Prime Costs of Heat Transmission in Electric Power Systems

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PRIME COSTS OF HEAT TRANSMISSION IN POWER SYSTEMS[1]

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Economies in district heating are characterized by a primary reduction in the expenditure of fuel by 50 percent or more below that consumed when heat is generated in local boilers and electric power at condensing stations.

Economies in fuel are offset by expenses in the transmission of heat, i.e. expenditures connected with the operation of the heating system. These expenditures at the present time are considerably high, and it is, therefore, of interest to look for ways of reducing them. (Based on the analysis of the given accounts of six wholesale heat systems for 1949).

The cost of heat transmission usually consists of: amortization of the primary equipment, service and running repairs of the systems and structures, heat losses, cost of pumping the heat carrier, and leakage of the heat carrier.

A synthetic index of the cost of heat transmission appears to be, in the final analysis, the expenditure per 1 thousand large calories of the delivered heat, i.e. the sum total of expenditures of heat transmission related to the useful output of heat available to the utilizing appliances. However, for the analysis of the individual component losses and for comparison of their magnitude at various heat contents, it is quite suitable to apply also other indexes, more characteristic of the heat generation technology.

If we take the cost of heat transmission in Moscow as 100, this index for other cities is: Leningrad - 195; Kharkov - 75; Yaroslav - 100; Kiev - 450; and Novosibirsk - 75.

Analysis of these figures leads to the conclusion that the heat density of the heating systems is a basic factor, i.e. the annual output, related to the length of the system. The higher the heat density, the lower the cost of heat transmission. As a rule, at the present time the heat density of steam systems, serving an all-year-around industrial load, is considerably higher than in water systems. The values of the proportion of the heat output carried by steam confirm this conclusion: Moscow - 64 percent, Leningrad - 42 percent, Kharkov 86 percent, Yaroslav - 79 percent, Kiev - 0, Novosibirsk - 0.

For deeper analysis it is essential to examine carefully the separate items of cost.

AMORTIZATION OF THE PRIME SOURCES

In the overall outlay of the heating systems the proportion of the expenses for amortization is composed of: Moscow - 10 percent; Kharkov - 6 percent; Yaroslav - 4 percent; Kiev - 3 percent; Novosibirsk - 5 percent. The apparent difference can be attributed to two basic causes.

The first cause is connected with the difference in cost of the heat conductors and other structures(balanced costs) depending on the year of installation.

The other cause - - the fact that the heating systems belong to different organizations. Many heat conducting mains are constructed by the consumer himself (most often industrial users), and the cost of these systems is charged to the consumer, thereby reducing the amount chargeable to amortization.

It is necessary to charge to the power systems all the main and distributing systems constructed by the consumers, if these systems serve groups of consumers belonging to different jurisdictions. This insures the necessary service and repair. Heat conductors going to individual consumers, regardless of their distances, may remain to the account and use of the consumer, but under constant control of the personnel of the power systems.

At the present time the annual amortization figures are in the order of 3.5 percent rather than the previous 7 percent.

The lowering of the percentage was based on tests on the performance of the heating-system headers in power systems. For this percentage to be sufficient it is necessary to take a series of measures for extending the useful life of the heating systems and for reducing the cost of repair to capital structures.

Current tests show that the most rapidly deteriorating element of the heating systems is the thermal insulation. Installed during the first years of the system's construction (1924 - 1937), the insulation at the present time, as a rule, needs complete replacement. To perform this great task without opening the conduits, it is necessary for the All-Union Thermotechnic Institute to speed up tests on blowing thermal insulation into the conduits by means of ejectors.

Starting with 1937 - 1938, a covering of asbestos cement reinforced by a metallic gauze has been successfully applied in underground heat conductors. If correctly installed, this covering placed above the heat insulation serves as a dependable wrapping, protecting the thermal insulation against peeling and deterioration.

The most durable construction is a solid casing of heat conductors, which serves both as a thermal insulation and as a supporting structure. In particular such casing is made of reinforced autoclaved foamed concrete or foamed glass.

Heat conductors are subject to considerable external corrosion, more so than other underground pipe conduits, because of temperature conditions.

If ground conditions are bad and there is ground water or frequently on the surface, the process of external corrosion may proceed at the rate of one millimeter of tube thickness per year. Therefore, if heat conductors are installed under such conditions - - without channels or in partially protected conduits - - steps must be taken to protect against external corrosion. Such steps include: covering the pipes with Borulin or constructing a solid casing made of foam-glass. (Reinforced foam concrete construction, as a rule, cannot protect against penetration of moisture to the pipe). Covering merely with varnishes or with liquid cement under bad ground conditions causes premature wear of the pipe and should not be permitted.

Long-lasting construction in heating systems considerably lowers the expenditures for the repair of capital equipment and lowers the expenditures for the repair of capital equipment and offers the possibility of further reducing the percentage of amortization deductions.

SERVICE AND MAINTENANCE REPAIRS

The three links of the power system (central station - - heating system - - heat receiver of the consumer) are each served independently by its own personnel. Leading should be the personnel of the heating system, which programs the work duties of the district-heating equipment in the central station, and controls the correct functioning of the heat-using installations of the consumers.

