views are shown on Plate V.
PLATE V

MISCELLANEOUS EQUIPMENT VIEWS

Booster pumping station  Heat exchange station
Tets No. 2 is equipped with four 24 MW turbo-generators and six boilers. Three of the boilers operate at 450 psi and three at 1500 psi. Two of the turbines are equipped for either extraction or condensing operation. Of the other two, one is a straight condensing unit and the other is solely a back pressure machine.

Over-all thermal utilization efficiencies were cited as 28 percent for condensing operation whereas back pressure operation during peak heating periods reached a high of 91.5 percent.

Fuel may be either coal or gas with the latter apparently the more utilized. Storage facilities for a four months' supply of coal are available. The latter fuel serves mostly to supplement gas during peak heating periods.

A novel feature of Tets No. 2 is the use of a heat storage system. Heat is accumulated in two tanks each having a capacity of 525,000 gallons of water. During periods when the availability of exhaust steam exceeds the requirements of the district heating system, the excess heat is used to raise the temperature of the water in the accumulator tanks to 305 F. This reserve is used to supply heat to the district hot water system when the electric power loads are low and available exhaust is inadequate.

Tets No. 15 supplies the heat equivalent of about 4 billion pounds of steam per year. Its utilization is divided as follows:

<table>
<thead>
<tr>
<th>Utilization</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Space heating</td>
<td>76 percent</td>
</tr>
<tr>
<td>Domestic hot water</td>
<td>18 percent</td>
</tr>
<tr>
<td>Industrial steam</td>
<td>2 percent</td>
</tr>
<tr>
<td>Unaccounted for</td>
<td>4 percent</td>
</tr>
</tbody>
</table>
Minsk - Main Board of Energetics

In 1963, the district heating enterprise delivered the heat equivalent of 8 billion pounds of steam to provide the requirement for space and domestic water heating for fifty-three percent of the residential and commercial structures in the city of Minsk. In addition to this which was generated in two Tets, over one billion pounds of steam at pressures of 120 to 200 psi were supplied to industrial consumers. The two Tets are interconnected.

Tets No. 3 has an aggregate electric generating capability of 400 MW. In the original section, four 1500 psi, 500,000 pound per hour boilers supply steam for four 25 MW turbo-generators.

In the newer section, 100 MW generators are installed and the boilers operate at 1,950 psi. This station is the backbone of the Minsk system. Coal, peat, oil, and natural gas are used. Plans call for constructing Tets in some 28 other towns in Byelorussia.

Kievenergo - Kiev Power Administration

Four Tets are in operation within the city of Kiev and in addition a number are operating elsewhere throughout the Kievenergo.

The heat generating capability of each of the Kiev plants expressed in terms of equivalent steam is as follows:

- Tets No. 1 - 100,000 Lb. per Hr.
- Tets No. 2 - 40,000 Lb. per Hr.
- Tets No. 3 - 1,325,000 Lb. per Hr.
- Tets No. 4 - 3,875,000 Lb. per Hr.

Tets No. 4 served as a prototype for a series of plants built in Ivanova, Riga and elsewhere during the 1950's. It is equipped with nine boilers. Each of five boilers deliver 375,000 pounds of steam per hour at 1350 psi. The other four operate at 1950 psi and are capable of producing 500,000 pounds per hour each. Electric power is generated with seven machines having an aggregate capacity of 250 MW.
Up to 4500 tons of 10,000 BTU per pound coal are burned per day. Natural gas is also used. Annually the fuel consumption is divided between 63 percent coal and 37 percent gas. The latter is used almost exclusively during the summer. Condenser water is obtained via six cooling towers each containing about 35,000 gallons of water.

Kharkovenergo - Kharkov Power Administration

The Kharkov district heating system can deliver the heat equivalent of 3.5 million pounds of steam per hour. In addition steam to industrials is supplied at 180 psi.

An interesting feature encountered in Tets No. 3 was a 50 MW experimental gas turbine which was under development and test. Short duration tests up to loadings of 30 MW had been made.

The installation appeared to have been assembled with available used components of major equipment (generators, compressors, etc.) augmented by auxiliary facilities fabricated at the site. It embodied two turbine stages with the equipments being assembled on two adjacent parallel shafts.

Ceramic materials were largely used in the heat exchangers between the exhaust gases and the heating system water. The feasibility of fully firing the turbine exhaust gases in the combustion chamber of conventional boilers was also under study.

Rostovenergo - Rostov Power Administration

The city of Rostov-on-Don has three district heating areas. The central area is supplied from a Tets and the north and west areas from local boiler plants. The development of an eastern district is contemplated, using district boiler plants rather than Tets. It was stated that "it was not profitable" to build a Tets because of the small requirement for industrial steam. The industrial use is considered necessary to provide a year-round balance between electric and heat loads adequate to insure economical operation of the Tets concept.

The temperature regulation as shown on the chart for the Northern district system of Rostov is typical of all systems, (Figure 2).
FIGURE 2
TEMPERATURE REGULATION

"TEMPERATURE GRAPH"
"REGULATION OF LEAVING TEMPERATURE FOR NORTHERN DISTRICT, HEATING SYSTEMS SUPPLY AND HEATING RETURNS"
(COPY & TRANSLATION OF CHART RECEIVED IN ROSTOV)

TEMPERATURE BUILDING SYSTEM RETURN WATER
TEMPERATURE BUILDING SYSTEM SUPPLY WATER
TEMPERATURE PLANT SENDOUT WATER
TEMPERATURE HEATING SYSTEM (°F)

OUTSIDE TEMPERATURE -( DEG. F.)

Typical, for all systems
HEAT DISTRIBUTION

Steam for industrial use and hot water for district heating are both supplied by all Tets. Hot water for district heating is also obtained from district boiler plants.

Steam Systems

Steam lines are normally installed in prefabricated conduit made of reinforced concrete bases and roofs, and brick or concrete side walls. Prefabricated segments of thermal insulation, comprised of mineral wool and diatomaceous earth, are applied to the pipe prior to installation. When in place and before the roof of the conduit is put on, the insulated line is wound with an asbestos sheet. Line movement is provided for by resting the insulated pipe on metal supports that slide on concrete pillows. Anchors and expansion joints are provided at strategic points.

Steam pressures vary from 40 to 240 psi, with temperatures up to 400 F. The temperature range cited implies that superheated steam is not distributed.

