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Power supply

Lecture No 2

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Lecture 2.
Methods of heat load control. Hydraulic calculation and regimes of heating networks operation

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Content of Lecture No 1

1. Methods of heat load control
2. Hydraulic calculation and regimes of heating networks operation

1. Methods of heat load control

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Types of regulation depending on the place of implementation:

1. Central regulation - conducted at a heat source (CHPP, boiler-houses).

2. Group regulation - conducted in Central Heat Point for a group of homogeneous consumers.

3. Local regulation - at the heat points (Central Heat Point, Individual Heat Point, subscriber's inputs).

4. Individual regulation - is carried out directly on the heaters.

5. Combined regulation - consists of several types of regulation, mutually complementing each other.

Heat balance equation of a heat exchanger: $Q = Gc(t_1 - t_2) = kF\Delta t, W$

The methods of heat load regulations follow from the heat balance equation:

- change of heat carrier temperature (t = var) – qualitative method;
- change of heat carrier flow G = var – quantitative method;
- periodic shutdown of systems – intermittent regulation.
- change of the heating surface of heat exchanger.

Three methods of central regulation are applied:

- Qualitative method - changing the temperature of the heat carrier at the inlet to the heating device, the flow of network water is constant G_{nw} = const;
  - “+” combined generation of electrical energy is greater than with other methods of central regulation;
  - “++” a constant flow of network water G_{nw} contributes to a stable hydraulic regime;
  - “-” the maximum water flow rate, and hence the increased cost of electricity for pumping the heat carrier.
- Quantitative method – changing the flow of network water G_{nw} =var, at t_1=const and t_2=var;
  - “+” Lower energy costs for pumping heat carrier;
  - “-”unprofitable for CHPP (reduced combined output);
  - “--“unstable hydraulic mode in the heat network, due to the variable flow of network water.
- Qualitative- quantitative method – G_{nw} =var, at t_1=var.

Regulation of heat supply in two-pipe heating networks

closed

by heating load
(domestic heating graph)

$Q_{\text{av. HWS}} / Q'_{h} < 15\ \%$

by combined load
(advanced or combined graph)

$Q_{\text{av. HWS}} / Q'_{h} > 15\ \%$

open

by heating load

$Q_{\text{av. HWS}} / Q'_{h} < 15\ \%$

by corrected temperature graph

$Q_{\text{av. HWS}} / Q'_{h} > 15\ \%$

Regulation of heat supply in four-pipe heating networks is central quantitative by heating load

The main equation of regulation

$$Q = G_1 c(\tau_1 - \tau_2) = G_2 c(t_1 - t_2) = kF\Delta t, W$$

$$Q' = G'_1 c'(\tau'_1 - \tau'_2) = G'_2 c'(t'_1 - t'_2) = k'F'\Delta t', W$$

$'$ - design (predicted) conditions – when outside temperature equals to predicted temperature for heatin t_h^p

without $'$ means non-predicted conditions – any other outside temperatures $(Q < Q')$

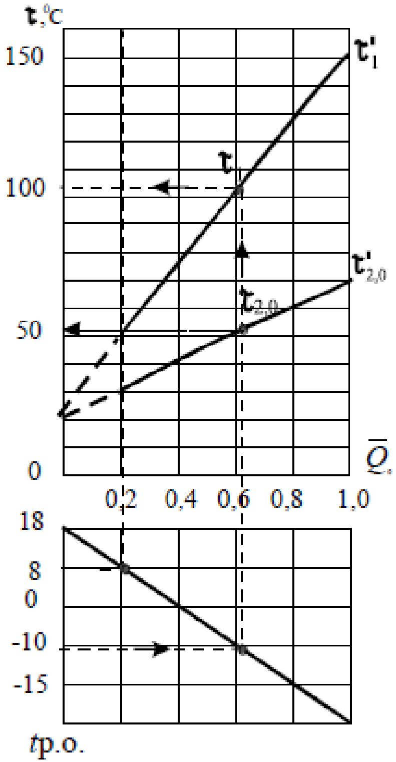
where Q is the current heat load;
G_1 is the flow rate of the primary (heating) coolant;
G_2 is the flow rate of secondary (heated) coolant;
τ_1, τ_2 the temperature of the primary coolant at the inlet and outlet from the heat exchanger;
t_2, t_1 the temperature of the heated medium at the inlet in the heat exchanger and at the outlet from it.

