CANADA

THE DOMINION FUEL BOARD

IN CO-OPERATION WITH

THE MINES BRANCH, DEPARTMENT OF MINES

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Departments of the Interior and Mines

Central and District Heating

POSSIBILITIES OF APPLICATION IN CANADA

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OTTAWA
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1924

The Honourable CHARLES STEWART,
Minister of Mines,
Ottawa, Ont.

SIR:—I have the honour to transmit herewith report on central and district heating.

I have the honour to be,
Sir,
Your obedient servant,

CHARLES CAMSELL,
Deputy Minister of Mines
Chairman, Dominion Fuel Board

83276—1½

Foreword

As a result of this investigation, the Dominion Fuel Board draws the following conclusions:

That central heating of groups of institutional buildings and community heating of residential properties have shown the economies and benefits to be derived from these methods, and that such systems may and will be adopted profitably to an increasing extent.

That while the increased use of district heating or the supply of heat as a public utility in sections of cities and towns may be looked for in the future, their introduction in any particular locality should be preceded by a detailed and careful study of local conditions and of all the factors bearing upon the problem in order that there may be reasonable assurance of financial success; and that the benefits to be derived by consumers are not so much a saving in cost of service, but rather, a greatly increased value of service in respect to convenience, relief from the handling of coal and ashes, increased cleanliness, etc., the total value of which it is extremely difficult to determine in terms of dollars.

The Fuel Board believes that, for a full utilization of available resources, consideration must be given to possible co-ordination in production and use of different forms of energy such as the establishment of central steam stations acting in conjunction with hydro-electric developments for the supply of light, heat, and power.

The Fuel Board finally concludes that while the application of methods of centralized heating alone may not be looked upon as a considerable factor in the solution of the "Fuel Problem" in the provinces of Ontario and Quebec, nevertheless the replacement of small anthracite-burning units by centralized plants burning low-grade fuels will contribute towards the reduction in importation from the United States of high-priced anthracite coal which is so rapidly becoming a luxury fuel of indeterminate availability.

Signed on behalf of the Board,

CHARLES CAMSELL,
Chairman

Letter of Transmittal and Author's Conclusions

Dr. Charles Camsell,
Chairman, Dominion Fuel Board,
Ottawa, Ontario.

Sir,—I beg to submit herewith my report on the subject of central and district heating in accordance with instructions received from the Dominion Fuel Board.

For the preparation of this report an investigation has been carried out to determine the present status and practice of district heating in other countries, particularly in the United States, and a survey made of conditions obtaining in Canada, to determine the possibilities of the application of this form of heating in different towns and cities in the Dominion.

During the course of this work I have found a widespread interest in the subject, and an endeavour has been made to include in the report general information of practical value in the consideration of any particular application.

I have formed the following conclusions and opinions, based partly upon the data presented in the accompanying report and partly upon confidential information from different sources:

(1) That central and district heating can be profitably employed to a considerable extent in Canada, and that the supply of heat as a public utility in the denser sections of cities and towns may be looked for as a general service of the future.

(2) Central heating of groups of institutional buildings and community heating of residential properties have shown the economies and benefits to be derived, and such systems undoubtedly will be adopted to an increasing extent.

(3) In the United States, district heating has now passed through the development period, and although financial failures and difficulties have been experienced in the past, as in the early stages of any other utility, the knowledge gained and advances made during recent years in design, construction, and method of operation assure the success of undertakings in suitable districts under proper conditions of application, correct engineering, protective rates, and efficient management.

(4) In many parts of Canada, conditions are particularly favourable to district heating: climate; high differential between the prices of coals commonly used for domestic heating and cost of low-grade fuels; and possible combination with electric power supply, both from steam and hydro plants.

(5) Application of methods of centralized heating and steam service will assist in the solution of the fuel problem in the provinces of Ontario and Quebec by making possible a reduction in high-priced coal importation from the United States and the greater utilization of Canada's own resources.

I have the honour to be, Sir,

Your obedient servant,

F. A. COMBE

416 Phillips Place,
Montreal, Que.

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Introduction

The object of this report is to furnish general information on the subject of central and district heating; to give a brief résumé of what has been done in other countries, with descriptions of typical installations; and to discuss economic factors governing the possible extent of its application in Canada.

The present high cost of fuel and the recent disturbances in domestic fuel supplies have led to considerable attention being given to possible economies and benefits to be derived from centralized heating, and it is hoped that the information contained in this report will be of interest and value to municipalities, institutions, and others, and will encourage the wider application of this method of heating.

For the purpose of securing reliable and complete information and to supplement and confirm data gathered from personal work, and experience, the author visited, and studied the operation of, fifteen representative district heating utilities in the United States, and ten district and central heating systems in Canada. Considerable additional information was secured also by correspondence and questionnaires from countries of Europe, United States, and Canada, and a general survey made of conditions obtaining in Canada and the northern United States having a bearing upon the matter: as climate, heating requirements, available fuels, power resources, favourable territory, etc.

Acknowledgments

The author wishes to express his appreciation of the assistance given him in this work by those who have furnished information and figures: Mr. C. P. Hotchkiss, Secretary, Dominion Fuel Board, for much data from Government departments; Mr. R. J. Durley, for facilitating the securing of information regarding practice in foreign countries; Mr. Wessel, of Hodenpyl, Hardy, and Company, New York; Mr. Bechtel, of United Gas and Electric Corporation, New York; and officials of other controlling companies, for information on the financial aspects of district heating in the United States; Mr. D. L. Gaskill, Secretary, and members of the National Heating Association; and many others by whose kind assistance this report has been made possible.

Particularly is the author indebted to the following gentlemen who kindly contributed much valuable data regarding the different operations and systems of which they had charge:

Mr. J. D. Hurd, Pres., Mr. C. A. Gillham, Vice-Pres., Mr. W. J. Baldwin, and other officials of the New York Steam Corp.

Mr. D. S. Boyden, Edison Electric Illuminating Co., Boston.

Mr. R. D. DeWolfe, Rochester Gas and Electric Corporation.

Mr. C. H. Day, Cleveland Electric Illuminating Co.

Mr. H. C. Hobbs, Allegheny County Steam Heating Co., Pittsburgh.

Mr. A. L. Rider, The Toledo Edison Co.

Mr. J. H. Walker, The Detroit Edison Co.

Mr. H. F. Eddy, Consumers Power Co., Jackson, Mich.

Mr. F. B. Orr, Mr. J. C. Butler, Illinois Maintenance Co., Chicago.

Mr. H. R. Wetherill, Peoria, Tech. Sec., Nat. District Heating Association.

Mr. C. B. Holliday, Central Illinois Lighting Co., Peoria.

Mr. J. Anderson, Mr. Wahanek, Milwaukee Electric Railway and Light Co.

Mr. E. Wenzel, town of Virginia, Water and Light Dept.

Mr. M. D. Cadwell, Supt. Utilities, North Battleford, Sask.

Mr. J. B. Harvey, Gen. Man., Canada Gas and Electric Corp., Brandon, Man.

Mr. S. S. Kennedy, Man., Winnipeg Service Co.

Mr. J. W. Sanger, Chief Eng., City of Winnipeg Hydro-electric System.

Prof. C. A. Robb, University of Alberta, Edmonton.

Mr. A. D. LePan, University of Toronto.

Mr. W. D. Lawrence, McGill University, Montreal.

Mr. R. Hall, Mr. W. Hillis, and officials of American District Steam Co.

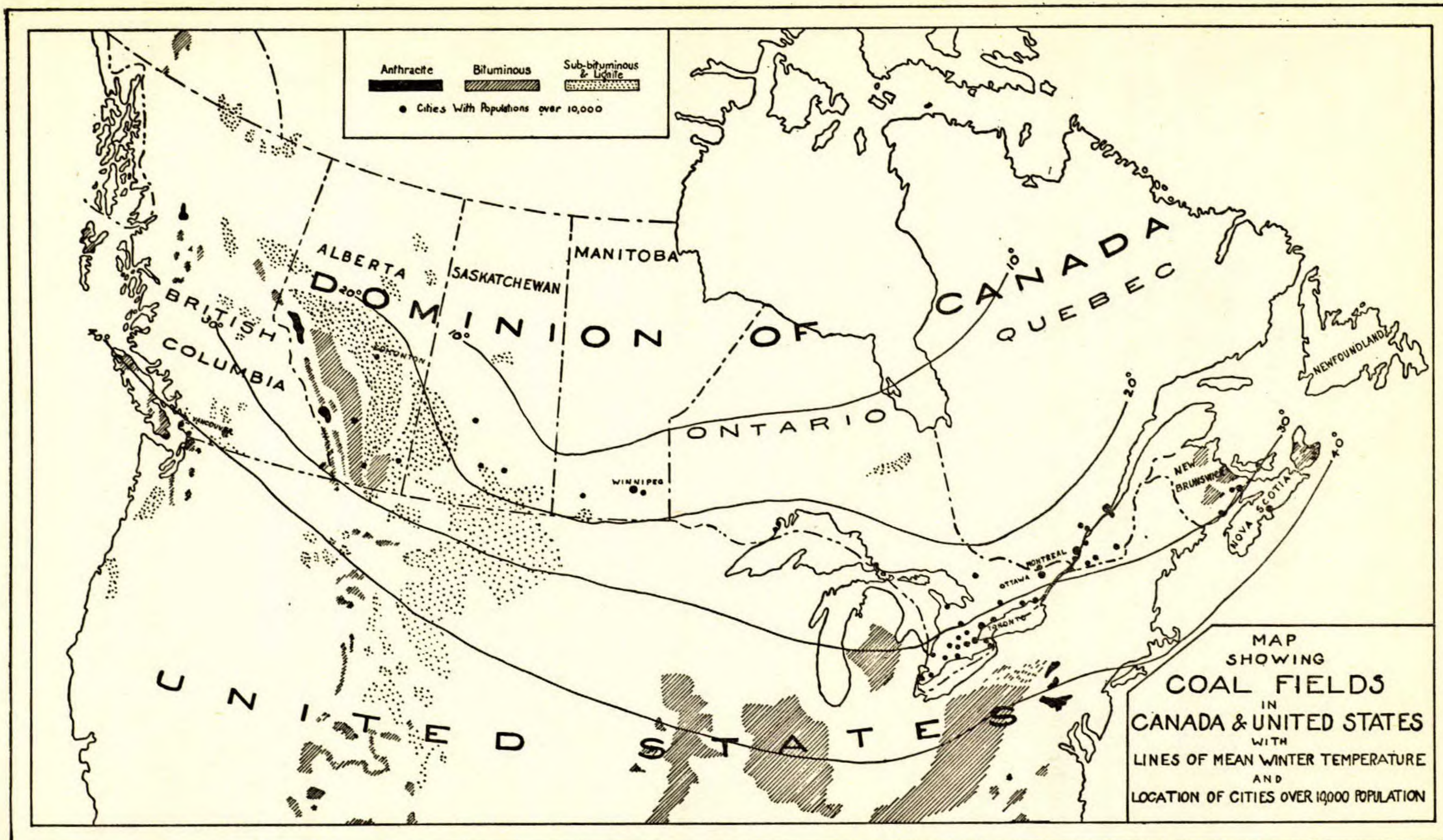
Anthracite
Bituminous
Sub-bituminous & Lignite
Cities With Populations over 10,000
MAP SHOWING COAL FIELDS IN CANADA & UNITED STATES WITH LINES OF MEAN WINTER TEMPERATURE AND LOCATION OF CITIES OVER 10,000 POPULATION
DOMINION OF CANADA
UNITED STATES
BRITISH COLUMBIA
ALBERTA
SASKATCHEWAN
MANITOBA
ONTARIO
QUEBEC
NEW BRUNSWICK
NOVA SCOTIA
NEWFOUNDLAND
VANCOUVER
EDMONTON
WINNIPEG
OTTAWA
MONTREAL
TORONTO
10°
20°
30°
40°

FIG. 1

PART I

GENERAL REVIEW

In almost every civilized country, during some period of the year, artificial heat is needed in dwellings and in the many different buildings required for modern social and commercial life. The supply of such heat becomes a very large, in fact a vital, factor to contend with in northern climates where temperatures are low during the winter and where the heating season extends over one-half of the entire year.

Under these conditions, efficient and economical methods of heating and utilization of fuels are of particular importance, and demand the most careful attention and study, both from the standpoint of the conservation of fuel and national resources, and of the health, comfort, and budget of the country and the individual.

Particularly is this the case in Canada where nearly 40 per cent of the entire coal consumed in the country is used for heating and where over 60 per cent of the total coal consumed is imported, in spite of the fact that the Dominion possesses immense resources of coal within her own borders.

FUEL SITUATION IN CANADA

Economic and geographic conditions have necessitated the importation of the large percentage of coal. The most highly industrialized section of the country is in the provinces of Ontario and Quebec where there is an abundance of waterpower for the generation of electricity, and, as shown on Figure 1, this section is fairly close to the largest anthracite and bituminous coal fields in the United States, but a considerable distance from Canadian coal areas.

MODES OF HEATING

Various methods of heating have been adopted and developed in different countries, dependent upon the climatic conditions and the requirements and progress of the inhabitants, ranging from open fireplaces and stoves in individual rooms to the more elaborate systems for distributing heat from a central source by means of steam, hot water, or hot air.

In the older countries of northern Europe it is customary to employ stoves for heating dwellings and small buildings, burning, as a rule, coke or wood as fuel. These stoves are commonly constructed of special tile, being built in as a permanent house fixture, and are nearly as high as the main living rooms in which they are placed. As heat generators they are undoubtedly efficient and economical, but call for considerable attention. In large modern residences and buildings, hot water or steam radiators are used in connexion with a central furnace, similar to the systems in North America (in Europe such systems are termed "central heating").

In England, open fire-places or gas grates are still used to a very large extent in ordinary dwellings, this form of heating suiting the normal climatic conditions where no low temperatures are experienced. In the larger buildings steam or water radiation is employed.

Throughout the northern United States and Canada where a more constant supply of artificial heat is necessary, the usual methods of heating are by means either of centrally placed direct heaters (for small dwellings) or hot water or steam radiation, or hot air supplied from furnaces placed in the basements.

CENTRALIZED HEATING

The tendency in recent years, especially on this continent, has been towards centralization of heating plants, the heat being distributed through pipes by the medium of steam or hot water to serve groups of buildings; or, as a public utility, entire sections of cities.

Just as the present day system of water supply has developed from the old-fashioned pump and water carrier; as gas supplanted the oil lamp and was in turn supplanted by electricity for lighting; so it is in the natural course of progress that heat should be supplied as a general utility service in place of the present wasteful methods of burning fuel in a multitude of small heating units.

Each progressive step in other public services has involved an increased cost to the user, but the additional comfort and convenience therefrom have been sufficient to warrant its general adoption. So with the supply of heat—wherever district heating has been available, it has come into general use even though the cost be higher than by individual heating. In many communities where district heating is in force, it is a popular saying that "Once a customer, always a customer."

The advantages of district heating are apparent, and, in general, may be stated as being:

To the User:

Cleanliness — absence of dust from coal and furnace
Comfort — uniform temperature; hot water supply
Health — no coal gas from furnace
Convenience — heat paid for as used instead of coal bought in advance; ease of regulation
Safety — reduced fire risk
Saving in furnace and coal bin space and in the cost of furnace equipment in new buildings

To the Community:

Elimination of smoke
Economy in fuel consumption
Possible use of low-grade fuels
Relieving of traffic from coal and ash cartage in streets
Appreciation in rental value of property

The actual cost directly or indirectly to the occupants and owners of buildings and to the community from smoking chimneys is, of course, impossible to determine, but must amount to an immense sum where bituminous or soft coal is burned. Especially is this loss large in the case of dry goods and similar merchandise which suffer from smoke and dust. The cost of the smoke nuisance to Chicago was recently estimated by a Smoke Abatement Commission at over $40,000,000 a year.

In the more populous districts of Canada anthracite coal is the usual heating fuel; but, on account of its rising cost, bituminous coal is being used to a greater extent, and the increase in smoke from chimneys in the cities of Ontario and Quebec during the past few years has been very apparent. Bituminous coal can be burned smokelessly in the specially designed furnaces of large plants, but this is difficult of attainment with the present designs of small heating boilers and furnaces.

HEATING COMBINED WITH OTHER SERVICES

Central or district heating can in many cases be advantageously combined with the generation of electricity from steam stations, the steam being supplied for heating after it has passed through the engines or turbines driving the electric generators. In the most efficient plants, rarely more than 15 per cent of the heat in the steam is utilized for the production of power or electricity, the balance, largely in the form of latent heat, being wasted. When used for heating, the latent heat as well as a considerable part of the sensible heat in the water of condensation can be effectively used. To the extent, then, to which exhaust steam can be economically used for heating, the cost of generating electric energy from steam can be proportionately decreased.

In addition to actual heating service, steam can also be supplied from large central stations for the requirements of laundries, hotels, manufacturies, and for miscellaneous industrial purposes with the same advantages, and as a rule at a lower cost than steam generated by small independent boilers. To the community such a steam service is particularly beneficial in overcoming the nuisance of the smoking chimney so prevalent in connexion with small boiler plants in a city, and to the steam supply company a power load is profitable by reason of its continuity throughout the year.

The present wasteful methods of independent production of the different forms of energy could be largely overcome by a properly balanced grouping, and the trend of future progress seems to be towards the combination of electric generation with the supply of steam for both power and heating to an entire district from one central plant, as providing for the greatest economy in the use of fuel, and the maximum benefit to the community.

CLASSIFIED FORMS OF CENTRALIZED HEATING

The subject of centralized heating or distributed heat can be conveniently defined and considered under three classifications:

(a) *Central Heating*—as applying to the distribution of heat by means of steam or hot water through a system of underground piping from a central boiler plant to a number of buildings comprising a school, university, hospital, asylum, or other institution which is included under one management.

(b) *District Heating*—as applying to a public utility or independent company furnishing steam or hot water to buildings in a city or town, the heat being purchased in the same manner as electricity, water, or gas.

(c) *Community Heating*—as applying to a block or group of dwellings heated from a central plant, either by private arrangement between the owners, or as a development by a company, selling or renting dwellings under special agreement for heating.

CENTRAL AND DISTRICT HEATING IN OTHER COUNTRIES

Examples of all these forms of heating are especially numerous in the United States where district heating has been very widely adopted and where it may be said to have had its origin.

EUROPE

In Europe, progress in this respect has not been so rapid, and although there are a number of institutions in Germany and Austria which are centrally heated, there are only two cases of actual district heating on any extensive scale, these being at Hamburg and Kiel where independent companies are furnishing steam to sections of the cities from central steam stations generating electricity.

Probably the largest installation of central heating in Europe is in Vienna where an asylum comprising sixty buildings with an aggregate volume of over 26,000,000 cubic feet is heated from a central plant.

The Poststrasse Station in Hamburg at present supplies heat to one hundred and forty-one office buildings, using approximately 28,000 pounds of steam per hour. By combination with another station, it is proposed to extend this system in the near future to 200,000 pounds of steam hourly.

The heating system in connexion with the electric light station in Kiel serves approximately forty buildings with a combined consumption of about 56,000 pounds of steam per hour during the cold weather.

ENGLAND

Little has been done up to the present time in England in the way of central or district heating, but attention has recently been drawn to the possibilities of utilizing the existing public service steam-electric generating plants in the capacity of combined heating and electric stations in connexion with the proposed scheme of super-power station development. These existing plants are in many cases situated favourably for heat distribution and could be profitably operated to feed electric current to the super-station service system in proportion to the heating steam demand.

UNITED STATES

In the United States about three hundred systems are in operation, varying in size from small privately owned undertakings to very large public utility companies supplying heat and steam in the large cities and having outputs up to 1,000,000 pounds steam per hour, equivalent to over 30,000 boiler horsepower. Descriptions of representative district heating systems in the United States are given in Part V.

INSTALLATIONS IN CANADA

Central heating has been adopted in Canada to a considerable extent for groups of institutional buildings, and, with the realization of the economy and convenience to be secured, many of the older installations of independent furnaces are being replaced by such systems. Regulation of the heat from one central point; the possibility of burning a cheaper grade of fuel in large, specially designed furnaces; and the elimination of labour and extra expense of operating a number of small heating furnaces make central heating well suited for such a class of buildings.

As representative of the larger central heating installations may be mentioned:

	Cubic feet
University of Toronto, Toronto, comprising 27 buildings aggregating approx.	29,000,000
Parliament Buildings, Ottawa, comprising 7 buildings, aggregating approx.	16,000,000
McGill University, Montreal, comprising 9 buildings, aggregating approx.	7,000,000
Alberta University, comprising 18 buildings, aggregating approx.	7,000,000
Queens University and Kingston Hospital, comprising 22 buildings, aggregating approx.	5,000,000

Descriptions of four of these central heating installations are given in Part VII.

Examples of community heating in Canada are to be seen principally in the cities of Toronto and Montreal. In a development by the Toronto Housing Company, two hundred and fifty-two small, self-contained cottages or cottage flats on Bain avenue are heated from a central plant. The dwellings and apartments are rented by the company with janitor, heat, and hot water services included and have proved very successful and economical.

In Montreal several centrally heated groups of residences have been built recently in which the houses are independently owned, heating and janitor service being provided by contract from the operating companies.

A very material saving in fuel has been effected by such methods and the convenience and many benefits to be derived by the tenants make the properties particularly desirable.

District heating has been undertaken as a public utility in only two small towns in Canada up to the present time—North Battleford, Sask., and Brandon, Man. In these towns exhaust steam from the electric stations is utilized and the undertakings have been entirely satisfactory and are very popular. This is of particular interest in the case of North Battleford which has a population of only 4,000.

Complete descriptions of these two district heating systems are given in Part VI with analyses of their operations.

PART II

SCOPE OF APPLICATION OF DISTRICT HEATING

CONDITIONS IN CANADA AND UNITED STATES COMPARED

There is a marked similarity in the mode of living, habits, and progress of the peoples in Canada and the northern United States, and the extent to which district heating may profitably be employed in Canada can be gauged by a study of conditions prevailing in the two countries. A detailed examination has been made of fifteen representative district heating systems in the northern United States, in addition to two in Canada, to determine the factors governing their operation; and a general survey has been made of the existing conditions in different parts of Canada.

TEMPERATURES

Figure 1 shows a map of Canada and the northern United States on which are marked isothermal lines of mean winter temperature, and the location of all towns and cities in Canada having populations of 10,000 and over.

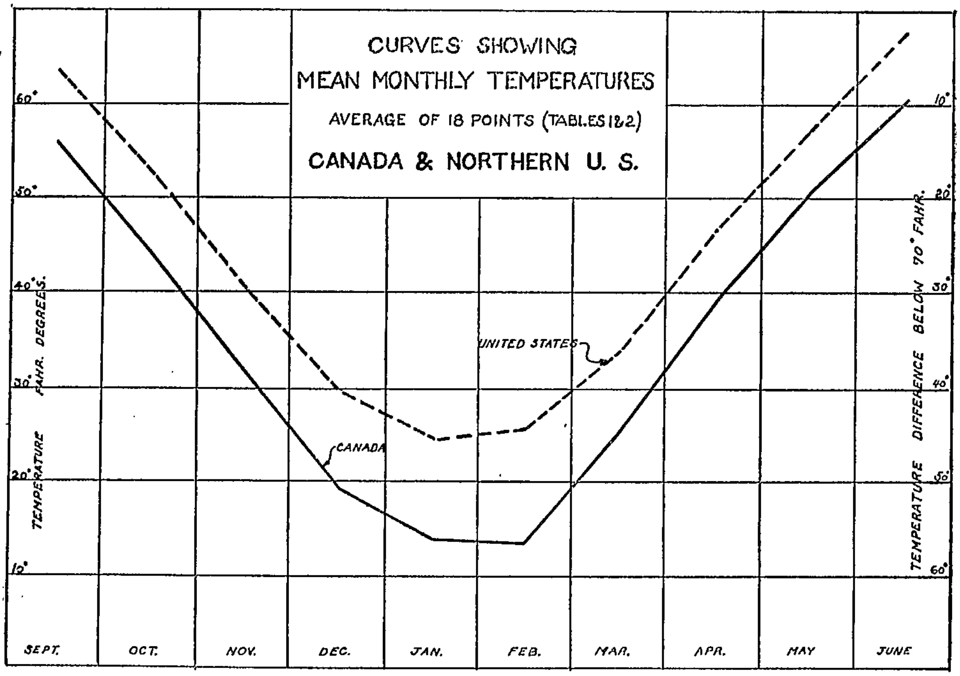

FIG. 2.

On Figure 2 is plotted a curve to show the average of the mean monthly temperatures over the heating season from October 1 to April 30 for eighteen points in Canada, distributed generally in proportion to the density of population, with a corresponding curve for eighteen places in the United States where district heating is in use.

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The points taken to make up these curves are listed in Tables I and II, with the mean temperature for each month given.

