CENTRAL AND LOCAL TEMPERATURE REGULATION FOR HIGH TEMPERATURE WATER HEATING

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1. Actuality of the problem

In the United States in about the seventies of the last century and in Europe at the turn of the 20th century pioneering efforts were made with distant-heating and distant heat supply. At the time of World War I the development was already fully advanced. The spreading of these has two basic motives:

endeavour for cheep and economical energy supply and transport;

social requirements of heat consumers.

From the two reasons mentioned above the former is the so-called "classical theory" — having been in full accordance with the 2nd main thesis of thermodinamics — saying heat energy cannot be transformed into work optionally, only within given upper and lower limits, according to the "Carnot cycle" thus determining the efficiency furnishing the greatest effect.

This rule has been though basically changed since by the creation of such heat consumers, requiring relatively low heat energy compared to the burning temperature of the combustibles (cca 1,000 °C). The heating and household water supply strictly belong to them.

This relatively low-temperature water requirement may be covered also by supplying the consumers with dead steam leaving the turbines after having accomplished their work, though warm enough for other consumers to use its heat content — in optimal cases — often till 100%.

To demonstrate the method mentioned above, see Fig. 1 showing an extraction-condensing power plant system, widely used formerly. Fig. 2 shows the respective formation of the efficiencies concerned.

The economy of the energy supply has greatly increased by these extremely useful condensers. The adequacy of the system is also proved by the fact that the characteristic specific energy supply of the condensing plant, has never surpassed the 4500—4600 kcal/kWhr, while for the new heating-power plant 1200—1400 kcal/kWhr indexes may be taken into consideration [1].

However a decisive turn can be encountered in our days by the continuous decrease of the specific heat consumption of the condensing heat-power plants and by increasing output of the machine groups as well.

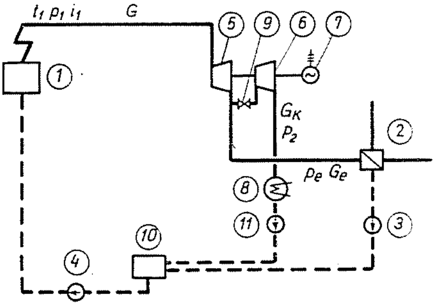

Fig. 1. Connection scheme for the extraction-condensing power plant. 1. Boiler with superheater, 2. Hot water producing heat exchanger, 3, 4, 11. Feed-pumps, 5. Back pressure section of the turbine, 6. Condensing section of the turbine, 7. Generator, 8. Condenser, 9. Regulating valve, 10. Condensate tank. ——— Hot water, ━━━ steam, — — — — condensed water

Great progress can still be encountered by the increasing pressure and temperature of the live steam, hoping its further development will probably continue in the future as well. See Fig. 3 [2].

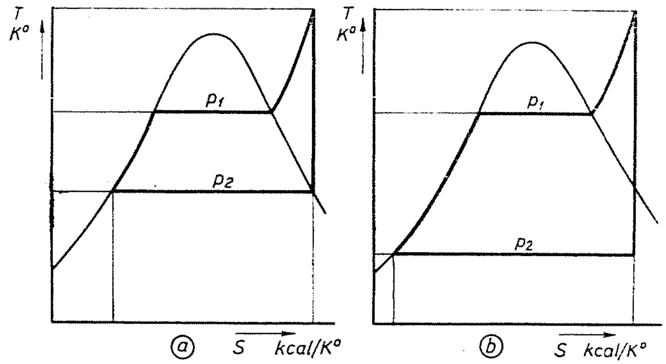

Fig. 2. The efficiency of an extraction-condensing power plant shown in the T—S diagram *a)* Cycle within the T—S diagram, referred to the quantity G_e kg/hr. Optimally 100% efficiency. *b)* Cycle within the T—S diagram referred to the quantity G_k kg/hr. Optimally equals the efficiency of the "Rankine cycle". The efficiency referring to the quantity G weighted average at the ratio $G_e : G_k$

In an especially sharp way the problem, however, rises if we have neglected the traditional methods of heat production and are considering the various combined cycle processes [3] in the steam- and gas turbine plant, the double steam cycles, hot air turbines, nuclear plants. For information see Figure 4 the specific heat comsumption of the condensing and heating power plants in accordance with the parameters of the live steam.

The specific heat consumption of the heating power plants slightly decreases by the greater efficiency of the larger feeding units, are however insignificant compared to the improving indexes of the condensing power plants.

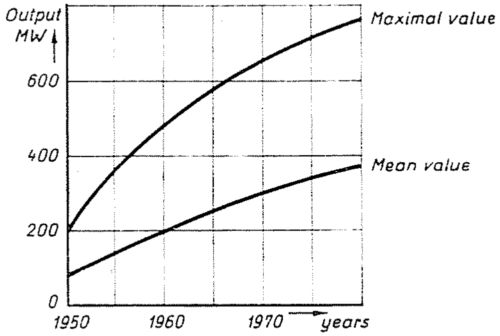

Fig. 3. The development of the efficiency of machine group units within the condensing power plant during the last 10 years and the same to be awaited for in the close future

Considering the resulting 2200 kcal/kW/hr values already reached in the condensing power plants [4] these are no longer so essential.

The already achieved 1400 kcal/kW hr specific heat consumption must not be overestimated if we compare them with the 2200 kcal/kWhr value,

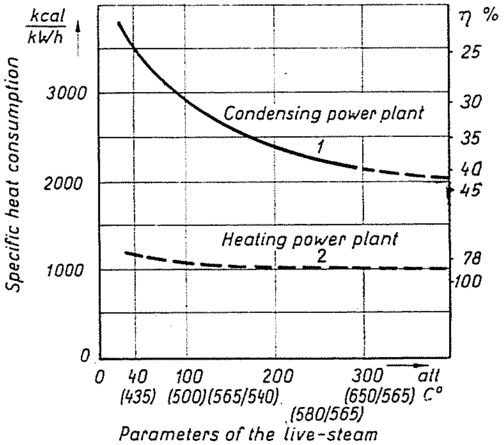

Fig. 4. Specific heat consumption of the condensing and heating power plants according to the parameters of live steam

achieved in the new condensing power plants, because of the several disadvantages of the former: the electric energy produced greatly depends on the outside temperature, and coordinations have to be made to a considerable extent between the steam and electrical energies produced.

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Thus this primary point of view, which has promoted the spreading of the distant heatings 30—40 years ago has still been surpassed by the technical developments. Thus the second motive has obtained a steadily increasing importance, the *individual requirements of the consumer.*

Here we have to emphasize that the trend to cover the increasing cultural and social requirements of the inhabitants in the last decades, public utilities have greatly developed. Now already we take it as natural that residential area departments have communal electricity-, water-, gas-supply centrally distributed by common networks instead of procuring them individually. Energy production, distribution, dimensioning refers to public utilities.

