1. INTRODUCTION

The technical facilities of buildings realized in the second half of the 20th century were designed in Slovakia with an emphasis on low construction costs. The operating costs were not the subject of realization projects. Technical and technological facilities were often designed without considering their environmental effects. Due to the constantly increasing costs of energy the consumption of heat and electrical energy is too high. It is necessary to design new technical facilities to achieve economic savings in their operation. The guiding regulation, which is superior to the law of power engineering in EU countries, is Directive No. 2002/91 EC. Hence one of the most important problems in sanitary engineering is also the optimal design and service of distribution systems of potable hot water (PHW) by central sourcing water, an inseparable part of which is a problem connected with the hydraulic stability of PHW distribution systems [3, 5].

In order to fulfil the above-mentioned requirements, suitable capacities of facilities for preparing PHW and the design for its circulation are very important. Several qualitative systems for heating potable water have been realised in recent years, despite the fact that less experienced designers use outdated technical documents, for example, [6] (STN 06 0320), and some components of systems, for example, the circulation of PHW and the pumps are designed based on experience without any calculations. The fact that designers use codes which are valid in the EU but are not yet generally applied in Slovakia, is rather negative. For example, requirements for the quality of heat insulation exist which are necessary in the regulations of the Czech Republic but are unknown in Slovakia.

Systems for central PHW supplies without a circulation pipe can be used in these cases:

a) an electrical heating system of PHW distribution pipes is used

A. SUMEC

HYDRAULIC STABILITY OF THE DISTRIBUTION SYSTEMS OF POTABLE HOT WATER

ABSTRACT

The paper describes a problem which is connected with the optimal design and operational distribution system of potable hot water (PHW). The author focuses on the fact that this problem has been seriously dealt with in Slovakia only in the past twenty years. He mainly discusses the calculating methods and processes and classification of types of PHW distribution systems.

KEY WORDS

- Hydraulic stability
- PHW
- circulation flow
- total pressure drop
- thermostatic valve
- incrustation

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2. THEORETICAL APPROACH TO SOLVING THE PROBLEM

2.1 DESIGN OF POTABLE HOT WATER CIRCULATION BY COMPUTER.

This design is precise and is characterized by a series of iterations. Distribution pipes, circulation pipes, pumps, control valves and their settings can be designed. This method can be used without any limitation of the length of the distribution system, e.g. [1 - 4].

2.2 SIMPLIFIED METHODS OF DESIGNING POTABLE HOT WATER CIRCULATION

The frequent inaccessibility of a reliable computer program solution or sufficiently precise simplified solution methods is the reason for using these methods:

- The design of a circulation flow based on the value of the linear density heat flow for different rooms and hydraulic examinations regarding pressure drop friction

This design method achieves results comparable with the design by [9, 10]. It can be applied to a distance of 200 m of a distribution system from a PHW heater. We can determine the design’s circulation flow and the specific energy of the pump based on an analysis of the pressure drop and set the control valve.

The design of the circulation flow in the pump (l.s⁻¹), (l.h⁻¹) can be calculated according to the formula

\[ Q = \frac{\sum q_i \cdot l_i}{\rho \cdot c \cdot \Delta T} = \frac{\Phi}{\rho \cdot c \cdot \Delta T} \]

where
- \( q_i \) – the linear density heat flow of \( i \) – section pipe (W.m⁻¹),
- \( l_i \) – the length of \( i \) – section pipe (m),
- \( \Phi \) – the total heat flow (W),
- \( \rho \) – the bulk weight (kg.m⁻³), (kg.l⁻¹),
- \( c \) – the specific thermal capacity (kJ.kg⁻¹.K⁻¹), (Wh.kg⁻¹.K⁻¹),
- \( \Delta T \) – the difference in temperature between the PHW temperature from an outlet from a heater and the most unfavourable discharge (K).

For the distribution flow of the circulation water to the following pipe and corresponding branch pipes, we can use the expression of “logical rate” for repartitioning according to the formula (Fig. 1).

\[ Q_i = Q \cdot \frac{\Phi_i}{\Phi_1 + \Phi_2} \]

where \( \Phi_i \) (\( i = 1,2 \)) are the flows of the individual pipe parts.

