DISTRICT HEATING

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IN THE POLISH MANNER

WHY WASTE ALL THAT HEAT?

COMMITTEE ACTIVITIES

AN OFFICIAL PUBLICATION OF
THE INTERNATIONAL DISTRICT HEATING ASSOCIATION
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In the Polish Manner

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A frank discussion of difficulties overcome and techniques established, including data on the use of combined heat and power generating plants and basic energy economy.

This article is particularly pertinent at this time because the Third International District Heating Convention will be held in Warsaw, Poland, April 6-9, 1976.

HEAT SOURCE

The characteristic of post-war housing and municipal building in Poland is significant for the rising standards in equipment and installations. Even in the first few years after the war, nearly 50% of urban buildings were equipped with central heating installations which, compared with the pre-war period, was very significant progress. At the present time nearly all new urban buildings are equipped with central heating systems. There are very few exceptions.

The taking over of all urban areas by the municipal authorities, and the immense destruction of many cities and their suburbs, were the reasons for grouped construction in the first years after the war. These buildings were put up by the municipal authorities or by dwelling cooperatives, and this was a supplementary reason for supplying them with heat from one central boiler room. The first central boiler rooms of this type, built before 1950, were equipped with cast-iron boilers sometimes in multiples; somewhat later with small welded steel boilers with a heating surface of 80 m^2 each. In such boiler rooms water was heated to a temperature not higher than 95 C (203 F)—used directly in the installation.

First Problem

The main difficulty, which appeared at the outset of these first post-war district heating schemes, was proportioning the proper distribution of water to each building and, then, to each building heating system. This difficulty was surmounted by power increase, output and pressure head, in pump duties.

In 1950, boilers manufactured by La Mont, with outputs of 1.25, 2.5 and lately of 5.0 and 10.0 Gcal/h, introduced a more rational solution to the problem of central heating, and an increase in maximum water temperatures up to 150 C (302 F) and sometimes 130 C (266 F).

Between the years 1950-1960 the largest installed load in these heating plants did not exceed 10 Gcal/h. At the moment, with type Wr 25 boilers, of which production in Poland was started in 1970, the maximum has reached 100 Gcal/h. Simultaneously with the expansion of central heating, distribution from thermal-electric power stations to housing estates and suburbs of towns was started.

From the rebuilt pre-war power station "Powisle" in Warsaw, the first combined thermal-electric power station emerged in 1953. During reconstruction, the condensing turbines were adapted to work to conditions of reduced vacuum—a pressure of 0.4 to one atmosphere. In this method of working, the condensers of the turbines are fulfilling the part of primary heat exchangers warming up the water to a temperature of 95 C. Where more heat is needed, this is added by supplying steam direct from the boilers serving the turbines, after pressure reduction. The maximum water temperature can be raised to 150 C.

Reconstruction of this heating plant supplying the centre of Warsaw, as well as projects for the construction of the first sections of the town heating network and the coupling of the main network with outlying dwellings, were effected after previous consultations with specialists from the USSR. As a result of those consultations different technical solutions were introduced, as well as the parameters used normally in the USSR. The maximum calculations were based on:

—a flow temperature of the water in the distribution mains of 150 C and a return of 70 C (158 F).

—a unified pressure of 16 atm in order to standardise both the network and method of installation. In the case of indoor installations, the pressure is limited to 6 atm.

Replacement of Individual Heaters

This last requirement arose from the use of water injectors in the case of connecting individual installations with the mains. Such a link needs a balance of pressure on both sides. This system also supplied heat for domestic warm water in the new buildings where individual gas water heaters were replaced by a central heat exchanger. At first, as well as later on, non-accumulative heat exchangers were used for that purpose.

At first, these heat exchangers were placed in parallel with the supply system (Fig. 1a); later on in the same manner, but also in series (Fig. 1b). The application of calorifiers in such systems requires considerable changes in the quantity of distribution water indispensable for covering the needs of a town's hot water. These changes are shown diagrammatically in Fig. 2. They result from the method adopted for regulating the mains in the heating season. The temperature of the water sent out from the thermal-electric power station is made to suit installation central heating needs by constant flow and temperature regulation.