In several European, Asiatic and American countries the population already requires — according to the geographical and meteorological situation — besides lighting, water supply, etc. centrally delivered warm water and distant-heating as well. This demand increases to a still greater measure in the new residential areas, departments, built after World War II.

Providing the new settlements with distant-heating serves not only the comfort, social and welfare conditions of the inhabitants, but also promotes the hygieny rooting out the smoke, ascending from the several thousands of stoves, ranges, minute boilers, etc. It also economically affects the investment-costs when erecting the residential area or settlement, for there is no longer need for wide and hard surfaced roads for the fuel- and combustible-transport; considering the whole towns great transport capacities (trains) can be set free as well.

Regarding the advantages of the distant heating from the point of view of the customer, esthetic motives are not to be forgotten either, further the decreased fire hazard, free spaces won in base-floors, cellars, etc. Centralized heating means great reliefs time- and work-savings for the entity of all the inhabitants, too.

The importance of the distant heating and heat supply has not diminished the slightest, compared to the past, only the further development has to be designed in close accordance with the up-to-date requirements and pretentions of the inhabitants to an increasing degree.

At the International Distant Heating Conference held in Duisburg in 1965 the following difficult task has been set: . . . to improve by the purity of the air and that of the hygienic conditions of the towns, settlements, departments . . . . . . [5].

We strongly endeavour to coordinate this task with the resolutions of the World Power Conference held in Lausanne in 1964, drawing the attention to a greater degree to more economical solutions of the distant-heating methods. Following the program mentioned above, we have worked out a new system to solve the temperature regulation of the water, say that of the heat carrying medium in full accordance with the requirements of the population considering furthermost the economical respects, too.

We endeavour to cover the requirement to the highest degree by minimal investment-, and energy production costs. For the making of the heat regulation curve, the first and base condition has been to correctly evaluate the heat demands. Then after having coordinated the requirements and the heat-output of the heat producing equipments were we only able to design the high temperature water temperature regulation curve.

As first step the heat requirements of the departments, settlements have to be accurately dimensioned.

2. Heat consumption of the residential areas

The heat consumption of the residential areas (departments) may be divided into two groups:

dwelling houses,
communal establishments servicing the inhabitants.

Within the classification above the heat consumptions can be discussed as follows:

a) constant technological warm water demands

arising evenly around the whole year such as household warm water supply, warm water demand of the servicing establishments, catering enterprises, laundries, medical ordination rooms etc., ventilations.

b) seasonal heat demands

heating of the dwelling-houses,
heating of the communal and welfare establishments.

Heat requirements in details

a) Constant heat requirements

Table 2 shows the summarized heat consumptions according to the data taken from Table 1.

b) Heat consumption with a seasonal character

Heat consumption with a seasonal character mostly includes the requirements of space heatings. As flats and communal establishments have to be provided with constant heat where the transferring medium is the same, say high temperature water for both, further separation of the consumers seems unnecessary.

Table 1

Number of communal welfare establishments for 1000 flats in average

Denomination	Unit
Educational establishments	
Primary schools	8 school rooms
Nurseries	for 70 children
Hygienic establishments:	
Public infant's nursery	for 50 babies,
English-chemist-shop	280 sq m
District medical ordination room	100 sq m
Commercial establishments (shops)	1225 sq m
Service establishments	350 sq m
Community establishments	100 sq m

The heat requirements of closed rooms, spaces have to be determined by their heat losses. Heat losses are highly variable depending on outside conditions, temperature, wind, sunshine, etc.

These factors have to be investigated in two relations. First we have to know the *quantity* of the heat losses for the right dimensioning of the heat-producing equipments, determining the necessary total volume of investments as well, second we have to know the *variations* of the heat losses for due regulation of the system and to become oriented on operational costs.

We may approach the heat-losses by the following stationary formula

$$\dot{Q} = (1 + \Sigma p)\Sigma A_{hi}\ k_{hi}(t_i - t_{ai})\ \text{(kcal/hr.)}$$

Where:

$\dot{Q}$ = heat losses of one room (space) for one hour
A_{hi} = surface of one limiting wall of the room (sq m)
k_{hi} = heat transfer of the limiting facilities (e.g. walls) mentioned above (kcal/sqm hr C°)
t_i = the main resultant (inside) temperature of the room (C°)
t_{ai} = temperature beyond the limiting wall mentioned above (C°)
p = supplementary coefficient for the heating-up period, sunshine, wind, etc. (%)

These formulas may be used for groups of rooms having the same character, for one or more buildings as well, accordingly.

Table 2

Constant heat demands for a settlement with 1000 flats

Denomination of the consumer	Hot water consumed daily lit/day	Peak demand covered by water-reservoir. The required heat quantity in kcal/hr
Inhabitants:		
Household water demand for the inhabitants	$(3 \sim 4) \times 10^5$ kcal /day/30 flats [13]	$4.85 \cdot 10^5$ kcal/hr
School-nurseries, infant nurseries:		
(8 school rooms for 30 pupils each)		
240 scholars .... 75 nursery inmates ..... 50 babies	for each child, including servicing personal 10 lit/day.	$3.75 \cdot 10^4$ kcal/hr
Altogether 365 children		
Servicing establishments:		
a) *Laundry:*		
3000 inhabitants, for one person 1.5 kg soiled clothes/week. For 1 kg clothings to be washed 16 lit warm water	6000 lit/day	$5 \cdot 10^4$ kcal/hr
b) *Catering establishments:*		
3000 persons(2.5 lit/day/person)	7500 lit/day	$6 \cdot 10^4$ kcal/hr
c) *Other establishments:* Hot water for cleaning purposes; English-Chemist shops .... Commercial establishments ...... Service establishments .... Community establishments	700 lit/day	$1.75 \cdot 10^4$ kcal/hr
	Altogether:	$6{,}495$—$6.5 \cdot 10^5$ kcal/hr

Maximal heat losses

To determine the *maximal heat losses* — besides the architectural characteristics of the buildings the influencing meteorological data have to be taken up accurately, too. The influence of the winter sunshine can be neglected entirely. Primarily influencing are, however, the outside temperature (t_{ai}) and the strength of the wind. These data are easily obtainable from the statistical evaluations.

Table 3 shows the variation of the temperature and wind strength measured in Beaufort degrees of 11 winter seasons (starting from the 15 October till 30 April for the years 1947—1964). Measurings have been made in Budapest daily at 7, 14 and 21 o'clock for both factors [7], [8].

From Table 3 it is to be seen that competent temperatures and wind strength have to be extremely accurately chosen. Taking into consideration the least advantageous conditions, when affording greater output from the equipment, we increase the dimensions and the sizes at the same time, needing greater investment costs, there is very little probability for the full using up of the capacity given.