Table I.—Mean Monthly Temperatures: Eighteen Cities in Canada

City	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	April	May	June	Period Oct. 1-April 30
Vancouver	56·00	49·20	42·40	38·90	35·00	37·80	41·90	47·00	53·50	58·40	42·00
Calgary	50·00	42·00	26·00	21·00	13·00	14·00	26·00	40·00	49·00	55·00	26·00
North Battleford	51·20	41·00	20·40	8·00	2·50	1·00	16·70	38·40	52·00	60·00	19·00
Regina	51·00	39·00	21·00	8·00	−4·00	−2·00	14·00	37·00	50·00	59·00	16·00
Brandon	53·00	40·00	20·00	6·00	−1·00	−1·00	14·00	38·00	49·00	61·00	16·00
Winnipeg	54·10	41·60	22·00	7·20	−3·00	−1·00	15·20	38·70	51·00	58·60	17·00
Port Arthur	52·80	41·50	26·70	13·40	5·00	7·00	19·60	35·00	46·00	57·10	21·00
London	61·00	46·00	38·00	27·00	22·00	24·00	30·00	44·00	56·00	66·00	33·00
Toronto	60·20	47·00	38·00	26·30	22·10	21·70	29·00	41·40	52·70	65·00	32·00
Windsor	59·00	48·00	42·00	35·00	23·00	24·00	34·00	46·00	58·00	64·00	36·00
Kitchener	57·00	42·00	33·00	17·00	19·00	13·00	30·00	41·00	49·00	59·00	28·00
Kingston	60·00	49·00	36·00	24·00	19·00	18·00	28·00	41·00	53·00	63·00	31·00
Peterborough	59·00	47·00	34·00	21·00	17·00	13·00	26·00	41·00	55·00	66·00	29·00
Ottawa	58·00	46·00	32·00	17·00	12·00	14·00	26·00	39·50	56·00	65·00	27·00
Montreal	58·50	46·00	33·30	19·60	12·70	15·00	24·60	41·00	52·90	63·90	27·00
Quebec	55·30	38·00	32·20	15·00	9·70	11·00	22·80	37·00	52·00	61·20	24·00
St. John, N.B.	57·00	47·00	37·00	24·00	20·00	18·00	30·00	39·00	48·00	56·00	31·00
Halifax	58·00	48·00	38·00	29·00	27·00	24·00	32·00	39·00	49·00	58·50	34·00
Mean	56·10	44·40	31·80	19·80	14·00	13·90	25·50	40·00	51·30	60·90	27·20

Table II.—Mean Monthly Temperatures: Eighteen Cities in the United States

City	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	April	May	June	Period Oct. 1-April 30
Seattle	58·00	52·00	46·00	43·00	41·00	42·00	45·00	50·00	55·00	60·00	45·00
Virginia	54·50	42·20	25·70	11·70	5·00	7·80	22·80	40·10	50·90	61·10	22·00
Milwaukee	63·85	52·75	39·65	25·85	20·70	22·75	33·35	43·20	56·45	65·40	34·00
Minneapolis	62·10	49·60	33·00	19·90	13·40	15·20	29·80	46·20	57·60	67·50	30·00
Chicago	66·30	55·10	41·20	30·00	27·10	27·40	36·30	47·70	58·50	68·20	38·00
Peoria	64·30	52·00	37·50	28·10	23·10	25·90	37·00	50·90	61·50	70·90	36·00
Dayton	66·80	54·70	42·30	32·80	29·60	30·70	40·40	51·60	62·60	72·10	40·00
Grand Rapids	61·80	50·10	38·10	28·80	23·80	25·50	33·00	46·20	59·00	68·10	35·00
Detroit	63·50	52·50	39·20	29·30	24·30	25·00	32·90	45·50	57·90	67·80	36·00
Toledo	64·40	53·40	40·40	30·40	25·80	27·30	35·30	47·60	59·40	68·70	37·00
Cleveland	64·30	53·10	40·40	31·20	26·20	26·80	34·20	46·00	58·50	67·90	37·00
Rochester	62·40	51·50	48·70	29·30	24·00	23·90	31·30	44·90	56·70	66·10	36·00
Erie	63·60	53·40	41·40	31·90	26·50	26·10	33·10	44·70	57·30	67·10	37·00
Pittsburgh	66·40	55·60	43·20	34·20	30·70	31·30	39·40	51·20	62·30	70·70	41·00
Reading	66·30	54·70	42·50	31·20	29·40	28·40	40·00	50·30	62·50	69·80	39·00
Philadelphia	68·00	57·00	45·00	41·00	37·00	40·00	40·00	51·00	62·00	72·00	44·00
New York	66·50	55·60	44·00	34·40	30·20	30·70	37·50	48·10	59·30	68·50	40·00
Boston	62·70	52·30	40·20	31·60	27·00	28·00	35·00	45·30	56·30	65·80	37·00
Mean	63·71	52·70	40·41	30·20	25·80	26·87	35·30	46·75	58·50	67·60	37·00

Table III.—Heating Data on Buildings: Canada and United States of America [1]

Type of building	Average of	Av. volume cu. ft.	Vol. sq. ft. rad.	Lbs. coal per year per cu. ft.	Lbs. coal per year per sq. ft. rad.	Lbs. steam per year per cu. ft.	Lbs. steam per year per sq. ft. rad.	Mean temp. Oct. 1-April 30
								°F.
OFFICE BUILDINGS—								
Chicago	11	3,810,000	111	....	....	6·67	742	38
Detroit	16	1,191,350	72	....	....	7·80	570	36
Cleveland	3	4,365,000	52	....	....	7·67	400	37
Average	**30**	**2,467,634**	**83**	....	....	**7·17**	**595**	....
Winnipeg	7	622,700	67	1·04	69·5	*6·24*	*417*	17
Toronto	9	915,000	91	1·26	114	*7·56*	*684*	32
Montreal	6	691,500	76·5	1·27	97·5	*7·62*	*585*	27
Average	**22**	**760,000**	**79·0**	**1·20**	**96**	**7·15**	**570**	....
Brandon	5	181,770	63	....	....	7·7	485	16
MISCELLANEOUS—								
Chicago	29	345,000	107	....	....	7·97	850	38
Detroit	24	343,000	126	....	....	4·67	588	36
Cleveland	4	834,000	86·5	....	....	7·50	647	37
Boston	13	516,000	....	....	96·5	....	695	37
Average	**70**	**404,000**	**109**	....	....	**6·64**	**720**	....
Winnipeg	34	455,000	....	1·08	....	*6·48*	....	17
Toronto	7	250,000	111	1·07	....	*6·42*	....	32
Montreal	14	247,000	....	1·02	....	*6·12*	....	27
Average	**55**	**376,000**	....	**1·065**	....	**6·45**	....	....
Brandon	6	172,500	59	....	....	6·84	402	15
North Battleford	8	84,000	67	....	....	8·80	596	19
RESIDENCES—								
Milwaukee	13	39,200	54	1·14	62	....	....	34
Milwaukee	26	....	47·3	*1·46*	*69·5*	8·76	416	34
Detroit	114	27,700	48	*1·98*	*95·5*	11·87	573	36
Winnipeg	....	....	....	1·25	50	....	....	17
Toronto	....	....	....	0·75	35	....	....	32
Montreal	....	....	....	0·95	40	....	....	27

[1]The figures given for cities in the U.S.A. have been kindly supplied by the National District Heating Association.

HEATING REQUIREMENTS

From a considerable number of figures obtained it appears that contrary to what might be thought to be the case the coal consumption for heating dwellings and other buildings in Canada is not appreciably more than in the northern United States, in fact is, in general, slightly less, in spite of the difference in temperature.

The actual coal or steam used for heating buildings varies over such a wide range that comparisons are difficult and figures regarding consumption are apt to be misleading. The size, construction, and exposure; the nature of occupancy; the system of heating; and the skill and attention of the firemen or janitor; all have a very marked effect on the consumption.

As a general guide, average figures from some four hundred buildings are given in Table III, showing the average coal or steam consumption in different classes of buildings in a few large cities in Canada and the United States, where the relative mean difference of temperature over the heating season coincides approximately with the curves in Figure 2.

District heating, with the metering of the actual amount of steam used, has furnished valuable information as to the heating consumption by different buildings, and has shown the economy of various types of heating systems (*See* Table III).

In Canada the steam consumption can seldom be determined for the larger buildings, but in such cases the amount of coal used for heating has been given (Table III) and, for purposes of comparison, the equivalent steam consumptions—based on an evaporation of 6 pounds of steam per pound of coal used—are shown in italics. This evaporation figure for steam usefully employed for heating, after deducting plant requirements and losses, is probably high, but if it were reduced, the resulting figures would show an even lower consumption for Canada compared with the United States.

Another factor which might reasonably be corrected in favour of lower consumption in Canada is that relating to the size of the buildings. In general, the steam consumption for heating is proportionally less with an increase in the size of the building, and since the buildings, particularly office buildings, in the United States cities included in Table II, average considerably greater volume than the Canadian buildings, their consumption on such basis should be proportionately lower, apart altogether from the difference in temperature.

For heating residences and dwellings in Canada, where hot water radiation is very generally employed, the amount of anthracite coal used per year is, on the average, very close to the figures given in the table, being generally proportional to respective differences between the mean outside and indoor temperatures in the cities indicated. In these cases, in particular, much larger consumptions are shown in cities of the United States.

With purchased steam the tendency is towards greater consumption. The convenience of the service and the possibility of easily obtaining all the heat required at any time is apt to lead to extravagance. With independent furnace heating labour is necessary to get heat, whereas with service heating the only effort required is in regulating or shutting it off. These factors must be taken into consideration and doubtless partly account for the apparent relatively higher consumptions in the United States compared with Canada, since most of the data available in the former case are from district heating services.

It is suggested that the seeming relatively lower coal consumption in Canada, compared with the United States, may be due in part to:

(*a*) The buildings in Canada being constructed to better withstand the cold, with general use of double windows, etc.

(*b*) Lower indoor temperatures being customary

(*c*) Artificial heat being maintained in many cases for a longer period in the United States than in Canada

(*d*) The greater use of hot water radiation in dwellings in Canada

FUEL

The principal coal areas of Canada and the northern United States are shown on the map, Figure 1, indicating the proximity of the American coal fields to the thickly populated and highly industrialized sections of Ontario and Quebec, which are devoid of coal.

Although served with hydro-electric power, the provinces of Ontario and Quebec consume approximately 60 per cent of the total coal requirements of the Dominion, and almost all this coal is imported from the United States, geographically the natural economic source for the supply of this district.

It will be seen from the map that Canada is handicapped in the full use of her own coal by the long freight hauls from point of mining to point of greatest consumption, and hence, although possessing vast coal resources, is not commercially self-supporting in this commodity.

The bituminous coals of British Columbia and Nova Scotia fill the needs of the eastern and western maritime provinces and part of Quebec, and the bituminous coals of the eastern foothills of the Rocky mountains and the lower grade coals and lignite of Alberta are in general use throughout the prairie provinces, meeting the competition of American coals at Winnipeg and eastward.

Lignite from Souris district has been used to a limited extent for power purposes between Moose Jaw and Winnipeg. It has been burned in pulverized form at the electric light and district heating plant at Brandon, and is proposed for use in connexion with the municipal heating plant projected for Winnipeg.

It will be realized that the economic possibilities of district and central heating depend to a very large extent upon the relation in price between available fuels. It is by reason of the lower grade fuels being utilized in central boiler plants in place of the better and more expensive coal which must be burned in independent heating furnaces that a system of distributed heat can be profitable both to the heating company and to the community. Present prices indicate a similar differential in such fuel costs in Canada and the United States, with a possibly greater supply of low-grade fuels in Canada.

SPECIAL FURNACES FOR LOW-GRADE FUELS

For the utilization of the lower grades of coal, several types of automatic stokers are adaptable for use with steam boilers. Figure 3 illustrates

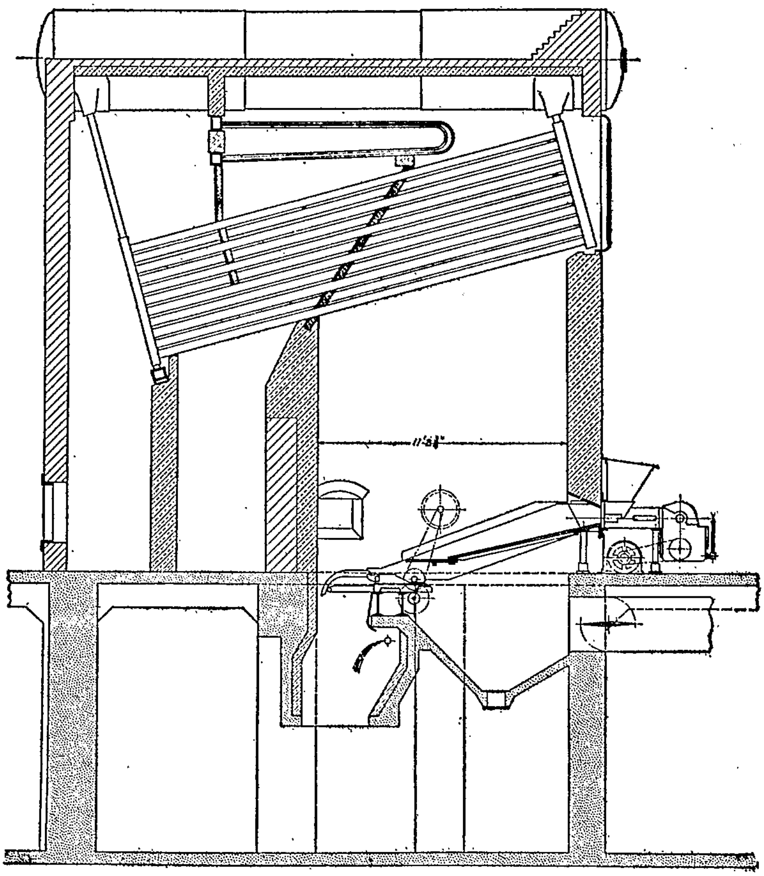

Fig. 3. Underfeed, forced-draft stoker.

an underfeed-stoker setting for burning the cheaper grades of coal; Figure 4 shows a pulverized fuel-burning installation suitable for the Saskatchewan lignites or for low-grade fuel; Figure 5, a chain-grate stoker with special arch setting for burning Alberta lignites; and Figure 6 a forced-draft, chain-grate stoker with a special arch construction for burning anthracite

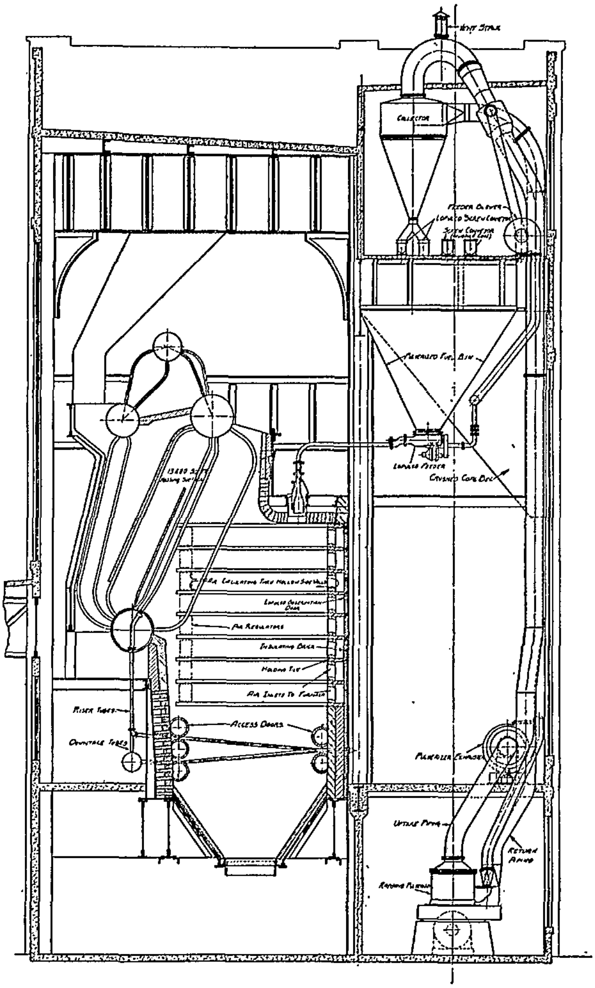

Fig. 4. Pulverized fuel installation.

screenings. For smaller plants, special hand-fired grates have been designed. The choice of equipment for any fuel must depend, of course, upon the particular conditions and requirements.

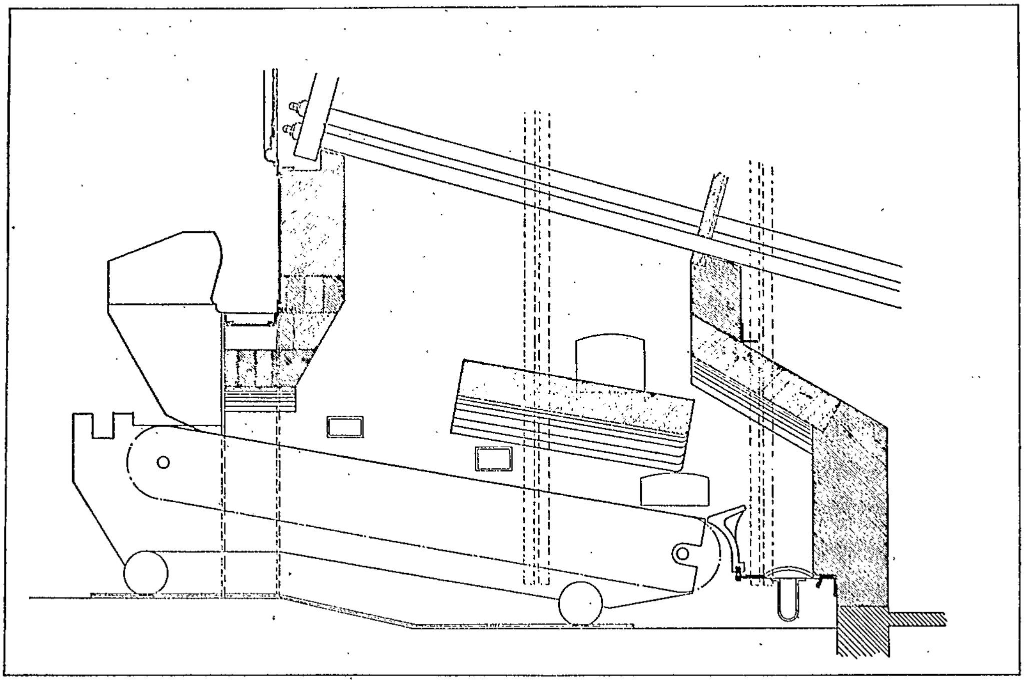

FIG. 5

Chain-grate stoker setting for Alberta lignite.

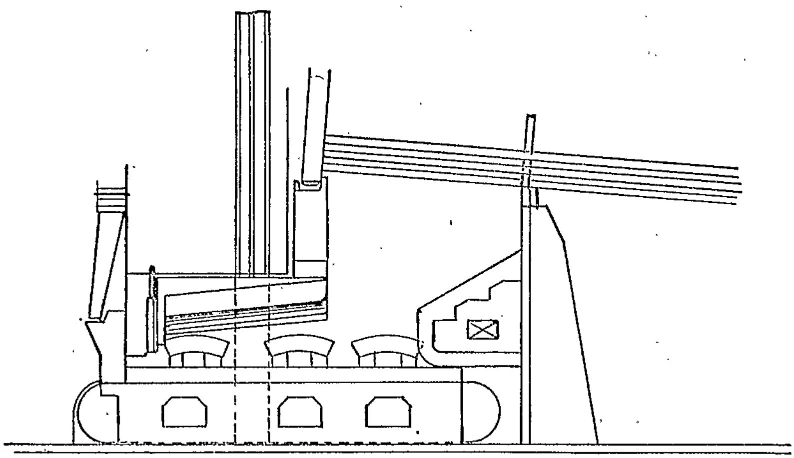

Fig. 6. Forced-draft, chain-grate stoker setting for anthracite screenings.

POSSIBLE EXTENT OF DISTRICT HEATING IN CANADA

According to the last Dominion census, 1921, approximately 46 per cent of the total population in Canada, or 4,021,756 persons, reside in urban centres of 4,000 population and over. Of these:

569,609 are included in 99 municipalities of 4,000 to 10,000 population.
818,892 are included in 46 municipalities of 10,000 to 50,000 population.
2,633,255 are included in 13 municipalities of 50,000 and over.
Table IV shows the distribution by provinces.

A town of 4,000 population can be taken as the low limit in which district heating could be considered, and in actual practice, conditions would have to be somewhat special for an economic undertaking of district heating in any town under 10,000 population, such as a possible combination with a favourably situated municipal steam electric station or industrial plant, or a particularly progressive community willing to bear an increased cost of heating for the convenience and benefits to be derived therefrom. North Battleford is an example of the former case, where with a population of only 4,000, district heating as a municipal enterprise in connexion with the steam electric station has proved satisfactory. In the United States several instances of successful small-town heating can be cited.

The principal field for district heating is found in the larger towns and cities, particularly in the business and shopping sections where the heating and steam load is greater and more concentrated. Whether, or to what extent, district heating may be profitably or commercially applied in any particular district depends upon local conditions: definite limitations cannot be drawn, but the main factors to be taken into consideration are discussed in some detail in Part III.

STEAM SERVICE FOR OTHER PURPOSES

In every city a considerable quantity of steam is needed by laundries, restaurants, hotels, industrial plants, etc., which is commonly generated in small boiler plants burning high-priced coal in a very inefficient manner—commonly sources of annoyance, dirt, and expense to the neighbourhood.

Steam can in many cases be profitably supplied for such purposes, in addition to heating, from central stations. A properly balanced combined service of steam power and heat will in many cases provide the means to secure a successful central steam business in districts where district heating alone would be unprofitable.

The New York Steam Corporation distribute high-pressure steam in the downtown section of New York, and serve a large number of isolated plants which draw steam from the street mains in preference to operating their own boilers. In Rochester, N. Y., the principal use of steam supplied by the district steam service is for industrial purposes, two large manufacturing concerns being served by independent lines at distances of approximately half a mile from the central station. A new system has been installed at Grand Rapids, Mich., which is regarded as representing the latest practice in district heating and steam service in the United States, and is arranged to distribute steam at three different pressures in separate systems for power, heating, and miscellaneous purposes through a section of the city.

Table IV.—Distribution of Population in Canada—1921 Census

Province	Towns 4,000 to 10,000 pop.		Cities 10,000 to 50,000 pop.		Cities over 50,000 pop.		Total population		Total %
	No.	Population	No.	Population	No.	Population	In province	In urban centres over 4,000 population	
Alberta	1	4,500	2	27,288	2	133,827	588,454	165,615	28·2
British Columbia	10	54,600	3	48,000	2	257,000	524,582	359,600	68·5
Manitoba	5	31,000	2	33,000	1	250,000	610,118	314,000	51·5
New Brunswick	4	25,625	1	15,000	1	63,000	387,876	103,625	26·6
Nova Scotia	8	53,725	3	45,000	1	65,000	523,837	163,725	31·3
Ontario	37	221,810	21	397,676	4	1,003,928	2,933,662	1,623,414	55·4
Prince Edward Island	1	7,000	1	13,000	...	...	88,615	20,000	22·6
Quebec	28	144,349	10	155,085	2	860,500	2,361,179	1,159,934	49·0
Saskatchewan	5	27,000	3	84,843	...	...	757,510	111,843	14·7
Yukon Territory	...	...	...	...	...	...	4,157	...	...
Northwest Territories	...	...	...	...	...	...	7,988	...	...
R.C.N.	...	...	...	...	...	...	485	...	...
	99	569,609	46	818,892	13	2,633,255	8,788,463	4,021,756	45·8

The economic advantages of such a central steam power service lie, as with district heating, in:

Decrease in use of high-priced coal

Utilization of low-grade fuels or other forms of waste heat energy

Direct fuel economy through improved efficiency of large, central plants

Possible combination with the generation of electricity

Elimination of smoke from small, isolated boiler plants, and coal and ash traffic in streets, with the consequent improvement in general conditions resulting therefrom

INFLUENCE OF STEAM-ELECTRIC AND HYDRO-ELECTRIC UTILITIES ON DISTRICT HEATING

In the United States, district heating in its early application was developed largely in connexion with the generation of electricity from steam, primarily to use the exhaust steam, but, also, by supplying heat as well as electricity to induce the abandonment of privately owned plants. Where the steam electric stations were situated within the city limits and convenient to the heating areas this could well be done, but with the increased use of electric power these stations have been replaced by larger ones situated at strategical points to serve not only one city but distribution power systems over wide sections of the country. As a consequence, in the large cities, district heating is now supplied either from independent boiler plants or from auxiliary steam plants that generate electric current as a by-product to the extent of the heating steam demand, and feed into the main electric power system. Local conditions govern the choice of plan. Where additional steam is required for an increasing district heating service, the cost of installation and operation of auxiliary steam electric generators may not be justified by the saving made over the cost of generating electricity at the main station. Also, if it is necessary to transmit steam for a considerable distance to feed the district heating area, small, high-pressure pipe-lines may prove more economical than the necessarily large distribution pipes needed for exhaust steam from auxiliary steam electric units.

In Canada, wherever electricity is generated from fuel stations, the same conditions apply, and the application in small towns where the electric stations are conveniently situated is already exemplified in the cases of North Battleford and Brandon.

In districts supplied with hydro-electric power—and they are the most populous districts—the possible combination of steam and electric service must be considered in a different manner. For such conditions there can seldom be reduced cost of generation of electricity by an auxiliary steam plant, even if the exhaust steam be utilized for heating, but there are opportunities for combination with stand-by steam stations or peak-load stations that are worthy of consideration.