Hot Water Systems

It was stated that hot water rather than steam is used as the distribution medium in district heating systems for the following general reasons:

(a) It lowers the investment requirements of the distribution systems.

(b) It facilitates the control of temperatures by plant technicians rather than by consumers.

(c) The temperature levels that can be used minimize thermal distribution losses and maximize the scavenging of heat at the generating station.
Regulations stipulate a minimum temperature of 149 F for domestic hot water and for safety reasons that the temperature of the water circulated through building heating systems shall not exceed 200 F. The inside design temperature for space heating is 64 F. To compensate for variations in outside temperatures and in distribution system characteristics, the temperature of the water leaving heat generating stations is regulated in accordance with schedules such as those shown in Figure 2. Thermal losses are reported to range from 7.5 percent to 10 percent annually. The main circulating pumps are located in the Tets and are regulated to maintain stipulated pressures up to 250 psi. Pipelines are sized so that velocities in the distribution system mains are of the order of 6 feet per second, and in services about 3 feet per second. Pumping power is quoted at about 25 Kwh per thousand gallons of water circulated.

Construction Methods - (See Plate VI)

It is common practice with hot water distribution systems to bury factory insulated pipe directly in the earth.

Under-drains are provided in an effort to control the moisture content of the fill surrounding the pipes. However, it is difficult in Leningrad where surface water is reported to be within 27 inches of ground level in some areas. For the most part, pipes are buried at depths of from 4 to 6½ feet, depending upon the frost conditions in the area. In Leningrad, the normal frost line was reported to be at 5 feet.

Heavy concrete anchors are placed at necessary intervals to restrict movement of the pipes due to thermal expansion. Provision is made for expansion at turns of the distribution piping by placing the pipes in prefabricated concrete channels having sufficient clearance to allow for pipe movement.
PLATE VI

DISTRIBUTION METHODS

The pressure foundation for a water main in cellular concrete
needs firm bearing material such as gravel or sand. The mixture is applied to
the pipe in section, and is covered with a high cover mix
and 10 cm space of some insulating material to prevent the supply from
loss. The pipe is filled with a plug of insulating material and on top of it
opened to allow material to run through to the supply head.
The preferred insulation for hot water mains is cellular concrete made from porous materials such as expanded slag. The material is applied to the pipes in factories, and is retained with a light steel mesh wire. About four inches of such insulating material is applied to the supply lines, and lesser amounts to the return lines. Prior to the application of the concrete, a protective coating of bitumen or other impermeable coating is applied to the pipe to control corrosion. An outer covering of about 1/2 inch to 1 inch of hard surface concrete is applied to provide mechanical durability in service and in handling.

The pipe sections are welded electrically in the trenches and the completed joints are then coated with bitumen and insulated with cellular concrete. The back-fill around the pipes is generally sand or other good draining soil.

Typical construction costs for distribution mains in Leningrad were reported to be as follows:

<table>
<thead>
<tr>
<th>Pipe Diameter</th>
<th>Soil Conditions</th>
<th>Cost - Dollars per Linear Foot</th>
</tr>
</thead>
<tbody>
<tr>
<td>40 Inches Wet</td>
<td>66</td>
<td></td>
</tr>
<tr>
<td>20 Wet</td>
<td>33</td>
<td></td>
</tr>
<tr>
<td>40 Dry</td>
<td>54</td>
<td></td>
</tr>
<tr>
<td>20 Dry</td>
<td>26</td>
<td></td>
</tr>
</tbody>
</table>

The reference to wet and dry soil conditions reflects the difference in costs due to the ground conditions experienced in the Leningrad area. The values given are based on the official rate of exchange between the U.S. dollar and the Russian ruble, and since there is no free money market for the exchange of Russian currency, the absolute costs cannot be compared directly with those in the United States. However, the relative costs between pipe sizes and ground conditions are of some significance.
Corrosion

Since the distribution systems are installed using pipe with minimum wall thicknesses, it becomes very important that all possible efforts be made to control corrosion. Laboratories are maintained to continuously monitor and control the effects of corrosion.

A typical laboratory visited cited as some of its responsibilities, analysis of distribution system water, control over water treatment to maintain chemical character within standards prescribed by the laboratory, continuing research of field conditions, technical direction of procedures to combat corrosion in the distribution system. The latter covers all facets such as construction methods, pipe metallurgy, electrolytic considerations, the interaction of materials such as insulation, etc., that could in any way effect corrosion.

Bitumen coatings are in regular use to control corrosion. Since 1961, external protection has been provided by first wrapping the pipe with a cotton fabric impregnated with asbestos and rubber. This coating is also applied to the welded joints in the trenches before covering them with thermal insulation.

Prior to the time that specific efforts were made to control corrosion, pipes with walls of about 1/4 inch were penetrated within six months. It is stated the life of similar pipes is now ten years or more.

A particular problem persists at a point about three feet outside of manhole walls, where external pipe corrosion is common. It is reported to result from the settling of the manholes and/or movement of the pipe which cracks the insulation and allows water to penetrate to the pipe surface with the result of intensive corrosion in these areas.
Some control of electrolytic corrosion is claimed for the cellular insulating concrete used as pipe covering. This is said to have a very high electrical resistance when in a dry state. Good drainage under the pipelines keeps this concrete dry, thus, maintaining the high resistivity and minimizing the flow of electrolytic current. As much as sixteen years of satisfactory experience with this type of insulation is reported.

In Moscow, hot water mains and services aggregate some 500 miles and steam mains about 32 miles. Hot water mains up to 48 inches in diameter and 6 miles long are employed. Main extensions and services are growing at the rate of 60 miles per year. A total of 19,000 buildings are supplied with hot water and 300 industrials with steam.

In Leningrad, water heating mains and services aggregate about 450 miles. Mains as large as 40 inches in diameter are sometimes used. They are buried from 48 to 80 inches below the surface. Provision is made for pipe movement by use of prefabricated concrete channels at turns. Mains are protected under street crossings by similar channels or by an outer conduit (Plate VI).

In both Minsk and Kiev, the length of heating mains and services totals 100 to 150 miles. In these cities booster pumps are required because of the hilly terrain. Figure 3 shows the growth rate of the distribution system in Kiev.

In Kharkov, heating mains and services total about 180 miles.