Table 3

Temperature and wind strength values for the heating periods of the last 11 years in Budapest

t_a [C°]	F_{sz} [B°]									
	0	1	2	3	4	5	6	7	8	Σ
<−15	9	2	2!	2	—	—	—	—	—	15
−15	4	5	0 !	1	—	—	—	—	—	10
−14	4	6	0 !	0	1	—	—	—	—	11
−13	8	3	8 !	—	—	—	—	—	—	19
−12	5	15	6	2 !	0	0	0	1	—	29
−11	10	11	7	3 !	0	2	—	—	—	33
−10	12	23	7	4 !	—	—	—	—	—	46
− 9	11	30	12	6	2 !	0	0	1	—	62
− 8	8	34	14	6	4 !	—	—	—	—	66
−7	15	45	14	8	2 !	—	—	—	—	84
− 6	14	34	27	14	2 !	—	—	—	—	91
− 5	25	72	28	4	3 !	1	—	—	—	133
− 4	25	71	36	6	9	3 !	0	1	—	151
− 3	19	83	43	8	9	4 !	—	—	—	166
− 2	23	113	58	18	8	2 !	1	—	—	223
− 1	28	123	61	24	6	5	3 !	—	—	250
0	33	142	69	26	9	5	3 !	—	—	287
1	65	175	103	38	16	10	1 !	1	—	409
2	62	203	125	56	28	6	0 !	2	—	482
3	52	167	90	37	34	12	2 !	—	—	394
4	52	137	87	47	38	14	2 !	0	1	378
5	48	140	86	58	37	7	5 !	—	—	381
6	50	149	87	54	24	8	2 !	3	—	377
7	39	107	106	34	24	7	2 !	1	—	320
8	46	127	82	38	16	7	6 !	2	—	324
9	34	125	91	41	26	6	1 !	2	—	326
10	23	115	80	41	19	7	4 !	1	—	290
Σ	724	2257	1329	576	317	106	32	15	1	5357

Σ! = 96

However, choosing less favourable conditions, using only the more often occurring data, may result sometimes in the inability of the equipment to answer to the requirements.

For up-to-date dimensionings the damping effect of the unsteady heatflow is also to be considered, flattening the peak-values lasting only for a short time. All these approaches result technically in still useable methods, though any logical method may be left out entirely by the trends of responsible officials or designers, to establish due reserves for the heating equipments, systems to egalize eventual mistakes which have occurred in the designing, production and operation.

To answer this reasonable trend, the data of the atmospheric conditions chosen in consequence of the conditions experienced (t_{am} and F_{sz}) may be corrected continuously according to the experiences of operation. E.g. for Budapest the dimensioning outside temperature has been : $t_{am} = -15$ °C, and according to the orders received additional 4.0 m/sec wind velocity had to be taken up into the base formulas, too.

Changings of the heat losses

The changings of the temperature are consequences of atmospheric conditions, affecting the temperature of the forwarded high temperature water (t_e). For the construction of the corresponding temperature regulation curve [$t_e = f(t_a)$] several methods are used. The most simple proved — considering economy and constructive characteristics, — to add to the outside temperature dimensions (t_{am}) the maximal dimensioning values determined for the heat transferring medium. It is thus assumed that the total heat loss rate for the moment given ($\dot{Q}$) compared to the maximal total heat loss ($\dot{Q}_m$) equals the rate of these heat losses ($\dot{Q}_a$ and $\dot{Q}_{am}$) are not to be supplemented. Furthermore the heat transfer coefficients are also taken as constant values, thus

$$\frac{\dot{Q}}{\dot{Q}_m} \cong \frac{\dot{Q}_a}{\dot{Q}_{am}} = \frac{\Sigma A_{hi} \cdot k_{hi} \cdot (t_i - t_a)}{\Sigma A_{hi} \cdot k_{hi} \cdot (t_i - t_{am})} \cong \frac{t_i - t_a}{t_i - t_{am}}$$

Thus the changes of the heat losses could be expressed by a straight line in Fig. 5 where the limiting values of the heating temperature have also been marked. This only theoretically constructed temperature regulating curve is often to be modified in the practice according to practical experiences gained by the effects of the wind.

Investigations carried out, however, showed this method as not being accurate enough, for the frequent over-heating is far from economical and besides does not satisfy the heat sensation of the inhabitants, therefore a more accurate method proved to be necessary for the building up of the temperature-regulating curve.

Controlling the distant-heating systems of the new residential areas and settlements, besides those of the dwelling houses of course, several factors have been discovered greatly influencing the temperature of the heat transferring medium. According to the positioning of the separate buildings by the points of the compass the movements of the air are different and even the sunbeams reaching the buildings affect the heat conditions differently. The construction scheme of the building may also differ and various heat storings and dampings also affect the heat losses.

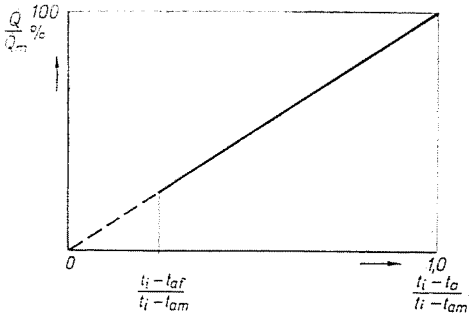

Fig. 5. Approximate changing of the heating heat requirements according to outside temperature

The heat-delivery of the radiators, built into the buildings, may also differ according to the temperature of the heat transferring medium. The heat transferring medium when passing through the pipe is cooled down thus arriving into the building at different temperatures.

All these heat influencing factors make it obvious that the heating of dwelling houses or whole residential areas cannot be regulated centrally, but only from the heat-producing station. The temperature of the heat transferring medium flowing in the pipe network of the distant heating, has to be regulated according to the factors individually and locally affecting their heat content and temperature, thus the regulation has to be made for each building to be heated separately, taking local conditions into consideration as well. This means *local regulation* has to be used.

From the common influencing factors, the most important is the *wind*, affecting by air-pressure differences the quantity of the air invading through the aperture closing facilities (doors, windows) and their cracks, splits. These air quantities also have to be warmed up. The wind furthermore influences the heat transfer values of the limiting facilities (walls, closings) by the convection heat transfer coefficients of the outer side. The influence of the wind velocity is so great in accordance with the changes of the heat transfer coefficient, that differences of temperatures may be neglected.

Beside the velocity and strength of the wind we have to know its direction as well, further what sides of the buildings are attacked by it. Meteorological statistics of Hungary [7] show for every environment of the country if the ruling winds arrive from all the points of the compass with even frequency and strength, or having steady ruling character, are always blowing from the same direction.