In practice, full series working (Fig. 1c) has been developed for reasons of regulation difficulties. This kind of system is equivalent to the accumulator system where the latter is represented by the calorific capacity of the building. Such an application requires the use of automatic two-way valves of a kind which have not yet been produced in Poland.

Using methods similar to those described, the basic solutions accepted for modifying the first thermal-electric power station and converting it from a single-purpose generating plant, have been applied to others of a similar nature including 12 totalling 800 Gcal/h. These units produce hot water and supply water injectors, others are equipped with La Mont-type boilers. The new urban thermal-electric power stations built up to 1960 have been equipped mostly with extraction/condensing turbines having outputs of 30 MW electric. The steam pressure taken from the extractors varies from 1-2—2.5 ata (psia). Heating of the mains water is on two levels. The first is through heat-exchangers fed by turbine extraction, in which the water is heated to about 105 C (221 F).

On the second level are heat exchangers fed with steam taken from high-pressure boilers through pressure-reducing precooling stations. These were not the most economic solutions since the wrong steam conditions applied, particularly on supplying primary heat exchangers. There were large fuel losses resulting from not taking advantage of the latent heat of condensation. As the result of research work carried out by the design office "Energoprojekt," a Polish heating method has been devised for a double-rotation turbine of 55 MW power with a water boiler of 120 Gcal/h for covering the highest heating loads (Fig. 3). The initial assumption for development of this method was its immobilization during summertime. Due to lack of electricity, this method has been adopted to work with low heat requirements during summertime, by building into the return pipe of the distribution main a supplementary exchanger cooled by water drawn from a river or from a cooling tower.

From a description of methods dating from 1970, evidence of further developments and the importance of the heating plant system can be seen.

At this time about 55% of all municipal buildings here are equipped with central heating: 43.5% by solid fuel heating, 1.5% by electric stove heating. The necessary heat was produced by:

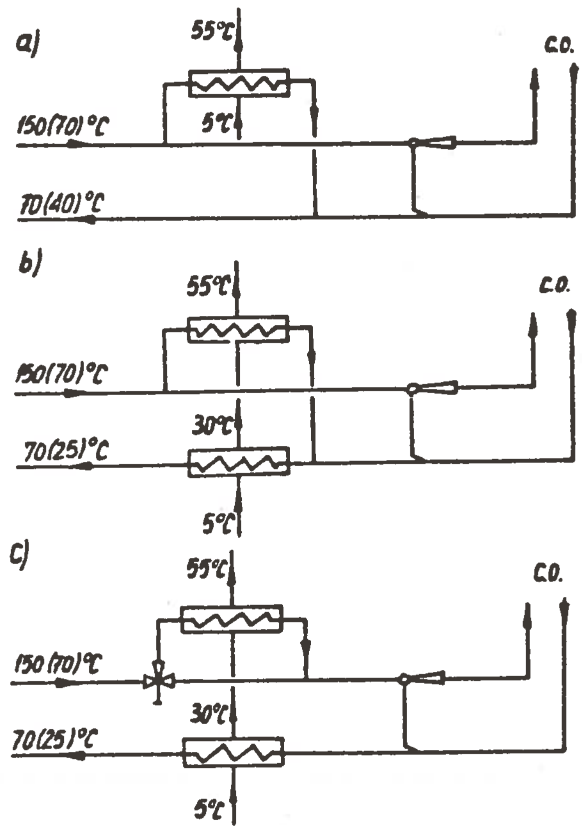

Fig. 1

—municipal heating plants	41%/about 14 500 Gcal/h
—municipal and industrial thermal-electric power stations	31%/about power abs 11 000 Gcal/h
—local boiler houses	28%

The above mentioned data do not include the greater part of the industrial demand. For example, industrial thermal-electric power stations produce heat principally for technological purposes and have a global heat power of about 11 000 Gcal/h, of which about 2 000 Gcal/h is transmitted for municipal needs.

