District Heating

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PART III—Operating conditions of selected existing systems

IN this article, the third in the series, it is proposed to discuss some representative district heating schemes in this country, on the Continent of Europe, and in North America. Wherever possible design details and cost figures are given.

Great Britain

The East Kilbride Scheme

In this system 88 houses and a three-floor block of flats are being heated by a station built in 1953. The total capital cost of building the station and network amounted to £24,500. The system is fed by two boilers which have capacities of 24·4 and 11·8 therms per hour respectively, and which are coal-fired using automatic stoking equipment. The plant supplies hot water at the rate of 60 gallons per day to each family. During December, 1957, when the outside temperature was an average of 42° F, the inside temperatures recorded were 60° to 63° F in the living rooms and between 55° and 58° F in the bedrooms. The amount of coal used by the boilers, which have an average efficiency of 53 per cent, was found to be 6·8 tons per annum and dwelling. Most tenants also used conventional coal fires in addition to the district heating supplied and the average consumption was estimated at 1 to 2 tons of coal per annum and dwelling. The cost to the consumer for the supply of district heating was 12s. 6d. per week for the smaller dwellings and 19s. per week for the larger ones (1952 figures). The heat losses in the mains of the East Kilbride system were estimated at no less than 22 per cent, a surprisingly high figure.

The Pimlico District Heating Scheme

This is probably the most efficient district heating scheme in the British Isles, and incidentally is also by far the largest in Great Britain.

The condenser water from the Battersea power station is used to heat a number of flats in an area of approximately 31 acres bordering the Grosvenor embankment of the River Thames. By the beginning of 1956, 1,220 flats were being heated at Dolphin Square and 1,183 at Churchill Gardens, making a total of 2,403 flats, i.e. just above the lower limit of economical operation of a district heating scheme.

During the first five years of operation, namely from October, 1951 to September, 1956, the turbo-generators of the Battersea power station sent out 31·6 million kWh of electrical energy and 6·36 million therms of heat to the district heating scheme. The amount of district heating received per flat per annum amounted to 595 therms for Dolphin Square and 623 therms for Churchill Gardens during the year 1956. When tests were made with regard to specific dwellings it was found that between 45 and 52 therms were also contributed per annum by means of gas and electricity. It was estimated that a living room temperature of 65° F and a temperature in other rooms of between 55° and 60° F should be maintained in this way. Comparing these figures with those of other countries, it would appear as if the degree of heating achieved by the fairly large amount of heat supplied to each dwelling is not good, especially as the number of degree days in the London area is low when compared to many Continental and American cities. The reason is undoubtedly the extremely poor degree of thermal insulation practised and the fact that the dwellings are equipped with the now outmoded single glazing. Probably another factor which has its limitations upon the efficiency of the Pimlico scheme is the absence of heat meters in the individual flats, which are considered essentials in most continental schemes.

In contrast to the East Kilbride station the overall efficiency in terms of thermal utilisation of fuel used is very high. Transmission losses only amount to a total of 6½ per cent, while the overall thermal efficiency varies between 71·6 and 81·6 per cent. This will indicate the importance of having large systems. The average temperature of the hot water to the flow mains is about 202° F and the temperature in the return lines is 144° F.

The maximum loading of the plant during the year 1956 was 480 therms per hour. Between the months of May and September the district heating is supplied for the hot water service only, which includes linen cupboards and towel rails. The average amount of hot water supplied is 0·78 therms per flat and day, or about 20 to 25 gallons of hot water per head and day.