In the latter case the various positionings of the buildings within a residential area lead to the unimportance of the wind direction regarding central regulation, for only the strength of the wind has to be regarded. The frequency of the wind direction, however, has to be kept in mind when designing the local heat regulations within the buildings.

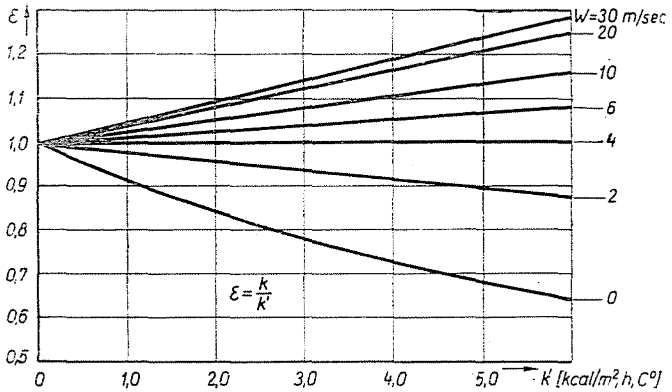

Fig. 6. Changing of the over all coefficient of heat transfer values considering also the velocity of the wind

The connections existing between the strength and direction of the wind (w_{sz}) furthermore between the former and the heat transfer coefficients of the limiting facilities, say walls, aperture closers, can be taken from KOPP [9], as seen on Fig. 6.

At the impact pressure of the wind notwithstanding the aperture closing facilities (doors, windows) cold air leaks through them needing certain amounts of heat to warm it up. This surplus of heat must be provided by using heat supplements in the dimensioning formulas.

This wind supplement however refers only to a given wind velocity, therefore the leakage of the wind through the closed apertures has always to be accounted for in close accordance with wind velocity. The average wind permeability of the different aperture closing facilities (e.g. windows, doors) is well-known (B — cu m/hr. run m. mm water column). This is given by the measured values in meters referring to the length of the permeable split and to the pressure difference. With the aid of this formula the quantity of air leakage — within one hours time — can be calculated.

$$\dot{V} = BL \cdot \frac{w_{sz}^2}{2g}\gamma \qquad \text{(cu m/hr)}$$

the heat requirement for the warming up of the air quantity above is

$$\dot{Q}_{sz} = \dot{V} \cdot c_p \cdot (t_i - t_a) \quad \text{(kcal/hr)}$$

where: L = the length of the air splits in the aperture closer (run m)
γ = the specific weight of the air (kp/cu m)
c_p = specific heat of the air kcal/cu m · C°

RAISS [10] suggests to keep in mind the location of the building too, by using certain coefficients taken from the practice. This may be however highly discussed for when multiplying the values belonging to the two factors above, these approximately result in the unit.

The problem still pending is how to calculate what wind velocities belong to the different outside temperatures. According to the opinion of the Soviet researchers increasing cold, say lower outside temperature, is always connected with decreasing wind velocity. This can be expressed at various geographical places by changing proportionality factors. Examining Table 3 it can be seen that the strength of the wind — though roughly — also follows the theory mentioned above.

It is evident that the strength of the wind or its velocity can never be a continuous curve regarding temperature, though in practice we have to use continuity.

The heat requirements for the distant heating, which is

$$\frac{\mathring{Q}}{\mathring{Q}_m} = f \cdot (t_a)$$

is shown on Fig. 7. The wind strength zero and marked values from Table 3 (e.g. 3 !) are shown in full-line and those having value by one unit less, are marked by dotted curve. The countings were made using the method above for rooms, having average dimensions. The point standing alone, see Fig. 7, means the heat requirement of the dimensioned condition.

Fig. 7 demonstrates further the well-known fact that all dimensionings of the heat requirements are exaggerated to a certain degree, real heat losses making out only the 80—85% of it. This fact has been supported also by measurings carried out by the Department for Heating. Ventilating and Air Conditioning at the Polytechnical University of Budapest [12].

The curve of the heat requirement appears in Figure 7 in a serrated form, having been influenced by the leaps of the strength of wind. To make calculations more simple we may assume the changes of the wind strength are continuous instead of having leaping character, or averages may also be taken replacing the serrated curve, but even then it appears that the maximal real heat requirement — that may occur — does not belong to the prescribed maximal value and proved to be considerably much lower on every occasion. It may often occur that the heat storing capacity of the building egalizes the effects of the leaping wind strengths.

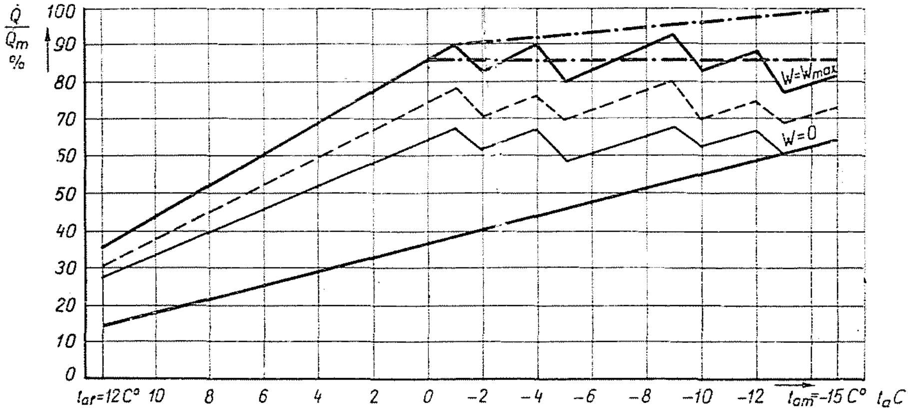

Fig. 7. Changing of the heat requirements in accordance with outside temperature and strength of the wind

Analysing the data of Table 3 in detail it clearly shows, the greater changings of the wind strengths generally last for a longer time surpassing the periods of dampings.

Summarizing the facts mentioned above for the regulations of distant heatings of residential areas regarding the heat requirements, the following conditions have to be taken into consideration:

Heat losses of the rooms having special character from this point of view have to be examined within the building separately for all influencing factors: e.g. for direction of the wind, frequency of the competent strength of it, effects of sunshine in close accordance with the air permeability of the aperture closing facilities and limiting factors, say walls.

The rooms within the building, having different heat requirements, have to be connected to distant-heating pipe-lines having local regulation (e.g. rooms) with walls facing the North or the South.