In Rostov-on-Don, there are three major distribution systems plus a number of smaller systems. In the center of the city, some distribution piping is housed in walk-through tunnels.
FIGURE 3

GROWTH OF KIEV DISTRIBUTION

GROWTH OF DISTRICT HEATING DISTRIBUTION IN CITY OF KIEV

YEAR

TOTAL MILES OF STEAM & HOT WATER DISTRIBUTION SYSTEMS

1940 1945 1950 1955 1960 1965

FIGURE 4

HEATING RISERS - PREFABRICATED PARTITIONS

HEATING RISERS IN PREFABRICATED WALLS, APPROXIMATION OF PIPING CONNECTIONS.
HEAT UTILIZATION

No steam utilization equipment was observed. Consequently, the following comments relate solely to the facilities providing hot water space heating and domestic hot water.*

Architectural Considerations

Virtually all buildings constructed since World War II are assemblies of factory prefabricated sections and components. Those currently under construction are being equipped with kitchen and bathroom facilities prefabricated as a unitary package.

Apartment construction (Plate VII) is somewhat modular in design. Four apartments on each floor are accessible from a common entrance. Thus, in a five story structure, 20 units would be so accessible. The modules are constructed so that the total number of apartments housed in a contiguous structure ranges from 80 to 160.

A typical apartment unit contains about 450 square feet of floor area. More spacious units are available in limited numbers and at higher rentals in "cooperative units." A project comprises a cluster of apartment structures plus service facilities such as laundries, shops, restaurants, gymnasiums, schools, etc.

All construction appears to be designed in a manner to afford the greatest conservation of materials, particularly metals, speed of erection, and functionality. They are devoid of frills. Because they are prefabricated, their erection necessitates a minimum of skilled mechanics in the field. Closet space is limited, incinerators are not provided, and elevators are installed only in buildings that exceed five stories. Concrete is the predominant material used.

*See Glossary for definition.
4,000 room hotel - Moscow

Floor plan of model apartment building

Construction method

New apartment
Building Heating Equipment

The building heating systems are similar to a one-pipe forced hot water system with vertical instead of horizontal mains. Balancing is accomplished without special fittings by several methods of flow control and by compensating for temperature drop with an increase in radiation surface towards the end of the supply loop.

One arrangement of particular interest, was the prefabricated installation of an insulated section of a heating riser in an inside partition wall at a point near where the partition would abut the outside wall of the structure (see Figure 4). In this arrangement, heat loss from the riser served the additional function of keeping the mastic in the joint of the outside wall at this point at a temperature high enough to prevent embrittlement during cold weather.

At each floor level, connections between the vertical supply risers are accomplished by a piping by-pass which connects to the room radiator. In some cases a small additional pipe by-pass is provided around the radiator. Heat balance is then obtained by "pinching" the latter by-pass as a means of flow control.

All apartments visited were heated with hydronic systems with the exception of one five-story unit. The latter was equipped with a forced warm air system of rather poor concept. The latter supplied 100 percent outside air to the structure. A centrifugal fan drew outside air through a steel tube, steel finned hot water blast coil exchanger. Filtering was limited to a coarse mesh screen over the outside air intake.

No provision was made for recirculation. Air was exhausted solely via natural exfiltration through bathroom vents, attic exhaust grills and leakage. Insulated ducts running horizontally through crawl spaces, delivered air to vertical ducts supplying the apartments.
PLATE VIII

RADIATION

LATEST CONVECTOR DESIGN

QUASI "BASE-BOARD" TYPE.
(OBSERVED IN NEWEST APARTMENT HOUSE IN MOSCOW)
STAMPED STEEL CONTINUOUSLY WELDED EXTENDED
SURFACE TIGHTLY FITTED TO STEEL TUBING.
APPROX. 3" DEEP BY 6" HIGH FREQUENTLY CONNECTED
IN SERIES—CONVECTORS VARY IN LENGTH.
The installation including the equipment was, quite obviously, of inadequate design and poorly assembled. Its performance was admittedly well below acceptability.

Hot water radiation was predominantly of the free standing cast iron column type. (Plate VIII). Some steel finned radiation was seen in the newest buildings. The design of the latter radiation is also shown on Plate VII. Its construction indicated the use of good automatic tooling. No non ferrous equipment was encountered.

In a new nine-apartment building in Moscow, (Plate IX) the entrance lobby was heated by a built-in stack type convector with finned hot water coils. Air intake was at the floor and the discharge was near the ceiling. This unit heated the entrance lobby directly and the elevator shaft, and stair wells by gravity circulation. This was a departure from the traditional use of cast iron hot water radiators in the entrance vestibules. One apartment was open as a model and views are shown on Plate IX.

Some experimental work has been done to develop radiant panels using ceramic and/or plastic tubing installed in precast concrete slabs. The results have not been satisfactory.

Space heating is provided from September to May of each year. Domestic hot water service is provided year round.

**Space Heating Connections**

Connections between the building space heating systems and the district heating systems include both "closed" and "open" methods. The closed systems employ heat exchangers between the district system and that of the building heating system. This method is found in the taller or larger structures or in services to groups of structures where the use of open method would place undue head conditions upon the district heating system.
PLATE IX

MODEL APARTMENT
pumps. The closed system also permits some degree of local temperature control. Similar arrangements are found where isolated loops are necessitated by hilly terrain or long service connections. Booster pumping stations, with or without heat exchangers are used also in hilly terrain areas.

The most prevalent arrangement is the "open" method. In this case, all pumping is done at the heating plant. Figures 5, 6 and 7 show schematic diagrams of two types of open system. Plate X gives views of such installations.

In Figure 5, the water entering from the district system is circulated directly through the building system with blending via an injector. The latter draws cooler water returning from the building system to temper the incoming hot water to the proportionate temperature desired in the heating system. The proportioning ratio is controlled by manual valve adjustments. The system in Figure 7 is similar except that the mix ratio is automatically controlled by pressure sensing regulators.

The scheme in Figure 6 is similar to that in Figure 5 except that the injector is replaced by a pump as a means of obtaining the desired blend of supply and return water.