It is very important to delimit exactly the rights and obligations of the personnel. While the division of functions between the personnel of the central station and that of the heating system is defined in the Regulations of Technological Operation, the division of functions between the personnel of the heating system and of the users requires further definition.

With the widening use of district heating in cities it is also essential to form a new organization for serving the subscriber installations. It is necessary to organize groups of stations for around-the-clock servicing of elevator centers and of heating, ventilation, and hot-water supply systems.

In this case it will be the duty of the personnel of the heating system to operate (service and maintain in repair) the mains and the feeder heat lines, and to allocate heat-carrying equipment to the installations of the consumer. Control of the heat consumption of the user, and the accounting is carried out either by the personnel of the heating system, or by the personnel of the central station.

The size of the heating system service personnel is most expediently related to the length of the operating main and feeder system, although undoubtedly some significance can also be attached to the number of individual points at the consumers. Subscriber heating systems should not be included in this. In all, power systems with heating systems of considerable length (Moscow, Leningrad, Yaroslav and others) have fairly good indexes around 1.5 - 2.0 men per kilometer of route. Further reduction in the size of service personnel is possible by improving above all the quality of the equipment (use of gasketless compensators, flangeless valves and faucets) as well as mechanization of the service (transportation along the route, water pumping, ventilation etc).

The cost of servicing one kilometer of heating system under present conditions is estimated to be, on the average (including the maintenance repairs) in the order of 15 - 20 thousand rubles per year. Heating systems of small length are somewhat less efficient.

The service cost usually constitutes the main part of all the expenditures in managing the heating systems. It is, therefore essential to pay serious attention to the sound organization of the personnel work and to exercise control for the efficient use of the working time. The most expedient routes of inspection, and the technique of all operations in inspecting and servicing the equipment should be worked out in advance. Teaching and instructing the subscriber personnel, and control to ascertain their compliance with all installation rules are in the field of the engineering-technical workers in charge of constant inspection of the heating systems.

HEAT LOSSES

At the present time heat losses are given only as percentages of the heat output. Such an index insufficiently takes into account the results of the work of the personnel and the technical state of the systems. In the same subject, let us compare the indexes of the individual heating systems.

Kiev	15.5 percent
Leningrad	6.9 percent
Yaroslavl'	4.4 percent
Moscow	4.8 percent
Kharkov	2.6 percent

Is it possible to say, on the basis of these indexes, that the condition of the heating system of Kharkov is considerably better (as to heat insulation and presence of leaks) than in Kiev? Does it mean that the personnel of the Kharkov heating system is better than that of the other systems? One cannot draw such a conclusion. In a great measure it depends on the fact that the predominant part of the heat output in Kharkov, unlike in Kiev, is transmitted as steam in steam pipes to the subscribers.

To detbermine the operating condition of the thermal insulation and to evaluate the work of the personnel, for the purpose of reducing the heat losses, it is necessary to work out differential norms of the heat losses, depending on the characteristics of the system and on the temperature at which it operates. In this case an overall norm of heat losses, subdivided according to the individual technical indexes, can effectively serve as a standard of the technical condition of the heating system and of the performance of the personnel.

At the present time it is possible only to say that at normal loading of municipal hot-water systems (10 - 15 thousand million calories per kilometer of heating system) it is possible to attain low losses in the order of 5 - 6 percent. For a branched steam system with several industrial customers the percentage is approximately the same. For the Moscow districts the losses in steam pipes fluctuate between the limits of 2 and 9 percent (the average being 3 percent.

To reduce the heat losses in the systems it is essential before anything else to discontinue the use of low-quality thermal insulation (various kinds of fill and asbestos putty and infusorial earth, brick of diatomaceous earth with density 700 kilograms per cubic meter, etc). Hung construction of thermal insulation is permissible only in connection with reliable and durable wrappings. Finally it is essential to replace in short time the deteriorated heat insulation of existing systems, particularly those of steam pipes.

Nothing is more harmful to the durability of present day construction of thermal insulation than intermittent operation of the heat appliances, During the time when these appliances are shut off the insulation absorbs much moisture and the wrappings corrode. As a result they become weakened and the entire installation is damaged. It is necessary, therefore, to aim at year-around utilization of the systems.

Thermal power can be measured at the central station and at the wholesale users with the aid of commercially produced registering flowmeters, thermometers, and manometers. It is necessary to aim at their correct installation and operation, in particular in order to eliminate gravity unbalances of the heat conductors.

The situation is much worse in the case of smaller users, whose number is many times greater than that of the wholesale users. For them, the use of the above-mentioned complex and expensive registering apparatus is prohibitive. This raises the problem of making commercially available simple heat meters for hot water. Such heat meter, modeled after the ordinary velocity-type water-meter, developed by Dr. Technician of Sciences Yakimovym, has undergone lengthy tests; it needs some factory "finishing touches" and organization of continuous production.

At the present time heat losses, as a fundamental techno-economical index of the performance of heating systems, are not reflected in the calculations of the cost of heat transmission; this reduces the effective importance of the calculated result.