$$\bar{Q} = \frac{Q}{Q'} = \frac{G_1 c(\tau_1 - \tau_2)}{G'_1 c'(\tau'_1 - \tau'_2)} = \frac{G_2 c(t_1 - t_2)}{G'_2 c'(t'_1 - t'_2)} = \frac{kF\Delta t}{k'F'\Delta t'}, W$$

Central regulation of homogeneous heat load

1. Qualitative regulation – <u>to calculate water temperature depending on heat load</u>

$$\bar{Q}_h = \frac{Q_h}{Q_h'} = \frac{(t_{int} - t_{out})}{(t_{int} - t_p^h)} = \frac{(\tau_1 - \tau_{2,0})}{(\tau'_1 - \tau'_{2,0})} = \frac{k\Delta t_h}{k'\Delta t'_h}$$

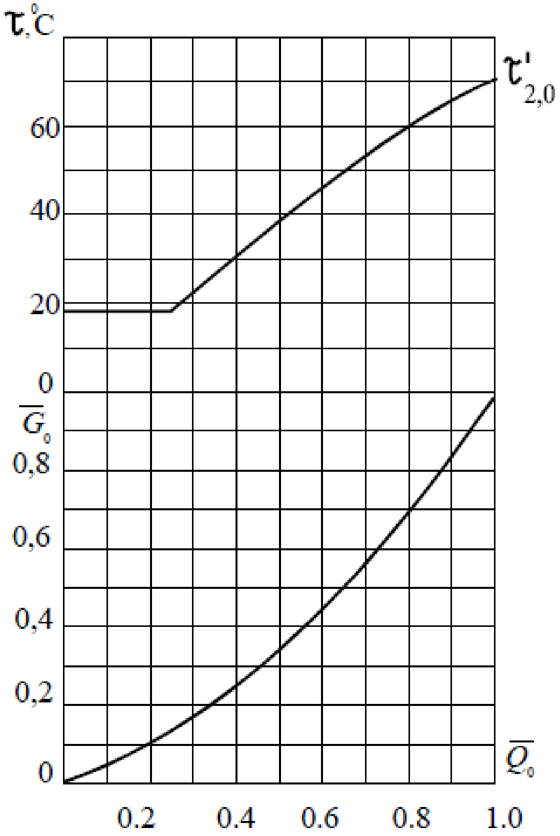


Temperature graph for the qualitative regulation of the heating load
(dependent scheme)
Or
Heating graph

$\tau_1' = 150$ °C, $\tau_{2,0}' = 70$ °C,

$\tau_3' = 95$ °C, $t_в = 18$ °C

2. Quantitative regulation – to calculate the flow and temperature of the return water, depending on the value of the heating load



Temperature graph for the quantitative regulation of the heating load

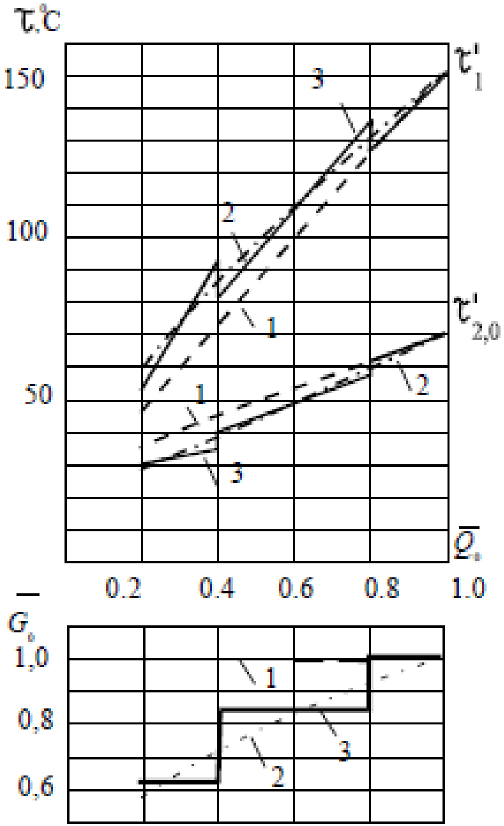
$\tau'_1 = 150\ °C$, $\tau'_{2,0} = 70\ °C$,