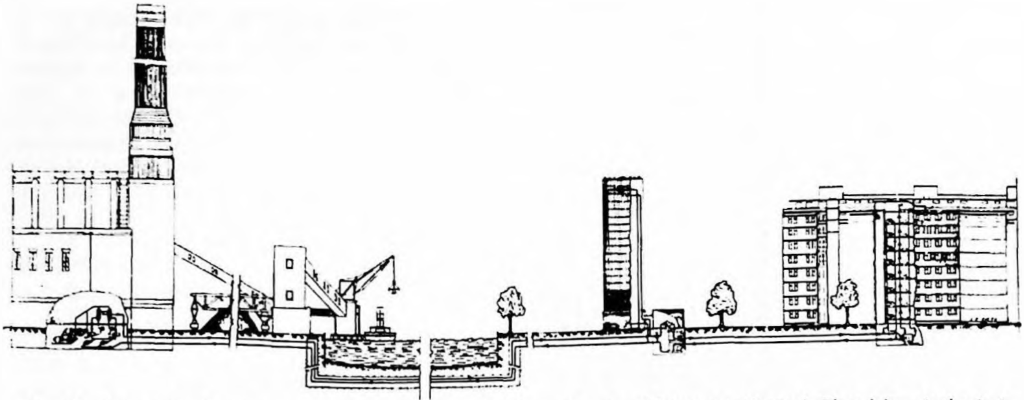

Fig. 18.—Schematic diagram of the Pimlico district heating scheme. (*Courtesy: Central Electricity Authority.*)

It has been estimated that the Pimlico plant saved no less than 13,694 tons of coal during the first five years of operation or about 29 per cent as against conventional power stations.

At the Battersea power station there are two turbine sets, each of continuous output of 1,350 kW producing its output at 3,300 v. The initial steam pressure is 600 lb/sq. in. gauge, while the back pressure steam pressure is 2 lb/sq. in. gauge. The turbine speed is 10,000 r.p.m. There are reducing valves and desuperheaters to provide low pressure saturated steam to the heat exchangers in case of an emergency.

The River Thames is crossed by a 12 in. diameter flow main and a 12 in. diameter return main. The hot water from the condensers passes through this line to the north side of the river, where it is stored in a large vertical vessel, called an accumulator. This has a capacity of 80,000 c. ft and is able to store 4,000 therms of heat. The vessel is 126 ft in height, has an internal diameter of 29 ft and is made from steel, being insulated on the outside by 3 in. of cork insulation. The weight of the accumulator is about 2,400 tons and it is enclosed in a steel-framed glass structure, which both enhances the appearance

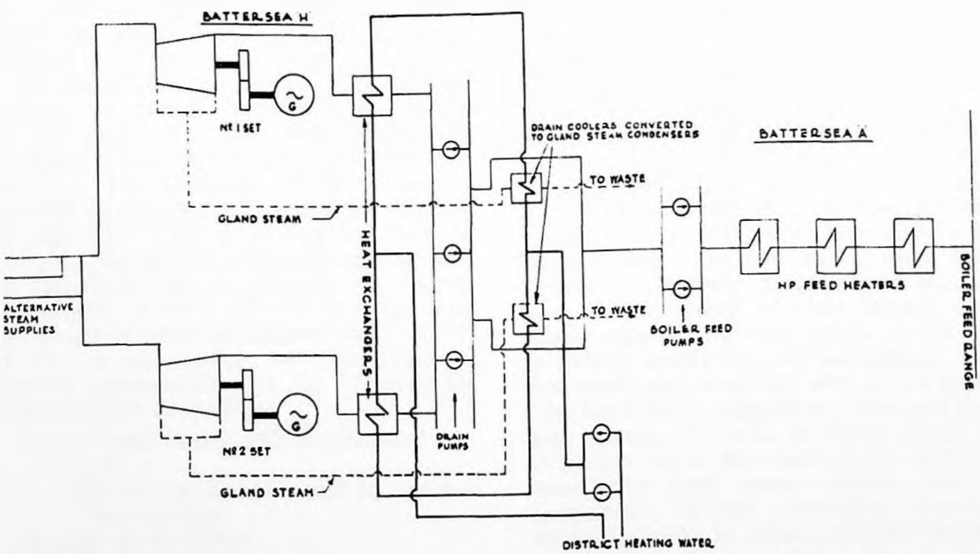

Fig. 19.—Pimlico scheme: line diagram showing route of condensate from Pimlico plant to boiler feed range. (*Courtesy: Central Electricity Authority.*)

of the gigantic tank as well as acting as additional insulation and weather protection. The control of the district heating plant is centralised at a sub-station. The heating water supplied to each block of flats is at a higher temperature than required for space-heating and is mixed with some of the return water. The hot tap-water is heated in calorifiers to 130° to 135° F.