Yet to Come

The latest developments show that by 1980, 75% of all buildings in the towns will be equipped with central heating installations of which 4/5 will be supplied by central sources of heating, and more than half of it from combined thermal-electric power stations.

The intense development of central sources of heat, and of thermal-electric power stations results from economic surveys. The cost of producing 1 Gcal of heat is compared as follows:

—from large thermal-electric power stations	110-130 Zloty
—from large heating plants and boiler houses	190-220 Zloty
—from small heating plants	210-240 Zloty
—from individual boiler houses	320-400 Zloty

(One Zloty is about One Cent)

The Polish National Inspectorate for the Economy of Fuel and Energy, created in Poland 15 years ago, has responsibility for developing central sources of heat, and thermal-electric power stations. This Inspectorate gives opinions and approves decisions concerning the thermal needs of towns and industries. The result of the activities of the Inspectorate is the elaboration of plans for future development of heating systems throughout Poland.

In most towns the supply of heat to blocks of flats, cooperative properties, office buildings and, also, frequently to industrial buildings situated in the town area, is being looked after by the Municipal Enterprises of Thermal Energy. These Enterprises control all individual built-in boiler houses and all, or the majority, of the district heating boiler houses. Thermal-electric power stations are exploited by electro-energy enterprises, from which the municipal enterprises buy thermal energy. The lower price of thermal-energy production encourages the exploitation enterprises to reduce the number of small individual boiler houses, and to connect all buildings to the network fed by thermal-

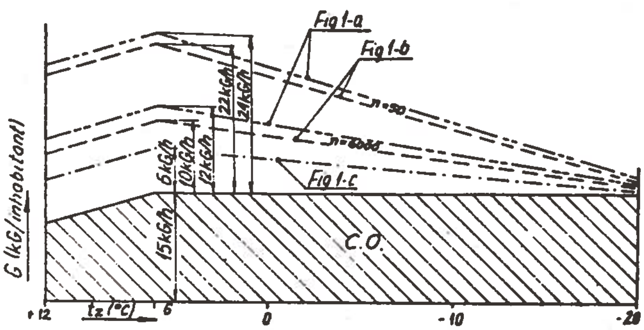

Fig. 2

electric power stations. This process is rather slow, considering the insufficient thermal power of the thermal-electric power stations. Users of heated buildings—the consumers—pay for heating and also for the supply of warm water, by a flat-rate charge related to $1 m^2$ of heated surface—between 3 and 4 Zloty/m^2 monthly.

URBAN DISTRIBUTION OF HEAT

In most cases the medium used for transport of heat is water; exceptions are made for the technological needs of industries, for which high-pressure steam is used. The maximum temperature accepted for thermal-electric power stations and boiler houses with La Mont-type boilers, is equal to 150 C. The temperature of the return water is 70 C and in the case of coupling by means of exchangers, 80 C (176 F). The maximum temperature of the feed water, 130 C, is also accepted for municipal boiler houses. The distribution mains are laid as flow and return pipes. With simultaneous industrial technical needs, a four-pipe system is used.

A triple-pipe system was given up, although tried experimentally. The reason for abandoning the three-pipe system was the difficulty of mastering pressure changes in the common return pipe, caused by changes in flow of water of constant temperature supplied for industrial purposes. By covering the needs of central heating and hot water, though for the latter the water should be of a constant temperature, the use of a three-duct system did not find economic justification because the smaller costs of the heat exchangers were not equalled by the increased costs of laying of a third pipe.

The temperature of the water in the municipal heating mains is controlled to suit the needs of central heating, and, depending on the outdoor temperature, varies from 70 to 150 C. Temperatures lower than 70 C, where there is a simultaneous need for central heating and town hot water, are not used; but with outdoor temperatures higher than about 6 C (42.80 F) this causes overheating.