HYDRO STAND-BY COMBINATION

Illustrative of the former is the municipal district heating system projected for Winnipeg in connexion with the hydro-electric system and other municipal services. This undertaking involves the installation of a 15,000 H.P. steam station to:

(a) Serve as a reserve to the hydro-electric system

(b) Furnish steam for district heating in the down-town section of the city to the full capacity of the plant, with the utilization of off-peak power from the hydro-system for the generation of steam

(c) Supply power in connexion with the municipal fire-pumping and water-works systems

The daily load curve of a hydro-electric service is in many cases such that there is a considerable amount of waterpower available and unused during certain periods of the day, and the use of this power for the production of steam by electric steam generators provides a means to increase the load factor on the hydro plant and to save fuel in the steam station—*see* graph Figure 7. Provided that this "dump" power can be supplied or shut off at short notice, it can be sold at a very low rate to outside consumers, and an independent hydro-electric company in Winnipeg, is at the present time supplying current on such terms for the heating of a large block of buildings in the business section, showing an appreciable saving in fuel to the heating company and a profitable use of waterpower which would, otherwise, be wasted.

There are similar opportunities for such applications in other cities and towns.

PEAK LOAD STATIONS

Waterpower plants cannot be forced and the highest load peak usually occurs during the winter months when water may be low or when ice creates difficulties. For these reasons the installation of steam stations to carry the peak load and to allow the hydro plants to operate at a high load factor is a matter which must receive increasing consideration, especially where the more favourably situated waterpowers are becoming fully developed. As distinguished from waterpower, steam plants can be located to suit the load distribution, and since such locations are as a rule in the neighbourhood of the large urban centres the possible combination of electric generating and steam service and heating stations may in many cases prove the most profitable solution.

Such a condition seems to arise in Ontario where steam peak load stations are already being contemplated and where there are the greatest number of cities of a size to support possible district heating and steam service. It would be useless, when dealing with districts which are covered by widely-embracing hydro-electric systems, to specify any particular place where a steam peak load plant might be profitably located, but the co-ordination of steam heating and hydro-electric service seems to provide a partial solution of the fuel problem in those provinces of Canada which are dependent upon imported coal.

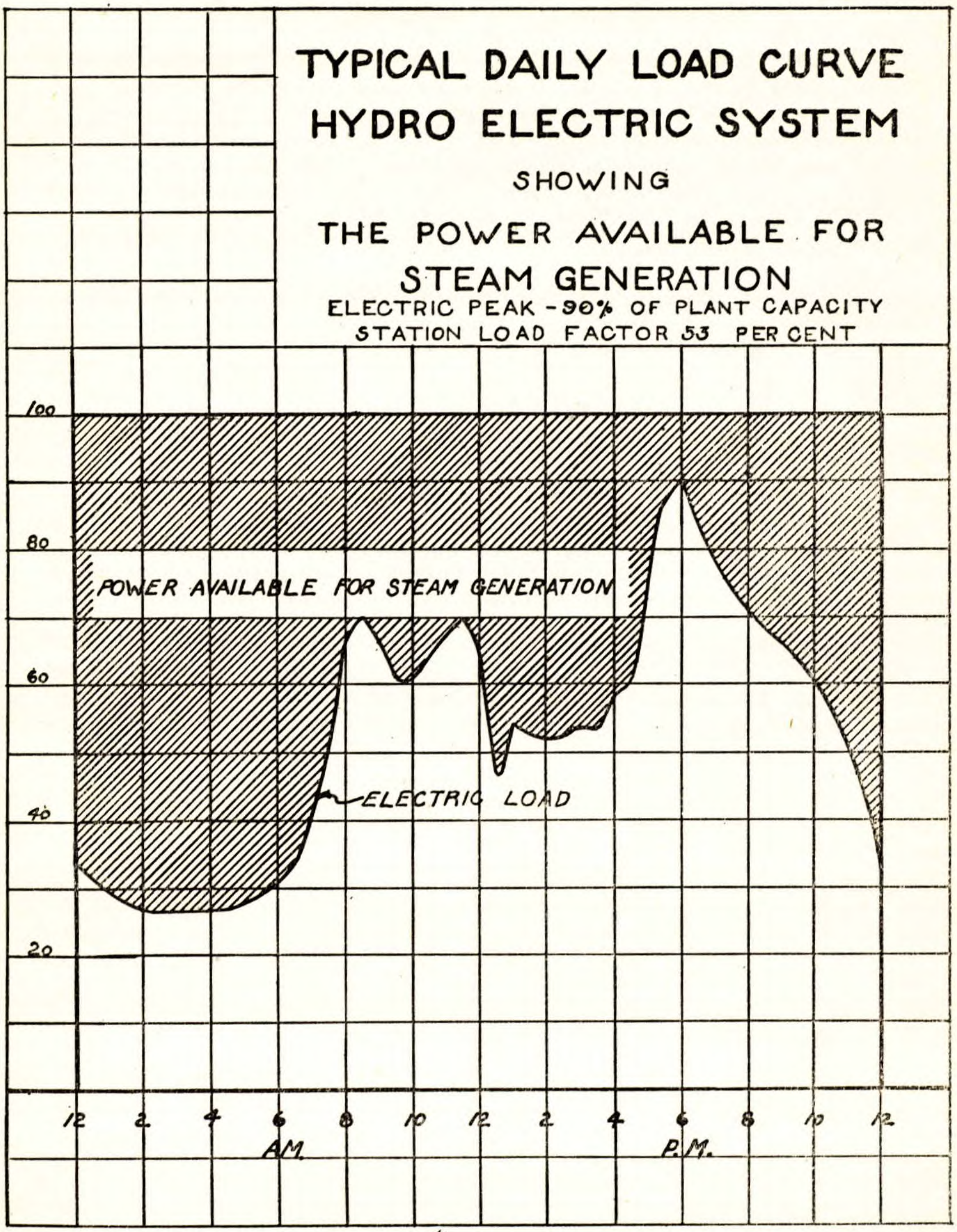
TYPICAL DAILY LOAD CURVE
HYDRO ELECTRIC SYSTEM
SHOWING
THE POWER AVAILABLE FOR
STEAM GENERATION
ELECTRIC PEAK - 90% OF PLANT CAPACITY
STATION LOAD FACTOR 53 PER CENT
100
80
60
40
20
POWER AVAILABLE FOR STEAM GENERATION
ELECTRIC LOAD
12
2
4
6
8
10
12
2
4
6
8
10
12
A.M.
P.M.

FIG. 7

UTILIZATION OF WOOD REFUSE

In the provinces of British Columbia and New Brunswick, in particular, there is now wasted an enormous quantity of wood refuse and sawdust from lumber mills, which might be employed as fuel for steam stations in towns favourably situated. In Vancouver it is contemplated to use this fuel in connexion with a proposed district heating service and there are several other cases in New Brunswick where similar undertakings would be profitable. In Virginia, Minn., a town of 14,000 population, high-pressure steam, generated from wood refuse, is supplied by a lumber mill to the municipal electric lighting and district heating station at a cost considerably less than steam can be generated at the station from coal at $5 per ton, permitting steam to be distributed for heating in the town at a price lower than the cost of fuel for individual furnace heating. This is another municipal enterprise which has been very successful and illustrates the possible utilization of waste fuel.

UTILIZATION OF CITY REFUSE

The burning of household waste, city refuse, and ashes from domestic furnaces, in modern destructor plants,[1] furnishes opportunity for utilizing the heat of combustion for the generation of steam which could in some cities well be combined with municipal district heating plants.

In Europe, such destructor plants are very commonly employed for the generation of electricity and the supply of steam for other services. In Canada, the possibilities for heat recovery are considerably greater owing to the larger amount of combustible matter discarded both in household refuse and coal ashes.

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[1] See paper "The Design and Economies of City Refuse Destructors", by F. A. Combe, read before Engineering Institute of Canada, December 7, 1922.

PART III

ECONOMIC CONSIDERATIONS

FACTORS GOVERNING THE COMMERCIAL SUCCESS OF DISTRICT HEATING

Causes of Failures

To say that district heating has been a profitable business wherever it has been adopted in the United States would be untrue. There have been many failures in the past, as in the early stages of any utility, but in every case the failures have been due to one or more of the following causes:

- Unsuitable territory in respect to density of load
- Poor design and installation
- Bad management or inefficient operation
- Failure to maintain system in proper condition permitting excessive deterioration and depreciation
- Inadequate rates

UNSUITABLE TERRITORY

Of first importance to the success of district heating and steam service is the assurance of a sufficient load per unit length of distribution pipeline in respect to the cost of installation and operation. This does not necessarily imply a congested building district where high-pressure steam is supplied for industrial or power purposes, for points of consumption can be widely separated if the demand be relatively large; but for the heating of buildings alone a comparatively dense building district is necessary.

Residential Districts. Many competent engineers claim that district heating in residential sections can seldom be made profitable, because the steam demand is too small compared with the length of distributing pipe. On the other hand, there are many instances of district heating in towns, including residential districts, which have proved very successful commercially. It is impossible to make any general statements as to the amount of connected load that will warrant the installation of a central plant. A great deal depends upon the relative cost of the fuel burned in a central plant and that normally used for independent furnace heating; but with the differential which commonly exists it has been generally established that, to give reasonable return to the heating company, a rate for heating dwellings must exceed the cost of fuel for individual heating, although this excess may be balanced by the cost of furnace attendance and the benefits to be derived from such service.

The class of residents and the sentiment of the community have a considerable bearing upon the possible commercial success of heating residential districts, through the willingness of the consumer to pay an increased price for added comfort and convenience. In the case of municipally owned heating plants, especially if operated in conjunction with electric light stations or other public utility, the same return on the business is not required as for a commercial enterprise and in several cases, as for instance in the city of North Battleford and the town of Virginia, the cost of district heating has been actually less than the cost of fuel, even for private dwellings.

Business Districts. Congested downtown districts, comprising office buildings, stores, etc., provide a density of load sufficient to make the factor of length of distribution line relatively unimportant, but the high expense of installing and maintaining service pipes in city streets or alleys, coupled with the fact that large buildings would probably use a fairly cheap grade of fuel in their own boiler plants, are other factors that must be considered.

Probably the most profitable heating business is with the retail stores in the principal shopping districts, where the advantages that accrue from the elimination of furnaces, their dust and cost of cleaning; and the possibility of using the furnace room space and basement for the storage of merchandise; justify an increased heating rate.

An attempt was made in this investigation to determine some unit of measurement which might be applied to determine readily in a general way the limits of profitable application of district heating, but so many variables arise that it was not found possible. A study of the representative systems described in this report and the data bearing upon different phases of the subject included herein, will indicate some of the points which must be considered, but it is essential for the success of any projected undertaking that the particular conditions be analysed by an engineer experienced in this branch of work, and familiar with Canadian conditions, to determine whether a certain territory can be profitably served with district heating. It is essential, also, that the details of the system be laid out by an engineer in touch with modern practice and design.

POOR DESIGN AND INSTALLATION

In the United States most of the district heating companies that have failed were started many years ago when the method of laying pipes and the materials used were somewhat crude compared with modern practice. Some of these systems should never have been put in, owing to the conditions being unsuitable, but others if designed by a competent engineer at the present time would no doubt prove successful. In the plant, also, the art of efficient steam generation has undergone a remarkable development during the past fifteen years.

BAD MANAGEMENT OR INEFFICIENT OPERATION

District heating is a business which demands careful management and efficient operation in order to give a satisfactory return on the capital investment.

EXCESSIVE DETERIORATION OF SYSTEM THROUGH LACK OF MAINTENANCE

A considerable advance has been made during recent years in the construction of conduits and the details of underground distribution lines. In the older installations the necessity for efficient drainage was not fully appreciated, and they were, consequently, subject to heavy deterioration and renewal expenditures became so heavy as to involve the company in financial difficulties.

INADEQUATE RATES

Previous to the development of satisfactory meters, the steam consumed was charged on flat rates that were in many cases quite inadequate, or, if sufficient when established, soon became inadequate as the costs of fuel and operation rose. Where district heating was carried on by the electric utility companies the sale of exhaust steam was as a rule looked upon as all profit, and contracts were entered into for heating chiefly with a view to giving a combined service of heat, light, and power, thus encouraging the purchased service in place of operation of isolated plants. As the demand for heating grew beyond the amount of exhaust steam available, or as the increase in the electric business led to the replacement of the smaller central stations by large power plants outside the city limits, the steam service took on a different aspect.

In such circumstances the heating business was left to stand on its own feet and as a rule with the handicap of excessive overhead and the necessity of furnishing steam at rates fixed by contract or franchise based upon exhaust steam.

Many of the larger companies are still unable to work their district heating at a profit by securing increased rates for steam, and look upon this branch as an unavoidable, unprofitable legacy due to the absorption of other companies. Some of these district heating services, therefore, have been allowed to lapse, but in most large cities attention has been given to the revenue possible with proper management and adequate rates, and the result is that the services are steadily becoming economically sound.

At the present time, district heating service is largely under the control of the Public Utilities Commissions in the different states, who fix rates to permit a reasonable compensation to the operating companies. The regulatory action of these commissions, together with the general adoption of metered service and improved efficiency of operation, have given an impetus to the industry, and the consensus of opinion is that the future success of this utility is assured.

As a matter of interest, Figures 8 and 9 have been prepared to show the charge for steam for heating in ten representative cities in the United States and for the three operating systems in Canada. In each case the average cost of fuel used by the heating companies in 1923 is given. Many factors enter into the determination of a proper rate under which steam can be sold—territory, cost of fuel, combination with other services, etc.—but in the examples taken the rates in general follow the cost of fuel except in the very large cities where it might be expected that the high costs of installation and distribution have a particular influence.

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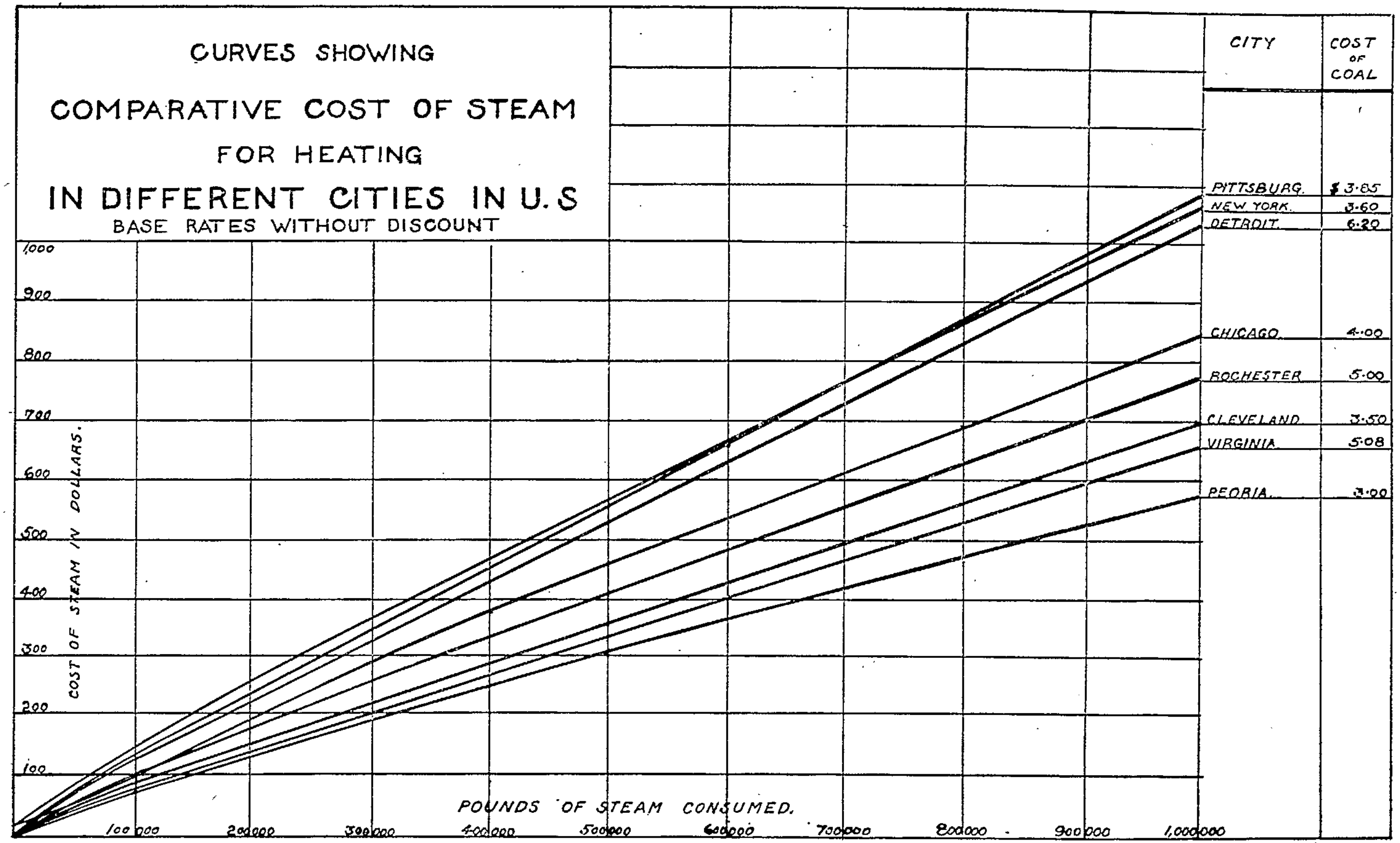


CURVES SHOWING
COMPARATIVE COST OF STEAM
FOR HEATING
IN DIFFERENT CITIES IN U.S
BASE RATES WITHOUT DISCOUNT
CITY
COST OF COAL
PITTSBURG $3.85
NEW YORK 3.60
DETROIT 6.20
CHICAGO 4.00
ROCHESTER 5.00
CLEVELAND 3.50
VIRGINIA 5.08
PEORIA 3.00
COST OF STEAM IN DOLLARS.
1,000
900
800
700
600
500
400
300
200
100
POUNDS OF STEAM CONSUMED.
100,000
200,000
300,000
400,000
500,000
600,000
700,000
800,000
900,000
1,000,000

FIG. 8

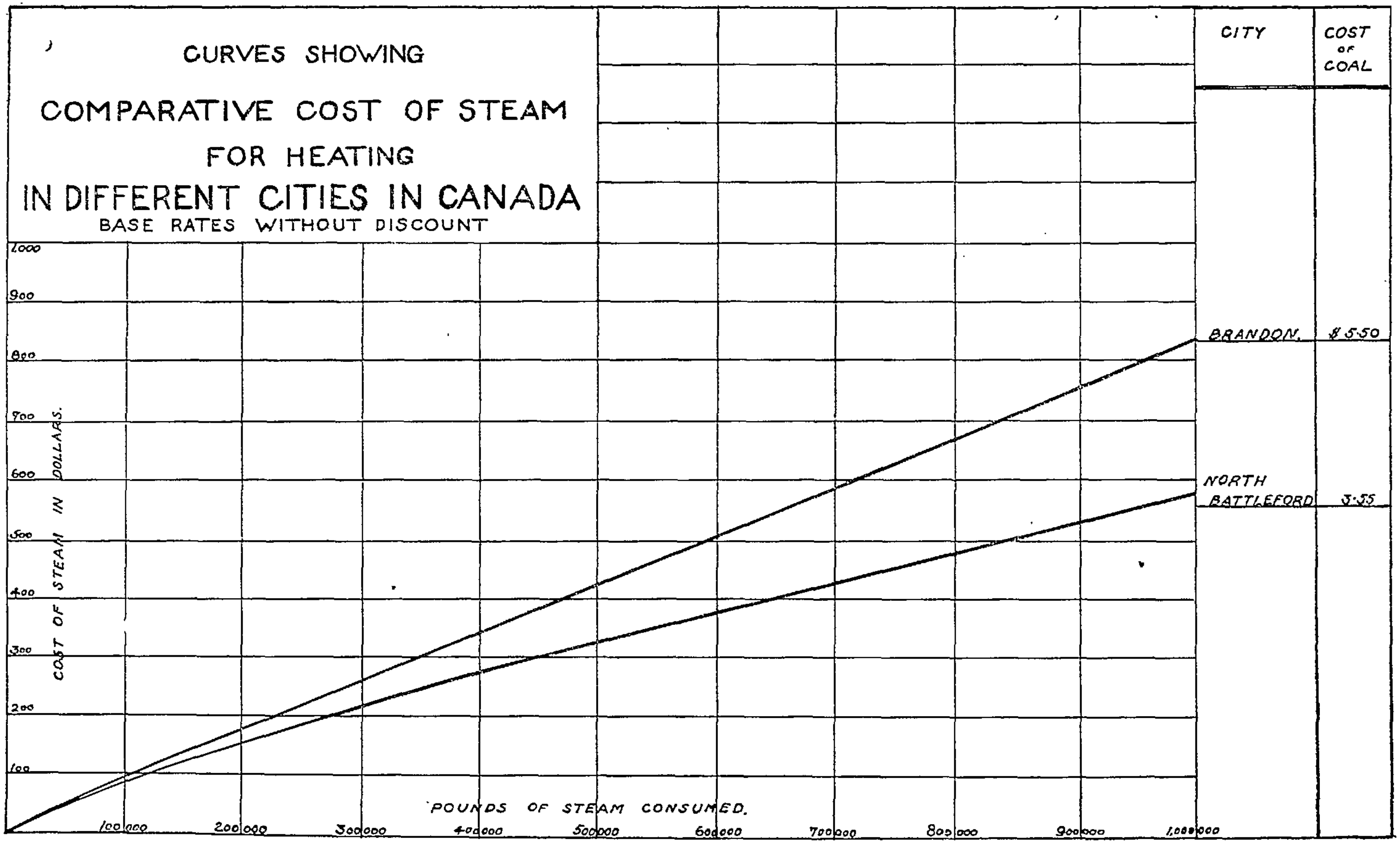

CURVES SHOWING
COMPARATIVE COST OF STEAM
FOR HEATING
IN DIFFERENT CITIES IN CANADA
BASE RATES WITHOUT DISCOUNT
CITY
COST OF COAL
BRANDON. $5.50
NORTH BATTLEFORD 3.55
COST OF STEAM IN DOLLARS.
1000
900
800
700
600
500
400
300
200
100
POUNDS OF STEAM CONSUMED.
100 000
200 000
300 000
400 000
500 000
600 000
700 000
800 000
900 000
1,000 000

FIG. 9

PART IV

GENERAL FEATURES

DISTRIBUTION SYSTEMS

Steam or hot water for district heating is as a rule distributed by underground pipes with branch pipes to the individual consumers. The design of any particular system is, of course, governed by the layout of the blocks to be served, but in the case of the rectangular block plan of most towns and cities in North America, it naturally takes a "gridiron" form with connexions at cross-points in the lines. Such a network with suitably placed cut-out valves permits of supply through alternative paths, equalizes the pressure over the system, and gives some degree of duplication in case of failure or trouble in one branch.

The size of pipe is determined by the amount of steam carried and the pressure. The utilization of exhaust steam from electric generating stations where reciprocating steam engines are used necessitates large pipes on account of the low back pressure usually permissible on the engines, but with the more modern forms of back pressure or bleeder turbines the generating units can be used practically as reducing valves and steam can be passed to the distribution system at comparatively high pressure.

For heating alone a pressure of 5 pounds per square inch at the consumer's premises should be ample and many systems operate with this pressure as a minimum. For small buildings lower pressure will as a rule be satisfactory; for instance, in North Battleford, pressures are run down to as low as 1 pound or even less. Where, however, steam is required for other purposes, either the whole system must carry the higher pressure needed, with reducing valves at the low-pressure customers' connexions, or separate high-pressure lines must be provided. Examples of each method are to be found, the choice being governed by relative economy under the local conditions.

The tendency in the large United States cities is towards independent district heating and steam service, with the possible use of auxiliary back-pressure turbo-generators, and the trend of modern practice appears to be towards the use of high velocity feeders from one or more strategically situated central plants to tap into the "gridiron" distribution system at different points. By such an arrangement steam is supplied at high pressure from the station, and a considerable pressure drop allowed through the feeders. In Detroit, steam velocities up to 75,000 feet a minute have been measured in the feeders. This results in a reduction in transmission loss from radiation and condensation and as a rule in lower cost of installation, although as regards the latter, the smaller high-pressure pipe-line is offset by the better construction and conduit required.

In this respect the district heating system can be considered as analogous to present-day high-tension electric power distribution.

LOCATION OF MAINS

Alleys running through the centre of building blocks in many cases provide a convenient thoroughfare for underground pipe-lines, avoiding much of the congestion under the main streets, but in some cities this location has proved undesirable owing to the difficulty of making repairs and the liability of injury to the pipes when excavations are made for new buildings. In the larger cities, the pipes may be laid in building spaces under the sidewalks, or in the basements of buildings; but, in general, it is preferable to keep the mains away from all buildings so as to avoid disturbances from structural changes, or disagreements with building owners. In the residential districts, there are seldom any serious obstructions from other services, but pipe-lines may conveniently be laid in the parkway or grass space between the sidewalk and road, to avoid cutting up the road paving.

TYPES OF CONDUIT

Many forms of conduit have been devised for the insulation and protection of underground pipes. The earliest installations consisted of bored logs slipped over the pipe and coated with a tar preservative, and where drainage has been good many of these conduits have deteriorated little in thirty years.

Figure 10 shows typical conduits in use today: (a) segmental or wood stave conduit, largely used for the smaller sizes of low-pressure lines; (b) special form of tile conduit; (c) concrete; and (d) hollow tile, construction, for higher-pressure or larger pipes, as generally adopted in slightly modified form by several of the larger district heating companies.

Efficient underdrainage is of the greatest importance with any conduit and the lack of it is probably the chief cause of troubles in distribution systems.