**Domestic Hot Water Connections**

Domestic (sanitary) hot water, in most cases, is heated via a heat exchange between incoming service water and the district heating system water. However, in a few instances (Leningrad and sections of Rostov-on-Don) where the hardness and mineral content of the water permits, the domestic hot water is drawn directly from the district heating system. Figures 5 and 6 show typical piping and valving arrangements for this method. In these figures cross connections may be noted between the domestic hot water supply and both the supply and return connections to the district heating system. By adjusting the valves in the cross connections, proportionate blending of the supply and return water results in domestic hot water of the desired temperature.
PRINCIPAL SKETCH SCHEME No. 5
PIPING FOR HEATING AND HOT WATER
SUPPLY THROUGH VALVED CONNECTIONS TO HEATING SYSTEM

Э — элеватор "ELEVATOR" (INJECTOR/BLENDER)
В — водомер — WATER METER
Г — гравдик — STRAINER
Т — термометр — THERMOMETER
М — манометр — MANOMETER
ОК — обратный клапан — VALVE

На систему горячего водоснабжения
TO HOT WATER SUPPLY SYSTEM

Рис. H12
FIGURE 6

PIPING DIAGRAM

PRINCIPAL SKETCH SCHEME
HEAT CONTROL BY MIXING WITH PUMPING

B - водомер - water meter
Г - гравикуг - strainer
T - термометр - thermometer
M - манометр - manometer
H - насос - pump
O.K - обратный клапан - valve

Приступичная Схема тепловаого узла с насосом на смешение

Рис. N10
Приципиальная схема № 4
абонентского теплового узла с двухступенчатым
подогревателем горячего водоснабжения

PRINCIPAL SKETCH SCHEME № 4
SUBSCRIBER CENTRAL WATER HEATING
WITH TWO STAGE HEAT EXCHANGER FOR
HOT WATER SUPPLY

Э - элеватор "ELEVATOR" (INJECTOR/BLENDER)
В - водомер - WATER METER.
Г - гризевик - STRAINER.
Т - термометр - THERMOMETER.
М - манометр - MANOMETER.
П1 - 1-я ступень подогревателя - FIRST STAGE
OF HEAT EXCHANGER
П2 - 2-я ступень подогревателя - 2ND STAGE
OF HEAT EXCHANGER.
РА - регулятор давления - PRESSURE REGULATOR.
РР - регулятор расхода - FLOW REGULATOR.
ОК - обратный клапан - VALVE.

FIGURE 7

PIPING DIAGRAM

Рис. №8
PLATE X

BUILDING PIPING
Figure 7 shows an automatically controlled heat exchange method which utilizes the reverse flow principal. Incoming cold service water is first tempered by a heat exchange with the cooler water returning from the building heating system. It then flows through a second heat exchanger where it is brought up to the desired temperature by an exchange of heat with the incoming hot water from the district system. The delivered temperature of the domestic hot water is controlled by a temperature sensing device which regulates the flow of district system hot water to the second heat exchanger.

The statutory minimum temperature for domestic hot water is 149 F. As a result the sendout temperature from the district plants must be at least 160 F. Where, as in Figure 7, the heat exchange method is used, the temperature of the water returned to the district heating plant is lowered to about 100 F by the cooling effect of the 40 F entering service water. This raises the transfer capability of the heat exchange operation in the district heating plant.
Many of the commercial factors encountered in a free economy are non-existent, in kind, in the U.S.S.R. Since, by decree, buildings within the reach of the district heating system must take the service, competitive and sales aspects are not present.

Although the rate making process is controlled by governmental agency and by other arbitrary financial edicts, many of the considerations familiar to rate making in the U.S.A. confront the Russian rate maker. His rate(s) must result in revenues adequate to supply funds to pay all operating costs and, although different nomenclature is used, sufficient balance to provide for amortization and surplus (profit) relative to funds used to construct facilities.

One major difference, however, is that pricing is varied as a function of the type of consumer. This feature, plus several adjustments, make the schedules appear more complicated than they actually are.

Tariff Structures

In 1955, the Ministry of Finance issued the basic tariffs for steam and for hot water shown in Table G. These have since been used with little change. It was indicated, however, that revisions thereto were to be issued.

The 1955 schedules were said to have been set to cover costs at the 1955 level, plus a return of about 6 percent upon investment.

Apparently, these schedules are essentially criteria for the formulation of contractual agreements between the authority which directs the consuming enterprise and the power administration which supplies the heat.

Modifications to the basic tariffs for steam are made:

1. In deference to recommendations of the regime.
2. In deference to the type of industry being served (chemical, metallurgical, food processing, etc.).
3. To conform to production costs at the supplying plants.
4. To penalize users violating peak load agreements.
5. To compensate for the pressures demanded by the using facility.
6. To compensate for condensate not returned to the steam generating station.

Rates are increased if peak demands exceed the average stipulated by contract for periods in excess of 15 minutes. The data in Table H show the penalties imposed to compensate for increased pressure, and for returning only
### TABLE G

**Basic Tariffs**

**STEAM (See Notes 1 & 2)**

<table>
<thead>
<tr>
<th>Location</th>
<th>Processing Uses</th>
<th>Space Heating</th>
<th>Residential and Commercial Buildings</th>
<th>Service Buildings*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Minsk</td>
<td>$1.80</td>
<td>$1.80</td>
<td>$1.52</td>
<td>$1.67</td>
</tr>
<tr>
<td>Kiev</td>
<td>1.30</td>
<td>1.30</td>
<td>1.18</td>
<td>1.28</td>
</tr>
<tr>
<td>Kharkov</td>
<td>1.00</td>
<td>1.00</td>
<td>0.74</td>
<td>0.95</td>
</tr>
<tr>
<td>Leningrad</td>
<td>1.90</td>
<td>1.90</td>
<td>1.36</td>
<td>1.80</td>
</tr>
<tr>
<td>Moscow</td>
<td>1.36</td>
<td>1.36</td>
<td>1.00</td>
<td>1.13</td>
</tr>
<tr>
<td>Rostov</td>
<td>1.08</td>
<td>1.08</td>
<td>0.81</td>
<td>0.88</td>
</tr>
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</table>

**HOT WATER (See Note 1)**

<table>
<thead>
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<th>Location</th>
<th>Processing Uses</th>
<th>Space Heating</th>
<th>Residential and Commercial Buildings</th>
<th>Service Buildings*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Minsk</td>
<td>$1.67</td>
<td>$1.67</td>
<td>$1.44</td>
<td>$1.57</td>
</tr>
<tr>
<td>Kiev</td>
<td>1.28</td>
<td>1.28</td>
<td>1.12</td>
<td>1.21</td>
</tr>
<tr>
<td>Kharkov</td>
<td>0.95</td>
<td>0.95</td>
<td>0.70</td>
<td>0.90</td>
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<tr>
<td>Leningrad</td>
<td>1.79</td>
<td>1.79</td>
<td>1.30</td>
<td>1.75</td>
</tr>
<tr>
<td>Moscow</td>
<td>1.27</td>
<td>1.27</td>
<td>0.93</td>
<td>1.09</td>
</tr>
<tr>
<td>Rostov</td>
<td>1.02</td>
<td>1.02</td>
<td>0.77</td>
<td>0.84</td>
</tr>
</tbody>
</table>

*Government buildings, theatres, hospitals, clubs, etc.