Table 4/1

Temperature and wind strength values

F_{sz} [B°]	0	1	2	3	4	5	6	7	Σ
t_a [C°]	Budapest								
<−15	2 !	—	—	—	—	—	—	—	2
−15	4 !	1	—	—	—	—	—	—	5
−14	4 !	1	—	—	—	—	—	—	5
−13	4 !	1	1	—	—	—	—	—	6
−12	3	1 !	2	—	—	—	—	—	6
−11	4	5 !	1	—	—	—	—	—	10
−10	6	6 !	1	—	—	—	—	—	13
− 9	6	8 !	1	1	—	—	—	—	16
− 8	2	13 !	0	1	—	—	—	—	16
− 7	6	19	5 !	1	1	—	—	—	32
− 6	7	15	6	4 !	—	—	—	—	32
− 5	13	28	13	0 !	1	—	—	—	55
− 4	10	25	11	2	5 !	3	0	1	57
− 3	8	40	18	2	4 !	2	—	—	74
− 2	14	51	28	11	7 !	—	—	—	111
− 1	15	69	24	14	2	3 !	2	—	129
0	21	78	42	14	4	4 !	3	—	166
1	47	96	54	18	10	3 !	—	—	228
2	39	132	62	25	15	5 !	—	—	278
3	28	105	50	24	20	10 !	1	—	238
4	27	101	50	28	21	6 !	2	—	235
5	32	92	54	32	15	6 !	2	—	233
6	28	100	43	39	15	6 !	1	1	233
7	20	53	70	21	13	3 !	1	1	182
8	23	67	45	20	13	3 !	2	1	174
9	20	67	47	22	11	2 !	0	2	171
10	12	58	36	17	12	4 !	3	—	142
Σ	405	1232	664	296	169	60	17	6	2849

Σ! = 169

As for the single buildings the dominating least favourable heat requirements have to be taken as a starting base condition for the central temperature regulations.

at various environments of Hungary

0	1	2	3	4	5	6	7	8	9	Σ
Kalocsa										
1	9 !	2	—	—	—	—	—	—	—	12
0	4 !	—	—	—	—	—	—	—	—	4
2	2 !	1	0	1	—	—	—	—	—	6
1	7 !	1	—	—	—	—	—	—	—	9
0	8 !	1	3	—	—	—	—	—	—	13
1	7 !	5	—	—	—	—	—	—	—	13
1	7 !	2	0	0	1	—	—	—	—	11
0	7 !	1	1	0	1	—	—	—	—	10
2	16	7 !	1	2	—	—	—	—	—	28
2	18	8 !	2	—	—	—	—	—	—	30
1	23	4	3 !	1	1	—	—	—	—	33
6	34	10	2 !	0	1	0	1	—	—	54
6	27	12	4 !	3	1	0	1	1	—	55
5	47	20	10	4 !	1	3	0	1	—	91
8	51	28	14	8	1 !	1	1	—	—	112
4	72	31	12	3	6 !	4	0	1	—	133
7	97	44	20	14	4	4 !	4	—	—	194
12	107	59	26	17	7	5 !	1	—	—	234
12	100	65	30	11	8	4 !	1	—	—	231
14	98	39	25	18	13	5 !	0	1	—	213
10	93	47	25	18	12	6 !	4	—	—	215
5	104	58	33	17	7	7 !	1	—	—	231
8	74	52	30	18	8	7 !	1	1	—	199
10	78	54	21	12	9	4 !	5	—	—	193
3	72	45	22	21	9	4 !	1	—	—	177
3	54	30	17	14	9	2 !	1	—	1	131
2	57	36	26	14	9	6 !	1	—	—	151
126	1273	662	327	196	108	62	23	5	1	2783

Σ ! = 210

Data of Table 3 also show that the occurring frequency of the winds having less strength than the dominating ones is rather even. Heat requirements belonging to them may be marked in Figure 7, too.

Table 4/2

Temperature and wind strength values

F_{sz} [B°]	0	1	2	3	4	5	6	7	8	Σ
t_a [C°]	Szombathely									
<−15	5	5 !	1	—	—	—	—	—	—	11
−15	1	2 !	—	—	—	—	—	—	—	3
−14	2	3 !	1	—	—	—	—	—	—	6
−13	0	5 !	3	1	—	—	—	—	—	9
−12	4	8 !	1	1	—	—	—	—	—	14
−11	2	10 !	1	—	—	—	—	—	—	13
−10	0	9	2 !	5	—	—	—	—	—	16
− 9	2	12	6	5 !	—	—	—	—	—	25
− 8	3	14	5	5 !	1	—	—	—	—	28
− 7	6	18	6	4 !	1	—	—	—	—	35
− 6	4	20	12	7 !	1	2	2	1	—	49
− 5	8	39	10	8 !	1	—	—	—	—	66
− 4	10	29	19	10 !	3	2	1	1	—	75
− 3	16	49	13	9	5 !	2	1	—	—	95
− 2	31	57	19	20	7	6 !	2	1	—	143
− 1	45	75	38	22	7	3 !	1	1	—	192
0	59	116	39	13	8	6 !	3	1	1	246
1	58	141	35	27	9	5 !	1	1	—	277
2	45	119	49	23	7	6	4 !	2	—	255
3	60	110	33	17	5	4	4 !	0	1	234
4	42	80	40	21	10	4	2 !	—	—	199
5	40	102	35	19	6	3	6 !	1	1	213
6	37	74	34	17	10	8	1 !	1	—	182
7	23	69	36	15	11	8	2 !	1	—	165
8	33	75	34	12	8	6	6 !	—	—	174
9	24	43	25	15	6	4	2 !	—	—	119
10	14	61	33	19	9	2	2 !	1	—	141
Σ	574	1345	530	295	115	71	40	12	3	2985

Σ! = 181

Data of Table 3 include daily three measurings, though they do not show the daily changes of the wind strength. The heat-lag of the distant heating-net may vary between 0.5—2 hours time, therefore with the aid of the array of the wind strength curves and the data of meteorological forecasts at various environments of Hungary

0	1	2	3	4	5	6	7	8	Σ
Nyiregyháza									
12	7	5 !	1	—	—	—	—	—	25
5	4	2 !	—	—	—	—	—	—	11
0	2	1 !	1	1	—	—	—	—	5
3	3	2 !	0	1	—	—	—	—	9
5	4	4 !	1	1	—	—	—	—	15
7	3	6 !	1	—	—	—	—	—	17
15	3	4	3 !	1	—	—	—	—	26
10	8	3	2 !	1	1	—	—	—	25
15	10	5	5 !	3	1	—	—	—	39
14	13	8	5	3 !	6	1	—	—	50
25	15	15	9	1 !	1	1	—	—	67
30	17	9	6	3 !	3	1	—	—	69
34	21	13	11	8 !	2	—	—	—	89
39	24	16	11	8	2 !	3	0	1	104
53	37	22	20	10	5 !	2	1	—	150
53	42	29	24	11	6 !	3	0	1	169
82	51	37	23	13	8 !	8	0	1	223
75	65	46	22	18	13 !	2	1	—	242
62	69	53	36	15	7	5 !	1	—	248
74	54	52	22	10	9	5 !	—	—	226
52	56	24	28	8	6	5 !	—	—	179
44	48	43	28	10	6	4 !	1	—	184
46	58	32	22	10	7	4 !	2	—	181
36	42	30	25	14	5	6 !	—	—	158
39	37	34	19	9	9	1 !	1	—	149
27	30	33	24	8	14	1 !	1	—	138
41	31	22	17	10	6	2 !	2	—	131
898	754	550	366	177	117	54	10	3	2929

$\Sigma ! = 167$

the central heat regulation may be carried out daily, serving economical purposes and the satisfaction of the requirements imposed on both.