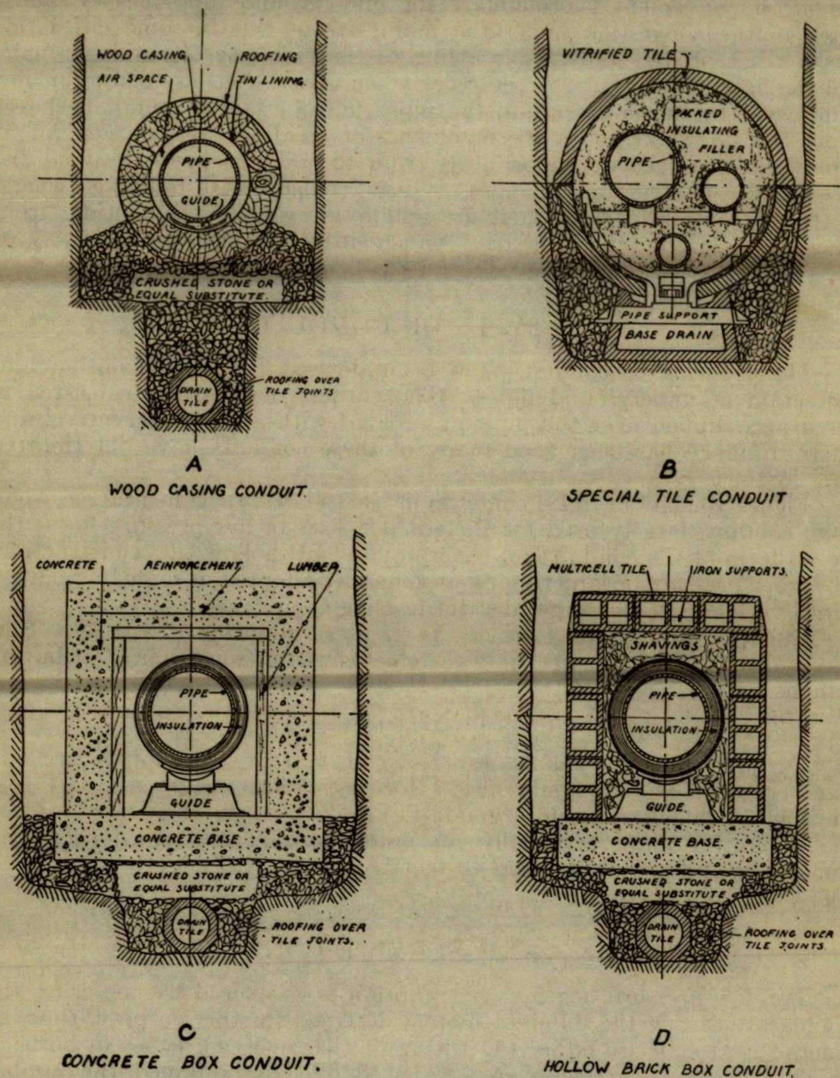
TUNNELS

For high-pressure mains, especially if two or more pipes are run together, tunnels give ready access for inspection and repair, but cost much more than any form of conduit. In Pittsburgh and Detroit, brick and concrete tunnels, artificially ventilated, contain the main feeders and trunk-lines and are built 25 to 40 feet below the street level, so as to be clear of all obstructions.

METERING AND SERVICE CONNEXIONS

For low-pressure heating consumption is measured by metering the condensation. Of the different meters designed for this purpose, those in general use today are either the tilting or the revolving type, in both of which pans or compartments are alternately filled and dumped, the number of motions being registered on a dial.

It is seldom profitable to return the condensate to the central station, the value of the salvaged hot water being more than offset by the cost of recovery, but a considerable amount of heat can be extracted from the water of condensation by the use of "Economy Coils" for domestic hot water service, or by other means.



TYPES OF UNDERGROUND CONDUITS

FIG. 10

High-pressure steam used for power or other purposes where it is not possible to measure the condensate must be metered as supplied. Several forms of steam meters are in use, but owing to the wide range over which they are required to register accurately, special designs are needed for this service.

LOCATION OF CENTRAL PLANTS

The location of a district heating plant must be determined with relation to: (a) shortest possible distance from centre of load (having regard to future extension); (b) cost of feeder lines; (c) facilities for coal and ash transportation; (d) land value; (e) possible combination with existing electric generating station.

It is very desirable, of course, that the heating plant be situated on a railway siding, but in large cities this may not be possible, and coal and ash must be transported through the streets.

Figure 15 shows a view of the Congress Street heating plant of the Detroit Edison Company in Detroit, Mich., and Figure 16 a coaling station on the railway from which large trucks supply the various plants connected to the system. The Congress Street plant is an example of a well-chosen design in a congested district and illustrates the possibilities from the standpoints of architecture, convenience, and cleanliness.

BLOCK HEATING

The difficulties attending the laying of steam pipes under the streets of large cities, where there is in many places a maze of other public utility services, led to the adoption in the United States—notably in Chicago—of independent block heating, whereby all the buildings in one block are heated from a plant in one of the buildings.

This method has many advantages. The operating company needs no franchise or permits to tear up and repave streets, and the initial cost and upkeep are small. On the other hand, with plants in the sub-basements, as a rule in restricted space, the efficiency of steam generation will not be so high as in a large central station, and the cost of coal and ash handling, and operating will be considerably higher. To improve this to some extent, in Chicago, the central boiler plants in each block have been connected by tie-lines crossing side streets at favourable locations, providing an interconnected block plan by which the smaller units can be closed down during the milder weather, and the system carried by the more efficient plants.

The block plan has several advocates and can be run successfully in places that do not lend themselves well to a main central station system. In Canada, the Winnipeg Service Company is heating a block of business buildings in this way, and in several towns in Ontario the system has resulted in considerable economy.

HOT WATER HEATING

As a distributing medium for district heating on a commercial basis, steam is particularly suitable, especially by reason of the possibility of measuring the quantity supplied, which is an obvious necessity for the sale of any commodity, but for heating residences and groups of buildings the use of hot water has many advantages. Water circulated under pressure from a central plant can be heated to a temperature just sufficient to give even heating throughout a properly designed system for varying outdoor temperatures. Under such conditions the supply of heat is under the direct control of the station, which is of particular importance for institutional groups of buildings.

The main advantages and disadvantages of steam and hot water for central or district heating may be summarized as follows:

Steam—	Accurately and easily metered
	Flexibility for various uses apart from heating
	Increased capacity of mains possible by high steam pressures
	Lower installation cost than for hot water
Hot Water—	Must charge on flat rate basis as not easy to meter heat consumption
	Improved efficiency with less transmission loss
	Limited for supply of high buildings by pressure on system

There are a number of commercial hot-water-heating district systems in operation, Toledo, Ohio, being a typical example (*See* Part V); but, on account of the points mentioned, the greatest field for hot-water heating would seem to be in the central heating of groups of buildings under one management.

PART V

DISTRICT HEATING SYSTEMS IN THE UNITED STATES

More than fifteen typical district heating plants in the United States have been studied by the writer to determine the economic factors that control the successful operation of such undertakings, and to examine the latest designs.

Five systems with features of special interest will be described.

New York Steam Corporation	Steam power and heating
Detroit Edison Co.	District heating in large city
Virginia, Minnesota	District heating in small town—municipal operation in connexion with electric station
Illinois Maintenance Co., Chicago	Interconnected block heating in large city
Toledo, Ohio	District heating by hot water, largely residential

NEW YORK STEAM CORPORATION

This is the largest steam service system in existence. The corporation serves a considerable area of the business buildings in the downtown financial district of New York with high-pressure steam for power and heating; also a separate heating system in the uptown district on each side of Madison avenue between Forty-seventh and Seventy-fourth streets. This uptown district includes commercial buildings, apartment houses, and large private residences.

DOWNTOWN SYSTEM

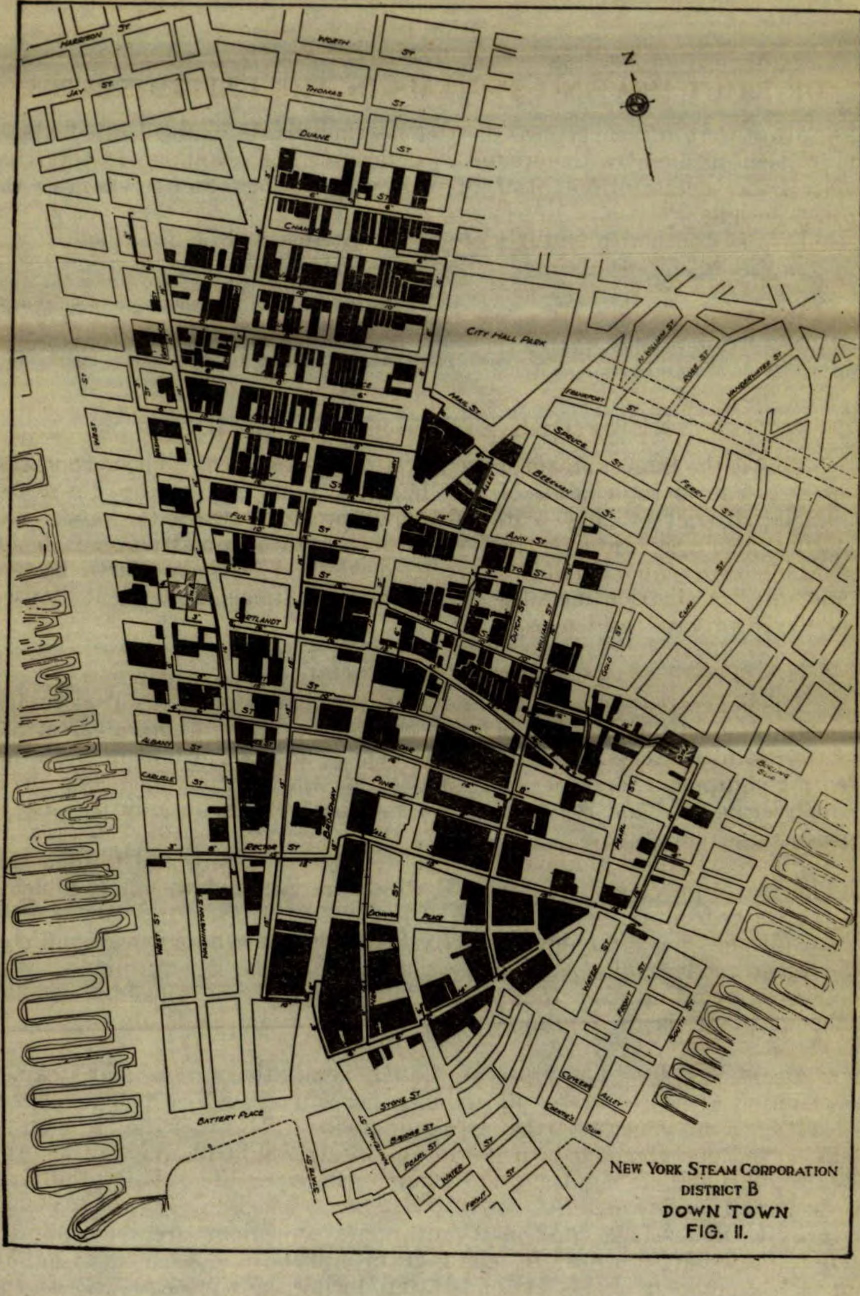
The congested sections of the downtown district present a particularly favourable field for the kind of service rendered. The high values of real estate result in excessive rentals for the space needed for boilers and other heating equipment, and for coal. The expense and inconvenience incurred in delivering coal and removing ashes increase very materially the cost of operating private plants.

Figure 11 shows the extent of the territory covered, and the location of the two supply stations A and B which are situated within two blocks of the water front on opposite sides of the system.

Station A has a nominal capacity of 30,000 boiler horsepower and is of the most modern type and construction. Station B is equipped with boilers aggregating over 15,000 horsepower, and, being an older and less efficient plant, is used primarily for carrying peak loads during severe weather.

Steam Supply. The pipes are laid beneath the streets and steam is distributed at a pressure of 125 pounds per square inch, which is reduced to suit each customer's particular requirements. Many of the large buildings served operate their own power and electric light plants, and use this steam to drive their engines. The steam on entering the different buildings is measured by flowmeters.

Fuel: Power. At Station A anthracite screenings are burned, as a general rule on forced-draft, chain-grate stokers. The boilers operate up to 270 per cent of the nominal rating during the winter months and at about full load during the summer.



NEW YORK STEAM CORPORATION
DISTRICT B
DOWN TOWN
FIG. 11.

The advantage of a power supply service is shown by this system, where the summer load is as high as 45 per cent to 50 per cent of the winter load, thus giving a good load factor on the station throughout the year. With a heating load only there is, of course, almost no demand for steam during the summer, and overhead charges have to be earned during a comparatively short operating period.

The maximum load carried by Stations A and B is approximately 35,500 boiler horsepower.

UPTOWN SYSTEM

This is primarily a heating system, very little steam being required during the summer. Figure 12 shows a plan of the district and the buildings served.

The stations, J and J-annex, are on the river side about three-quarters of a mile from Madison avenue, two feeder pipe-lines connecting the stations to approximately the centre of the main "backbone" line along Madison avenue.

A pressure of about 76 pounds is maintained in the Madison Avenue line, and a high velocity of steam is allowed through the feeders, resulting in a pressure drop of about 35 pounds during peak loads.

Station J, which has recently been remodelled, is equipped with three large boilers totalling 11,500 horsepower capacity. Anthracite screenings are burned on chain-grate stokers as at the down-town plant. Station J-annex has a capacity of 13,500 boiler horsepower and is used as peak load and reserve plant.

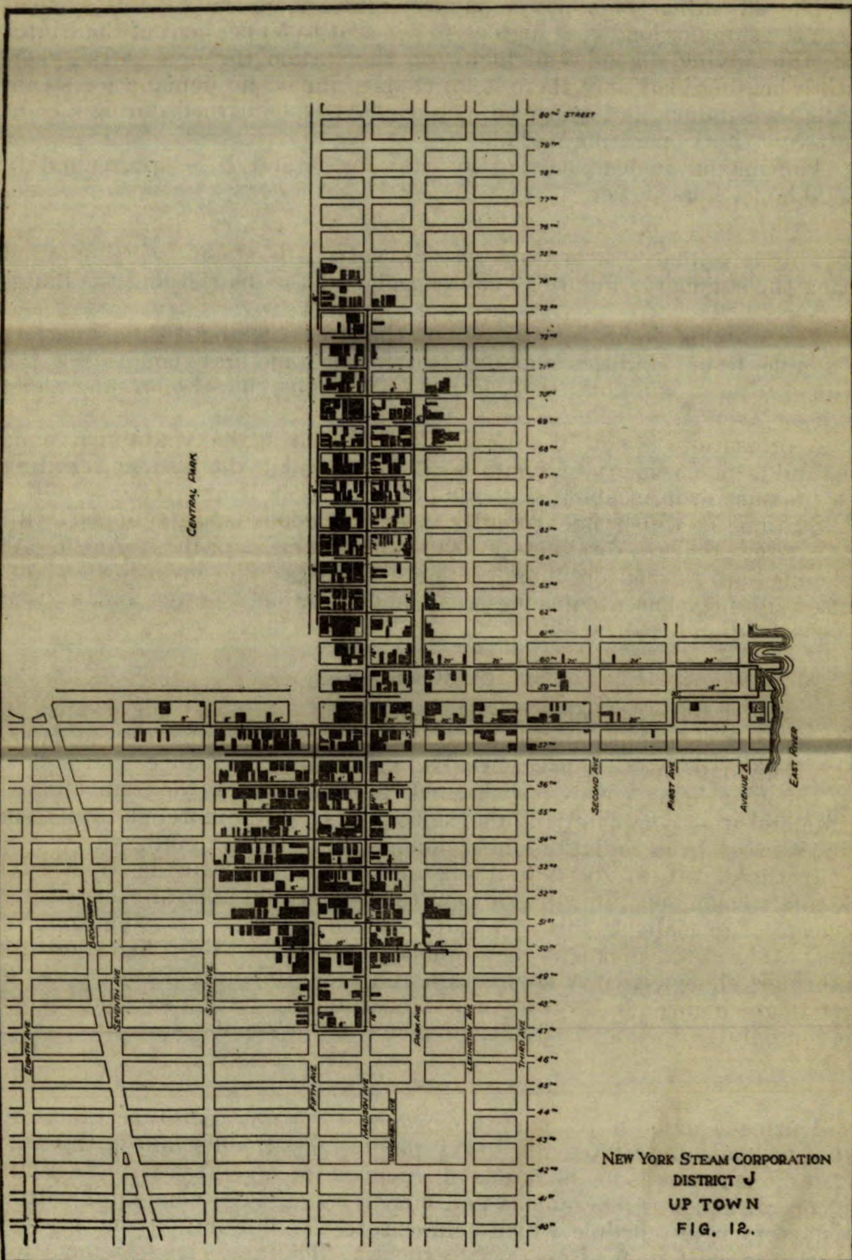
DISTRIBUTION SYSTEMS

About 1,400 customers are served by the uptown and downtown systems, the distribution pipe-lines and services totalling over 155,000 feet. The main lines are in general laid in conduits of concrete and hollow tile, the pipe being covered with thick asbestos lagging and surrounded by mineral wool completely filling the conduits. This thorough insulation reduces losses from radiation and condensation to a minimum.

In the downtown districts the laying of pipes beneath the street level presents tremendous difficulties owing to the large number of other utility services. Especially is this so at street intersections, where the maze of pipes, cables, etc., makes it seem almost impossible to lay high-pressure steam lines; however, it is done and found profitable, although the cost is exceedingly high and the rates must consequently be higher than under the comparatively simple conditions met with in smaller towns.

RATES AND EARNINGS

During a period in the past, the property was not operating profitably owing to inadequate rates and heavy plant commitments during the war, and the business was in the hands of receivers for several years. In 1921, the corporation was reorganized and put on a sound financial basis with a satisfactory rate schedule which compensates for fluctuations in the cost of fuel, the chief item of operating expense. The financial statement for 1922 shows that the net earnings for the twelve months were two and a half times the total annual interest requirements on the first mortgage 6



NEW YORK STEAM CORPORATION
DISTRICT J
UP TOWN
FIG. 12.

per cent bonds (the only funded debt of the corporation) and after deductions of all interest charges, the balance available for dividends and depreciation amounted to $456,986, as compared with annual dividend requirements on the corporation's outstanding preferred stock of $68,530.

The company is carrying out large extensions in both uptown and downtown districts, an indication that the future of the business is considered bright.

Rates

The rates charged for steam vary with the service, depending upon the purpose for which steam is used.

Rate A—General service
Rate B—Annual power service
Rate C—Apartment house service
Rate D—Summer power service

with other special rates for emergency or special services.

Rate Adjustment. The rates in force are based upon a cost of fuel delivered to the plants of $3.35 per gross ton for anthracite steam coal and $4.00 per gross ton for bituminous steam coal; a surcharge or credit being made on all monthly bills for any variation in these fuel costs. The base rates for general service and annual power service are as follows:

Rate A—General Service

For the first 20,000 kals.[1] consumed in each monthly period at $2.00 per thousand kals.
For the next 30,000 kals. consumed in each monthly period at $1.75 per thousand kals.
For the next 50,000 kals. consumed in each monthly period at $1.20 per thousand kals.
For the next 100,000 kals. consumed in each monthly period at $1.10 per thousand kals.
For the next 100,000 kals. consumed in each monthly period at $1.05 per thousand kals.
For the excess over 300,000 kals. consumed in each monthly period at $1.00 per thousand kals.

Discount. Under "rate A—general service," where steam is supplied during twelve (12) consecutive months of the year, a discount of 20 per cent from the above schedule is made for all steam furnished during the six (6) months' period from May 1 to November 1 inclusive.

Rate B—Annual Power Service

For the first 500,000 kals. consumed in each monthly period at $0.90 per thousand kals.
For all excess over 500,000 kals. guaranteed in each monthly period at $0.50 per thousand kals.
For all excess over 500,000 kals. consumed but not guaranteed in each monthly period at $0.90 per thousand kals.

Discount. None.

DETROIT EDISON COMPANY

The development of district heating in Detroit is illustrative of the general trend in the practice of heating in the United States, starting originally with the utilization of exhaust steam from small electric generating stations within the city and later turning to independent live steam heating as the increase in the electric business led to the removal of the generating stations beyond the city limits.

A brief history of this development, as given in a publication by the company, is of interest:

"In 1903 The Detroit Edison Company was organized for the purpose of building and operating an electric power plant to supply current to the two distribution companies which were then operating in Detroit, utilizing the existing plants of these companies as substations. When the application of this plan to the Willis Avenue Station of the Edison Illuminating

[1] 1 kal = 1,000 pounds steam

Company—one of the two companies referred to—was considered, the idea was presented by certain local business men that the operating of the generating units might be continued and the exhaust utilized for heating the buildings in the neighbourhood, thereby eliminating, for as much current as might be generated locally, the conversion losses involved in charging the alternating current received from the main generating station to the direct current required for distribution in that district. The Willis Avenue station contained two 500 kw. D.C. generators and one 400 kw. alternator driven by McIntosh and Seymour engines which were being operated non-condensing. The station was situated in what was at that time a high-class residential section in the uptown district which offered a promising field for the development of the business.

Accordingly, in 1903, a separate corporation, the Central Heating Company, was organized, and a franchise was obtained from the city of Detroit, permitting the company to install distribution lines in the streets and alleys. The Central Heating Company was to own and operate the heating system and purchase the exhaust steam from The Edison Illuminating Company.

In 1904 the Central Heating Company began the construction of a boiler plant and distribution system in the downtown business district of the city, to distribute live steam. There were at this time many isolated electric plants in downtown buildings whose owners were unwilling to purchase current from the Edison Company, partly because the necessity would still remain of operating their boiler plants for heating, and partly because of the expense involved in substituting electric-driven equipment for their steam-driven pumps, etc. The Edison Company's assistance in the construction of the heating plant was believed to be justified by the possibility of obtaining this electrical business; and in order to serve the steam-driven pumps and cooking apparatus it was decided to install in the central part of the district a high-pressure power-line as well as the lower-pressure heating main. Provision was made to use the high-pressure line as a feeder to supply steam to the low-pressure main through reducing valves. The high-pressure main was operated at about 100 pounds pressure and low-pressure mains at about 15 pounds pressure. On the theory that some generation of electricity and some sale of exhaust steam might be possible, room was left for generating units but they were never installed.

The plant was erected on Farmer street north of Grand River avenue. The pipes were installed in tunnels as far as the high-pressure lines extended and the remainder of the system was installed in trenches in the usual way.

In 1912, owing to extensions of the distribution system and the connecting of new business, it became necessary to increase the boiler capacity in the downtown district, and accordingly the construction of a new plant on Park Place, near Grand River avenue, was begun and the first boiler unit was put into service in December of that year.

In June, 1914, The Detroit Edison Company purchased the mains and business of the Murphy Company which had been engaged since 1904 in the supply of steam heat in the southern part of the central business district of the city. This company operated an electric generating plant, the turbines exhausting into the heating system. The Murphy Company's power plant was leased and operated during the season of 1914-15, after which steam was supplied from the Central Heating Company's existing plants.

In 1917 the first boiler units were installed in a new plant at the corner of Congress street and Cass avenue. Additional boilers have since been added and in 1923 the final unit was installed. This plant supplies the former Murphy Power Company district and a considerable territory to the north of it also.

As of July 1, 1915, all the plants and business of the Central Heating Company were bought by the Detroit Edison Company, and since then the steam-heating business has been carried on directly by the latter company.

In 1916, reconstruction of the Willis Avenue plant, made necessary by the increasing load, was begun and the engine-driven generators were removed and replaced by a separate, converting sub-station and the heating system has, thereafter, been supplied for the most part with live steam from a boiler plant devoted exclusively to this purpose. The entire combined heating system has since been fed almost entirely with live steam.

Reasons for Using Live Steam

The use of live steam, fed directly to the heating mains without passing through electrical generating units, is admittedly uneconomical from a strictly thermal standpoint, but there are other factors of cost which must not be overlooked. First of all, the factors of cost which might be produced by the heating plants must compete in cost with that generated in the company's large and economical main electrical stations, which have an economical capacity in excess of 300,000 kilowatts in modern plants. The total unit cost of such electricity as might be generated at the heating plants would be high, notwithstanding the high thermal efficiency, because of the poor load factor, small size units, etc. Further, the heating plants would be burdened with the investment of their electrical generating units, which would be a duplicate investment inasmuch as it would not affect the size or number of the much larger units in the main stations.

The capacity of distribution network has been enormously increased to keep pace with increasing loads by raising the pressure and by the use of high velocity feeders, neither of which practices could be followed in a low-pressure, exhaust steam system. Full exhaust steam operation would require the enlarging of many miles of mains.

The future relation between coal costs and investment costs may possibly invite a change from the present practice, but it has been a successful practice under the existing conditions, and no change is in the present prospect."