The Churchill Gardens Estate has the following staff:

1 Superintendent engineer,
1 Deputy engineer,
9 Operators and maintenance men.

This staff is in charge of the district heating scheme, the general plumbing and the sewage scheme in the blocks of flats.

West Germany

The Hamburg System

At present there are 10,000 dwellings district-heated in Hamburg and further district heating schemes encompassing another 25,000 flats are under construction. The larger of the stations delivers 26 G cal per hour (1,000 therms per hour). The boilers used are vertical water tube boilers, fired by means of coke using chain grate stokers. There are also small sub-stations which supply hot water during the summer months. Some of the stations are part of 16 floor high tower blocks. The maximum quantity of water running through the system is about 200 tons per hour per 1,000 flats. In order to avoid corrosion inside the piping network, some hydrazine is added to the circulatory system.

The temperature of the hot water pumped through the system varies with the season of the year. The maximum temperature employed is between 110° and 130°C.(230° and 266° F). The efficiency of the boilers is between 80 and 90 per cent with an emission of only 0·044–0·068 g. of dust per cu.m of flue gas. The capacity of the system is adjusted so that it is able to maintain an internal temperature of 20° C (68° F) in every room at an external minimum temperature of —15° C (8° F). It was found that the maximum thermal requirements were the following for different types of dwellings:

Single family houses with single-glazed windows
200 kcals per hour for each sq. metre of floor surface.
Average block of flats
130 kcals per hour for each sq. metre of floor surface.
Modern flat with well insulated walls and double glazing
90 to 95 kcal per hour for each sq. metre of floor surface.

The investment costs were found to vary between 800 and 1.400 DM, per dwelling unit (£90 to £155), while the network costs were found to amount to between 8 to 14 DM per sq. m dwelling area (19s. to 26s.). The following tariffs were employed with regard to the Hamburg district heating system (1 DM = 1s. 10d.) The heat delivered is measured by means of heat meters:

Basic price: DM 0·24 per sq.m floor area and month.
Supplied heat price: DM 12·25 per G cal (40 therms)
Additional fixed charge: DM 2·00 per month.

Hot water is charged for at the following rate:
Fixed charge: DM 2·00 per month + DM 0·055 per sq.m floor area and month.

The variable cost is DM 1·25 for each cu.m of hot water supplied. It is intended that with average demand 63 per cent. of the heating costs should be fixed costs and 37 per cent variable costs. This is to equalise the heating costs somewhat for tenants of different flats with differing degrees of thermal insulation and exposure.

For the supply of the hot water for consumption, there are heat-exchangers in the basements of the blocks of flats. A three-pipe system is used for the network.

The Berlin District Heating Scheme

Berlin has a district heating system which is at present yielding a maximum of 6,500 therms per hour, *i.e.* about 12 times the capacity of the Pimlico scheme. The density of heat supplied is between a maximum of about 9 therms per acre in the Siemensstadt area, 6·5 therms per acre in the Charlottenburg area and only 2·5 therms per acre in the Moabit area. The last has a much lower thermal requirement per acre than has been considered practical in Great Britain, yet it would appear as if heat supply to this area is entirely satisfactory and economical. Both hot water and steam are used in the system. The hot water is supplied in a standard three-pipe system. In order to obtain better fuel utilisation use is also made in the system of waste heat from power stations, and the temperature of the condensing system is adjusted strictly to accord with the demands for heating. It was found that a better utilisation of fuel could be obtained by using circulating temperatures which were kept as low as possible and simply adjusting the flow of liquid through the pipelines to help with slight fluctuations in demand. The following table shows the data found with regard to the circulating and return temperatures: Steam used at 88 lb/sq. in.