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**Tab. 1 The maximum distance \( l_{max} \) of a PHW pipe dimension \( D_i \) without any circulation**

<table>
<thead>
<tr>
<th>Discharge armature</th>
<th>Maximal time ( T_{max} ) (s)</th>
<th>Steel pipes ( D_i ) (mm)</th>
<th>Steel pipes ( l_{max} ) (m)</th>
<th>Copper pipes ( D_i ) (mm)</th>
<th>Copper pipes ( l_{max} ) (m)</th>
<th>Pipes from PP - R ( D_i ) (mm)</th>
<th>Pipes from PP - R ( l_{max} ) (m)</th>
<th>Pipes from PVC - C ( D_i ) (mm)</th>
<th>Pipes from PVC - C ( l_{max} ) (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bath</td>
<td>15 - 25</td>
<td>15,7</td>
<td>11 + 19</td>
<td>16</td>
<td>11 + 19</td>
<td>14,4</td>
<td>14 + 23</td>
<td>15,4</td>
<td>12 + 20</td>
</tr>
<tr>
<td>Shower</td>
<td>10 - 15</td>
<td>15,7</td>
<td>8 + 11</td>
<td>13</td>
<td>11 + 17</td>
<td>14,4</td>
<td>10 + 15</td>
<td>12</td>
<td>13 + 20</td>
</tr>
<tr>
<td>Bidet</td>
<td>8 - 10</td>
<td>15,7</td>
<td>3 + 4</td>
<td>13</td>
<td>4 + 5</td>
<td>11,4</td>
<td>5 + 7</td>
<td>12</td>
<td>5 + 6</td>
</tr>
<tr>
<td>Wash-bowl</td>
<td>5 - 10</td>
<td>15,7</td>
<td>2 + 4</td>
<td>13</td>
<td>3 + 5</td>
<td>11,4</td>
<td>3 + 7</td>
<td>12</td>
<td>3 + 6</td>
</tr>
<tr>
<td>Wash-basin</td>
<td>8 - 10</td>
<td>15,7</td>
<td>3 + 4</td>
<td>13</td>
<td>4 + 5</td>
<td>11,4</td>
<td>5 + 7</td>
<td>12</td>
<td>5 + 6</td>
</tr>
</tbody>
</table>

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**Fig. 1 The scheme of the distribution flow and the heat flow**
In our design codes the maximum difference $\Delta T = 5K$ is considered. When we apprehend that in a period of the maximum consumption of PHW, the fall in temperature is limited to the lowest value of 45ºC in the housing sector, then calculating the PHW costs only according to the number of housing water meters is not appropriate. In other countries the value $\Delta T = 2 K$ is the temperature difference which enables paying for PWH consumption only according to the measured values of the housing’s water meter.

One of the practical solutions we can consider is the linear density of the heat flow according to Tab. 2. From this table it is obvious that the heat flow is resolved for a water pipe in a heated environment with a half thickness of the heat insulation separately, and in a heatless environment, with the required thickness of the given insulation, respectively.

Tab. 2 The recommended values of linear density heat flow $q_l$ for PHW pipes

<table>
<thead>
<tr>
<th>The thickness of thermal insulation</th>
<th>Linear density heat flow of pipes $q_l$ for $\Delta T$</th>
</tr>
</thead>
<tbody>
<tr>
<td>35 K</td>
<td>40 K</td>
</tr>
<tr>
<td>Rate 1:1, 100%</td>
<td>8</td>
</tr>
<tr>
<td>Rate 1:2, 50%</td>
<td>12</td>
</tr>
</tbody>
</table>

The design of the specific energy requirements of the pump

In order to design a pump, we must know the pressure drops in the circulation pipe. The speed of flow from 0.2 to 0.5m/s is recommended, but the maximum speed is 1.0m/s. The minimum calibre of a circulation pipe is 10mm. The recommended calibre of the circulation pipe with respect to the distribution pipe is given in Tab. 3.