By the data of Table 4 we want to demonstrate, that for the determinations of the heating heat requirements, first we have to decide the wanted air temperature and wind strength values; these however strongly depend on the geografical location of the consuming residential areas. Table 4 shows the data for the above-mentioned four most characteristic environments of Hungary, collected during six subsequent same heating periods.

3. How to build up and use the temperature regulation curve

According to the facts discussed — on Figure 8 two heat requirement groups are to be seen, entirely differing in their characteristics from each other.

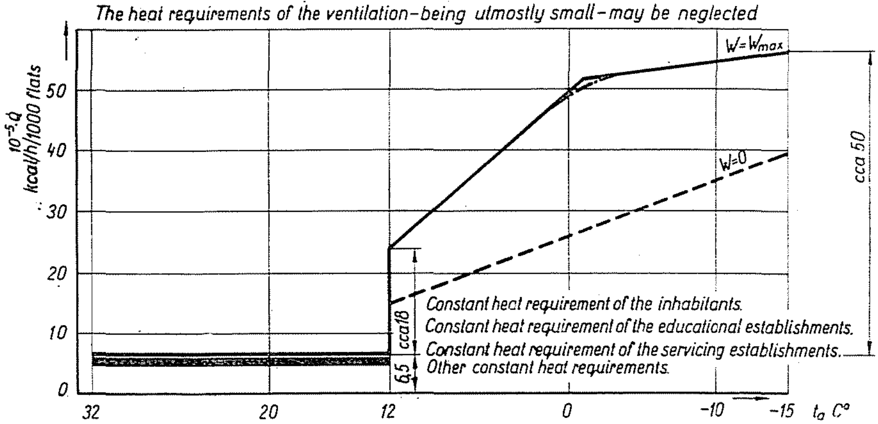

Fig. 8. Heat requirement for a residential area having about 1000 flats

a) *Characteristics of constant heat requirements arising evenly around the whole year* :

— warm water demands during the day have far from even character for frequent peak consumption occurrence, similarly on Sundays and holidays water consumption increases over the normal [13]; to answer these peak demands warm water reservoirs have to be installed,

— these demands are satisfied with warm water having a steady temperature.

b) *Characteristics of requirements having seasonal character.*

— the heating demand arises during the day in a continuous form, however to a varying degree.

— these demands are to be covered by hot water having adequate temperature according to the outside atmospheric conditions.

Taking into consideration the above facts, the temperature regulation curve may be divided into two large parts:

a) until the outside temperature is reached, when heating begins, temperature of the supply (forward) and return water is steady.

b) after having reached the outside temperature when heating begins, the supply (forward) and return water temperature is varying according to the outside conditions.

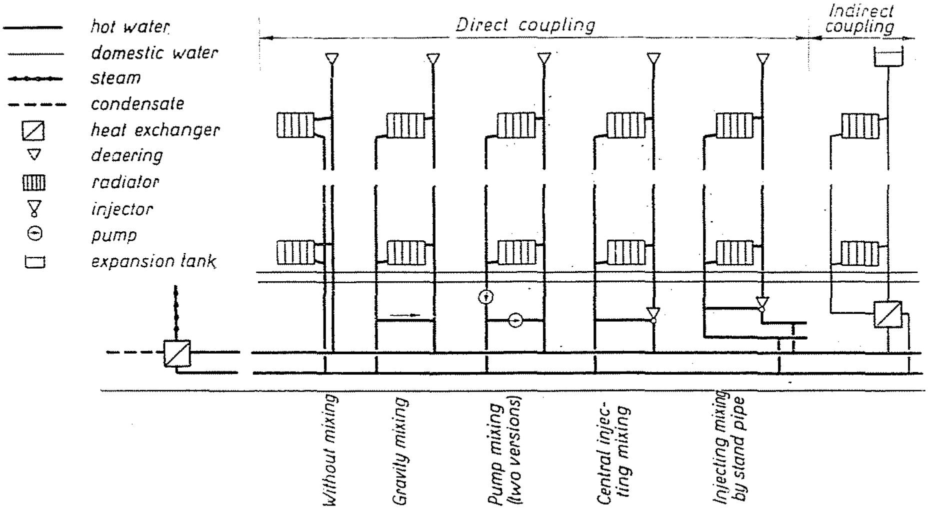

Fig. 9. Coupling of domestic systems to the high temperature water system

Our further task is then to finally build up the regulation curve at *b.)* The shape of the curve depends — besides the regular heat requirements — from the heat delivery of the heating equipments applied within the building.

The domestic heating of buildings may be coupled, as consumers, to the main distant heating piping-net in two ways

indirectly and

directly.

Regarding heat delivery, it is essential if the high temperature water, used for heating purposes, arrives from the main pipes through an intermediate heat exchanger, or directly joining the high temperature water net.

In the former case the heat transfer coefficient of the heat exchanger and that of the heating equipments (radiators) varies directly according to the high temperature water and to the temperature of the domestic water, heating up the building. In the latter case only the varying of heat transfer rate of the heating bodies have to be taken into consideration.

The summarized possibilities, how to carry out the indirect and direct coupling, is shown on Fig. 9, marking the heating equipments only symbolically.

Next to make possibilities for the heating equipment marked on Fig. 9 are only symbolically discussed. Such possibilities are:

when indirectly coupled to the main pipes:
radiator heating and
radiating-screen heating;

when directly joined :
radiator heating,
forced convection heating,
radiating-screen heating.

Below the heat transfer rate characters of the heating methods discussed above are determined.

The character of the heat transfer rate is a function, describing the variations of the heat transfer, depending either on the mean temperature differences (Δt_k) or on the temperature of the forwarded (supply) water (t_e).

This means:

$$\text{either} \quad \mathring{Q} = f(\Delta t_k) \qquad \text{kcal/hr}$$

$$\text{or} \quad \mathring{Q} = f(t_e) \qquad \text{kcal/hr}$$

The heat quantity transferred by any heating body can be expressed by the formula

$$\mathring{Q} = F \cdot k \cdot \Delta t_k \qquad \text{kcal/hr}$$

where: F = heating surface (sq m)
k = overall heat transfer coefficient (kcal/sq m. hr. C°)
Δt_k = mean temperature difference (C°)

But as $k = f(\Delta t_k)$, therefore the functions have to be supervised.