**Note 1:** Dollars per 1,000 pounds of steam or equivalent at exchange rate of $1.10 per ruble.

**Note 2:** Applicable only where all condensate is returned and service pressure does not exceed 45 psi. See Table F for adjustments for other conditions.
TABLE H

STEAM RATE ADJUSTMENTS

For service pressures

<table>
<thead>
<tr>
<th>Psig</th>
<th>Percent of Base Rate</th>
</tr>
</thead>
<tbody>
<tr>
<td>Up to 30</td>
<td>100</td>
</tr>
<tr>
<td>30 to 90</td>
<td>106</td>
</tr>
<tr>
<td>90 to 180</td>
<td>112</td>
</tr>
<tr>
<td>Over 180</td>
<td>130</td>
</tr>
</tbody>
</table>

For Percent of Condensate Returned

<table>
<thead>
<tr>
<th>Percent Returned</th>
<th>Percent of Base Rate</th>
</tr>
</thead>
<tbody>
<tr>
<td>100</td>
<td>100</td>
</tr>
<tr>
<td>90</td>
<td>105</td>
</tr>
<tr>
<td>80</td>
<td>110</td>
</tr>
<tr>
<td>70</td>
<td>120</td>
</tr>
<tr>
<td>60</td>
<td>125</td>
</tr>
<tr>
<td>None</td>
<td>200 (approximately)</td>
</tr>
</tbody>
</table>

Tenant Charges

Heating is usually charged for on the basis of the area occupied. In most cases, kitchens, baths, and corridors are not classified as occupation areas. The flat rates charged vary geographically from about 0.5¢ per square foot per month in Minsk, to 0.83¢ per square foot per month in Kharkov, to 1.5¢ per square foot per month in Kiev. Domestic hot water is charged for on a per capita basis within the range 35¢ to 45¢ per person per month. Both are included in the rentals. Other utility charges per month were quoted as follows: Electricity $1.50 per room; gas $0.85; water $1.00; telephone $1.00; radio antenna $0.70. The average Russian family's rent bill is said to be about $10.00 per month.
Metering

Little precision metering was observed. It is apparent that the quantities used for the determination of charges are derived more from allocations developed through experience than upon precise metering. Volumetric type water meters and thermometers, in the supply and return lines at the TETS station, are read periodically and the total heat delivered is calculated. From this total, calculated distribution system losses are subtracted and the remainder becomes the basis for allocating charges.

The present methods of pricing the heating service offers little incentive to develop accurate metering. Notwithstanding, a Russian-designed meter was seen under test in the laboratory in Leningrad. It was of simple and rugged design. The basic element was a standard volumetric water meter equipped with a standard register to record flows. Added to the standard register was a special device designed to measure the temperature differential between the inlet and outlet legs of the flowmeter, thereby adding an integrating factor to the volumetric flow so as to record, on a second register, the total quantity of heat passed.

The special temperature differential device consisted essentially of two U-shaped pipes made of similar metals with their open ends clamped solidly to prevent motion. The free ends of the U-tubes move differentially in accordance with the temperature of the fluid passing in each one. The differential motion is detected by a lever arrangement that positions a register counter over an integrating disk driven by the volumetric meter. The amount of registration on the calorific counter is determined, then, by the differential temperature and the total volume of the fluid passed. It was estimated that ultimately this instrument would become available for about 45 rubles.
SUMMARY

The magnitude of district heating in the U.S.S.R. is manyfold that of any other nation. The present commitment to ultimate standardization on TETS systems is exceptionally compatible with the present balance.

However, as technological advances are achieved, the growth of electric energy requirements will increase to a point where changes in the heat balance may well necessitate a careful review of the feasibility of the present TETS concept.

Virtually all equipment observed was produced within the U.S.S.R. Priority seems to have been placed on operational capabilities, the conservation of minerals and the "make do" use of available resources at the greatest overall efficiency.

District hot water heating systems supply heat and domestic hot water to all types of old and new buildings.

Building heating system designs are simple. The temperature of the circulated water is not within the control of the occupants of the individual apartments. To effect temperature changes, appeals must be made through a committee representing the building's occupants.

Interestingly enough it was noted that our counterparts were concerned with the same management problems that we encounter. Their concerns and aspirations were primarily for successful and profitable operation. Philosophically, their approach to these problems varied little from ours, even in areas involving economics.

As stated in the foreword, no mission of this scope could have been possible without assistance and guidance from many sources. In closing this section of the report the occasion is taken to express a special degree of appreciation for the consideration and courtesies extended us
PLATE XI

RUSSIA - GROUPS

Conference in Minsk

Conference in Moscow

Guide and chauffeurs - Moscow
by our hosts and the members of their staffs in each of the countries visited.

Plate XI and XII show a few scenes of such associations which are of fond memory to the members of the mission.
PART II

DISTRICT HEATING IN OTHER COUNTRIES.

A widely prevailing opinion has been that further exploitation of hydro resources for production of electricity is considered to be of increasingly doubtful economic utility, while concurrent in the increase in owning and independent control of district heating facilities required to transport the hydrowater from the more remote sources to the load centers.

As a result, there is a trend towards combined heat-electric stations located in high density load areas. In such cases, the heat normally rejected in the expansion water is recovered and put to profitable use in district heating systems. Revenue derived from the latter provides support for facilities investment which otherwise might be considered excessive.

These conditions, together with governmental support and supply of capital, is producing an increasing rate of growth in district heating operations.

There are 13 district heating systems in Europe, located in eight cities. These were visited, in Stockholm and the suburbs. Those visited are municipally owned and are operated by the Electric Supply Authority of Stockholm under the jurisdiction of the Board of Public Utilities. The Gas and Water Authorities of that city are also under the jurisdiction of the same board.