Circulating temperature:				
(° C)	90	110	130	Steam
(° F)	194	230	266	
Return temperature:				
(° C)	50	56	65	
(° F)	122	133	149	
Per cent loss in electricity:	13	15·5	19	45·5
Electricity generation in kWh per ton of steam	283	274	263	177
Useful heat for heating in therms per ton of steam	20	20	20	20

Under practical conditions it was found that it was possible to have an inlet water temperature of 91·5° C (196° F) at the lowest mean temperatures found in Berlin, namely —12° C (10° F).

The average annual heating requirements for a flat of floor area 700 sq. ft was found to be 490 therms, in order to maintain each room at the standard internal temperature of 20° C (68° F). The number of degree days in Berlin are 6,180 against 5,304 in London. Yet each flat in the Churchill Gardens area in Pimlico required no less than 623 therms of heat to achieve a much lower degree of comfort. The answer is almost certainly to be the difference in thermal insulation practised. The cost of heating works out at 9·1 pence per sq. ft floor area and year. With more modern large-scale installations the price is being reduced to about 8 pence per sq. ft floor area and year. The charge made for the supply of hot water is 1·3 per cu. ft hot water supplied.

Large accumulators are used in order to be able to adjust for short term variations in requirements.

The Wolfsburg System

The heating/power station of the Volkswagen factory supplies not only the factory but also the town of Wolfsburg with electricity and heat. Apart from a 50 kv. connection with the National grid, from which it is possible to obtain about 18,000 kW during periods of maximum demand, the entire district of Wolfsburg is self-sufficient from the point of view of energy requirements.

The district heating network is a hot water network. For space heating a constant water quantity is employed, but with a temperature dependent upon the external temperature: 130° C inlet and 80° C outlet (266°, 176° F) to 95° C inlet and 65° C outlet (203° 1,419° F). Apart from the space heating network there is also a so-called technical heating network, where the inlet temperature is 165° C and the outlet temperature is 80° C (329°, 176° F)

This technical heating network is intended for smaller and medium-sized industrial undertakings in the Wolfsburg district, for public buildings, etc.

During the year 1960 the production of the heating power station amounted to 610,000,000 kWh and 904,000 G cal* of heat. The town of Wolfsburg utilised 51,000,000 kWh of electricity and 243,000 G cal of this for domestic consumption. Due to increase in production of the factory and the growth of the town, further developments are taking place. In the new power-station there are two new machines each of capacity 48,000 kW (130 atm. 530° C). The appropriate boiler capacity is 200 ton/h. each. The fuel used is coal, heavy oil and natural gas. Three chimneys, each of a height of 390 ft are built so as to get rid of the dust and the SO_2 from the heavy oil. The boiler is equipped with pulverised fuel firing, but can be used with fuel oil up to 70 per cent of its capacity. The town of Wolfsburg takes about 25 per cent of the total heat production of the Volkswagen factory and the heat used is charged for by quantity using heat meters.

Sweden

The Hässelby Station

The Hässelby station was built at a cost of about £5,500,000 to supply heat and hot water to about 60,000 inhabitants of four towns, as well as supplying about 80 megawatts of electricity to the National grid. It was taken into full operation in 1959. The station contains three boilers operating at a normal steam pressure of 1,130 lb/sq. in. The maximum steam production per boiler amounts to 130 tons/h. The fuel used is either pulverised coal or oil. The plant is able to work as a normal condensing power-station or as a heating/power station. During periods of low heating demand the water of the lake on which the plant stands is used as the condenser water. During periods when neither heat nor