$\Theta' = 25^{o}C$ $t_в = 18\ °C$

$\Theta' = \tau'_3 - \tau'_2$

τ'_3 water temperature in the heating system supply pipe after the mixing device

3. Qualitative-quantitative regulation – <u>to calculate the flow and temperatures of the flow and return water, depending on the value of the heating load</u>



Temperature graph for the qualitative-quantitative regulation of the heating load

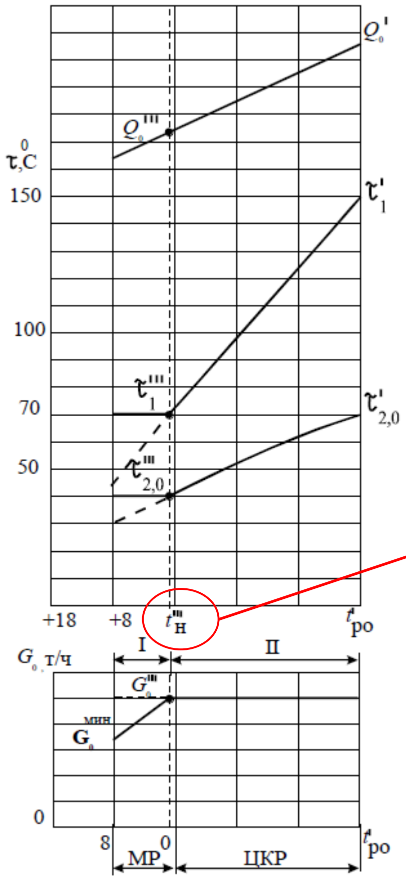
1 - heating graph; 2 - qualitative-quantitative regulation with a smooth change in water flow; 3 - qualitative-quantitative regulation with a gradual change in water flow

Central regulation of closed systems by heating load

Connection of subscriber units to the heat network is usually performed in a parallel or two-stage mixed scheme

Parameters to be defined:

τ'_1 temperature in the flow line



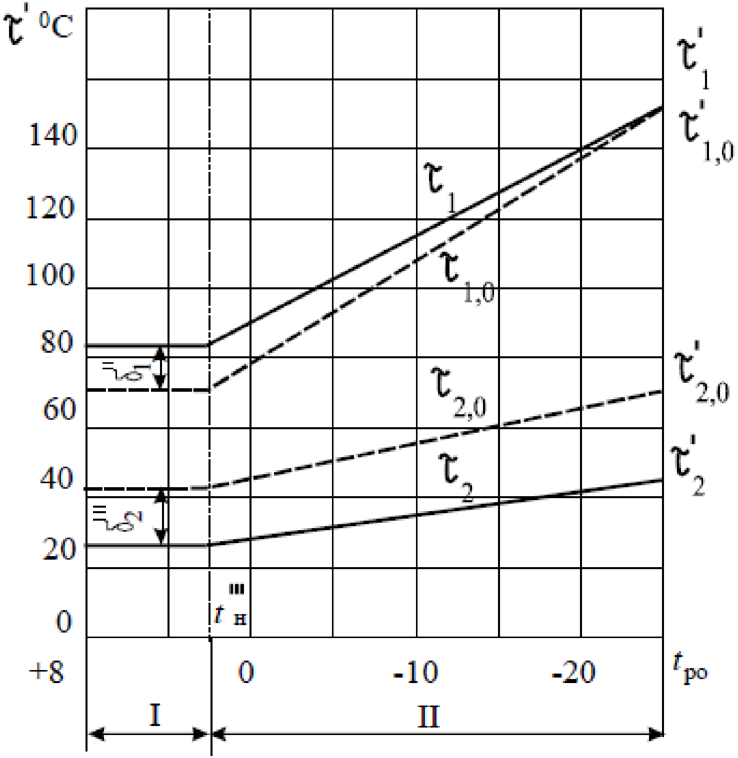
domestic heating graph

When an average hourly load for HWS does not exceed 15% of the predicted heat consumption for heating