Over 90 percent of the total annual electric power used in the Greater Stockholm area is obtained from hydro-electric plants owned by that city. There are however, three combined heat-electric plants located within the urban environment as shown on the map in Plate XIII. These plants have an electric generating capability in the order of 25,000...
DISTRICT HEATING IN SWEDEN

A marked impression is encountered that further exploitation of hydro resources for production of electricity is considered to be of increasingly doubtful economic value. The reason for this concept is the increase in owning and maintenance costs of transmission facilities required to transport the hydro power from the more remote sources to the load centers.

As a result, there is a trend towards combined heat-electric stations* located in high density load areas. In such cases, the heat normally rejected in the condenser water is salvaged and put to profitable use in district heating systems. Revenues derived from the latter provide support for facilities investment which otherwise might be considered excessive.

These conditions, together with governmental support and supply of capital is producing an impressive rate of growth in district heating operations.

There are 12 district heating systems in Sweden, located in eight cities. Three were observed, in Stockholm and its suburbs. Those visited are municipally owned and are operated by the Electric Supply Authority of Stockholm under the jurisdiction of the Board of Public Utilities. The Gas and Water Authorities of that city are also under the jurisdiction of the same board.

Over 90 percent of the total annual electric power used in the Greater Stockholm area is obtained from hydro-electric plants owned by that city. There are however, three combination heat-electric plants located within the urban environment as shown on the map in Plate XIII. These plants have an electric generating capability in the order of 250 MW.

*See Glossary for definition.
They also provide heat to the district heating systems. The Vartael system is the oldest and smallest of the three heating systems. It supplies the commercial district of the city. About 10 percent of the revenue derived from the sale of heat comes from this system. Modernization, by the addition of 80 MW of capacity and an extension of the district heating system into those areas of the city called Gordet and Upper Ostermalm, is now under way.

The Hasselby system is the largest district heating system in Sweden. It serves the relatively new suburbs of Vallingby and Hasselby. Presently, some 60 percent of the heat marketed annually is from this system. Future plans call for increasing the megawatt capability of this plant but not its district heating capability. The latter decision stems from the fact that virtually all of the land in the area, suitable for building, is already occupied.

The Hasselby plant (Plate XIV) has the unique feature of three hot water accumulators holding about 1,800,000 gallons of water. Heat is stored in these accumulators and used as a peak relieving reserve. Their jackets comprise 18 inches of insulation covered with an aluminum skin.

This plant is also equipped with electrode type electric steam boilers to take further advantage of the availability of hydro power. Thus, hydro power can be used for redistribution or for heat generation for either immediate supply to the heating system or for supply to the reserve accumulators.

The operation of the accumulators takes advantage of the stratification discipline. The boundary between the hot water in the upper portion of the vessels and the cooler water below is quite sharply defined, due to inlet arrangements designed to minimize mixing.
PLATE XIV

HASSELBY PLANT

Underwater coal storage

Entrance to oil storage reservoir

Turbine floor

Heat accumulators

Electrode steam boilers

Exterior plant
Heat is delivered to this reserve (a) when the district heating load is low and electric power demand from the turbo generation is high or (b) as previously mentioned, when excess hydro power is available. In this way low cost heat is stored for use during high heating load periods and during weekend or holiday periods when electric loads are low. In this way the overall net heat balance is improved.

The flow diagram (Figure 8) shows the steam and water cycles of this plant and the connections to the district heating system.

The turbines can be operated in accordance with a number of combinations where the heating load can be carried by each of the units, or combined, depending on the current loading. The design conditions call for condenser G1 to raise the incoming water temperature from 130 F to 160 F; for the water to then flow to condenser G2, where the temperature is further raised to 185 F; and finally to condenser G3 for output at the design temperature of 215 F.

Turbine unit G3 is also equipped with a sea water condenser to permit full condensing operation when electric needs overbalance the heating load. Conversely a standby condenser with a direct steam connection is available for use when the heating load exceeds the amount available in the combined turbine exhausts, or when the use of available hydro-power is more economical than turbine operation.

The total dependence upon imported fuel results in a high degree of sensitivity - from a civil defense viewpoint - relative to fuel storage. At Hasselby 55,000 metric tons of coal can be stored under water. Handling facilities at this installation are shown on Plate XIV. Nearby the plant, construction is underway to create a huge oil storage capacity by excavating a reservoir in a hill of rock. The entrance tunnel is also shown on Plate XIV.
FIGURE 8
FLOW DIAGRAM - HASSELBY

FIGURE 3
STEAM AND WATER CYCLES OF
THE HASSELBY PLANT
The Agesta Nuclear power station (Plate XV) has the first nuclear reactor in Sweden and it is the first of its kind in the world. The pressurized water principle has been applied to a heavy water moderated and cooled core in a pressure vessel type reactor. The plant is built into the side of a rock outcrop.

The plant is designed for the combined production of electric power and district heat for the commercial and residential buildings in the planned community of Farsta located nearby. It has an overall rating of 65 MW thermal. Steam conditions were conservatively chosen to fit an existing 10 MW back pressure turbine. A facility for the treatment of nuclear waste is available on the site.

Since this project is primarily an experimental installation a conventional heating plant is also available to meet the needs of Farsta. Here again a heat accumulator is used. Anyone interested in details of the nuclear plant will be well rewarded by obtaining a copy of a staff report by the A B Atomenergi, entitled "The Agesta Nuclear Power Station," * edited by B. McHugh (1964).

Stockholm, especially the commercial area, is built upon rock. Water is used as the principal heat distribution medium. Main construction is difficult and construction costs vary from $200 to $270 per foot. Notwithstanding, tunnels blasted out of the rock at an average depth of 100 feet are used to a surprising extent. The photograph on Plate XVI shows such a line, connecting the Agesta plant with the Farsta system. The line passes under Lake Magelungen for a distance of about two miles.

PLATE XV

AGESTA NUCLEAR PLANT

Agesta Plant

Model of Agesta Plant

Refueling machine

Refueling floor

Farista boiler plant

Farista
Distribution mains up to 24 inches in diameter are used at about 200 psi, and flow velocities up to 10 feet per second. Steel pipe, preinsulated at the factory, is installed in walk-through tunnels and/or reinforced concrete conduit.

Heat exchangers (Plate XVI) are used to isolate the water in the distribution system from that circulated in the using buildings. Standardized exchangers are used. Their selection is based upon the number of standard apartments (or their equivalent) to be served. A standard apartment is comprised of four rooms totaling about 850 square feet.