The overall heat transfer coefficient — never mind for what heating system it has been taken — is always a function of the inner and outer heat transfer coefficient (α_k and α_b), furthermore that of the heat transfer resistance of the heating body itself. This means:

$$k = f\left(\alpha_b ; \alpha_k ; \frac{s}{\lambda}\right)$$

where: s = wall thickness of the heating body (m)
λ = thermal conductivity (kcal/m. hr C°).

On the heating system in every case from the three base elements the overall heat transfer coefficient may be influenced decisively by the outside heat transfer coefficient (α_k).

For the outside (airside) heat transfer coefficient is less of several orders of magnitude than that of the water-side (inside) heat transfer coefficient (α_b).

Thus $\alpha_k \ll \alpha_b$.

Consequently the function sought for $k = f(\Delta t_k)$ can be expressed by the formula $\alpha_k = f(\Delta t_k)$, too.

The value of the outside heat transfer coefficient (α_k) may significantly differ to a great extent from each other — according to the various heating systems or to the many types of heating bodies.

Using radiating heating the greatest part of the heat transfer rate is carried out by radiation heat transfer, in using radiators the same is achieved mostly by convection.

For forced convection heating (carried out by thermoventilators or using central air heating) the heat transfer coefficient can be expressed by the formula according to forced convection

$$Nu = C_1 Re^n Pr^m$$

For radiator heating the gravitation convection on the air side is characteristic expressed by the equations

$$Nu = C_2 (GrPr)^k$$

As it can be seen when using forced convection heating the *Nu* value — containing the outside heat transfer coefficient — is influenced by the *Re* value, however by the use of radiator heating instead of the *Re* the *Gr* value is employed. In the *Gr* value the dimensions of the heating body and the temperature difference is decisive.

In the course of our studies we have determined the heat transfer ability of different heating bodies in the form of functions, based on our own measurements. The results for the heat transfer of same inside (room) temperatures are shown in the form of the characteristic curves on Figs 10, 11, 12, and 13, [14] and [15].

When the values for the heat requirement and heat transfer rate character are already known, as a last step we may easily *construct already the temperature regulation curve*, only having to coordinate the heat demand and heat transfer rate values.

The method to be used is shown in Figure 14. The basic condition is, however, to use right dimensions according to the maximal component heat requirements when calculating heating surfaces. Further base condition, the heat transfer rate must cover the heat requirement in every case.

Designing the curve we have to determine the heat demand of an outside temperature deliberately chosen and what forwarded (supply) and return water temperatures were necessary for the same heat transfer rate of the heating system. This following we have only to coordinate the outside and supply water temperatures.

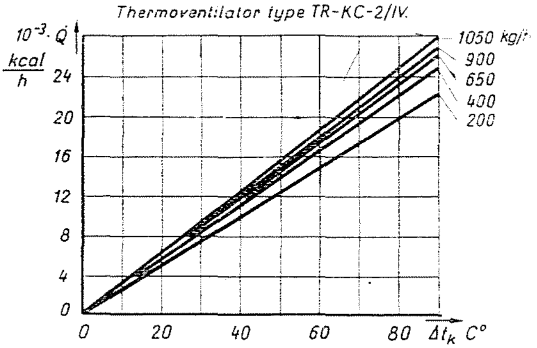

Fig. 10. The changings of the heat transfer rate for a thermo-ventilator depending on mean temperature differences and water quantity

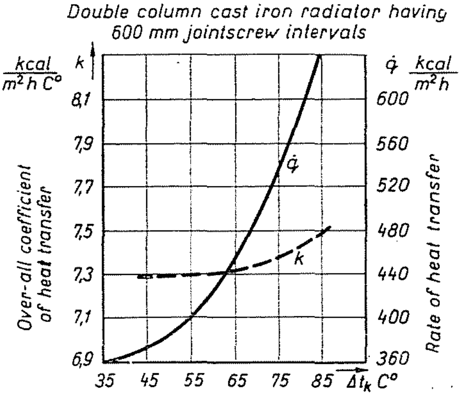

Fig. 11. The changing of the heat transfer rate and over'all coefficient of heat transfer of directly coupled heat radiators, in accordance with the mean temperature differences

The building up of the curve may be carried out in the reverse order as well. We have to ensure that for a given temperature regulation curve and heat transfer rate characteristic the real effective heat delivery covers all requirements.

From the above discussed statements it follows, that when using different types of heating systems — even at the same heat requirements — the regulating curve shows a somewhat varying character, being influenced by the differences of the heat transfer rate character.

Based on our measurements and countings we came to the result that, the radiating-screen heating needs the greatest supply (forwarded) water temperature. Next is ranked the thermoventilation, then indirect radiator heating, followed at the end by the direct radiator heating needing the least supply water temperature.

The necessity to build up temperature regulation curves arises in two ways:

α) if, for an already given ready-built residential area (settlement of dwelling houses) a new district heating system has to be designed. For the right construction of the temperature regulating curve, the character of heating in the group of buildings concerned has to be measured and decided which heating method is in majority (e.g. indirect radiator heating by 80%, forced convection heating by 20%).

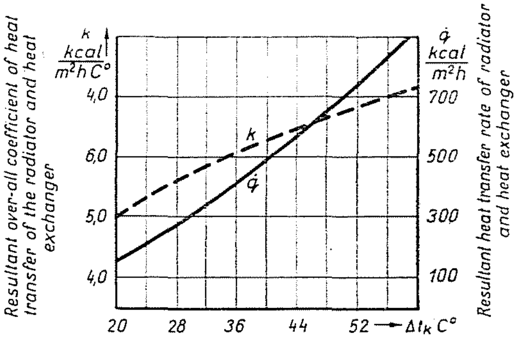

Fig. 12. The changing of the heat transfer rate and over all coefficient of heat transfer of indirectly coupled heat radiators in accordance with the mean temperature differences

The temperature regulation curve has to be built up always based on the dominating heating system, playing a governing role. Considering heating systems *in minority* two varieties exist:

needing a lesser supply water temperature than the dominating system. In this case the temperature needed can be achieved by mixing the supply (forwarded) water with the returning one by any method (see Fig. 9);

needing greater supply water temperature than the dominating system. It is certain that in this case, the heat transfer rate is less than the heat requirement. For this case it has to be ascertained which one is the very outside temperature, when the curves of the temperature regulation of the main system and those of the heat delivery of the heating system show the greatest differences between delivery and demand. The heating surface has to be dimensioned for this very outside temperature. For all other outside temperatures we thus dispose of heating surface surpluses. Overheatings have to be avoided by mixing regulations.