PUMPING THE HEAT CARRIER

In the majority of actual heating systems the electrical power consumed for pumping the district-heating water fluctuates within relatively narrow limits - - 16 to 18 kilowatt-hour per delivered megacalorie. With increasing thermal loading of the central station, this expenditure is growing, reaching 10 percent and more of all the electric power used by the station for its own needs.

Fundamental factors affecting this index are, as is known, the temperature chart of the operation of the system, the pressure of the system's pumps, and the method accepted for regulation.

At high coefficients of utilization of the steam bled from the turbine (higher than 1.5 - 1.6) it is expedient to have a temperature change from 150 to 70 degrees Centigrade so that with all other conditions equal, one obtains an economy of electric power for pumping in the order of 25 percent as compared with a temperature change from 130 to 70 degrees Centigrade.

It is important to employ widely this temperature differential, considering that this measure simultaneously raises the output capacity of existing systems and permits, in the case of new additions, to use pipes of smaller diameter.

The pressure head of the system's pumps at the central station, and more so the pressure losses in the system, are as a rule selected without a techno-economical basis, at the very time when in our establishment exists a strictly scientific method for such calculations, developed by Prof. B. L. Shifrinsonom. As a result of this, the pressure losses in main and feeder sections of the systems reach 10 - 15 millimeters of water, and sometimes more, which is by 2 - 2.5 times more than economical. Hence - - excessive use of electric energy for pumping and frequently an unsatisfactory hydraulic system in the heating system.

Extensive use of large scale regulation, is nevertheless hindered by extremely bad conditions in regulating internal heating systems and by the great sensitivity of the present-day two-pipe system to low consumption of district-heating water. The higher the building, the more difficult it is to obtain in it an even air temperature. The unevenness in temperature unavoidably leads to excessive use of heat since it is necessary to adjust the system to the coldest suites.

Considerable economy in electric power can also be obtained with automatic regulation of subscriber lead-ins. Such action is currently taken on a large scale in the Moscow heating system.

In analyzing general expenditures for pumping district-heating water it is also necessary to consider the pumping substations in the systems and at the consumers. When calculating this cost a particularly conspicuous role is played by the elevator scheme of joining, which has received a wide application in the soviet district-heating practice. It is necessary to aim at eliminating all pressure-mixing installations at the consumers and at the transition of heating system to elevations.

Condensate pumped at the central station is usually delivered to consumers, and it also should be considered in an accurate breakdown of the transmission costs. From the usually increased power of the motors under average conditions, it amounts to about 1 kilowatt-hour per cubic meter of recovered condensate at the central station.

Losses in pumping, as in heat losses, are not reflected in the calculation of expenditures of heat systems.

LEAKAGE IN THE HEAT CONDUCTORS

It is most difficult to detect, and, therefore, difficult to eliminate leakages in the heat conductors in distributing water systems and in condensate pipes. In some cases where the operation is badly organized these leaks range between 5 to 10 percent of the maximum quantity of heating water delivered by the central station. Such magnitude of leakage can cause serious difficulties in the heat-supply equipment of the consumer.

According to operating circular No T-41 of the technical section of MES of February 1949, the magnitude of leakage per cubic meter of system capacity must not exceed under normal conditions 4.5 liter per hour during the heating period of operation of the system, and 3.5 liter per hour in the summer.

Experience shows that with good performance of the operating personnel this magnitude can be reduced to 2-3.0 liter per cubic meter-hour. But even under these conditions the losses in preparing heating water, for example in the Moscow heating systems, amount to about one million rubles per year. This forces paying very serious attention to the maximum efficiency of the systems.

The summer interruption in the operation of the heating systems should be used for thorough inspection and removal of defects. The results of this preparation should be checked by testing each subscriber system for hydraulic pressure (usually at 6 atmospheres). Distributing systems in yards between individual buildings should be subjected to separate tests at higher pressures.

In the summer time it is essential also to check the tightness of the main and distributing heating systems. It is customarily accepted to test them as a unit with the station pumps. However, such method does not permit full separations of the radial systems into sections. It is necessary to test the systems section by section, separating the sections with plugs. Pressure in lines is conveniently applied with centrifugal or reciprocating pumps driven by a gasoline engine.

Special attention must be given to the summer inspection of the system if household or industrial water is drawn directly from the system. The reason is that, in contrast with a closed system, it is impossible in the case of direct use of water to determine the amount of leakage at each instant by reading the flowmeter at the central-station feeder. It is,therefore, quite difficult to detect leaks in the winter in the case of direct tapping of water from the systems.

In the analysis of the expenditures due to leakage it is impossible to avoid the question about the cost of preparing feed water for heating systems.

In the absence of direct tapping of water, the preparation of the feedwater is usually done by chemical treatment at the electric station. In small systems with feedwater consumption of 5 - 10 ton per hour this does not cause particular difficulty. However, the maximum output from the central station often exceeds 100 million great calories per hour. In such cases the best solution may be the use of Orgres film deaerators. It is the task of our educational institutions and installing organization to develop further this method to be applied to the waters in the various regions of the USSR.