* 1 G cal = 40 therms.

electricity is required, as the load is taken by hydroelectric stations, the main plant can be shut down and electrically heated boilers can supply hot water for domestic consumption purposes. The maximum power capacity in a condensing operation is about 32,600 kW, while the top capacity with full back-pressure operation during maximum demand periods is 22,600 kW. The highest temperature of the hot water in the inlet pipes to the district heating system is 120° C and the amount of heat sent out is a practical maximum of about 130 G cal/h (5,200 therms/h). About 75 different organisations are taking the hot water produced and the distance between the works and the most distant consumer is about 2½ miles.

There are three large accumulators of a capacity 2,300 cu.m each. These accumulators are insulated by means of fibre glass and covered on the outside by polished aluminium.

The Gothenburg Stations

There are several large district heating systems in Gothenburg. Typical of these is Biskopsgarden, where 7,650 dwellings belong to a system including 4 heating stations. In Kortedala, a single station serves 8,300 dwellings. The cost of running these stations during the year 1959 were as follows :

Annual cost in pence per sq. ft consumer's floor space.

	Plant and maintenance	*Fuel*	*Total*
Kortedala	1·12	2·60	3·72
Biskopsgarden	1·25	2·52	3·77

A very valuable addition to the district heating of Gothenburg is given by the burning of refuse. It was found that the amount of refuse collected per dwelling and day amounted to 2 to 3 lb, of which about 65 per cent consists of cartons and paper. The effective CV is about 600 to 1,000 B.t.u./lb. This, however, varies considerably with the time of the day as paper is very hygroscopic. If the refuse is burned at about 800° to 900° C the efficiency of combustion is about 60 per cent, thus yielding about 500 B.t.u./lb of refuse incinerated. It was found necessary to have a large combustion chamber for the burning of the refuse and the maintenance costs are considerable, especially in the superheater. Burning reduces the weight of the residue to about 20 to 25 per cent and the volume to between 5 to 10 per cent. It was found that a plant for the combustion of refuse for a town of 100,000 inhabitants costs about £280,000 to erect. Chimneys have to be in excess of 150 ft and the furnances used are, in general, specially designed for the job (Osby, Gustavsberg, M. T.) It was found that refuse burning for district heating is uneconomical if the refuse of less than 5,000 to 6,000 dwellings is dealt with. When refuse burning was used together with the Gothenberg district heating stations, the net annual efficiency of the installation was reduced by between 3 to 5 per cent. This reduction in efficiency was, however, compensated for by an increase in the amount of heat evolved. The cost of refuse disposal in Gothenburg used to be £9 per year and dwelling. After using the refuse as fuel in the district heating stations the cost of rubbish disposal fell to only £1 15s. per year and dwelling.

The Sundbyberg Refuse incineration—District Heating Station

The town of Sundbyberg lies north of Stockholm and possesses a district heating station fired entirely by refuse, able to supply heat and hot water to 3,600 dwellings as well as high pressure steam to certain local industries. The plant cost £410,000 to build and was equipped to burn either coal, oil or refuse. It was found that during normal operation the refuse supplied from about 75,000 people is adequate to keep the plant running without any other fuel being required. In spite of the fact that the refuse contains between 20 to 30 per cent moisture and about 20 per cent ash its calorific value was found to be about 1,000 B.t.u./lb. The capacity of the rubbish burning furnaces is about 4 tons per hour, and the boilers are capable of producing 20 tons/h of steam at a pressure of 570 lb/sq. in. The plant is operated by one engineer in charge and six shift workers as well as one maintenance man. The hot water, which is pumped out from the station to the dwellings is at a temperature varying between 212° and 220° F and the return water is at 120° F. No smoke is emitted from the high stack because of the existence of very efficient mechanical filters. The plant is stationed in the centre of a residential district and in order to avoid undesirable odours from the plant, it is operated at a slight vacuum inside the plant using special double doors to maintain this vacuum when either goods or personnel enter from the outside. It was found after installation that far more heat was produced than could be used economically by either the housing estates in the vicinity or by nearby industry. Dynamos were therefore installed to utilise some of the steam produced and the current fed into the grid system.

