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RECICULATION OF DOMESTIC HOT WATER USING LOCAL SOLUTIONS

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Abstract: *In the distribution network of domestic hot water, the temperature drops significantly even if the consumption is low or missing.*
Failure to ensure promptly the temperature at the consumption points causes waste of resources – water and energy – being also one of the main reasons why people tend to disconnect themselves from the central heating and domestic hot water supply system. The modernisation of the existing systems from the collective housing such as block of flats, is in need for technical solutions capable to compensate the heat loss from the domestic hot water network, when it is not used.
The classical solution is to double the entire transportation and distribution network, starting from the source all the way to the consumption point.
In most of the cases, applying these ideas in the existing situation is extremely difficult and, most important, the costs are very high for the investor. In this paper we have approached innovative solutions, capable to avoid the difficulties that might be encountered, by resolving them both local and at the source.
There are presented constructive and functional diagrams and computational models for dimensioning the system.

Key words: *domestic hot water, recirculation of hot water, compensation of heat loss, energy saving.*

1. Introduction

Considering the contemporary standards for civilisation, equipping buildings with water supply installation represents an important need both sanitary and for the comfort of the users.

Technology's evolution and energy matters raise outstanding problems to meet mandatory requirements for optimal customer service, namely the promptness, continuity and stability of product delivery within rational limits of insurance and energy and economic efficiency.

Assuring the domestic hot water need depends on 3 parameters – temperature, instant flow and available quantities – and the acceptable values depend, also, on these requirements in the social context – way of living and education – on the level and state of equipment of the building.

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Considering this, a very important part in the water supply system is the recirculation of domestic hot water installation, having the main role of providing promptly the needed temperature at the consumption point. The lack of this type of installation causes discomfort and, most important, it is not energy efficient.

In Romania the situation is found in urban assemblies built before 1990, that are provided with domestic hot water and heat fed into a centralized system, through thermal power stations dimensioned in order to serve 300/400-1000/1200 flats located in buildings, starting with 4 and up to 12 levels.[1]

Long distance transportation and the unevenness of hot water consumption, with significant interruptions during the night, causes water to cool and delays it at the consumption point, but most importantly in the morning when the demand is high, it takes too much time and energy to provide the desired temperature for users. This can be translated into discomfort and waste of resources.

2. Functional and Constructive Solutions

Because it is impossible to correct the entire system, there have been analysed and proposed technical solutions to eliminate the deficiencies that may be encountered in the recirculation network, such as locally domestic hot water supply system.

Speaking only about the installations that are just inside the buildings, the thermal capacity and the investment are reduced by facilitating the access for the interested users.

The intervention involves realising a local system for heating water and recirculate it between the source and user.

To ensure continuity in operation, the source must be of a bi-energy type, using as primary agent the heating agent (during the winter) and electric energy (during the summer) and have the needed stock to cover the simultaneous flows after the interruption that happen during the night.

For water recirculation it is foreseen the doubling of the circulation pipes - columns and distribution - throughout the installation, Figure 1, or only in the lower distribution, Figure 2.