Fig. 4 shows the theoretical and actual change of temperature of the supply water following outdoor temperature. As can be seen from this diagram, the real temperature of the mains water is lower than the theoretical one. This phenomenon is observed in the majority of heating systems, and confirms the suggestion that the real need of warmth from a heating installation represents 80-85% of the normally accepted design load figure.

The distribution of water for individual buildings, which in the first period of exploitation of district heating indeed produced trouble, is now successful through the use of all service tappings. Although three diaphragms are used, the automatic flow control system still produces fluctuations of $\pm 10\%$ due to the consumers' varying use of hot water affecting the temperature sensitive equipment.

The loss of water in the town hot water system is rather considerable, and amounts to 3% of the water in circulation. This causes difficulties in maintenance of pressure, and the frequent insufficient output of the water stations supplying the make-up water is the indirect reason for corrosion. At times of low ambient temperature the increase of water volume, due to increasing circulation, compensates for leakage. The automatic extraction valves that are built into each heating plant do not work in practice.

The reasons for such substantial wastage of water are leakages, principally through the throttling expansion pipe bends, venting water as well as air in central heating installations not equipped with automatic vents, loss of water by users of inefficient central heating installations, and loss of water from the system during building construction.

Distribution Mains

Circulating water is generally, but not always, carried underground, principally in pipe ducts. Before being covered with insulation material the pipes are, after de-rusting by thorough sandblasting or wirebrushing, painted with rust inhibitor paints as generally used for marine work. For insulation glass wool blankets are used, covered with a metal mesh and a casing of cement/sand mortar for mechanical protection, and often covered supplementarily with roofing felt. Ducts with walls built at first of brickwork are now carried out in reinforced concrete products of 'L' or 'C' shape in the case of smaller dimensions. The top covering of the duct, as well as its side walls, are painted with liquid bitumen in order to provide damp-proofing.

In the case of a high water table, there is drainage by open ditches alongside the duct. Apart from laying mains in ducts without walkways, experiments have also been made in laying mains without ducts. In these cases the insulation used is either:

—blocks of precast foam concrete
—asphalt-coal powder
—abestos-cement concentric pipe systems in which glass wool insulation was used.

It is perhaps noteworthy that plastic insulated, plastic cased mains are not used.

In comparison with other insulating materials, the best results have been obtained with foamed concrete insulation laid in comparatively dry soil. Fill-type insulation of asphaltic coal powder, in general use some years ago especially in Warsaw for suburban mains, did not fulfill expectations. Corrosion of the outside part of the pipes began, believed in many cases to be due not only to the sulphur content of the coal used as fill-type insulation but also to careless workmanship.

Now it is necessary to change some parts of these mains. On the other hand, all the pipes insulated in the proper manner and laid in a not too damp ground are in good condition. However, this method was given up some years ago. Much the same has happened in the widely used system of laying sections of small diameter in asbestos-cement pipes. The service life was very short, from six to ten years, so that system also has been given up. The asbestos-cement suffered a lot of damage in installation.

For these reasons mains systems are now generally built in ducts without walkways, using an insulation of glass wool.

Above-ground mains, which are found very rarely in towns, are insulated with glass wool covered with galvanized iron sheeting.

Thermal compensation for straight runs of pipe is provided by U-bends for medium diameters; and in the case of sizes larger than 100-150 mm, expansion pipe joints which are very expensive and inconvenient to use.

Mains systems do not reveal particularly dangerous, in relation to durability, effects of internal corrosion, although the quality of the circulating water is not good. This is due to losses and in many cases to an insufficient output from water treatment stations in different towns, or are not in accordance with the regulations in force in that area. But there are noticeable deposits which increase the internal resistance, as well as an appreciable quantity of suspension carried by the water in the pipes. That is the reason why considerable attention is given to every improvement and to new solutions in the availability of lime-scale separators. These are installed at the input of each consumer's installation connected with the town hot water system.

Sections of pipes in these systems are matched to a velocity of water flow of 1-2.5 m/sec. The greater velocities correspond to large diameters, 500-1000 mm, and loss of pressure is determined by an assumed irregularity of the wall surface of -0.5 mm. The pressure head of the circulating pumps reaches 30-50 m head of water in the heating plant and 150 m in thermal-electric power stations.