U.S.S.R.

The Moscow District Heating Network

District heating in Moscow has been expanding very rapidly during the last few years and is showing signs of expanding even further in the future. In 1945 there were five stations and in 1959 eight stations were open. On Jan 1st, 1959, there were 465·1 kilometres of hot water lines and 31·3 km. of steamlines in the system which supplied a maximum 2,380 G cal/h by means of hot water and 400 G cal/h of steam heating. The amount of electricity supplied by these district heating stations was 680 megawatt in 1959. The Moscow stations are under very heavy load during the winter. When the outside temperature is at –26° C (–15° F), which occurs for about 1,770 hours each year, the plant is utilised to 71 per cent of its maximum capacity, the remaining capacity apparently being kept in hand for buildings not yet erected at the time. To allow for different capacity needs over the year, the circulation temperature is varied according to the outside temperature. Over the year the ratio :

Electricity produced/heat produced was kept at about 0·33 kWh per therm of heat. The amount of heat supplied per mile of district heating network was 290 therms in the case of the hot water system and 950 therms in the case of the steam system, per hour maximum loading.

The Moscow District Heating network employed 3,300 men in 1959. The output per man was 0·8 G cal/h and 0·5 megawatt. Considering the low temperatures existing in Moscow the heat losses from the district heating circuit were moderate. The heat losses from the hot water system averaged 5·86 per cent and those from the steam system averaged 3·35 per cent.

Taking the system as a whole it was found that for each G calorie of heat produced, an expenditure of 174 kg of coal was necessary. As no figure for the CV of the coal used was given in the literature it is impossible to evaluate the overall efficiency of the plant used.

Plans are at present afoot to increase the output of the Moscow district heating system very drastically. It is intended to increase the supply of district heating to industry from the 16×10^{14} B.t.u. in 1958 to 27×10^{14} B.t.u. by 1965 and the district heating supplied to domestic dwellings from the $8{\cdot}2 \times 10^{14}$ B.t.u. in 1958 to $16{\cdot}4 \times 10^{14}$ B.t.u. by 1965.

Canada

The Inuvik Thermoelectric System

Inuvik is a small Canadian town where most of the people live in their own small houses. In 1953 the population of Inuvik was 1,500 and expanding rapidly. Inuvik has no less than 18,190 degree days per annum as against London's 5,304 using a 65° F base. It was decided to construct a thermoelectric station to heat the entire, sparsely occupied neighbourhood using water which circulates at a pressure of 150 lb/sq. in. and a temperature of 350° F. Due to the hilly terrain of the district it is not economical to return all the return water and therefore the high temperature of the water in the system helps to minimise heat losses. The peak capacity of the plant is 2,400 kWh and 80,000,000 B.t.u./h. The lines used are 8 in. supply and return lines, well insulated in fibre glass wadding.

Three oil-fired boilers are used, each of a capacity of 30,000 lb of steam per hour at a pressure of 500 lb/sq. in. and 500° F. This is then passed through the two 375 kW and the single 1,000 kW generators operating at a back pressure of 150 lb/sq. in. This steam is then fed into two de-aerating heaters to heat the H.P. water. No cooling water is used on the plant, but instead an air-cooled condenser is employed for the turbine gland steam. The pipes are passed around the town in the form of several ring mains using a few basic loops. In the various buildings conversion to secondary heat takes place using water to water heat exchangers. The Inuvik district heating station was first put into service in 1959, and has operated satisfactorily since then.

U.S.A.