Other than to government projects, the service must be sold upon a competitive basis. Some help along this line is a recently enacted law limiting the height of chimneys. Newly constructed large buildings are literally forced to accept the service.

In the past, the heat exchangers for individual buildings were supplied as a part of the service. Now, ownership by the customer is required. Prices for exchangers, auxiliary apparatus, and controls vary from about $800 for a building with 15 apartments to $4,000 for a building with 105 apartments. Space heating load factor is equivalent to about 3,100 hours annual use.

The incoming water temperature is modulated according to the outside temperature within the range of 165 F to 250 F. Tempering within the buildings is controlled to assure return water temperatures within the range of 120 F to 160 F. Circulating times vary from 3 to 6 hours.

All buildings are metered at the service entrance. Temperature-compensated meters are in general use. Meters are of standard commercial accuracy in the range of ±5 percent. Each meter is equipped with two registers - the first records the integrated volumetric flow, and the
PLATE XVI

TUNNEL --

District heating trunkline in rock tunnel

Heat exchanger
second integrates the heat delivered. Each meter costs approximately $230. They are the property of the Electric Supply Authority.

The meters are read monthly and the readings are correlated very carefully with degree-day records. In the event of misreadings or metering troubles, calculations are made against the correlated degree-day data. To do this, curves are kept for each customer as a part of the regular billing function.

The tariff applied to district heating customers is made up of three parts: the first part is an area change based on the interior dimensions of the flats, the second is a charge made for the volume of water passed, and the third is a metered "heat used" charge. A fuel adjustment charge is also applied.
In Finland, district heating owes its origin and growth to the adverse economics associated with the further extension of hydro-power development. Historically, electric power generation started with steam turbo-generators, swung almost completely to hydro supply, and currently, because of prohibitive costs of transmission from remote "rapids", is trending to the combined thermal-electric stations where the condenser waste heat is used for district heating.

The Suvilahti condensing power station, the first in Helsinki, went into operation in 1909 and supplied the power requirements of Helsinki until 1919. Electricity from hydro stations progressively replaced steam generation until the early Forties. At this time, 80 to 98 percent of all power requirements were supplied from hydro. However by 1948, due to wartime power needs, dry years, and load growth in general, the proportion of power supplied by steam generation had grown to 50 percent.

These factors, coupled with the difficulties experienced with fuel procurement, focused attention upon the heat being rejected to the sea via the Suvilahti condensers. At the conclusion of studies in 1953, the City Council decided to begin district heating by using this rejected heat for heating the city. In addition, waste heat from a projected refuse incinerator was also to be used.

One of the major circumstances influencing this decision was the concept that additional hydro development was not feasible because of the far off locations of the "best rapids". The corollary was the high feasibility of thermal stations which would be located near both the load and importation points for fuel.
CITY OF HELSINKI
POWER STATIONS AND HEATING PLANTS

LEGEND
HOT WATER PIPE LINES
IN OPERATION ———
PLANNED ————
STEAM PIPE LINES
IN OPERATION ————
PLANNED ————

KYLASAARI PLANT
ILAHTI PLANT
SUVILAHTI PLANT
HANASAARI PLANT
SAMISAARI PLANT
The principal area served and the location of the heating plants are shown on Plate XVII. About 25 percent of central Helsinki is connected to the district heating systems. Some 80 percent of the heat is marketed as hot water, the remainder as steam.

Prior to the mid fifties steam had been supplied from the Suvilathi plant to a few nearby industrial plants. Steam lines will connect this plant to both the Kylasaari refuse incinerator plant and to the Hanasaari plant. Extracted steam from the latter can be available to the Suvilathi plant or the output of the two steam producing stations can be delivered to the hot water district heating system via heat exchange facilities in the Hanasaari plant.

The first heat delivered to the district system came from the Samisaari plant in 1957. The latter was connected to the Hanasaari plant in 1961.

Load growth was great and in addition to the expansion of heat-electric facilities, it became necessary to provide low cost peaking boiler plants. The latter absorb about 40 percent of the peak heating load but supply only 3 to 4 percent of the annual requirements.

One of these, the Appilla peaking plant, was being built within an excavation of a rock hill. The housing thus obtained was reported to cost about 40 percent of that for a conventional above ground structure. (See Plate XVIII) The ultimate capacity of this plant will be 119 MMBTUH.

In the existing district heating systems, heating is in the role of a buy-product of electric generation. Two large dwelling areas - Myllypuro and Kontula - with 40,000 inhabitants, now under construction will, by decree of the City Council of Helsinki, be supplied heat and electric service from a single plant. In this case, electricity will be the minor load.
PLATE VIII

APPILIA PLANT

Entrance

Stack and air intake
The terrain of Helsinki is not well suited to the installation of distribution equipment. The area within the city's boundaries is 160 square miles but 96 square miles are covered with water. Most of the land is low and rocky. Much of the commercial area is filled-in land. Distribution main construction is predominantly of the semi prefabricated duct type in city streets where ground is dry. On curves, where ground is wet and for services to buildings, poured in place ducts are used. Outside the city totally prefabricated duct is used. Experimental installations of the latter in the city streets have been made. Asbestos cement jacketing for pipe is under study.

Steam send out conditions are in the order of 190 psi and 400 F. Two-thirds of condensate is returned. Send out temperatures for the hot water system range from 167 F to 248 F depending upon the outdoor ambient temperature. In 1963 the annual heat used was the equivalent of 2,900,000,000 pounds of steam, with 84 percent having been supplied via the hot water district heating system.
DISTRICT HEATING IN DENMARK

There are seven sizable district heating systems in Denmark serving, collectively, about 17,000 buildings in five cities through some 400 miles of piping. Of these, the two systems in Copenhagen were observed. The latter are municipally owned and are operated by the Copenhagen Lighting Department, which also has comparable responsibilities for electrical energy and gas. Both steam and hot water are marketed.

During the 40 years since district heat has been available in Copenhagen, the load has grown steadily. Now over 1,600 customers are served through 80 miles of mains. About 80 percent of the buildings connected are supplied with steam and 20 percent with hot water. Of the total heat energy sold -

47% is utilized by industrial and commercial buildings.
33% is utilized by apartment buildings.
10% is utilized by hospitals.
10% is utilized by miscellaneous users.