DISTRIBUTION SYSTEM

The territory served by the combined uptown and downtown systems covers an area about 2 miles long by $\frac{1}{2}$ mile wide. Figure 13 shows the general layout and the buildings supplied with steam. The first impression gained by looking at this map might be that the heaviest load carried was in the uptown district. Although a larger superficial area is covered by buildings served, yet the actual consumption per square foot in the down-

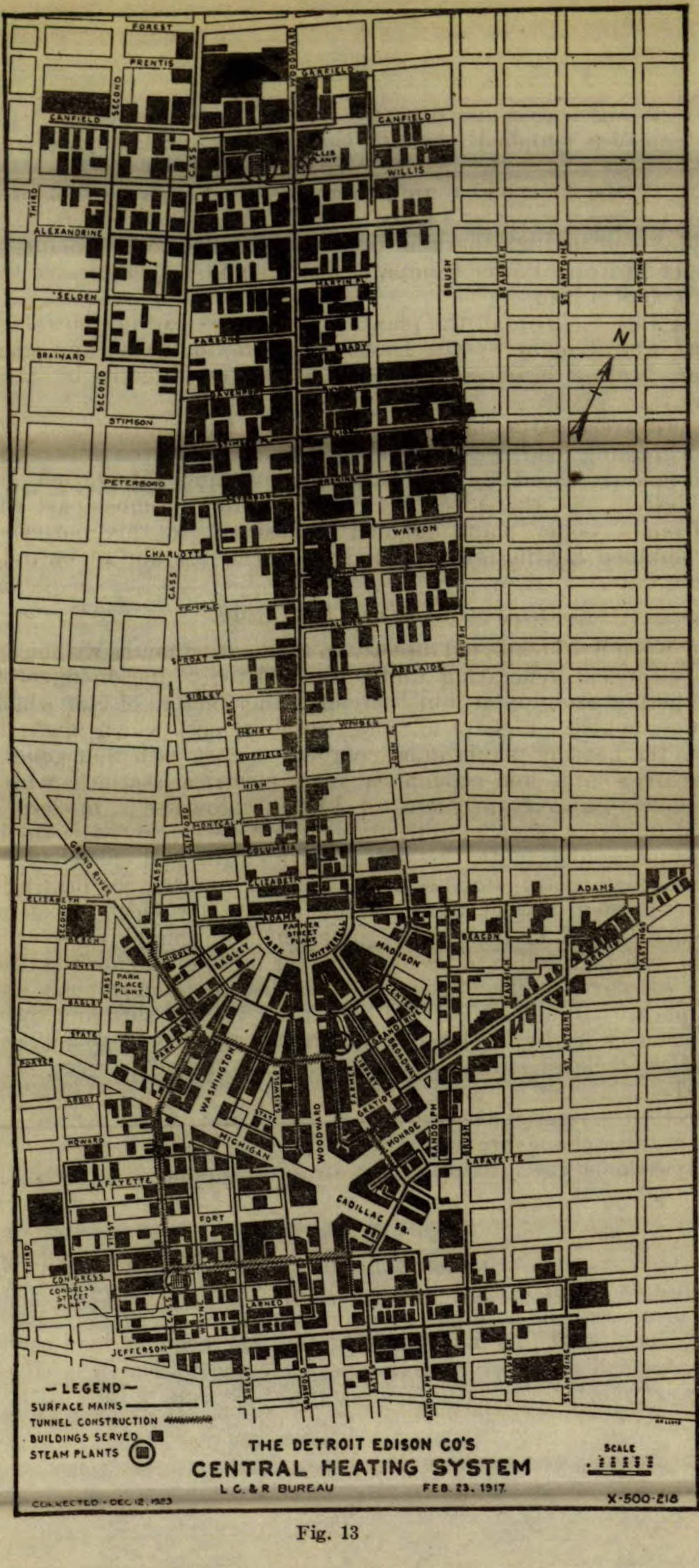

- LEGEND -
SURFACE MAINS
TUNNEL CONSTRUCTION
BUILDINGS SERVED
STEAM PLANTS
THE DETROIT EDISON CO'S
CENTRAL HEATING SYSTEM
L. C. & R. BUREAU
FEB. 23, 1917
SCALE
X-500-218
CORRECTED - DEC 12, 1923
FOREST
PRENTIS
GARFIELD
CANFIELD
WILLIS
ALEXANDRINE
SELDEN
BRAINARD
STIMSON
PETERBORO
CHARLOTTE
TEMPLE
WATSON
ADELAIDE
ADAMS
ELIZABETH
COLUMBIA
MONTCALM
HIGH
HENRY
SIBLEY
GRAND RIVER
WASHINGTON
MICHIGAN
WOODWARD
GRATIOT
MONROE
RANDOLPH
BRUSH
BEAUBIEN
ST. ANTOINE
HASTINGS
LAFAYETTE
FORT
CONGRESS
LARNED
JEFFERSON
CADILLAC SQ.
CASS
SECOND
THIRD
FIRST
FARMER STREET PLANT
PARK PLACE PLANT
CONGRESS STREET PLANT
WILLIS PLANT

Fig. 13

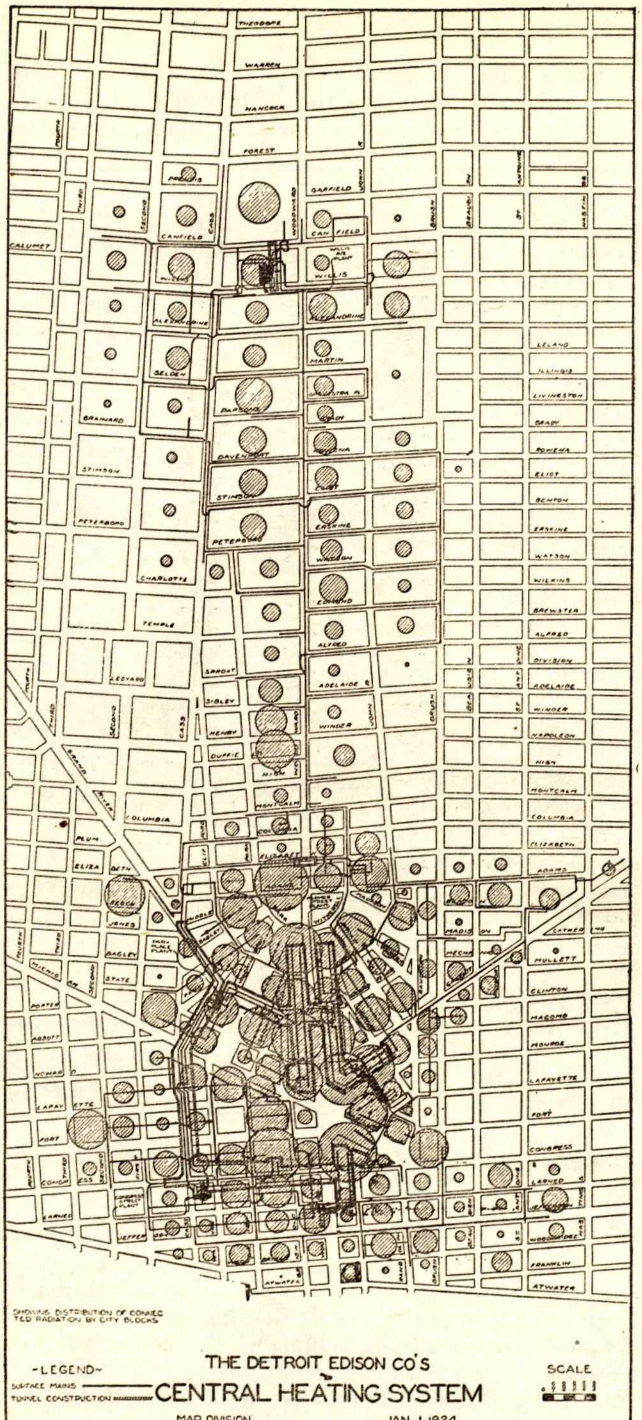

SHOWING DISTRIBUTION OF CONNEC TED RADIATION BY CITY BLOCKS
-LEGEND-
SURFACE MAINS
TUNNEL CONSTRUCTION
THE DETROIT EDISON CO'S
CENTRAL HEATING SYSTEM
MAP DIVISION
JAN 1, 1924
SCALE

Fig. 14

town area is many times as great owing to the high buildings. This is clearly shown in Figure 14, where the distribution of connected load is indicated by the area of shaded circles for each block of buildings.

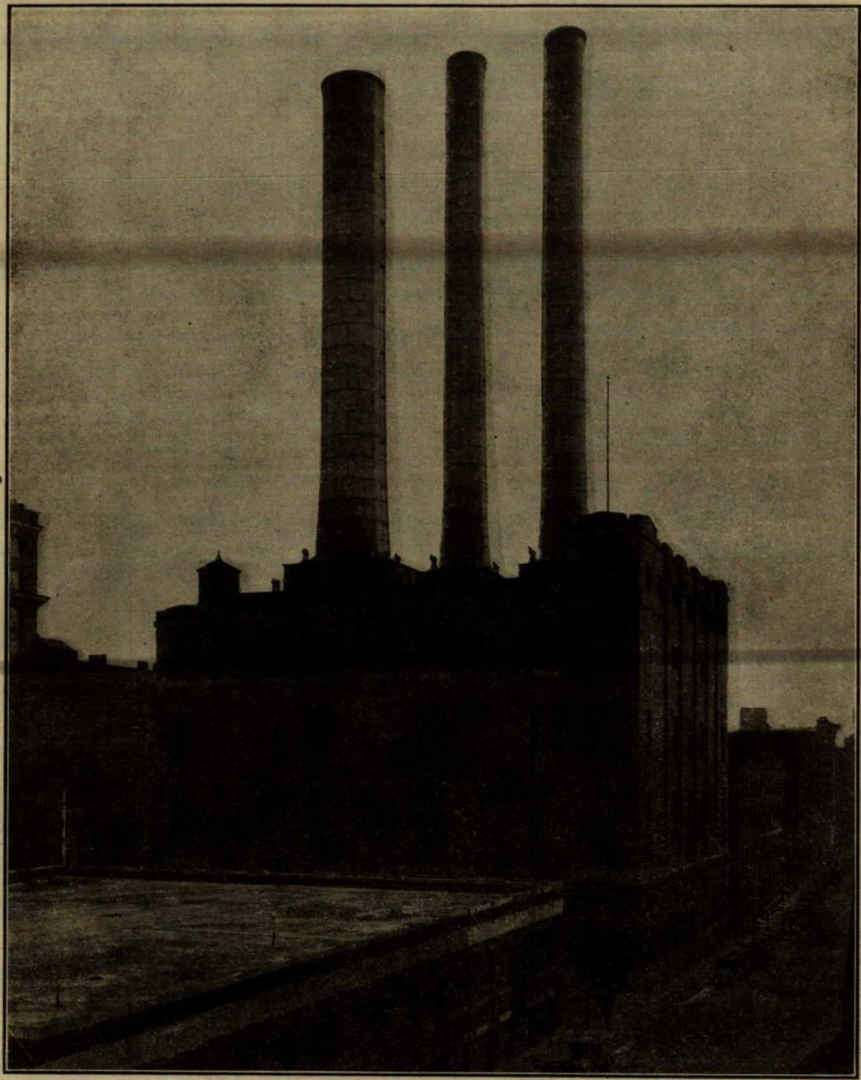


Fig. 15. Detroit Edison system: Congress street plant.

Altogether, approximately 2,000 customers, with a total demand of 4,000,000 square feet of steam radiation, are connected to the system which includes 20 miles of underground mains and 2 miles of tunnels. Where not carried in tunnels, the mains are mostly laid in concrete box conduits, the pipes being covered with asbestos and asphalt waterproofing paper. Some of the older lines and the small pipes are laid in wood log conduit.

The four steam stations have an aggregate of 29,595 boiler horsepower, and are situated to feed into the system at different points to suit the load requirements.

Since the plants are located, perforce, at some distance from railways, the coal must be hauled to them by truck. There are two coaling stations located on railway sidings where the coal is crushed and elevated by belt conveyors to overhead bunkers. It is hauled to the plants by a local contractor in trucks and trailers, each carrying a bucket of five tons capacity, making a delivery of ten to eleven tons per trip.

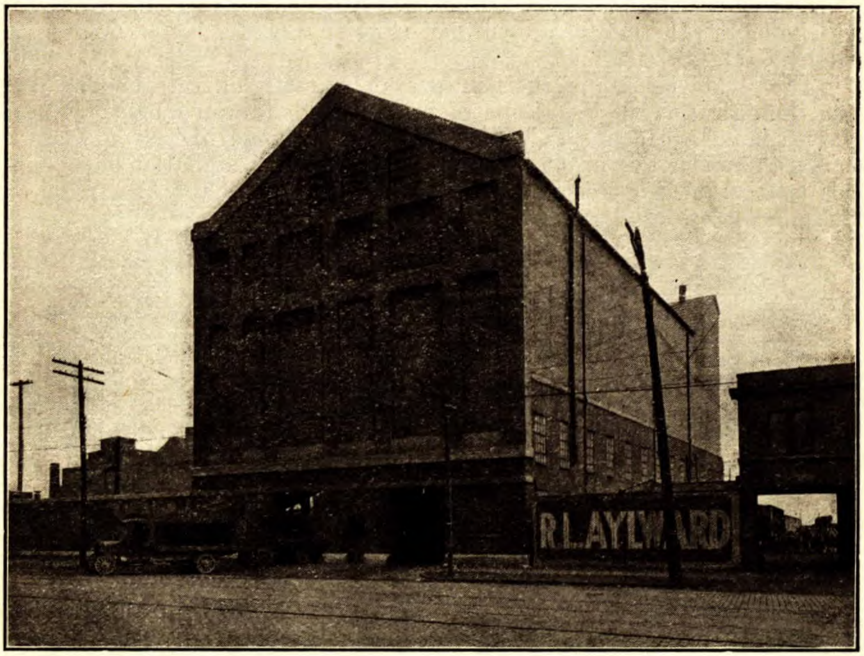


Fig. 16. Detroit Edison system: coaling station.

The photographs, Figures 15 and 16, show views of the latest steam station at Congress street and one of the coaling stations. As will be seen from Figure 15 the Congress Street plant is in a dense business district and shows the advance in boiler-house design. Nearly 52,000 tons of coal are burned annually at this plant alone, the four stations consuming a total of approximately 142,000 tons per year.

This amount of coal, burned at an average efficiency of 75 per cent, smokelessly, in four plants, with ten chimneys, replaces over two thousand plants which would have an average efficiency of probably not over 50 per cent, with two thousand chimneys, the majority of which would smoke badly unless high-priced anthracite coal were burned, and is a splendid example of the advantage of district heating.

PRESSURE CARRIED

In general, steam is supplied to the different buildings served at a pressure of approximately ten pounds, no steam being furnished for power purposes.

The high-pressure feeders from the steam stations, however, carry a much higher pressure, enabling small-sized pipes to be used. Velocities up to 75,000 feet per minute are reached in these feeders, the resulting high-pressure drop having the effect of superheating the steam and reducing transmission loss to a minimum. The pressure is regulated at the station end of the feeders to maintain a nearly constant pressure at the remote end, where they tap into the distribution system. Electrically-operated, long-distance, pressure gauges adjust this regulation at the station.

During the summer most of the mains are shut off; but a few lines are kept in service in the downtown district to supply steam for cooking and water heating.

The steam consumption is measured by metering the condensate in each building served, by means of rotary condensation meters. Except where connexions can easily be made to the tunnel lines, the water of condensation is not returned to the stations, but the installation of economy coils by customers is recommended to salvage part of the heat from the water before its discharge into the sewer.

OPERATING STATISTICS

Year 1922

Pounds steam sold		1,729,981,000
Pounds steam delivered to system		2,112,801,000
Tons coal burned		131,965
Pounds steam delivered to system per pound coal		7·99
Pounds steam sold per pound coal		6·55
Ratio steam sold to steam delivered to system		0·819
Thirty-minute maximum load—pounds per hour		861,000
Yearly load factor—per cent		28
Earnings	$	1,852,829·20
Connected radiation on Dec. 31, 1922		3,707,970
Number of customers on Dec. 31, 1922		1,983
Pounds of steam sold per square foot of radiation		466
Earnings per thousand pounds steam sold	$	1·07
Earnings per square foot of radiation	$	0·499
Cost of coal per ton	$	6·20
Average outside temperature—heating season		40·80°

Rates

For the first 100,000 pounds per month $1.30 per M.

Discount for prompt payment 10 per cent.

Excess—no discount—$1.00 per M.

The rates in force prior to 1920 were inadequate and did not cover the cost of production, the supply of steam for heating being apparently looked upon as a necessary burden on the electric business, to encourage the purchase of electric power. Since that time, the rates have been gradually increased to enable the district heating to stand on its own feet, and under the prevailing rates a return is yielded.

At the present time, steam is being sold for about the cost (of the coal only) of generating it in small house-heating boilers which are of low efficiency and for which fuel is expensive. But when steam is purchased from the central station, more heat is used and the actual amount spent by a small customer is greater than the cost of operating his own plant. He gets better service, however; in fact, he keeps his house or store warmer on the average than if he were tending his own furnace and this fact should not be overlooked in cost comparison. On the other hand the larger business building is mostly heated at a cost rather less than the sum of fuel, labour, ash removal, repairs, and a fair rental value of the boiler space.

Mr. J. H. Walker, Superintendent of District Heating, Detroit, makes the following remarks:

"As a result of experience in Detroit it has become evident that live steam heating plants, delivering steam to the distribution system at a relatively high pressure, are more desirable from a broader economic standpoint, under present Detroit conditions, than is the combination central heating and electric generating plant, even though the thermal efficiency of the latter may be higher. The underlying reason is the low generating cost of electricity at the main generating stations which reduces the relative cost of economies which are obtainable by the operation of small combination plants.

"Furthermore, the economy of the combination plant depends upon the extent of the coincidence between the electrical load and the steam heating load; and the hours during the year when the demands of a district for the two services approximately coincide are very few, making it necessary during the heating peaks to transmit current out of the district, involving conversion and transmission losses.

"The investment in distribution mains is much greater when exhaust steam is transmitted and the size of pipes required may even become prohibitive.

"These conclusions apply to the central heating business only under Detroit conditions or similar conditions and will not necessarily hold true under other relationships of coal costs, construction costs, and the cost of capital which may exist in the future. A return at a future time to some method of exhaust steam distribution is not inconceivable."

VIRGINIA, MINNESOTA

An interesting application of district heating in a small town is found at Virginia, Minn., with a population of between 14,000 and 15,000.

The average temperature from October 1 to April 30 is 22·3 degrees, so that the climatic conditions to be met compare with those of many towns in Canada, in fact it is considerably colder than the average Canadian town.

The municipal electric generating station supplies current to the city and neighbourhood, the peak load being about 1,500 kilowatts. This station is supplied with high-pressure steam up to 20,000 pounds per hour from a large lumber mill about 300 feet from the electric station, making possible very low rates for electricity.

The opportunity arose, with the building of a large school in 1918, to build an extension to the municipal boiler plant to supply heat both to the school and to buildings on the main street, to which the station was conveniently situated.

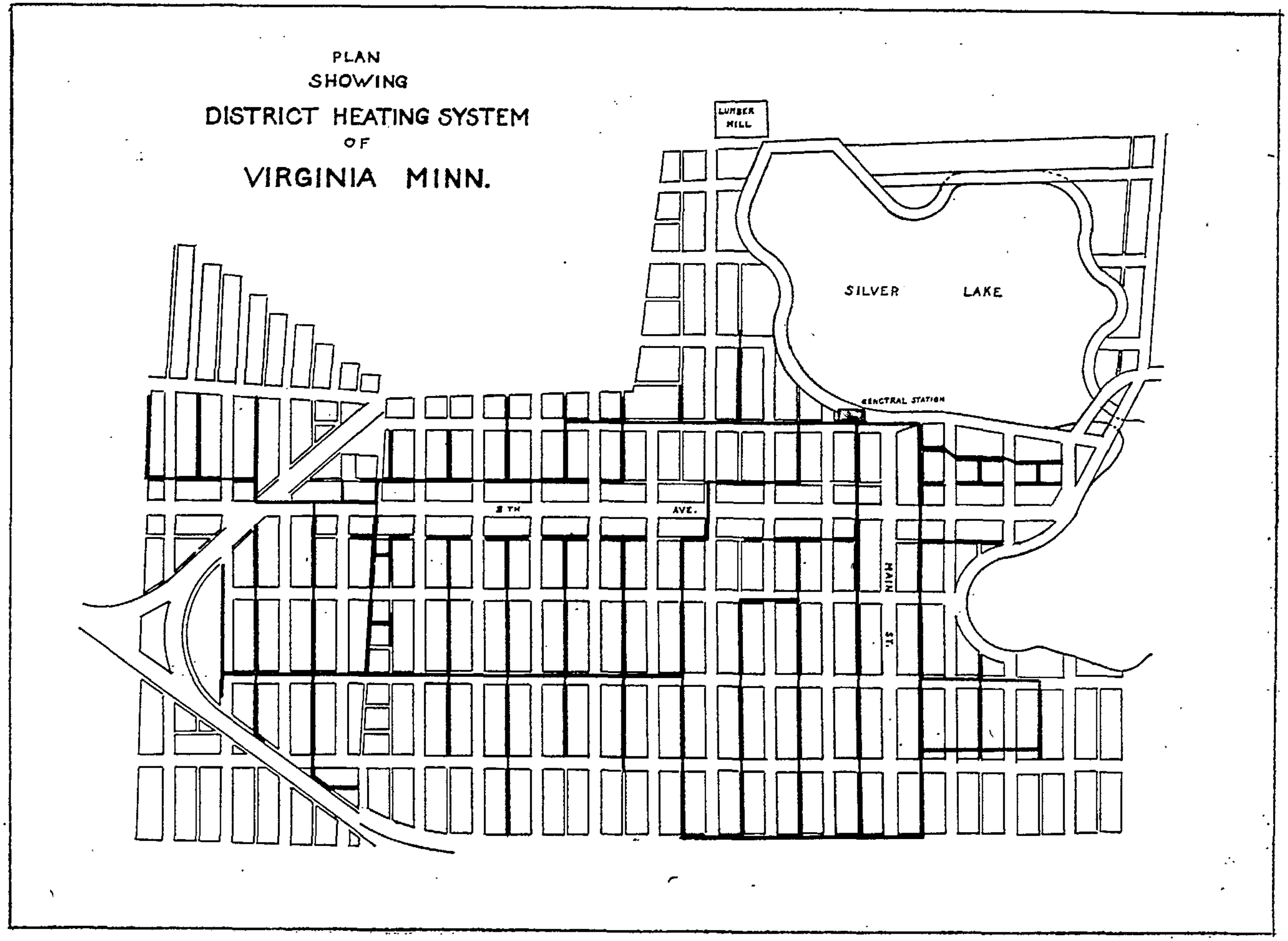

PLAN
SHOWING
DISTRICT HEATING SYSTEM
OF
VIRGINIA MINN.
LUMBER MILL
SILVER LAKE
CENTRAL STATION
AVE.
MAIN ST.

FIG. 17

The cost of the plant was borne partly by the school and partly by the city, and the cost of distribution pipe-lines by assessing property owners along the street served in proportion to length of frontage or per foot of main.

The service was very generally taken up and has been extended each year to cover a greater area. Figure 17 shows a map of the territory covered, which includes sixty-nine city blocks, representing almost the entire southern section of the town, and including business and residential districts. About six hundred customers are now connected to the system. the farthest point served being approximately three-quarters of a mile from the station.

The same method of assessing property owners has been carried out for extensions to the mains; if steam is desired for the majority of lots in a city block (i.e. for seventeen or more lots out of thirty-two lots comprising one block) the mains are laid and all the property owners are assessed.

Rates

The rates charged are only sufficient to cover operating costs, and interest and reserve charges, and vary with the price of fuel, refunds being made from any surplus revenue. The present rate, with coal costing $5.08 per ton delivered, is 60 cents per 1,000 pounds of steam used.

With this rate, the cost of heating even for a small frame house is less than the cost of fuel that would be used for independent heating. The local retail price of anthracite is $17 to $18 per ton and of bituminous coal about $15.

DISTRIBUTION SYSTEM

A pressure of from 7 pounds at the remote end of mains to 15 or 18 pounds at the station is maintained; most of the buildings are equipped with atmospheric steam heating systems with individual regulating valves.

The mains are run as a rule in the grass-way, between sidewalks and main streets, with lateral lines down alleys through the centre of building blocks, service connexions being taken off to the houses or buildings on their side.

Pipes larger than 4-inch diameter are carried in concrete box conduits, the pipes being lagged and waterproofed. Smaller pipe-lines are similarly lagged and encased in tile.

Condensation is measured by rotary meters in each house and the users are encouraged to economize by frequently checking their consumption.

STATION EQUIPMENT

The boiler installation has a nominal rated capacity of 4,058 horsepower and is of modern design. The steam supplied from the lumber mill to the station is sufficient to operate the steam generators for the summer load in addition to hot water requirements in the heating system, and the station boilers are shut down during that period.

During the heating season exhaust steam from the station turbines can be passed into the distribution pipe-lines, the supply being supplemented by reduced-pressure, live steam from the boilers.

The maximum load on the station in 1923-4 was approximately 115,000 pounds of steam per hour.

OPERATING DATA

The following figures give the pounds of steam sold monthly for the years 1919-20 and 1922-23, showing the expansion of the service. A further extension made last year is expected to result in a total consumption of around 250,000,000 pounds for 1923-24.

Pounds Steam Sold

	1919-1920	1922-23
October	4,190,000	12,177,900
November	10,385,000	19,822,100
December	24,535,000	37,125,600
January	24,630,000	37,190,600
February	23,612,000	39,148,200
March	15,667,000	36,434,500
April	12,300,000	22,846,600
May	3,583,000	8,355,300
June	1,358,000	2,290,900
July	985,000	1,838,700
August	875,000	2,280,000
September	1,838,000	6,188,100
	123,958,000	225,698,500

ILLINOIS MAINTENANCE COMPANY, CHICAGO

As distinctive from the general district heating utility supplying entire sections of cities from pipe-lines laid in the streets or lanes, "Interconnected Block Heating" has been adopted in some cities and has distinct advantages under certain conditions.