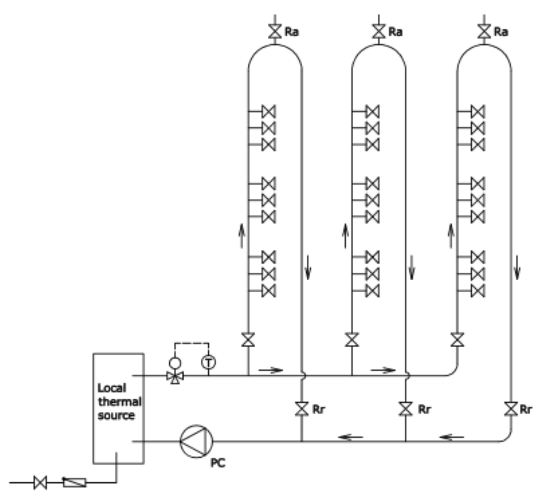

Fig. 1. *Horizontal distribution*

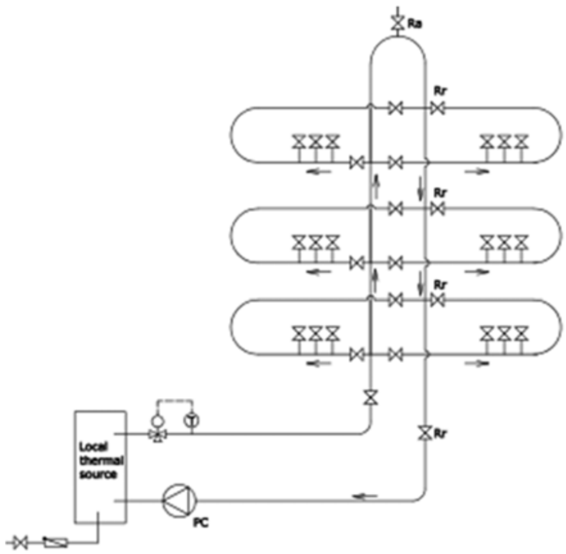

Fig. 2. *Distribution on the column*

The second variant represents an innovative, investment-friendly solution in which the water recirculation is carried out by means of the inner feeding columns at the top and connected to the base, alternatively, to the horizontal distribution and recirculation pipes. The supply of the sanitary fittings connected to the interconnected columns is, in this case, ascending, respectively descending

The total removal of the recirculation system can be accomplished by compensating the heat losses in the domestic hot water distribution ducts with electric heating cables attached to the pipes and distribution columns.

Compensating the effect of low-temperature water quantities taken from the outside network at the first use is provided with a local accumulating source – Figure 3.

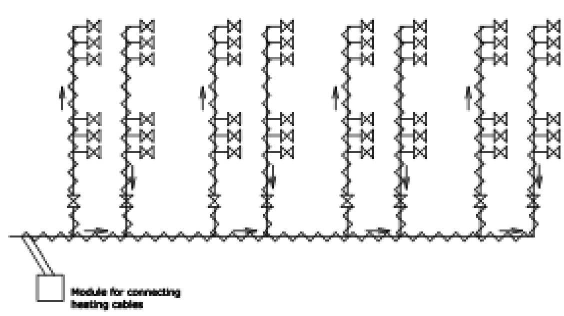

Fig.3. *The scheme of the heat loss compensation with electrical heated cables*

The specific power for the heating cables, the thermal power and the capacity of the local source storage are determined similarly to the recirculation installations.

The calculation of the installation consists in choosing the recirculation pump, sizing the heat exchanger and determining the storage volume.

3. Dimensioning the Installation

The setting of the functional parameters and the sizing of the installations are made according to the dynamic / stationary heat losses corresponding to the geometry and the thermophysical characteristics of the materials and working agents.

3.1 Determining Heat Loss

The determination of the heat losses in the distribution network of the recycling flow is made from the differential equation of thermal balance and heat transfer:

$$d\_Q = D\_total * c * dt = k\omega d(1-\eta)(t\_a - t\_e)dL \tag{1}$$

resulting the amount of heat that is ceded:

$$Q_{circ} = D_{total} * c * \left(t_{ainitial} - t_{afinal}\right) \tag{2}$$

or

$$Q_{circ} = k\pi d(1-\eta)(t_a - t_e)L \tag{2'}$$

Separating the variables in equation 1 and integrating the length of a section (L1) between the water temperature values in the extreme sections:

$$\int_{tainitial}^{tafinal} \frac{dt}{t_a - t_e} = \frac{[k\pi d(1-\eta)]}{c * D_{total}} \int_{v}^{Li} dL \tag{3}$$

it is possible to determine the water temperature value in the final section of the section:

$$t_{afinal} = t_e + \frac{(tainitial - te)e[k\omega d(1-\eta)]}{c * Dtotal} \tag{4}$$

where: te=ambient temperature
η = 0.3-0.6 – thermal insulation yield
k = global transfer coefficient