Pumping substations are rarely used unless essential to deal with hilly districts—not typical in Poland. But in Warsaw, where the distance between the thermal-electric power stations and furthest consumers amount to 15 km (9⅜ miles) there are two pumping stations. One of them is situated on the principal water main.

Several heat sources are used in the big networks feeding isolated areas, but inter-connection of different sources allows interchange of feeders during repairs, but such work is not done during the main heating season.

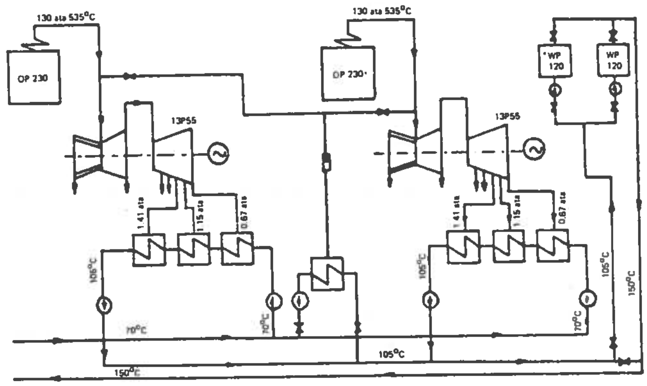

Fig. 3

INDOOR INSTALLATIONS

A common type of indoor installation of central heating was, and is still today, made up of a circulating pump with two pipes and low level feed, equipped with radiators of cast-iron sections. The calculated temperatures of water for this installation were, until 1955, 90/70 C or 95/70 C. In 1955, these temperatures were changed and are now 110/70 C, in order to lower the cost of piping in consumer installations, but only in those cases where there was otherwise no necessity to use special means for maintaining pressure.

Correct distribution of water between the different radiators and heaters had to be considered, together with calculated temperature drop. In the past, this distribution problem was the cause of a number of cases of insufficient heating. The use of radiator valves with two-stage regulation, to adjust water circulation, made very laborious work but not always successful. Even when valves were shut off, the closed position leakage was too great. An analysis of the reasons for insufficient heating in the lower stories of buildings, when outdoor temperatures were low, lead to an explanation of the consequences and methods of counteracting the variability of pressure in a gravity heating system.

Pipe blockage, as the result of pollution of the cir-

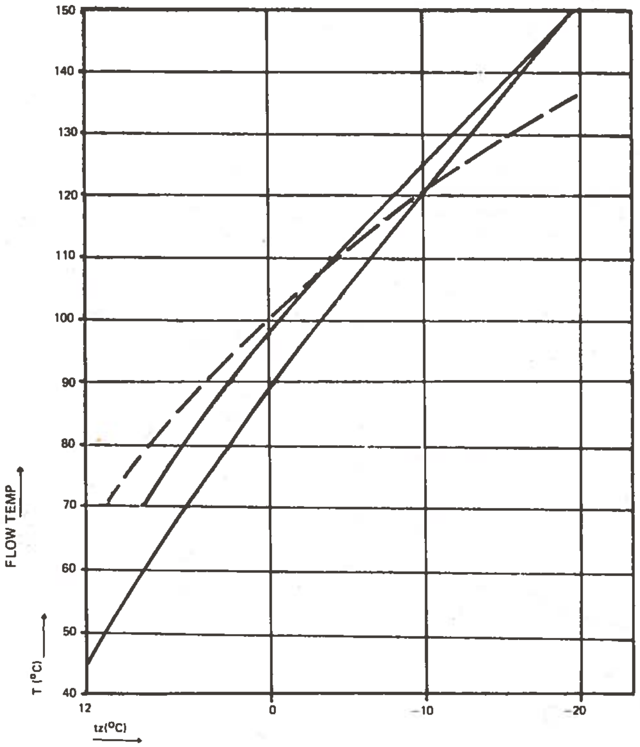

Fig. 4

culating water, may occur as well as noise and whistling. The latter occurs when the seatings are loose or when there is too much resistance, e.g., in the case where the pressure produced by a circulating pump is higher than the designed one. To make it possible, in these specific cases, to make a rapid exchange of flange, a method has been worked out consisting of freezing the pipework by using dry ice—solid CO_2. So far this method has not yet been widely used.