The Porchester Community Scheme

In this scheme district heating is supplied to about 12,000 dwellings by means of steam generated in solid fuel fired boilers. The pressure used is between 80 to 100 lb/sq. in., which is reduced to about 25 to 45 lb/sq. in. before the steam enters the distribution mains. The heat is abstracted at the dwellings by means of calorifiers to heat hot water for both the heating circuits and consumption circuit. The temperature to be maintained inside the dwellings is about 70° F. Heat losses of steam pipes are about 19 per cent. The condensate is not returned to the station. The cost of installing return mains was not considered to be economical, as such would have to be constructed of stainless steel, any other type being extremely liable to corrosion.

The Hartford, Connecticut Station

This station is unusual as it provides both district heating and district cooling by gas-fired boilers and refrigeration plants to a 14 acre central business and residential area in the town. The project cost $4,500,000 (£M 1·6) to carry out and uses three boilers of a combined steam capacity of 225,000 lb of steam per hour. The steam is sold for heating and is also employed in both the steam turbine driven and the absorption type refrigeration plant. The advantage of this is that a far more even annual loading of the available steam plant is given. Gas is used for firing the boilers except in very severe winter conditions when fuel oil is used. The plant is adjacent to the Connecticut river so that plenty of water is available for condensing excess steam produced.

The central plant consists of about 20,000 sq. ft of floor space containing the three boilers, one Carrier centrifugal refrigerator of 3,000 tons capacity and two of 1,500 tons capacity each, as well as an absorption type refrigerator with a capacity of 500 tons. A further refrigerator of capacity 4,500 tons is on order.

There are 14,000 ft of cathodically protected pipelines. The steam supply line is a 12-in. steel pipe insulated and running in the centre of a protective steel casing. The condensate return line is 5 in. in diameter and insulated with granulated gilsonite. The cold water lines are 24 in. in diameter each. The cooling lines, which carry water at 40° F are insulated by means of a 1-in. thick layer of expanded polystyrene, while the return lines, which carry water at 55° F are left uninsulated.

The pipes are buried at depths between 2 and 10 ft below ground. The average daily gas consumption is about 1,000,000 cu. ft of gas, and it is expected that this will rise to about 1,500,000 cu. ft in the future.

The consumer is charged according to the volume of cooled water consumed and the number of lbs of steam used for heating. Both are measured by means of meters.

From this account it can be seen that the district heating plants in existence in different parts of the world vary extensively in design to accord with the special economic and social conditions as well as climatic variations of the area to be supplied. It will be noticed, however, that the most successful plants are large ones, preferably using waste heat from power-stations, refuse burning, or in the case of the United States readily available and cheap natural gas. The author is of the opinion that the most fruitful promise of establishing district heating in this country would be for the supply of an entire new town. Comparing continental experience it would appear essential to observe the following points :

(1) The supply area must be a really large one, with a minimum of 2,000 consumers and preferably with well over 5,000 consumers.

(2) The best system would appear to be a coal-fired thermo/electric system, preferably incorporating refuse incinerators and being sited close to a river or the sea to be able to dispose of unwanted heat during the summer months.

(3) The dwellings will need to be insulated to a much higher degree than is customary in Great Britain. U-values of walls below 0·1 and double glazing would appear to be obligatory. Adequate insulation would also have to be practiced with respect to the pipe lines.

(4) It would appear as if the best distribution system would be a three-pipe system using cathodically protected steel pipes. Addition of hydrazine to the distribution water is advisable to cut down the oxygen concentration. Hot water for consumption purposes to be prepared in a water/water calorifier at either sub-stations or at the dwellings themselves.

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(To be continued)

HEBRON AND MEDLOCK—GYDAR AGREEMENT

Hebron and Medlock, of 33, Oldfield Road, Bath, have taken over the outside contracts division of Gydar Ltd., and have purchased the "goodwill" of that firm with the exception of Admiralty Contracts. The acquisition of these interests of Gydar Ltd., extends the activities of Hebron and Medlock into the fields of medium, heavy mechanical and chemical plant engineering.