In almost any case two or more adjacent buildings with similar systems of heating can be operated more economically from one central plant than independently, and many instances can be found of such service.

In the downtown sections of large cities the advantage of combined heating becomes more pronounced, due, in part, to the high value of building space, saving in plant and labour, reduction in smoke, and concentration of coal and ash handling; but, in particular, on account of the larger combined steam requirements which allow for the installation of boiler equipment of higher efficiency than is possible for smaller capacities.

The Illinois Maintenance Company, for a considerable number of years, has undertaken the heating of buildings in different blocks in the loop district of Chicago. One of the largest and most suitable boiler plants in a block, having room for additional equipment, would be leased from the owner and operated by the company to furnish steam to the other buildings in the same block, connecting the different systems by pipe-lines running through the basements.

As the number of these independently heated blocks increased it became advisable to connect adjacent blocks by tie-lines to protect the service and to effect further operating economies by carrying the load on the more efficient plants during mild weather and using the less efficient for peak loads. At the present time there are a number of such interconnected groups of blocks, Figure 18 showing the largest system which embraces forty-nine buildings contained in thirteen blocks in the down-town loop district.

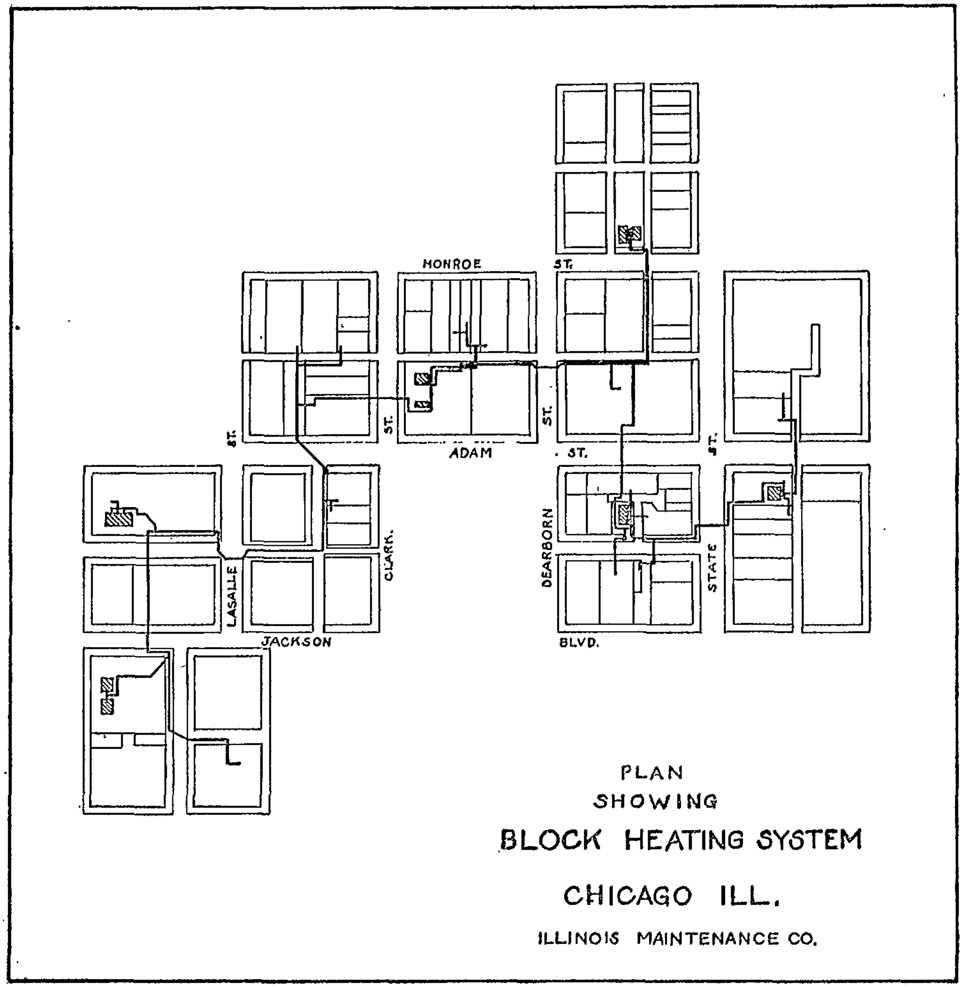
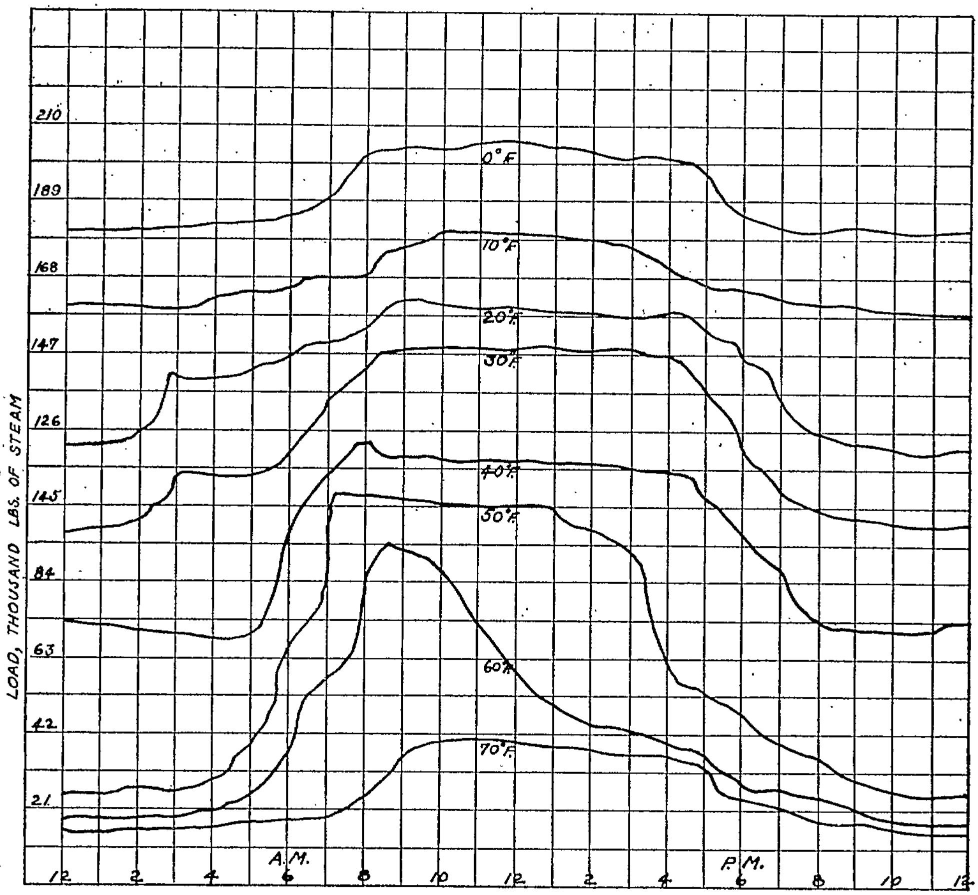


FIG. 18.

Steam for heating this group is generated in six boiler plants, as shown on the plan, the principal unit being located in the basement of the Edison building in which are the offices of the company.

LOAD DISPATCHING

An interesting feature in connexion with the operation of the system is the method of load dispatching or regulation of the load carried by the different plants. Figure 19 shows hourly load curves for different outside temperatures for this group of buildings, and indicates the variation in steam output required from the boiler plants.



DAILY LOAD CURVES FOR VARIOUS OUTSIDE TEMPERATURES
FIG. 19

In the office of the chief engineer, in the Edison building, is installed a meter board carrying a number of electrically operated, steam-flow meter instruments registering the flow of steam at distant points in several connecting pipe-lines. Twin meters are used for each measuring point to register the amount of steam flowing in either direction. By this means the demand on any section of the system can be readily seen at all times, and the engineers at the different plants are instructed by telephone as to the output required from their boilers.

ECONOMY

The main advantage of the block and interconnected block systems lies in the saving, in installation and maintenance cost, that results from elimination of the pipe mains in the streets. Usually a franchise is not required for operation.

On the other hand, the efficiency of steam generation is lower, and the cost of operation considerably higher, in the several comparatively small plants, as a rule located in cramped quarters in the sub-basements of buildings, than in larger district heating stations.

OPERATION AND DISTRIBUTION

The Illinois Maintenance Company furnish steam for heating to sixty buildings, with a total consumption of around 852,700,000 pounds a year, the maximum load amounting to about 13,000 boiler horsepower. The cheaper grades of bituminous coal are burned on automatic stokers, the average cost for fuel in 1922 being $5.77 per ton.

Steam is generated and distributed at 125 pounds per square inch and is used both for heating and power purposes. Steam-flow meters and condensation meters are used, and the water of condensation is returned to the boiler plants wherever possible.

During the summer, approximately 24,000,000 pounds of steam per month are used for power purposes, with a maximum load of 2,000 boiler horsepower.

RATES

The following is a copy of the rates under which steam is sold by this company. It will be noted that surcharges are made on the base rates to compensate for varying costs of both fuel and labour.

Base Rates

$2.00 per 1,000 lbs. for consumption up to and including 10,000 in any month
$1.60 per 1,000 lbs. for excess consumption in each month over 10,000 and up to and including 30,000 pounds
$1.30 per 1,000 lbs. for excess consumption in each month over 30,000 and up to and including 60,000 pounds
$1.00 per 1,000 lbs. for excess consumption in each month over 60,000 and up to and including 100,000 pounds
90 cents per 1,000 lbs. for excess consumption in each month over 100,000 and up to and including 200,000 pounds
85 cents per 1,000 lbs. for excess consumption in each month over 200,000 pounds
Monthly bills subject to 10 per cent discount if paid within 10 days

Coal and Labour Surcharge

"The foregoing base rates are fixed upon an assumed average cost of coal delivered to all the plants of the company of $4.00 per ton and an average cost of all plant labour of 50 cents per man per hour. As such cost of coal or such cost of plant labour, or both, shall increase, the rates above specified shall increase, and as such cost of coal or such cost of plant labour, or both, shall decrease, said rates shall decrease as follows: for each 10 cents increase or decrease in such average cost of coal per ton in any month, 1 cent per thousand pounds, without the discount provided for in paragraph 3 hereof, shall be added to or deducted from, as the case may be, the net base rates above specified in the bill for service hereunder for such month; and also for each 3 cents increase or decrease in such average cost of plant labour per man per hour in any month, 1 cent per thousand pounds, without discount provided for in paragraph 3 hereof, shall be added to or deducted from, as the case may be, the net base rates above specified in the bill for service hereunder for such month.

"By the term 'plant labour,' as hereinabove used, is meant the operating force in all the company's plant, consisting of engineers, firemen, coal passers, ash men, meter readers, and all other employees of the company who are directly concerned with the production and distribution of steam; but said term does not include general officials, general superintendent, chief operating engineer, or office employees.

No discount allowed on surcharges."

During the year 1923 the monthly surcharges were as follows:

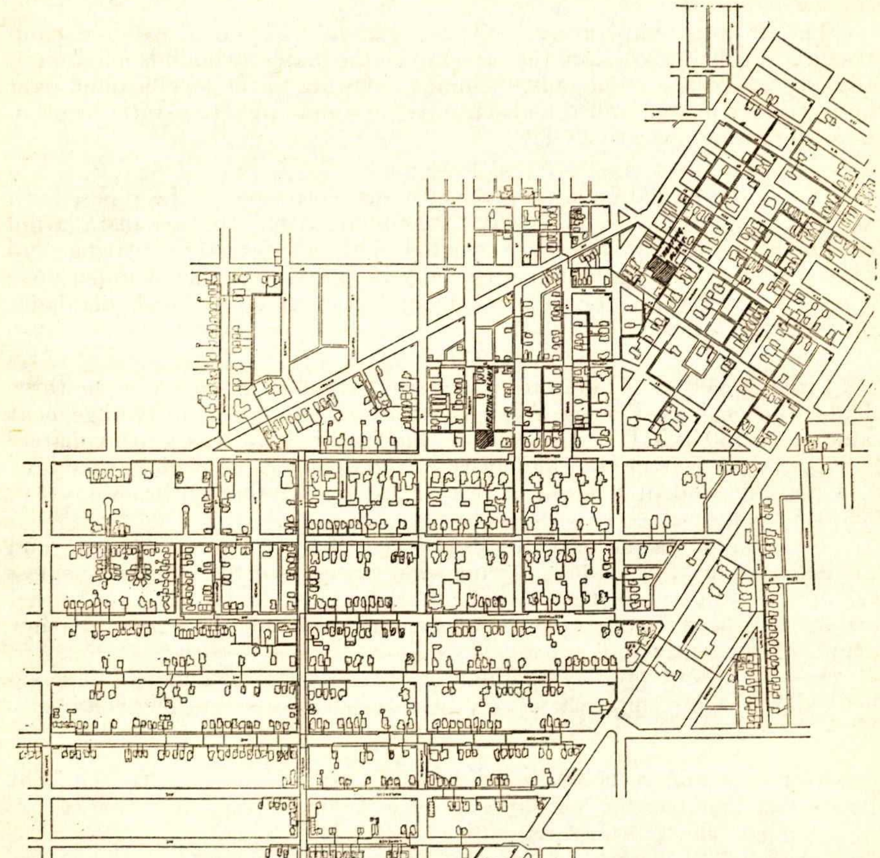
1923	Surcharges		
	Coal	Labour	Total
January	0·19	0·07	0·26
February	0·21	0·08	0·29
March	0·22	0·07	0·29
April	0·19	0·08	0·27
May	0·20	0·06	0·26
June	0·15	0·09	0·24
July	0·10	0·10	0·20
August	0·09	0·09	0·18
September	0·07	0·10	0·17
October	0·07	0·09	0·16

TOLEDO EDISON COMPANY

The Toledo Edison Company operates a service system of district heating by hot water in the residential district of Toledo, a city of about 300,000 population. Figure 20 shows a map of the territory served, which covers about 3½ square miles of better-class residences, mostly detached and of frame construction, with a number of miscellaneous buildings. Altogether about 1,400 buildings, with a hot-water radiation demand of approximately 6,000,000 square feet, are supplied with heat from September 15 to May 31. During the summer the system is closed down. As will be seen from the map, the service is in general use, over 75 per cent of the total number of houses in the territory being heated.

The water in the system is heated either directly in boilers or indirectly in steam heaters, and circulated around circuits of flow and return pipes laid in conduits along the streets, as a rule under the grass-way, between the sidewalk and curb. Service connexions are taken off the flow and return mains to the radiator systems in the different houses, which are thus under the full pressure of the mains. There are in all about 70 miles of mains and 50 miles of service laterals included in the distribution system.

Three heating plants are in use, one of 4,000 rated boiler horsepower and two of 2,000 boiler horsepower each, which are connected to different parts of the system to maintain the circulation and the required temperature. The total amount of water circulated by the pumps in the heating plants varies from 5,000 to 11,000 gallons per minute and the water is heated to a degree depending upon the outdoor temperature. In this way an even temperature can be maintained without any adjustment by the consumers, all regulation being taken care of at the stations.



PLAN
SHOWING
DISTRICT HEATING SYSTEM
OF
TOLEDO OHIO.
(HOT WATER)
FIG. 20

A definite schedule of temperatures of the outgoing water from the stations is followed, the following figures showing the general range. Corrections are made to take care of different wind conditions.

Air Temp. °F.	Water Temp. °F.	Air Temp. °F.	Water Temp. °F.
60	118	20	178
50	134	10	192
40	150	0	208
30	165	−10	222

The drop in temperature between outgoing and return water is from 30 degrees to 40 degrees, and the pressure on the mains 90 pounds maximum, outgoing, and 10 to 30 pounds, incoming. Owing to the level ground over the territory covered and the absence of high buildings, the static head on the system is comparatively low.

MAINS

In forced-circulation, hot-water systems, corrosion of the pipes, both external and internal, is a factor to contend with. In this installation the underground pipe-lines are treated with a protective coating and covered with insulating material specially prepared to render it impervious to moisture; they are then laid in concrete box conduits, with manholes conveniently located.

OPERATING DATA

From 30,000 to 35,000 tons of coal are burned each season in the three plants, the coal used being West Virginia or Ohio with an average heat value of 12,130 B.T.U. The cost of this fuel in 1923 was approximately $3.85 per ton delivered. The price of household coal which would be used for independent heating of residences is $16.50 for anthracite or $12 to $14 for coke.

The system was started thirty-four years ago, but many changes and extensions have been made. During some years prior to 1918 the business was in a very unsatisfactory state and showed an annual loss; but, under new management, improvements were carried out and the plants are now operating efficiently and the business shows a good return.

This is an outstanding example of the necessity of efficient management and of the results which may be secured from sound engineering.

RATES

Unlike steam, it is not possible to measure conveniently the heat supplied in a hot-water heating system and, in consequence, the sale of heat must be charged on a flat rate basis.

The schedule of rates adopted by this company is based on the square feet of radiation necessary to heat the customer's premises to the desired temperatures under the rules and formulæ established by the company. These rates are approved by the Public Utilities Commission of Ohio and are as follows:

Rate "A"

1st 500 sq. ft. or fraction	$0·4628 per sq. ft. per season
2nd 500 sq. ft. or fraction	0·4242 per sq. ft. per season
3rd 500 sq. ft. or fraction	0·4113 per sq. ft. per season
4th 500 sq. ft. or fraction	0·3734 per sq. ft. per season
Next 3,000 sq. ft. or fraction	0·3473 per sq. ft. per season
Over 5,000 sq. ft. or fraction	0·3220 per sq. ft. per season

Monthly payments are made in accordance with the following percentages of the total charge for the heating season:

	Per cent		Per cent		Per cent
September	2	December	17	March	15
October	5	January	20	April	9
November	12	February	16	May	4

PART VI

DISTRICT HEATING SYSTEMS IN CANADA

District heating in Canada is in its infancy, the only two public heating utilities being in North Battleford, Sask., and Brandon, Man. These, however, show what can be done in small towns, in combination with steam electric generating stations.

NORTH BATTLEFORD, SASKATCHEWAN

This city, with a population of only 4,000, situated in the north section of the wheat-growing province of Saskatchewan, is supplied with electric light and power by a municipally owned steam station, situated approximately 900 feet from the main street.

ELECTRIC STATION

The station equipment comprises a battery of Babcock and Wilcox boilers, aggregating 1,000 rated boiler horsepower and two high-speed compound reciprocating engines directly connected to generators, having a combined capacity of 760 kva. The engines are arranged to exhaust as required into a surface condenser, a cooling pond being provided for the circulating water, and a large underground treating tank for feed water.

The boilers are hand fired with the lower grades of Alberta coal screenings, costing about $3.55 per ton delivered.

Power is used chiefly by a flour mill, and the maximum peak on the system is approximately 550 kw., including power and lighting.

HISTORY

In 1916, a pipe-line was laid from the station to heat with exhaust steam a new library building about 750 feet distant, and this proving very successful, it was decided to extend the system to provide steam for heating throughout the main section of the town.

The undertaking was financed in an interesting manner. Prospective customers advanced money on the basis of 75 cents per square foot of radiation installed in their buildings, the city paying interest on this money until the service was connected, when payment was made in steam supplied. In this way, with the further assistance of favourable terms arranged with the suppliers of material, the distribution system, costing to date about $37,000, has been installed with very small expense to the town.

The entire installation was carried out by the town utilities department under the direction of the Superintendent, M. D. Cadwell, who was responsible for the undertaking. Figure 21 shows a map of the system.

Fifty buildings are heated with exhaust steam from the station, and the service has proved very popular. In many cases an actual saving, under the rates in force, is shown over the cost of individual furnace heating, the retail price of the better grades of coal used for heating ranging from $6.50 to $12.00 per ton.

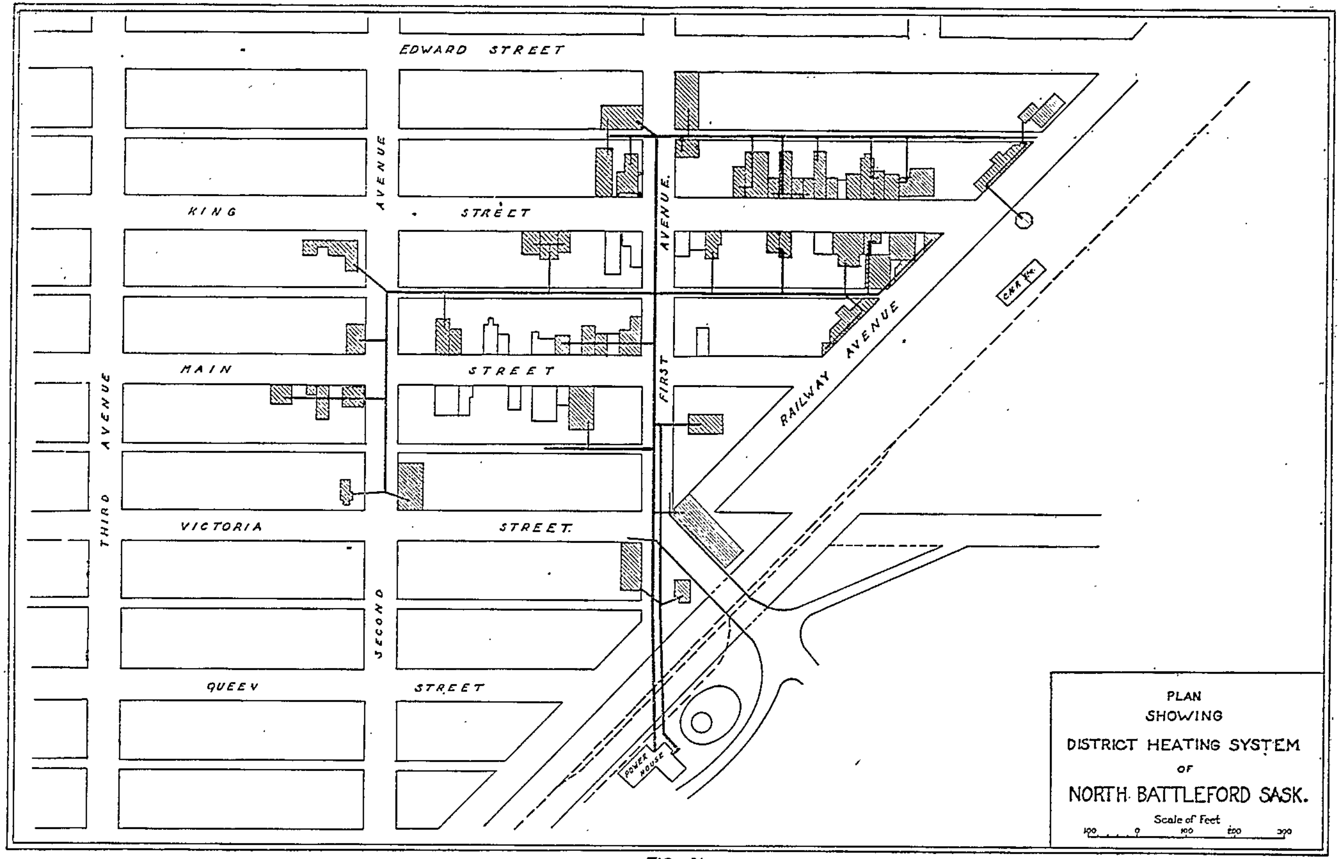

EDWARD STREET
KING STREET
MAIN STREET
VICTORIA STREET
QUEEN STREET
THIRD AVENUE
SECOND AVENUE
FIRST AVENUE
RAILWAY AVENUE
POWER HOUSE
PLAN
SHOWING
DISTRICT HEATING SYSTEM
OF
NORTH BATTLEFORD SASK.
Scale of Feet
100 0 100 200 300

FIG. 21

SERVICE AND CONSUMPTION

The buildings served during the past year comprise:

37 business premises
4 hotels
3 public buildings
6 apartments
1 residence

having a total volume of approximately 1,870,000 cubic feet and a total radiating surface of 30,124 square feet.

The steam is also utilized for hot water, kitchen, and other services, and a small amount of high-pressure steam supplied is for process work.

The total amount of steam sold during the year 1922-23 was 19,027,978 pounds, the monthly consumption with corresponding outside temperatures being as follows:

	Lbs.	°F.		Lbs.	°F.
September	523,900	51·2	March	2,674,195	16·7
October	1,003,051	41	April	1,394,575	40·4
November	2,118,339	30	May	487,145	53·7
December	3,875,300	8	June	311,890	60
January	3,020,546	2·5	July	303,600	64
February	3,048,865	4·8	August	266,572	62

The revenue from the sale of steam for this period was $18,015.85.

Unit consumptions and average costs over the whole system work out as follows for the entire year, including steam for miscellaneous purposes:

Average condensation per season per sq. ft. radiation	631 lbs.
" " " " " cu. ft. space	10·25 lbs.
" cost " " " sq. ft. radiation	59·8 cents
" " " " " 100 cu. ft. space	96·0 cents
" " " " " 1,000 lbs. steam	94·6 cents

DISTRIBUTION SYSTEM

Slightly over 5,000 feet of underground mains and service lines have been laid, the most distant point to which steam is supplied being about 2,000 feet from the station.

Pipes are of wrought iron and are encased in segmental, wood log conduits, particular care having been taken to ensure efficient drainage and correct alignment. The system has given no trouble and has required very little attention.