It is also possible to suppress difficulties arising from the consequences of alterations in gravity pressure—by using a quantity and quality control, so that the quantity of water in circulation has a fixed gravitation pressure during the whole heating season. This method of regulation is very difficult to achieve in practice.

One-Pipe Trials

There are difficulties in producing adequate flow resistance in high buildings, e.g., 15-storied buildings with a flow and return temperature of 110/70, the minimum resistance of the heat exchanger should amount to about 1100 mm pressure head and with temperatures of 95/70—about 700 mm water. These were the reasons for attempting to apply one-pipe heating on a larger scale, with vertical systems susceptible to changes of gravitation pressure. These types of heating systems are widely used in the USSR. A number of such systems have had trouble due to insufficient knowledge, principally of changes in the quality of water and the effect of overestimating radiator sizing: on one-pipe systems alteration of flow affects radiator output; overestimating radiation surface produces an irregular change of output, handicapping the end of system radiators at the same time.

These results are cumulative with the calculated temperature difference: in the first one-pipe systems connected to the system by means of solid-built injectors, there was insufficient pressure and a lower quantity of water than designed resulted; and since there were additional radiators, the difference of indoor temperature between the highest and the lowest stories amounted to more than 10 C (50 F).

Present Trends

These experiences caused a slowdown in the use of one-pipe systems which, considering the possibilities of prefabrication and insensitiveness to changes of gravitation pressure, deserve more extensive application. At present, there is a tendency to use, as in the past, one-pipe systems in the vertical mode with two-way by-pass valves. In heating installations in office buildings and dwelling houses, a return has been made lately to a designed water temperature of 95/70 C. This decision was due to difficulties in obtaining the required resistance of radiators in high buildings, and to deposits and residual products of corrosion occurring in the small diameter pipes. In Poland, pipe systems are made exclusively of steel. The used design temperatures of 110/70 for piping with a minimum diameter of 10 mm is in the majority.

Heating installations in office buildings and dwelling houses are generally connected to the mains by means of injectors. Connection by means of heat exchangers is used only where the difference of pressure in connection points is smaller than about 15 m head, or when the pressure existing in the return is too high considering the strength of the installation.

When there is too little pressure difference in the mains, when connecting large installations, or when it is impossible to use injectors, pump mixing is used.

The ground floors of dwelling houses and office buildings or shop premises, as well as industrial buildings, are directly connected to the heating mains, fed with water of nominal temperatures of 150/70 C for radiators, finned steel pipes of 70 mm diameter are generally used. The value of the coefficient of heat transmission in this type of radiator depends on the water flow $K = Ct^m G^a$. Ignorance of this, and it also concerns convectors, was for some years the reason for which the wrong size was chosen. Also the mean differences of temperature cannot be taken as the so-called arithmetic or logarithmic means values. To establish this value, the variability of the coefficient of heat transmission, together with the change of difference of temperature in the respective surface elements of the heat exchanger, have to be taken into consideration.

As was mentioned above, the common type of radiators used in central heating installations now in Poland are the cast-iron radiator and steel-finned pipe. To heat rooms with little heat loss, radiators with smooth pipes are used, the so-called riser pipe system in many-storied buildings. Now, welded steel radiators are being produced; they are actually imported in small quantities. The statutory undertakers are not in favour of this type; they think the poor water quality will lead to corrosion.

Attempts to develop the use of convectors were unsuccessful because of the lack of information at that time concerning their reaction to water flow, and for that reason efficiencies were wrongly estimated.

AUTOMATIC CONTROL

There are few occasions where automatic devices can be used in heat generating appliances or in heating networks.