$$D_{total} = D_{distrib} + D_{recirc} \tag{5}$$

3.2 Distributed Flow

Is determined by the number of columns (i) and number (N) of receptors of type (j) running simultaneously from each column having the specific flow (q apa) and the coefficient of simultaneity according to:

$$D_{distrib} = \sum_{i=1}^{n}\sum_{j=1}^{m}(N * s * q)ij \quad (6)$$

Where the coefficient of simultaneity is:

$$s = \frac{1}{\sqrt{N-1}} \quad (7)$$

3.3 Recirculating Flow

Is calculated the amount of heat delivered by the water from the column / installation to the outside environment (Qrecirc) and the permissible reduction of the temperature at the receptors

$$\Delta t_{admis} = t_{distr} - t_{min.adm} \cong 50 \,/\, 55 - 40 = 10 \,/\, 15°\mathrm{C} \quad (8)$$

$$D_{recirc} = \frac{Qrecirc}{c*\Delta tadmis} \quad (9)$$

The cured heat is determined by the specific heat dissipation (Q0) and pipe length

$$Q_{recirc} = (t_a - t_e)\Sigma(Q_0 * L)I \quad (10)$$

where the specific failure (Q0) is calculated for each pipe according to diameter (d), the overall transfer coefficient (K) and the thermal insulation efficiency (η) using:

$$Q0 = k\omega d(1-\eta) \quad (11)$$

where: ta = water temperature in the pipe

te = ambient temperature

η = thermal insulation efficiency, representing the ratio between reducing heat loss through pipe insulation (Qizol) and losses in non-insulated pipes (Qt)

$$\eta = 1 - \frac{Qizol}{Qt} \quad (12)$$

In "Assessing the energy efficiency of hot water transport and distribution systems" by Mateescu Th & Hudisteanu R.[1] there are presented diagrams for determining the specific failure for different types of pipes, diameters and thermal insulation solutions.

Depending on the scheme adopted for water recirculation, flows through the pipes are adopted with the values resulting from the equation 5 for double-duty columns, respectively with:

$$D_{total} = D_{recirc} \quad (5')$$

for the pipes through which only the recycling flows are circulated.

3.4 Recirculation Pump Flow (DP)

The flow rate of the recirculation pump is taken equal to the total flow corresponding to the first section downstream of the thermal source resulting from the summing up of the total flow rates for all distribution (ND) and recirculation pipes (NR):

$$DP = \sum_{i=1}^{Nd+Nr} D_{total} * i \quad (13)$$

3.5 The Recirculation Pump Discharge Height

The distribution and recirculation piping assembly operates in non-consuming periods as an equivalent binary type network.

Knowing the geometric characteristics (length and diameters) and the hydraulic ones (equivalent unitary resistance) we are able to calculate the linear load losses corresponding to the recirculation flows:

$$h_{ri} = (S_{0ec} * L * D_{recirc})i \quad (14)$$

The pumping height compensates the total load losses on the longest binary circuit:

$$HP = 1.25\Sigma h_{ri} \quad (15)$$

To cover the local load losses, in relationship (15) the coefficient for increasing the linear losses by 25%.

Equivalent Unitary Resistance

A bar (ii') of the binary network is formed by catenating the distribution (i0) and recirculation column (0i'), having the same length (L) and the unitary hydraulic resistances (s0i) and (s0i') with s0=8λ/gπ2d5.

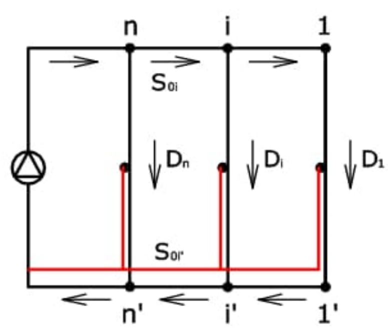

Fig. 4.