Overall thermal losses for the distribution systems were said to approximate 15 percent per year.

The tariff provisions in use since 1953 are particularly of interest because of the economic factors for which adjustments are specified. The schedule includes:

1. A meter charge which is a fixed charge depending upon the size of the meter and the kind of service rendered (steam or hot water.)
2. A load charge fixed as a function of the connected load as determined by the size of heat exchangers, radiators, etc.
3. A metered heat charge, based on the heat delivered via either steam or water. This charge is further subject to automatic adjustments to reflect variations in fuel and/or labor costs.

A discount is allowed on large consumptions. An additional charge is made for condensate not returned.

A great deal of detailed data may be obtained from the following bibliography.


(b) District Heating in Copenhagen, Denmark (in English), by A. K. Bock, April and July (1959) issues of District Heating (an NDHA publication).

(c) A Brief Description of the District Heating System (in English), dated March 1962, by the Chief Engineer of the District Heating Division of the Copenhagen Lighting Dept.

(d) The 1963-64 Annual Report (in Danish and English) of the Copenhagen Lighting Department.
DISTRICT HEATING IN OTHER COUNTRIES

The 1962 UNICHAL report gives the magnitudes of district heating in selected cities of other countries as shown in the following tabulation. Both steam and water systems are used with steam predominating.

<table>
<thead>
<tr>
<th>Table I</th>
<th>Total Send out (Millions of Pounds of Steam)</th>
<th>Linear Length Distribution Piping in Mines</th>
<th>Total Customers</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>West Germany</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Berlin</td>
<td>3,625,000</td>
<td>62</td>
<td>1,115</td>
</tr>
<tr>
<td>Hamburg</td>
<td>8,550,000</td>
<td>72</td>
<td>940</td>
</tr>
<tr>
<td>Hameln</td>
<td>347,000</td>
<td>7</td>
<td>43</td>
</tr>
<tr>
<td>Mannheim</td>
<td>600,000</td>
<td>36</td>
<td>448</td>
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<tr>
<td>Oberhausen</td>
<td>236,000</td>
<td>12</td>
<td>257</td>
</tr>
<tr>
<td>Stuttgart</td>
<td>2,160,000</td>
<td>29</td>
<td>310</td>
</tr>
<tr>
<td>Wuppertal</td>
<td>2,000,000</td>
<td>29</td>
<td>683</td>
</tr>
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<td><strong>Austria</strong></td>
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<td></td>
<td></td>
</tr>
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<td>Klagenfurt</td>
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<td>Wels</td>
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<td>3</td>
<td>110</td>
</tr>
<tr>
<td>Vienna</td>
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<td>5</td>
<td>18</td>
</tr>
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<td><strong>Belgium</strong></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Intercom</td>
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<td>670</td>
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<td><strong>France</strong></td>
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</tr>
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<td>Chalon-sur-Saone</td>
<td>118,000</td>
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<td>30</td>
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<tr>
<td>Macon</td>
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<tr>
<td>Massy-Antony</td>
<td>326,000</td>
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<tr>
<td>Metz</td>
<td>337,000</td>
<td>11</td>
<td>70</td>
</tr>
<tr>
<td>Paris</td>
<td>3,960,000</td>
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<td>1,205</td>
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<tr>
<td>Saint-Denis</td>
<td>322,000</td>
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<tr>
<td>Villeurbanne</td>
<td>220,000</td>
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</table>
DISTRICT HEATING IN OTHER COUNTRIES (Continued)

Netherlands

<table>
<thead>
<tr>
<th>City</th>
<th>Heat Load</th>
<th>Population</th>
<th>Energy Consumption</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rotterdam</td>
<td>1,000,000</td>
<td>26</td>
<td>400</td>
</tr>
<tr>
<td>Utrecht</td>
<td>940,000</td>
<td>35</td>
<td>1,689</td>
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</table>

Switzerland

<table>
<thead>
<tr>
<th>City</th>
<th>Heat Load</th>
<th>Population</th>
<th>Energy Consumption</th>
</tr>
</thead>
<tbody>
<tr>
<td>Basel</td>
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<tr>
<td>Bern</td>
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<td>Lausanne</td>
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<tr>
<td>Zurich</td>
<td>337,000</td>
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</table>

Roumania

District heating started in Roumania in 1950. As in the U.S.S.R. the combined heat-electric concept is employed. Bucharest has the largest system with total heat load which is the equivalent of 1,200,000 pounds of steam per hour. Residential areas of other towns are now being supplied relatively small amounts of heat. Growth potential is evaluated with enthusiastic optimism as indicated by the predicted energy peaks given in Table J.
<table>
<thead>
<tr>
<th>City</th>
<th>Heating Demand as 1,000 Lb of Steam per Hour</th>
<th>Mw Capability</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bucharest</td>
<td>9,000</td>
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<tr>
<td>Jassy</td>
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<td>Galati</td>
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<td>150</td>
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<tr>
<td>Ploesti</td>
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<td>100</td>
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<tr>
<td>Craiova</td>
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<td>100</td>
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<td>Timisoara</td>
<td>1,000</td>
<td>67</td>
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<tr>
<td>Constanta</td>
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<tr>
<td>Arad</td>
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<td>Onesti</td>
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<tr>
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<td>Suceava</td>
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<td>Hunedoara</td>
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</tbody>
</table>
GLOSSARY

BTU - British Thermal Unit (of Heat).

DISTRICT HEATING: The large scale production, distribution and sale of heat to multiple consumers over substantial areas.

DISTRICT HEATING: Facilities used for district heating.

DISTRICT BOILER PLANT: (In Russia) A boiler plant supplying a localized hot water district heating system.

DOMESTIC HOT WATER: Hot water supplied for domestic use.

ENERGO: Roughly the equivalent of the words "power company."

EQUIVALENT STEAM: Steam with net heat content of 1,000 BTU per pound.

HEAT-ELECTRIC-STATION: A generating plant supplying heat to a district heating system in addition to electric power.

ISOTHERMAL LINES: Continuous lines of equal temperature (used on weather maps).

LAYDOWN AREA: Space available in a plant for temporary placement of components for inspection, overhaul and/or storage during overhaul of major equipments.

PACKAGE BOILER: Prefabricated boiler as contrasted to one assembled in the field.

PSI: Pounds per square inch - unit of pressure.

TETS: Russian abbreviation with equivalent meaning of "heat-electric-station."