The specific energy of the pump is usually expressed by the in drop pressure (e.g., kPa, mbar) and is calculated based only on the pressure losses due to friction, while the pressure drops due to local resistance are added by a percentile surcharge of 20% to 40%. The biggest barrier to the application of this type of solution for steel zinc-coated pipes is the different value of operating the inner harsh surface, which, according to our code, is eight times higher than is recommended in DIN [9], (Tab. 4). This is due to the fact that when STN 73 6655 was being developed (20 years ago), devices for water modification had not been designed; the inner surfaces of pipes were not smooth; and zinc-coated coverings were not of a high quality. With respect to the above mentioned facts, we recommend the application of tables for determining friction losses according to [9] (DIN 1988) in cases of the application of high quality zinc-coated pipes as well as the adequate modification of the water

The total drop in pressure $\Delta p_c$ (kPa) needed for the design of a circulation pipe is given by the formula

$$\Delta p_c = 1.0 + 1.3 \left( \sum R_i \cdot l_i \right) + \Delta p_m$$

(3)

where $R$ - total length of the loss due to friction (kPa.m$^{-1}$),

$l$ - the length of the pipe-section (m),

$\Delta p_m$ - pressure drop in the control valve, 6 kPa (10 kPa).

The local resistances are obtained in a surcharge to losses due to friction and are recommended:

a) for zinc-coated pipes with $k = 2 \text{ mm}$

- 0% for modified water
- 10÷20% for unmodified water

where $k$ is the roughness coefficient of the pipe surface

b) for zinc-coated pipes with $k = 0.25 \text{ mm}$ and 30% quality water modified

In the case of smooth hydraulic pipes, the requirements of Slovak and foreign norms are not very different, and the increase in pressure drops for local resistances can be 20 to 30%.

The total drop in pressure can also be calculated using a more precise equation:

$$\Delta p_c = 1.0 + 1.3 \left( \sum R_i \cdot l_i + Z_i \right) + \Delta p_m + \Delta p_p$$

(4)

where $Z_i$ - local pressure drop (kPa),

$\Delta p_m$ - pressure drop in the reverse valve by the pump (kPa),

$\Delta p_p$ - pressure drop in the devices, for example, data transfer, etc. (kPa).

Tab. 3 The recommended dimensions of circulation pipes

<table>
<thead>
<tr>
<th>Distribution PHW</th>
<th>Circulation PHW</th>
</tr>
</thead>
<tbody>
<tr>
<td>DN</td>
<td></td>
</tr>
<tr>
<td>20</td>
<td>12 (15)</td>
</tr>
<tr>
<td>25</td>
<td>12 (15)</td>
</tr>
<tr>
<td>32</td>
<td>12 (15)</td>
</tr>
<tr>
<td>40</td>
<td>20</td>
</tr>
<tr>
<td>50</td>
<td>25</td>
</tr>
<tr>
<td>65</td>
<td>25</td>
</tr>
<tr>
<td>80</td>
<td>25</td>
</tr>
<tr>
<td>100</td>
<td>32</td>
</tr>
</tbody>
</table>
The design of the control valve

The PHW circulation systems of should be completed by control elements of the flow, too. The most commonly used are control valves and complete sets. The basis for the design of control valves must always be more or less an exact calculation.

There are some practical possibilities for regulating flow:

a) by the type of armature (the valve or stop valve) without any regulation wheel,
b) by orifices,
c) by a control valve with the manual setting of the choke,
d) by a thermostatic valve without the manual setting of the choke,
e) by a thermostatic valve with the manual setting of the choke,
f) by a control valve with the thermostat and disinfection of the system by 70 ºC hot water.

Regulation by orifices is only used for temporary solutions, for example, in house exchanger rooms.

For the armatures referred to in c), e), f), it is necessary to use such hydraulic checking where the flows and pressure drops are known. Thermostatic valves with the setting of the required temperature can also be recommended in hydraulically checking the constant value in the length of the pressure drop.

• The design of the circulation flow by the volume of the water in the distribution system and hydraulically checking constant value of the length of the pressure drop.