OPERATION

Figure 22 shows a typical winter, daily-load curve, with the steam required for heating, from which it will be seen that during the day the engine steam is considerably in excess of the heating steam demand. To meet this condition, without surplus exhaust steam to the atmosphere, the smaller of the two engines normally exhausts to the heating system lines, and supplementary steam, as required, is bled from the exhaust from the high-pressure cylinder of the larger engine, through a reducing valve, the balance of the steam being condensed. A pressure of from 2 to 3 pounds on the distribution mains at the station is sufficient to meet the requirements of the system at the present time. With further extensions, a higher pressure will doubtless have to be carried.

RATES

The following rates are charged for steam:

For the first	3,000 lbs. of condensate from steam supplied in any month	.....$1.25	per 1,000 lbs.
For the next	4,500 " " "	.... 1.00	"
"	7,500 " " "	.... 0.95	"
"	20,000 " " "	.... 0.90	"
"	40,000 " " "	.... 0.85	"
"	75,000 " " "	.... 0.75	"
"	150,000 " " "	.... 0.65	"
"	200,000 " " "	.... 0.55	"
And for all over 500,000 lbs.	" " "	.... 0.50	"

Under the conditions existing at North Battleford, the advantage of district heating in conjunction with the generation of electricity has been clearly shown and has resulted in a substantial revenue to the city.

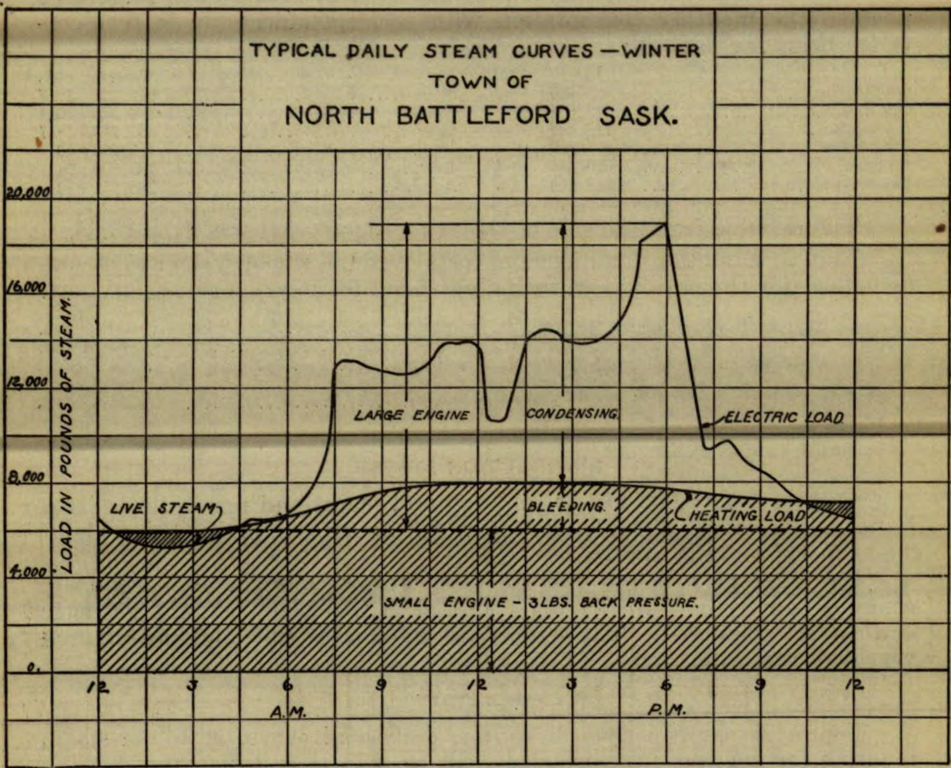


FIG. 22.

BRANDON, MANITOBA

The city of Brandon, population 16,500, has a mean temperature from October 1 to April 30 of 15 degrees Fahrenheit.

In 1910, a district heating system was installed in connexion with the steam electric station, which is located in the centre of the town, to serve the business and shopping district, covering an area approximately 1,500 feet by 1,000 feet.

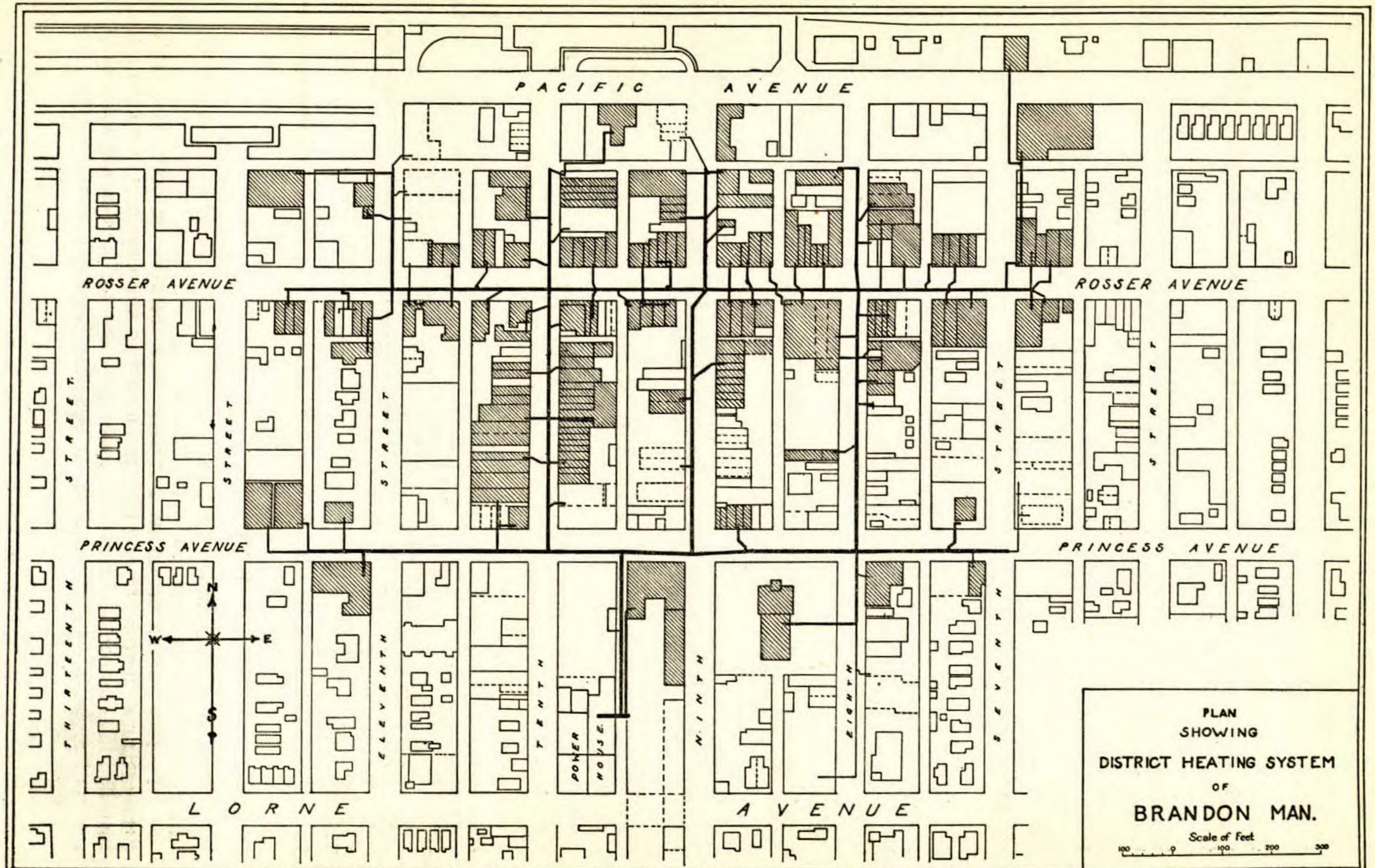

PACIFIC AVENUE
ROSSER AVENUE
ROSSER AVENUE
PRINCESS AVENUE
PRINCESS AVENUE
LORNE AVENUE
THIRTEENTH STREET
STREET
ELEVENTH STREET
TENTH
NINTH
EIGHTH
SEVENTH STREET
STREET
POWER HOUSE.
N
W
E
S
PLAN
SHOWING
DISTRICT HEATING SYSTEM
OF
BRANDON MAN.
Scale of Feet
100 0 100 200 300

FIG. 23

In 1917 the gas, electric, and heating utilities were acquired by the Continental Light and Power Company of Cleveland, Ohio, and since that date have been operated under their control in the name of the Canada Gas and Electric Corporation.

The franchise for district heating includes the entire town; but service is mandatory or obligatory only in the central business district embraced by the present lines.

Almost all the buildings in the heating district are served, and it is reported that during the twenty-three years that the system has been in operation there has never been a shut-down nor a customer disconnected. Figure 23 shows a general layout of the system, with the location of the central plant, the buildings heated, and the main pipe-lines.

LOAD

Electric current is supplied during the summer months from a hydro-power development outside the town, up to about 80 per cent of the requirements. This waterpower is not available during the heating season, and the entire load, with a peak up to 1,500 kw., is then carried by the central steam station. Generally speaking, during the colder months, the steam demand for the heating system approximates closely the average electric requirements, the engine exhausting to the atmosphere during peak load and live steam being required as make-up during certain periods in very cold weather.

In all, there are one hundred and ninety-two customers supplied with steam, the buildings heated aggregating 9,566,312, cubic feet, and having an installed active radiation of 167,914 square feet.

OPERATING STATISTICS

The following figures show the amount of steam supplied during the twelve months of 1923, with the corresponding mean monthly outdoor temperatures:

	Lbs.			Lbs.	
January	15,605,000	9·9°	July	754,000	67·8°
February	12,585,000	2·5	August	686,000	58·5
March	14,022,000	4·6	September	1,233,000	54
April	7,652,000	29·9	October	3,777,000	39·8
May	2,399,000	51·5	November	7,424,000	31·5
June	632,000	64·1	December	11,363,000	12·8
Total steam for year				78,132,000	

Gross revenue from steam sales	$69,743.09
Average cost per 1,000 lbs. steam sold	89·2 cents
Total electric current generated	4,733,300 kwh.

PLANT

The central station equipment includes a battery of H.R.T. boilers having a total rating of approximately 2,780 boiler horsepower, and three Corliss engine generators of 1,800 kw. combined capacity.

The fuel burned is partly Youghiogheny slack bituminous coal and partly Souris lignite. Recently, pulverized fuel equipment has been installed in connexion with two of the boilers, and lignite running up to 35 per cent moisture is being burned in powdered form.

The prices of the different grades of fuel used and the cost of generating 1,000 pounds of steam in each case are given as follows:

	Price delivered	Fuel cost per 1,000 lbs. steam
Youghiogheny slack	$8.54	47 cents
Crowsnest slack	9.70	50 cents
Souris lignite—r.o.m.	3.55	30 cents
Souris lignite screenings	2.75	32 cents

In this district, as generally throughout the west, the water is very hard, and as practically no condensed steam is returned from the district heating system, special treating tanks are provided for softening the raw water before feeding it to the boilers.

The engines operate at a back pressure, normally, of 4 pounds to 6 pounds, when exhausting into the steam-heating system, with a maximum of 8 pounds in the coldest weather.

DISTRIBUTION SYSTEM

All underground pipe-lines are lagged and laid in tin-lined standard wood log conduits, all material and fittings being of the American District Steam Company's standard construction. Various types of heating systems are installed in the different buildings served, the majority being either one- or two-pipe, direct steam or atmospheric systems. A few buildings heated with hot-water radiation utilize the steam in indirect heaters or converters.

Steam is measured by means of condensation meters of the tilting type, the water of condensation being discharged to sewer.

RATES

The following schedule of rates has been in force since 1921, at which time a reduction was made from previous charges.

Up to and including 3,000 lbs.	$1.75 per 1,000 lbs.
3,001 to 7,500 lbs.	1.20 per 1,000 lbs.
7,501 to 15,000 lbs.	1.00 per 1,000 lbs.
15,001 to 35,000 lbs.	0.95 per 1,000 lbs.
35,001 to 75,000 lbs.	0.90 per 1,000 lbs.
75,001 to 150,000 lbs.	0.85 per 1,000 lbs.
150,001 to 300,000 lbs.	0.84 per 1,000 lbs.
300,001 and over	0.83 per 1,000 lbs.

WINNIPEG SERVICE COMPANY, LIMITED

An example of block heating and the use of off-peak, hydro-electric power for steam generation is furnished by the heating of a number of buildings in a business block in Winnipeg by the Winnipeg Service Company.

This company commenced on October 1, 1923, to furnish steam for heating six buildings, with a total radiation of 59,720 square feet; and for kitchen and hot-water service in three restaurants, all contained in one block.

The boiler plant in one of the buildings has been leased and additional equipment installed and piping connexions made to tie together the different systems.

ELECTRIC BOILERS

In addition to the coal-fired boilers, two electric steam generators are provided to utilize "dump" power from the railway hydro-power system. These electric boilers carry almost the entire load from 9 p.m. to 4 a.m. and, except in severely cold weather, about 60 per cent of the load from 9 a.m. to 4 p.m.

Load

The maximum load on the system in cold weather amounts to slightly over 18,000 pounds of steam per hour, and the monthly consumptions for the first few months in operation were as follows:

Name of building	Sq. ft., radiation	Steam consumption in lbs.			
		November	December	January	February
Winnipeg Street Railway bldg..	18,700	1,058,000	1,431,000	2,190,000	1,542,000
Montgomery bldg.............	3,420	267,000	362,000	618,000	530,000
McArthur bldg................	14,000	1,030,000	1,591,000	2,308,000	1,861,000[1]
Nanton bldg..................	5,200	316,000	432,000	615,000	465,000
Robinson's store..............	10,000	667,000	1,106,000	1,875,000	1,300,000[1]
McIntyre block...............	8,400	582,000	847,000	1,470,000	909,000

[1]Includes kitchen service.

RATES

The following rates are charged for steam sold:

Base Rates

$1.70 per 1,000 lbs. for the consumption up to and including 60,000 lbs.

$1.40 per 1,000 lbs. for the excess consumption in each month over 60,000 lbs. and up to and including 100,000 lbs.

$1.30 per 1,000 lbs. for the excess consumption in each month over 100,000 lbs. and up to and including 200,000 lbs.

$1.25 per 1,000 lbs. for all excess consumption in each month over 200,000 lbs.

all as measured by a suitable steam meter; or, at the option of the company, by a standard type of condensation meter, such meter to be furnished by and to remain the property of the company.

"The foregoing base rates are fixed upon an assumed average cost of Pocahontas coal or its equivalent delivered in coal bunkers of the company of $12.00 per ton. As such cost of coal shall increase, the rates above specified shall increase, and as such cost of coal shall decrease, said rates shall decrease as follows: for each 25 cents increase or decrease in such average cost of coal per ton in any month, 1¼ cent per thousand pounds, without the discount provided for in paragraph 3 hereof, shall be added to or deducted from, as the case may be, the net base rates above specified in the bill for service hereunder for such month."

During the season of 1923-24, the price of coal has permitted a reduction on these rates of 6 cents to 8 cents per 1,000 pounds steam.

WINNIPEG, MANITOBA

Although not yet undertaken, a brief description of the proposed district heating by the city of Winnipeg, in conjunction with the hydro-electric system, may be of interest.

Winnipeg, population 180,000, has the lowest mean temperature of any of the large cities in Canada (*See* Figure 1). This fact, among others, has led to a decision by the city to install a district heating system to serve the business and shopping districts, in connexion with a steam stand-by station, which is needed in any case for electric power supply.

Under the proposed plan, the central steam plant will co-ordinate the following utilities:

- Stand-by and reserve power service to the hydro-electric system
- District heating to serve the business and shopping districts
- Utilization of surplus off-peak power from the hydro-electric system for the generation of steam for district heating
- Electric power service to high-pressure fire-pumping plant (which is now operated by producer gas engines)
- Electric power service to water works pumping plant (eliminating present boiler plant)

The site for the central steam station is close to the river, with railway connexions, and is about 3,000 feet (pipe-line) distant from the centre of the main heating district.

The boiler plant is already built, and includes large units with powdered fuel furnaces for burning Souris lignite, which can be delivered to the plant at a cost of approximately $4 per ton.

The main heating territory, covering an area of about one-half mile square, has been divided into four districts for purposes of development, and it is intended to connect up one of these districts each year, reaching an ultimate load of approximately 500,000 pounds per hour at the end of five years.

From preliminary reports and announcements made the rate for steam sold will be in the neighbourhood of $1 per 1,000 pounds. The estimated costs for plant and distribution system are as follows:

—	Boiler plant	Distribution system	Total
1st year	$ 485,000	$ 404,196	$ 889,196[1]
2nd year	485,000	618,970	1,103,970
3rd year	669,949	871,490	1,541,439
4th year	858,216	926,167	1,785,383
5th year	858,216	937,034	1,795,250

[1]$325,000 of this amount has already been provided in the boiler installation for the hydro-electric stand-by plant, leaving a net amount of $550,000 to be raised under the by-law.

The above figures represent the accumulated expenditure from year to year.

PART VII

CENTRAL HEATING INSTALLATIONS IN CANADA

The following descriptions of representative heating installations in Canada may be of interest as indicating the general features and operation of such systems. A large number of these installations are in use, and the economies and benefits to be secured from central heating of groups of institutional buildings have been well proved.

UNIVERSITY OF TORONTO, ONTARIO

This is the largest group of buildings heated from a central plant in Canada and comprises twenty-seven buildings with an aggregate volume of nearly 29,000,000 cubic feet. Figure 24 shows the general layout, with the location of the central plant.

DISTRIBUTION SYSTEM

The distribution pipes are carried, throughout, in tunnels, which have a total length of slightly over 7,000 feet, the farthest point at which steam is delivered from the mains being 4,535 feet from the station.

Low-pressure steam, at about 4 pounds per square inch, is the heating medium, most of the buildings being equipped with vacuum heating systems; and the water of condensation is pumped back to the plant through return lines in the tunnels.

Steam-electric generators in the central station furnish light and power to the University buildings, and in mild weather the heating requirements can be taken care of by the exhaust from these steam units. At other times, the balance of steam is supplied directly from the boilers, through reducing valves. High-pressure steam is also furnished through a separate pipe-line to several of the buildings.

PLANT EQUIPMENT

The boiler house contains four Babcock and Wilcox boilers, each of 400 nominal boiler horsepower, and one B. and W. boiler of 516 horsepower, operating at 160 pounds pressure. These units are equipped with Murphy automatic stokers, fed from an overhead coal bunker, having a total capacity of 600 tons. The plant is built partly beneath the surface of sloping ground, enabling coal to be delivered directly into the bunkers, and the low setting of the building provides for gravity discharge from the distribution return lines in the tunnel.

The electric generating sets comprise one 500 kw. Curtis turbine, one 300 kw. high-speed Allen engine, and two Robb-Armstrong, single cylinder, vertical engines of 100 kw. and 50 kw. capacity directly connected to electric generators supplying direct current at 220 volts.

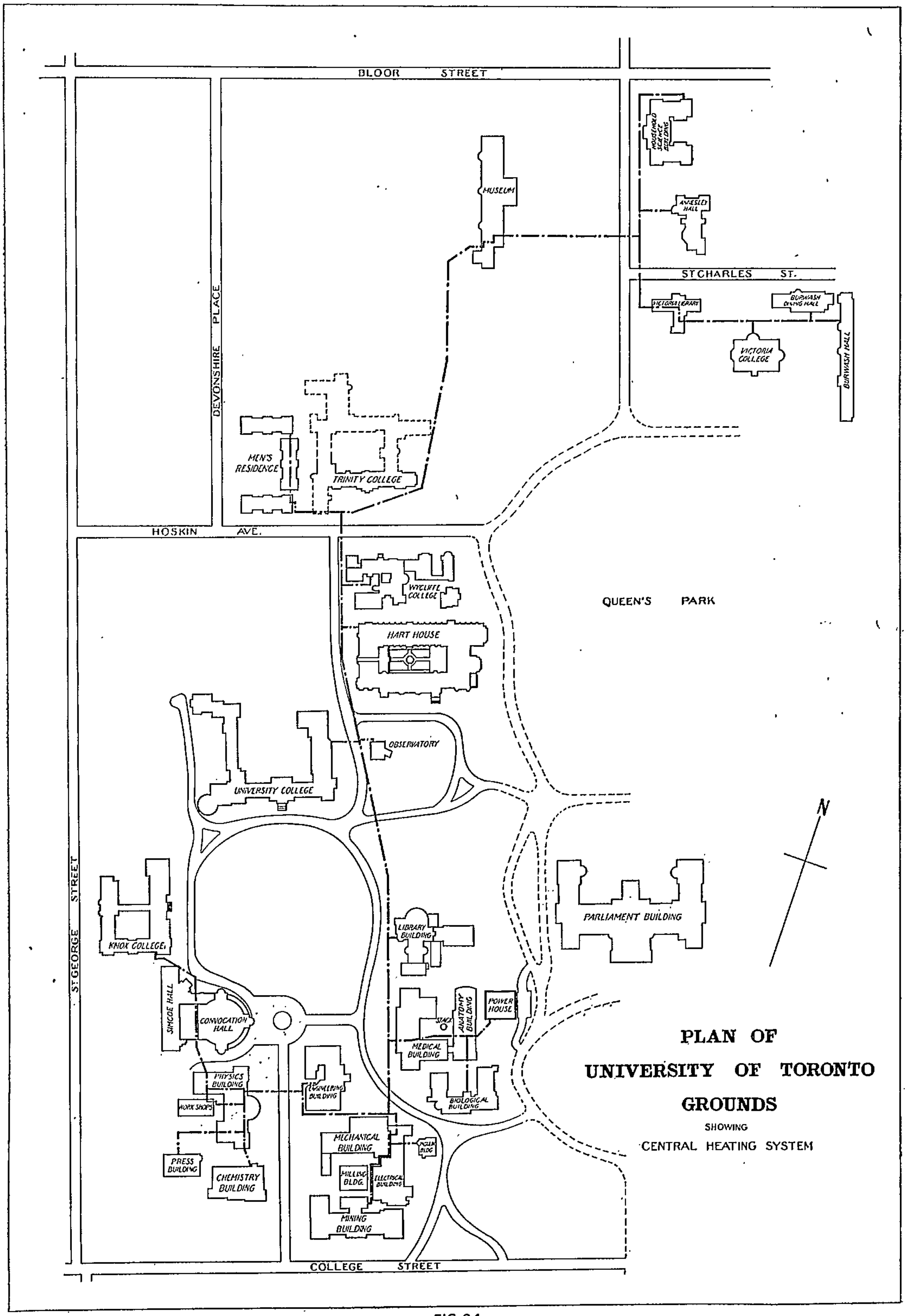

PLAN OF
UNIVERSITY OF TORONTO
GROUNDS
SHOWING
CENTRAL HEATING SYSTEM
BLOOR STREET
ST CHARLES ST.
HOSKIN AVE.
COLLEGE STREET
ST GEORGE STREET
DEVONSHIRE PLACE
QUEEN'S PARK
N
MUSEUM
ANNESLEY HALL
VICTORIA LIBRARY
BURWASH DINING HALL
VICTORIA COLLEGE
BURWASH HALL
MEN'S RESIDENCE
TRINITY COLLEGE
WYCLIFFE COLLEGE
HART HOUSE
OBSERVATORY
UNIVERSITY COLLEGE
PARLIAMENT BUILDING
KNOX COLLEGE
LIBRARY BUILDING
SIMCOE HALL
CONVOCATION HALL
POWER HOUSE
STACK
ANATOMY BUILDING
MEDICAL BUILDING
PHYSICS BUILDING
ENGINEERING BUILDING
BIOLOGICAL BUILDING
WORK SHOPS
PRESS BUILDING
CHEMISTRY BUILDING
MECHANICAL BUILDING
MILLING BLDG.
ELECTRICAL BUILDING
MINING BUILDING

FIG. 24

METHOD OF CHARGING FOR HEAT SUPPLY

The cost of operation of the central plant is charged to the different buildings connected to the system, generally in proportion to the amount of radiation installed and the electric power requirements of each. The heating charge is also checked from time to time from condensation meters in the individual buildings. The following table shows the distribution of operating costs for the season of 1922-23, with the amount of radiation installed.