The unit equivalent resistance of the bar (s0iechiv) that's equal with 2L results from the equivalent of the corresponding load losses Dtotal i and Dcirc i.

$$h_{ri0} + h_{ri0}' = h_{riiech} \quad (16)$$

or

$$S_{0i}L_i\,(Di_{distrib} + Di_{circ}) * 2 + S_{0i}'L_i'Di_{circ2} = 2L_{isoiech}\,Di_{circ2} \quad (17)$$

where:

$$S_{0iech} = S_{0i}\left[\left(\frac{D_{idistrib}}{Di_{circ}}\right) + 1\right] * 2 + S_{0i}{}' \tag{18}$$

Considering the random character of the consumption and, of course, of the column distribution flows, the network is rebalanced hydraulically in relation to their size.

3.6 The Power of the Thermal Source

The thermal power of the local source must compensate for heat loss related to the indoor installation: distribution system and storage system

$$P_{sursa} = Q_{retea} + Q_{stocator} \tag{19}$$

where:

$$Q_{retea} = (t_a - t_m)\Sigma(Q_{S0} * L)i \tag{20}$$

$$Q_{stocator} = (t_a - t_m) * A_{lateral}/(0.1 + \frac{\delta_m}{\lambda_m} + \frac{\delta_{iz}}{\lambda_{iz}}) \tag{21}$$

Where Alateral, δm, λm, δiz, λiz - the geometric and thermophysical characteristics of the reservoir shell.

3.7 Store Storage Volume

The accumulation volume of the storage facility is determined by the volume of the hot water supply network, so that the water reserve in the stockpile compensates for the volume of input needed for the first use after the resumption of consumption.

In relation to the total volume of the power supply:

$$V_{retea} = 0.785\Sigma L_i D_{i2} \tag{22}$$

the storage volume is determined using:

$$V_{stoc} = p * V_{retea} \tag{23}$$

with: p=i, networks with a reduced length

p=1/number of connected blocks, exterior networks

4. Functional Regimes

According to the solution adopted for the installation and operation of the installation, the following situations may occur:[2]

4.1 Bi-energy Boiler Generator and Variable Speed Recirculation Pump

In the absence of consumption, the pump operates at the point 0 corresponding to the flow rate of the recirculation.

When increasing the flow rate by changing the speed, the operating point moves on the network characteristic to the point n (when the pump is switched off, the system is fed to the external supply network pressure in n).

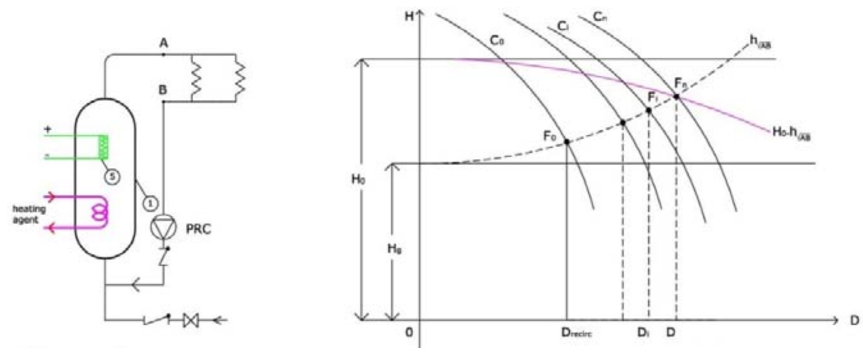

Fig. 5.

4.2 Bi-energy Generator, Reservoir and Constant-Speed Circulating Pump

The PC circulation pump works continuously. In non-consuming periods, recirculation of the water volumes in the distribution network and in the battery without external input is made through the generator.

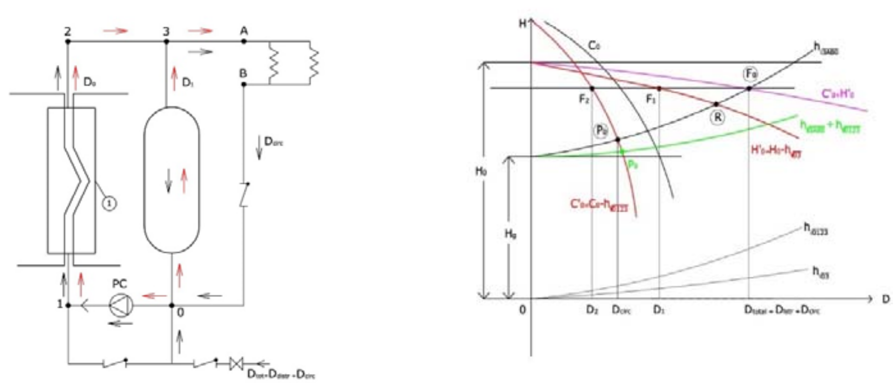

Fig. 6.