This calculation method is suitable for orientation and can make a basis for the design of thermostatic valves without setting the choke. If we keep the specified values of the quality of the insulation and suitable dimensions of the distribution and circulation pipes are designed, we can design a sufficient flow by n – times the renewal of the water in the reservoir. The amount of the water renewal in the system depends on the highest required decrease in the temperature (Tab. 5). The volume of the water in the selected pipes is in Tab. 6.

Tab. 4 A comparison of the losses due to friction by STN 73 6655 for steel zinc-coated pipes (potable hot water) and DIN 1988

<table>
<thead>
<tr>
<th>Norm</th>
<th>Flow Q</th>
<th>DN 15</th>
<th>DN 20</th>
<th>DN 25</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>R (kPa.m⁻¹)</td>
<td>v (m.s⁻¹)</td>
<td>R (kPa.m⁻¹)</td>
<td>v (m.s⁻¹)</td>
</tr>
<tr>
<td>STN 0,02</td>
<td>0,03</td>
<td>0,11</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>DIN</td>
<td>0,02</td>
<td>0,1</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>STN 0,05</td>
<td>0,32</td>
<td>0,28</td>
<td>0,06</td>
<td>0,15</td>
</tr>
<tr>
<td>DIN</td>
<td>0,1</td>
<td>0,25</td>
<td>0,02</td>
<td>0,14</td>
</tr>
<tr>
<td>STN 0,07</td>
<td>0,62</td>
<td>0,39</td>
<td>0,11</td>
<td>0,21</td>
</tr>
<tr>
<td>DIN</td>
<td>0,18</td>
<td>0,35</td>
<td>0,04</td>
<td>0,19</td>
</tr>
<tr>
<td>STN</td>
<td>0,1</td>
<td>1,25</td>
<td>0,56</td>
<td>0,22</td>
</tr>
<tr>
<td>DIN</td>
<td>0,35</td>
<td>0,5</td>
<td>0,08</td>
<td>0,3</td>
</tr>
</tbody>
</table>

Tab. 5 The recommended values for water renewal in the distribution system of potable hot water

<table>
<thead>
<tr>
<th>∆T (K)</th>
<th>The recommended water renewal n.x per hour</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>3,5 ÷ 4,5</td>
</tr>
<tr>
<td>3</td>
<td>2,5 ÷ 3,5</td>
</tr>
<tr>
<td>4</td>
<td>2,0 ÷ 2,5</td>
</tr>
<tr>
<td>5</td>
<td>1,5 ÷ 2</td>
</tr>
</tbody>
</table>

The design of the pump be realised as in the previous part.

• The design of PHW circulation of without any calculations

The design method can only be used for the small buildings, for example family houses, duplex houses, etc., and must fulfil the following conditions:

a) the length of all the sections of the pipes is not more than a maximum 50 m,
b) the distance between the heater and the furthest discharge is a maximum 30 m.

If the following conditions are fulfilled, we can design:

• a circulation pipe for the bathroom of a min. DN 12 or, for the kitchen, DN 10
• for each riser pipe, a regulator of the pressure,
• a DN 15 pump with a minimal flow and specific energy.

CONCLUSION

A simplified solution in which the requirements accepted for quality insulation and the values of the dimensions of the circulation pipe becomes exact and makes an adequate basis for the design of control valves.
In order to make the solution complete, we must consider that only a theoretical (numerical) solution of problem is not sufficient. To its complete solution belongs:

- the choice of an appropriate armature (the appropriate characteristic of the valve, a low degree of noise, resistance against corrosion and incrustation to ensure against damage, etc.),
- the assignment of setting control valves by the actual state of the distribution system, especially in older buildings,
- the verification of the precision of the control valve’s setting (based on the indicated measured temperature of the PHW intake and outake pipes)

**REFERENCES**


[6] STN 06 0320 Ohrivanie úžitkovej vody (Heating service water)

[7] STN 73 6655 Výpočet vnútorných vodovodov (Calculation of internal water pipes)

[8] STN EN 806 Technické požiadavky na zhotovenie vodovodných potrubí na pitnú vodu vnútri budov (Technical requirements for the construction of potable water pipes inside a building)