Buildings	Total radiation	Percentage charge	Light	Heat	Total	Credits
			$ cts.	$ cts.	$ cts.	$ cts.
Main	13,844	6·670	352 38	6,232 03	6,584 41	8 00
Political science	...	...	23 12	...	23 12	...
Hart House	29,664	10·920	2,490 94	10,202 96	12,693 90	...
Library	10,900	4·047	284 96	3,781 26	4,066 22	...
Medical	8,423	3·756	1,802 02	3,509 37	5,311 39	1 50
Biological	8,407	3·072	141 60	2,870 28	3,011 88	...
Engineering	9,453	4·258	465 28	3,978 41	4,443 69	8 00
Thermodynamics	5,236	2·441	96 48	2,280 72	2,377 20	...
Observatory	674	0·243	388 56	227 04	615 60	...
Mining	14,083	6·705	1,154 66	6,264 73	7,419 39	20 00
furnace	...	...	54 46	...	54 46	...
Milling	...	...	73 60	...	73 60	...
Chemical	6,867	2·706	373 28	2,528 32	2,901 60	...
Physics	20,462	7·142	952 52	6,673 04	7,625 56	20 00
Convocation Hall	6,161	2·641	150 00	2,467 59	2,617 59	761 50
Mens residence	9,336	4·354	450 00	4,068 11	4,518 11	...
Household science	10,137	3·691	113 62	3,448 64	3,562 26	2 75
Museum	17,231	5·977	201 76	5,584 54	5,786 30	...
Electrical	8,977	3·598	256 04	3,361 75	3,617 79	6 00
Elec. Eng	...	...	504 76	...	504 76	...
Press	2,812	0·982	400 40	917 52	1,317 92	...
Anatomy	7,888	3·491	145 00	3,261 77	3,407 17	1 00
Wycliffe College	12,371	5·807	313 60	5,425 70	5,739 30	...
Victoria College	9,028		166 88		166 88	
Burwash Hall	8,377	8·338	511 20	7,790 51	8,301 71	
Vic. Coll. Lib.	4,021		42 44		42 44	
Burwash D. Hall	...	...	146 16	...	146 16	...
Annesley Hall	4,481	2·221	276 00	2,075 16	2,351 16	...
Knox College	15,402	6·940	507 40	6,484 30	6,991 70	...
Univ. Coll. Wom. Un.	...	...	36 20	...	36 20	...
No. 85 St. George St	...	...	9 24	...	9 24	...
No. 4 Queen's Park	...	...	49 22	...	49 22	...
Social Service	...	...	17 74	...	17 74	...
No. 184 College street	...	...	16 58	...	16 58	...
No. 100 Queen's Park	...	...	53 25	...	53 25	...
Grounds	...	...	250 00	...	250 00	...
Stadium	...	...	398 16	...	398 16	...
	244,235	100·000	13,669 91	93,433 75	107,103 66	828 75

NOTE. The total radiation includes slightly over 10 per cent indirect surface. As this is only used part time, it is considered as equivalent to direct surface for basis of season's consumption.

During the eleven years that have elapsed since central heating has been in use the connected load has increased from 136,000 square feet radiation to 250,000 square feet, several buildings having been added during the past year.

COST OF INSTALLATION

The total cost of the central light, heat, and power station and the distribution tunnel system, which was built mainly in 1910 and 1911, amounted to approximately $400,000.

ECONOMY RESULTS

In 1910-11, prior to the installation of the central heating system, the cost of heating alone for the buildings then erected was 41 cents per square foot of radiation, anthracite coal at about $7 per ton being used in the individual heating furnaces. Electric current for light and power was at that time partly generated in different buildings and partly purchased.

With the central plant, in 1914-15, before prices of coal and labour started to rise, the cost for heat and light was 20·1 cents per square foot of radiation, including all charges for distribution up to the building lines. Bituminous coal was then burned, at a price of approximately $3.50 per ton, delivered.

In 1922-23, bituminous coal averaged $8.34 per ton, delivered, and the total cost for supplying heat, light, and power amounted to 43·852 cents per square foot of radiation; or, for heating alone, 38·255 cents per square foot.

During the season of 1922-23, 9,706 tons of coal were used, which corresponds to a consumption of 0·7 pound per cubic foot of building for heat, light, and power, or seventy-nine pounds per square foot of radiation installed. A boiler test carried out in the central plant in 1921 showed an efficiency of 76·4 per cent.

These figures speak for themselves as to economy of central heating. The present cost of heating is less than was the cost of individual heating thirteen years ago, although the price of coal has increased approximately 230 per cent during that time. The complete services of light, heat, and power are now supplied at only a very slight increase over the cost of heating alone in 1910, with anthracite at $7 per ton. Considering what the present cost of individual heating would be with anthracite at $16 per ton, coupled with the conveniences obtained by heat generation and control at one source, the results more than justify the installation, after allowing for all fixed charges on the investment.

DOMINION GOVERNMENT BUILDINGS, OTTAWA

With the rebuilding of the Parliament Building, following the destruction of the old building in 1916, it was decided to install a central plant to heat a number of the main Government buildings, and the system as shown in Figure 25 was put into service in 1920.

The following buildings are heated from this plant:

	Cu. ft.
Parliament Buildings and Library	7,007,950
West Block	2,569,790
East Block	2,472,654
Langevin Block	1,993,830
City Post Office and garage	672,064
No. 22 Vittoria street	681,000
Supreme Court	335,196
	15,732,484

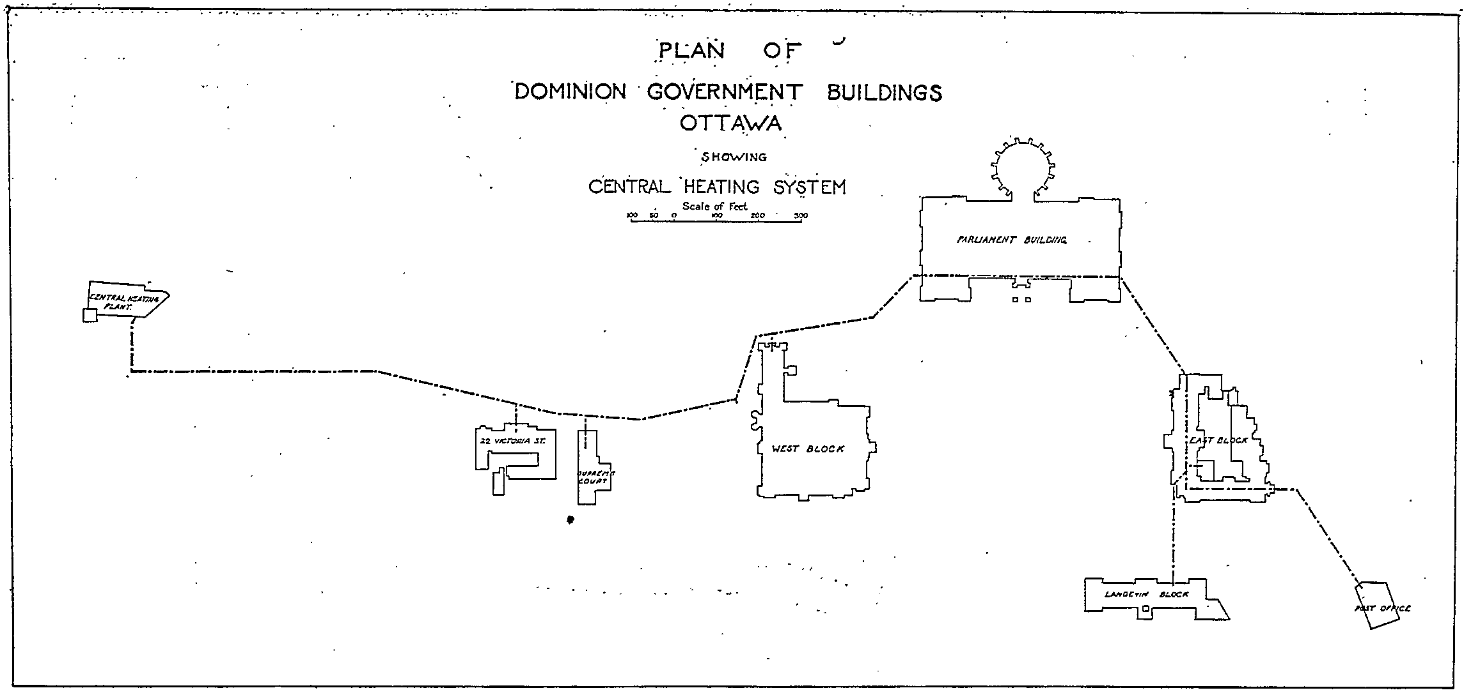

PLAN OF
DOMINION GOVERNMENT BUILDINGS
OTTAWA
SHOWING
CENTRAL HEATING SYSTEM
Scale of Feet
100 50 0 100 200 300
CENTRAL HEATING PLANT.
22 VICTORIA ST.
SUPREME COURT
WEST BLOCK
PARLIAMENT BUILDING
EAST BLOCK
LANGEVIN BLOCK
POST OFFICE

FIG. 25

Forced-circulation hot water is used for the direct radiation in the main Parliament Building and Library, and steam is supplied for the heating systems in the other buildings, in addition to the indirect heating stacks for ventilating systems, restaurant, hot water supply, and some air compressor units and other services in the main buildings.

The steam and water-pipes are carried in tunnels between the different buildings, the total length of steam-line from central plant to the Post Office at the extreme end being approximately 3,710 feet.

The station has a capacity of 2,000 boiler horsepower, the boiler plant consisting of four 500 H.P. Goldie and McCulloch water-tube boilers with Murphy automatic stokers. The present equipment is capable of serving additional building space of some 2,500,000 cubic feet, and provision is made for extension to the boiler house for an ultimate capacity of double the present output.

Water for circulation through the system is heated in three Ross tubular heaters by exhaust steam from the station auxiliaries or reduced-pressure live steam; and meters and recording thermometers are provided to permit of a close regulation of the heat to the buildings, in accordance with the outdoor temperature.

Coal from Minto, New Brunswick, is burned and costs $6.95 per ton delivered. Approximately 10,500 tons are normally used during the heating season, corresponding to a consumption of about 1·34 pounds per cubic foot of building heated.

In this connexion it is to be noted that the coal used is of comparatively low grade, also that in the Post Office and some other buildings heat is maintained throughout the twenty-four hours. A considerable amount of steam is also used for ventilation, restaurant, and other purposes.

COST OF PLANT

The total cost of the plant and distribution system was $761,469.97, made up as follows:

Power house, buildings, and tunnels	$ 474,244 94
Boilers	83,362 00
Coal and ash-handling equipment	20,037 00
Electric motors, etc	19,697 13
Piping, bends, valves, expansion joints, welding, etc	129,586 19
Pumps and generators	18,309 00
Compressor and expansion tanks	5,961 04
Temperature control, gauge board equipment	9,723 67
	$ 761,469 97

OPERATING RESULTS

The following statements of comparative operating costs have been furnished by the Department of Public Works. Statement "A" shows the annual operating costs, including overhead charges, of individual furnaces in the buildings as originally heated. Statement "B" shows the annual operating costs with overhead charges of the central heating system.

These figures indicate an annual saving by the central heating system over the individual building heating of $29,824.49 for fuel and operation; or, including interest on investment and depreciation, an annual saving at the present time of $3,172.76.

With the ultimate plant capacity, the present comparatively high overhead will be proportionately reduced, and statement "C" shows the estimated annual saving by doubling the present plant, allowing for overhead charges, of $58,258.53.

Statement "A" Showing Annual Operating Costs for Individual Units for the Several Buildings Now Heated by the Central Heating Plant

Cost of coal and wages (based on tonnage used and wages paid when buildings were heated by separate plants)		$ 148,445 65
6% interest on estimated cost separate power house buildings or basement space, boiler stacks, etc., for each of the seven separate buildings, $200,000	$ 12,000 00	
Depreciation of buildings and stack 1½%, $200,000	3,000 00	
		15,000 00
6% interest on mechanical plant, estimated cost $200,000	12,000 00	
Depreciation on mechanical plant 5% $200,000	10,000 00	
		22,000 00
		$ 185,445 65[1]

Statement "B" Showing Annual Operating Cost Central Heating Plant

Coal, 10,500 tons bituminous slack at $6.95	$ 72,795 00	
Salaries: engineers, firemen, etc., at plant	27,353 56	
Salaries: engineers, firemen, etc., in charge of separate buildings	18,292 40	
		$ 118,444 96
Interest on cost power house and tunnels $474,244.94	$ 28,454 70	
Depreciation on cost power house, ½% $334,023.83	1,670 11	
Depreciation on tunnels, 1½% $140,221.11	2,103 37	
		32,228 18
6% interest on cost plant $287,225.03	$ 17,233 50	
5% depreciation cost plant $287,225.03	14,361 25	
		31,594 75
		$ 182,267 89[1]

Statement "C" Showing Estimated Operating Cost Central Heating Plant
(on basis of doubling its present capacity)

Coal, 21,000 tons bituminous slack at $6.95	$ 145,590 00
Salaries: engineers, firemen, etc., at plant	34,723 56
Salaries: engineers, firemen, etc., in charge of separate buildings	36,584 80
6% interest on cost power house and tunnels	42,682 05
Depreciation on cost of power house, ½% $501,035.75	2,505 17
Depreciation on cost of tunnels, 1½% $210,331.67	3,155 06
6% interest on cost plant $430,837.55	25,850 25
5% depreciation on cost plant $430,837.55	21,541 88
	$ 312,632 77
Annual operating cost of fourteen separate heating plants (for buildings double the cubic feet now heated)	370,891 30
Surplus after paying all interest, depreciation, and annual operating charges	$ 58,258 53[1]

[1]Land value is not included.

UNIVERSITY OF ALBERTA, EDMONTON

The University of Alberta shows some interesting results illustrating the use of the low-grade lignite coals of Alberta for central heating.

The present buildings, forming part of the ultimate layout, are arranged in three separate groups separated by distances of 620 feet and 830 feet respectively, and comprise the following:

Building	Construction	Cubic feet	Radiating surface	Sq. ft.
Group 1—				
Arts Building	Brick	1,850,000	Direct	18,900
			Vento	5,600
Medical Building	"	1,572,000	Direct	13,400
			Vento	5,120
Mining and Agricultural Laboratory	"	476,500	Direct	10,000
Engineering Laboratory	"	476,500	Direct	10,000
Elec. Eng. Laboratory	"	215,000	Direct	3,600
Group 2—				
Pembina Hall (residence)	"	470,000	Direct	7,000
Assiniboia Hall (residence)	"	470,000	Direct	7,000
Athabaska Hall and dining hall		778,000	Direct	8,000
Group 3—				
Staff houses	Brick and lumber 4 at	50,000	Direct	6,000
	2 at	30,000		
	4 at	25,000		
		6,668,000	Direct	83,900
			[1]Indirect	10,720
			Total	94,620

[1]As the indirect radiating surface for ventilation is used only part time, it is taken as being equivalent to direct surface for basis of season's consumption.

CENTRAL PLANT

The central plant is situated within Group No. 1 and in addition to the boilers for heating, contains steam-generating sets for the supply of electric current for light and power requirements during the heating season. An outside electric power connexion is made for supply from the city service when the exhaust from the generating sets is not needed for heating.

The steam units in the central station operate at 150 pounds pressure, the exhaust being utilized for heating the adjoining buildings at a pressure of approximately 1½ pounds. Live steam, reduced to 40 pounds pressure, is distributed to the distant groups of buildings through pipes in conduits, partly of tile construction and partly of wood, the pressure being again reduced at the different buildings served to suit the requirements. All condensation is returned to the central plant by pumps located at different points.

Fuel. Lignite slack and dust are burned on B. and W. chain-grate stokers with special furnace setting, these fuels costing $1.50 and 75 cents per ton, respectively, delivered. A typical analysis of the lignite slack shows:

	Per cent
Moisture	22·0
Volatile matter	33·8
Fixed carbon	35·2
Ash	9·0

During 1923, 5,763 tons of lignite slack and 3,540 tons of lignite dust were consumed.

OPERATING COSTS

The coal cost for evaporating 1,000 pounds of water from and at 212 degrees F. is 13·6 cents with the slack and 6·7 cents with the dust. The total operating costs for 1923 were as follows:

Coal	$	13,500
Wages		19,260
Sundries		6,400
Total	$	39,160

During the season, electric light and power were generated at the station to an amount equivalent to a commercial value of $18,000 based on the cost of purchased current. Deducting this figure for current, which is charged out under the accounting system to the various departments in proportion to use, a net cost of $21,160 is given for heating. On this basis, the cost for heating alone works out at 21·2 cents per square foot of radiation; or, inclusive of heat, light, and power, 41·3 cents per square foot of radiation.

As a comparison with individual heating in the same district, the cost of heating a large hospital containing 12,500 square feet radiation, with independent hand-fired furnaces burning lignite pea and nut at $2.50 and $3.50 per ton respectively, amounts to 72·5 cents per square foot radiation.

COST OF INSTALLATION

The cost of the central heating installation built in 1915, with subsequent additions, was:

Power plant No. 2	$	114,680
Conduit line to Arts Building		5,770
Conduit line to dormitories from P.P. No. 2		8,000
Conduit line to staff houses from P.P. No. 1		9,800
Steam line to Medical bldg. (in tunnel)		11,050
	$	149,300

McGILL UNIVERSITY, MONTREAL

The central heating of this university was the first application on any extensive scale in Canada of forced-circulation hot water for heating buildings. The main plant and distribution system were installed in 1908 to heat five main buildings, and with extensions made since, the number of buildings now connected are as follows:

Building heated	Approx. cubic contents	Direct radiation sq. ft.	Steam or hot water	Air for ventilating cu. ft. per min.	Steam charged for year
	Cu. ft.				Lbs.
New Medical	1,650,000	16,000	H.W.	65,000	13,700,000
Greenhouses	....	1,920	S.	....	1,700,000
Biological	{800,000	8,800	H.W.	25,000	12,500,000
	{625,000	4,000	S.	....	....
Arts	730,000	6,500	H.W.	....	6,200,000
Engineering and Workman	1,450,000	15,000	H.W.	45,000	14,500,000
Chemistry and Mining	670,000	10,000	H.W.	20,000	5,500,000
Physics	530,000	6,000	H.W.	....	2,600,000
Forest Products Lab	For heating and laboratory work				2,100,000
Power house	....	400	H.W.	....	no record
Animal house	20,000	120	S.	....	connected June 1923
	6,475,000	68,740	....	....	58,800,000

Figure 26 shows the general layout of the buildings.

PLANT AND SYSTEM

The central plant contains four 250 H.P. Babcock and Wilcox boilers, equipped with B. and W. chain-grate stokers, the fuel burned being bituminous slack coal mixed with about 10 per cent of anthracite screenings.

Electric current is generated for the use of the University buildings during the heating season by high-speed engine-generators, the exhaust from which is utilized to heat the water for circulation through the mains. When the heating load does not warrant the running of the station units, current is purchased from an outside supply company.

High-pressure steam is supplied for the requirements of the engineering building; low-pressure steam is utilized for heating the greenhouses and animal house, in addition to air-heating coils of the ventilating systems in different buildings. A concrete tunnel connects the central station with the Biological and Engineering buildings, in which the main steam and water pipes and electric cables are carried, the lines leading to the other buildings being encased in underground tile conduit.

To meet the particular conditions and requirements of the University several special features have been embodied. Although the Engineering building is heated by hot-water radiation, an independent installation of pumps and heaters is provided, to enable tests and experiments to be carried out on it by the students, and steam is supplied from the central plant for this purpose.

The Physics and Chemistry buildings are situated at a considerably lower level than the new Medical building and as the hot-water radiator systems in these buildings were old at the time the central plant was installed and possibly might not have withstood the pressure due to the difference in level, if connected into the same system, secondary heaters were installed to transmit the heat from the higher temperature circulation water in the mains to the gravity systems of the buildings.

The cost of the main plant and distribution system, including electric services in 1908, was approximately $167,000.

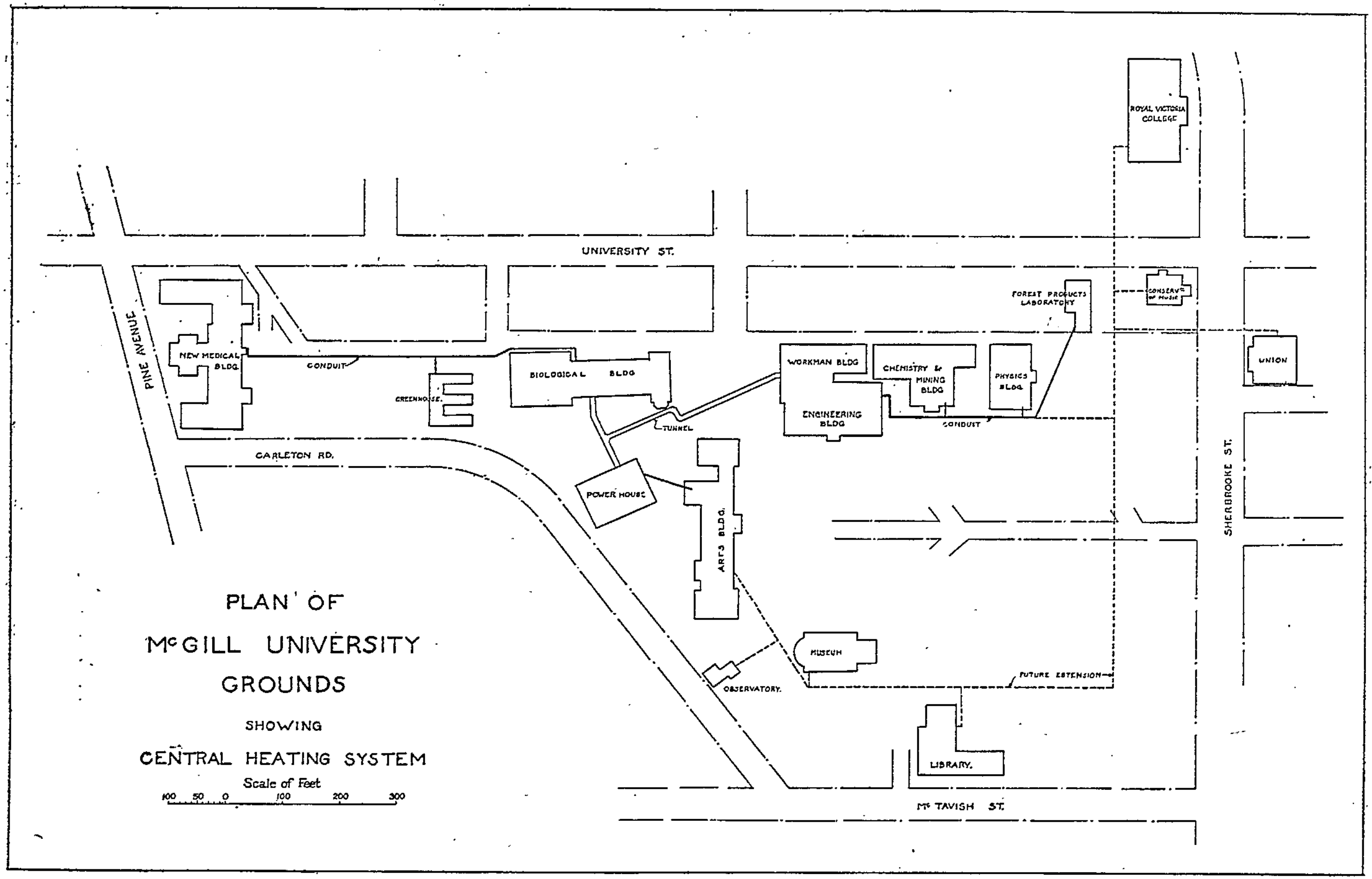

PLAN OF
McGILL UNIVERSITY
GROUNDS
SHOWING
CENTRAL HEATING SYSTEM
Scale of Feet
100 50 0 100 200 300
UNIVERSITY ST.
PINE AVENUE
NEW MEDICAL BLDG.
CONDUIT
GREENHOUSE.
BIOLOGICAL BLDG
TUNNEL
WORKMAN BLDG
CHEMISTRY & MINING BLDG
PHYSICS BLDG
ENGINEERING BLDG
CONDUIT
FOREST PRODUCTS LABORATORY
ROYAL VICTORIA COLLEGE
UNION
SHERBROOKE ST.
CARLETON RD.
POWER HOUSE
ARTS BLDG.
MUSEUM
OBSERVATORY.
FUTURE EXTENSION
LIBRARY.
McTAVISH ST.

FIG. 26

OPERATING RESULTS

The steam used by the various buildings is given in the last column of the table of building data. All steam supplied directly is metered, and the steam used at the station for heating the circulated hot water is charged in proportion to the amount of radiation in the different buildings connected on one circuit.

It will be noted that a considerable amount of steam is used by several of the buildings for the complete fresh-air ventilating systems installed.

The following figures give the output of the central plant during the year 1922-23, and the approximate cost of operation. During this period the price paid for bituminous coal averaged $9.80 per ton, delivered, and for hard coal screenings $6 per ton. For the present season the price of bituminous coal is $7.50 per ton, which will make a considerable reduction in the operating costs.

Total steam generated for year..................66,700,000 lbs.
Total coal consumption for year................8,920,000 lbs. Reynoldsville slack, 740,000 lbs. hard coal screening
Maximum boiler load for year...................990 H.P.
Maximum power and light load.................600 H.P.
Total power generated.........................700,000 K.W. H.
Approximate cost of operating (not including fixed charges)............................$66,000

Many of the University buildings have not yet been connected to the central heating system and the coal consumptions of these for the year 1922-23, are given as follows:

—	Approx. cu. ft. cubic contents	Sq. ft. radiation	Furnaces	Coal consumption
Observatory	33,000	800	Star—H.W.	19 tons anthracite
Redpath Museum	350,000	2,000	Daisy—H.W.	80 "
Redpath library	600,000	10,000	Crane—H.W.	185 "
McCord Museum	60,000	1,100	Buffalo—H.W.	31 "
Conservatorium—music	130,000	2,500	Sirdar—H.W.	44 "
Hostel	45,000	1,100	Daisy—H.W.	45 "
Old law building	30,000	700	Buffalo—H.W.	22 "
Learmont house	30,000	600	Daisy—H.W.	17 "
Union	350,000	5,000	Daisy—H.W.	120 "
Royal Victoria college	810,000	6,500	Inglis RT Steam	550 "

With the exception of the Royal Victoria College, which uses steam for heating and other purposes, all the buildings listed are heated by hot water furnaces burning anthracite coal, costing at the present time between $16 and $17 per ton.

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