β) For the case, when the newly installed heating system of the newly built dwelling houses has to be coupled to a distant heating system having been given a temperature regulation curve, concerning heating equipment in minority we have to act as already discussed above.

Fig. 15 summarizes all the facts discussed above, showing a characteristic regulation curve for an already existing residential area. The greatest

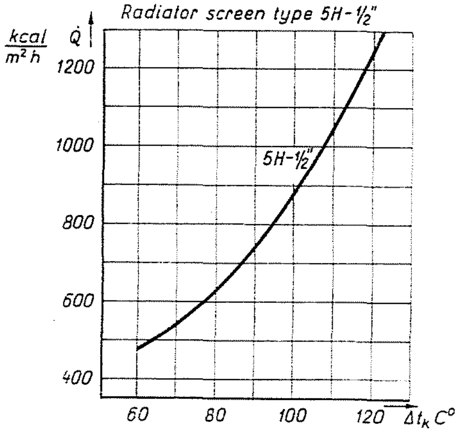

Fig. 13. The changing of heat transfer of the directly coupled radiating screens in accordance with the mean temperature differences

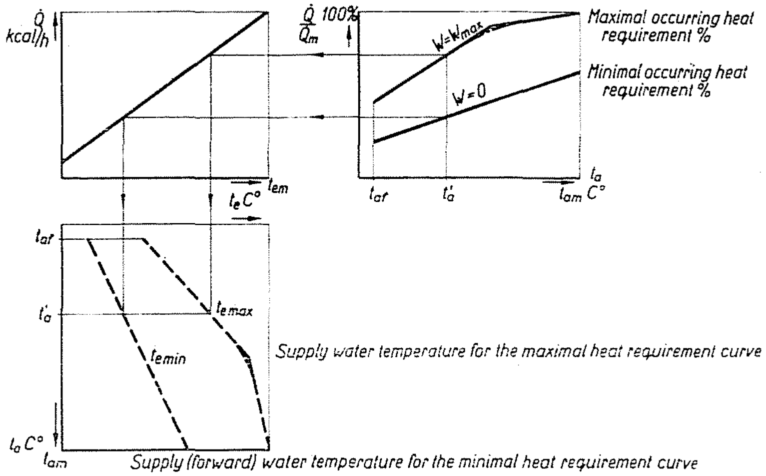

Fig. 14. The designing of a temperature regulating curve

part of the heating has been solved by indirectly coupled radiators, household warm water temperature: about 60 °C.

As already mentioned household water peak demands arising in the course of the day have to be covered by using adequate reservoirs. Here we have to remark, for the domestic heating and household warm water-supply several heat coupling and connecting methods are already used.

However, we are not dealing with these here, so temperature modifications occurring as a consequence of different couplings are not marked on our temperature regulation curve.

Summarizing the problems discussed above we may determine that a high temperature water temperature regulation curve — ensuring the satisfaction of consumers and economy — may be built up in the following steps:

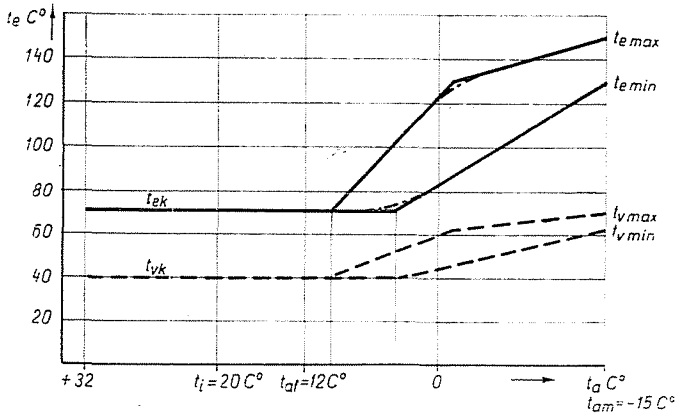

Fig. 15. The usual temperature regulating curve

— accurate measuring of the heat requirements,

— determination of the heat transfer rate for the existing heating equipments,

— coordination of the requirements and heat transfer rates when constructing the temperature regulating curves concerned.

As has already been proved when heat requests were sought for and determined, the heat demand is far from the same for all parts of the residential area, not even within the buildings either. Within residential areas often several kinds of heating systems are used, having different couplings and even heating bodies.

Taking into consideration all the influencing factors *the central regulation curve has to be determined by the due coordination of the dominating heat demands and heat transfer characteristics.*

The heat requirements of the separate buildings, differing from the usual methods mentioned above — should they arise from heat demands or by using different heating bodies with other heat transfer rate — are to be covered by *local regulation.*

The temperature regulation of the energy saving distant-heating needs, besides the theories discussed, still other operational modifications, too. It is obvious that theoretical calculations, based on values measured or statistics include many uncertain motives and factors. To eliminate these, the characteristic values of the operation to be coordinated (t_a, t_e, t_i) have to be registered accurately from the very beginning of the operation continuously and analysing these modifications they have to be made to serve individual requests and economical postulations as well.

A correctly constructed temperature regulation curve including the effects of the strength of the wind — even if accounted statistically — may considerably modify the diagram of the efficiency of the energy used. Figure 16 represents the diagram of the energy used, constructed after having kept in mind the outer atmospheric temperature and the frequency of the wind strength, too. This diagram clearly shows the importance of a temperature regulation based on accurate measurings concerning heat demands.

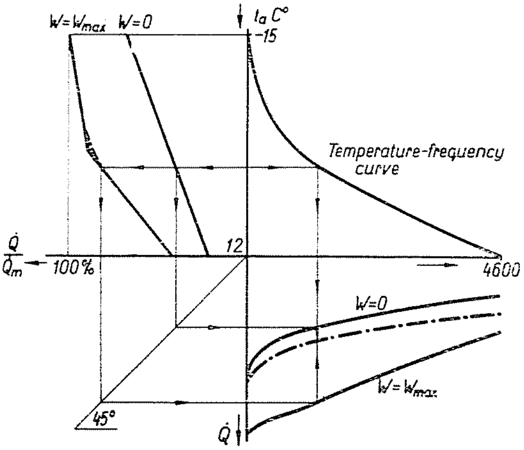

Fig. 16. The construction of the diagram showing energy consumption

Finally we should like to emphasize the need for a complex degree-day, demonstrating by taking into account the strength of the wind for the various environments of the country. This means for the future that not only the outside temperatures arising, but also the strengths of the wind should be reported to enable us to construct such degree-days [16, 17, 18].

Summary

When determining the heat requirements of a residential area (settlement), the heating demand is never the same for the various parts of the residential areas, not even within the separate buildings themselves. Usually within the settlements different heating systems, kinds of heating-bodies and couplings are applied. Keeping in mind all these facts, the temperature regulating curve has to be constructed always according to the dominating heat demand and heat delivery methods, by their right coordination.

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