In periods of consumption with lower flows than the nominal volume of the pump, consumers are supplied directly through the generator with the reduction of the recirculated volumes, and at higher flows the deficit is compensated from the reservoir.

The F_0 operating point results at the intersection of the system's characteristic with the cumulative characteristics of the pump (c'0) hot water service-line (H'0).

When switching off the circulation pump, the consumption is directly assured at the supply line pressure (H0) by pumping the pump - the operating point is set in R

4.3 Bi-energy Generator, Reservoir, Circulation Pump and Constant-Speed Recirculation Pump

To reduce the energy consumption for pumping, the recirculation pump (PRC) works only during the non-consuming period of time to drive the volume of water in the distribution network in order to compensate for heat loss.

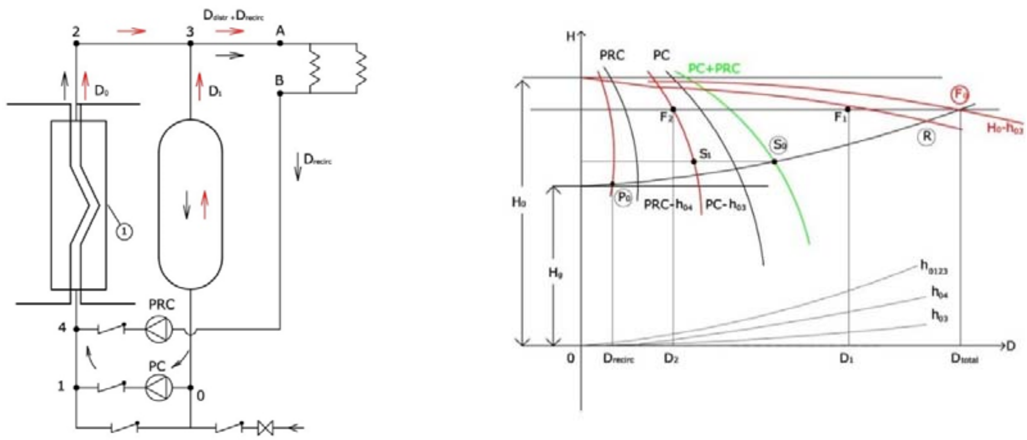

Fig. 7.

Maintaining the temperature of the water in the reservoir is under the action of the circulating pump (PC) that can work synergistically or in parallel with the recirculation pump (PRC).

The power supply of the receivers can be made directly from the outside network by passing or in parallel with the circulation pump, according to the phases presented above.

5. Conclusions

- In hot water distribution networks, the temperature drops significantly when consumption is low or zero
- Supplying flows, resuming consumption below the minimum comfort temperature leads to waste of resources (water and energy)
- In order to keep the temperature within acceptable allowable limits, it is necessary to recirculate a flow that compensates for the heat loss in the installation
- The classic solution requires the doubling of transmission and distribution pipelines throughout the section, from the centralized source to the points of consumption
- The difficulty of intervening in the existing underground network and the related costs are the main impediments to promoting the solution

- As an alternative solution, it is proposed to carry out recirculation installations with local-centralized thermal sources, located at the level of dwelling blocks
- To reduce the investment effort it is envisaged to eliminate the recirculation columns and take over their function by interconnecting the distribution columns
- Compensation of heat loss from the domestic hot water distribution system can be done with electric heating cables
- Technical solutions can be differentiated in relation to local situations and financial availability
- The efficiency of solutions is conditioned by the correct dimensioning of all system components

References

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