Considering the type of fuel—coal—used as source of heat, automatic control of water temperature is rather problematic. Automation is only used in safety devices, such as for stabilizing pressure.

Neither do heating networks have automatic devices because, in principle, no automatic control is needed with the exception of large, extensive district heating systems with several heat supply stations.

Automatic control is a necessity at consumer supply points. At present, only those heat exchangers used for domestic hot water, which without exception need automatic control devices, are equipped with direct acting thermostatic valves. To a large extent these are imported. Electromagnetic valves of home-made production, controlled by water temperature from the heat exchanger, are also used, but only rarely.

Automatic water level controls, which open a valve to admit water to the heating installation, are considered desirable according to the type of radiators, the method of connecting and the design temperature. This control is especially important when the main distribution system has to cover the needs of hot water. Electromagnetic valves, controlled by indoor temperature in some specific areas, or alternatively by outdoor temperature, are actually used for this purpose, but in a relatively small number of buildings. Maintenance of too high an indoor temperature in too many heated buildings is the result of the absence of control devices.

In order to find the most adequate form of automatic control, ten buildings have been equipped this year in Warsaw with several control devices assembled from components produced in different countries. The results of that experiment will facilitate the choice of the most suitable automatic control system in the future.

The application of individual thermostatic controls on each radiator is considered to give the best results, and although the production of such types of valves has started this year in Poland, these devices will be, taking in consideration the high costs, only used on a limited scale.

PREPARATION OF DOMESTIC HOT WATER

About 25% of the buildings receiving heat from central sources are also equipped with central hot water installations. The number of these buildings is rising, because the major part of all newly-built houses is equipped with this type of installation. The selection of suitable equipment for such installations is a matter of engineering, coupled with economics. Apart from lower working costs, the durability of the distribution network is prolonged because hot water is supplied all the year round. A flat rate payment is imposed for the supply of hot water, explaining the noticeable increase of consumption, amounting now to 120 litres per inhabitant per 24 hours.

The temperature of this water is kept to a 55 C (131 F) level, although at times of peak water consumption it drops to 40-45 C (104-113 F). This is also when non-storage type calorifiers are used. Fairly widespread use of the centrally prepared hot water has markedly increased municipal water consumption, and has produced concomitant difficulties for municipal water supply undertakings.

As mentioned when discussing heat sources, non-storage calorifiers are used almost exclusively. Satisfying peak requirements with heating regulation control as described, requires a very considerable quantity of mains water. Difficulty in meeting this requirement was the reason for lowering the water temperature to 25-30 C (77-86 F) in the peak hours. The restriction on the quantities of water taken from the heating network in any 24 hours can be met by a full series coupling (Fig. 1c) or by using hot water storage. Regulation difficulties have determined the use of hot water accumulators in recent years. System design does not entirely ensure the balance of heat supply and the availability of hot water in any 24-hour period. Non-storage heat exchangers with a capacity of 25-30 C, superior to the average requirement, have been designed. These accumulators have sufficient storage capacity to cover higher water consumption than the output of the heat exchanger alone.

Because the level of fluctuation of water consumption is smaller when the number of users supplied in this way are more numerous, the design and building of group units for central preparation of hot water has begun. These cater to more than a dozen buildings at a time. This project aims at reducing the cost of investment and to raising the standard of efficiency of the whole undertaking. ✱

(Editor's Note: This was the text of a talk presented by Dr. Wasilewski to the London Branch of the District Heating Association (of Britain) and subsequently printed in the JOURNAL of the DHA. Our appreciation to the DHA, and to the Editor of their JOURNAL, Norman Jenkins, for granting us reprint permission.)

IDHA PEOPLE

Alvin B. Spetz, IDHA's immediate Past President (1973-74 term), recently became a 35-year employee of the Rochester (N.Y.) Gas and Electric Corporation.

Owen D. Brown, formerly Steam System Superintendent, is the new Chief Engineer for the Eugene (Ore.) Water and Electric Board. He is his company's Official Representative in IDHA.