$Q_{\text{av. HWS}} / Q'_h < 0,15$

t'''out

Central regulation of closed systems by combined load (heating and HWS)



$\tau_{1,0}$, $\tau_{2,0}$ is domestic heating graph

τ_1, τ_2 is advanced graph

advanced or combined graph

When an average hourly load for HWS exceed 15% of the predicted heat consumption for heating

$Q_{av.\,HWS} / Q'_h > 15\ \%$

Two-step consequent scheme

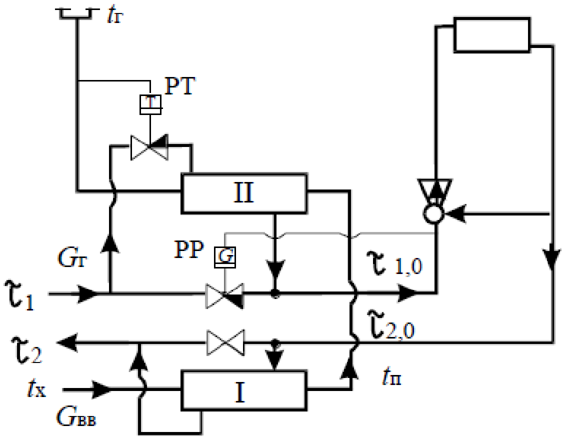


Рис. 4.14. Присоединение подогревателей горячего водоснабжения по двухступенчатой последовательной схеме

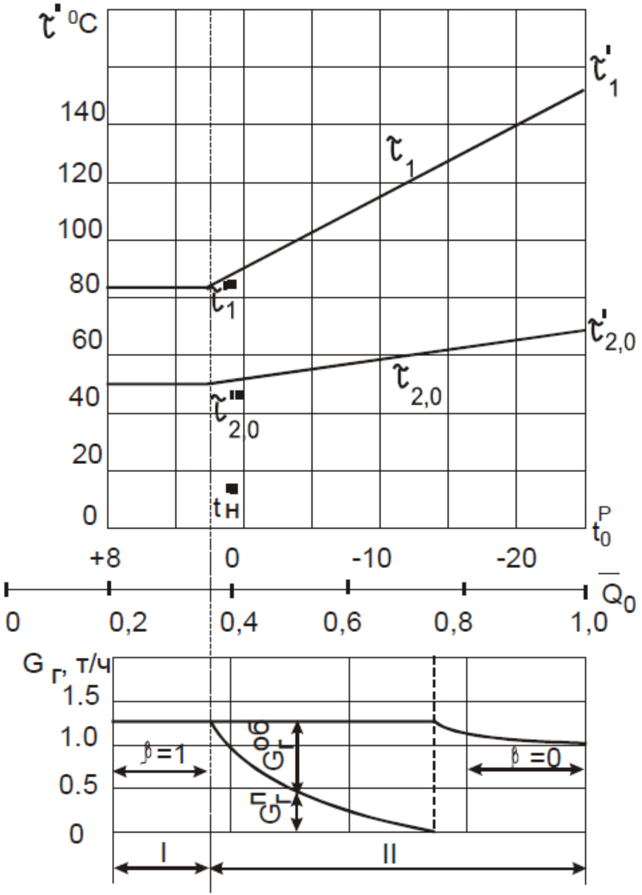
Parameters to be defined:

$$\delta_1 = \tau_1 - \tau_{1,0}$$

$$\delta_2 = \tau_{2,0} - \tau_2$$

Central regulation of open systems by heating load

$Q_{av.\,HWS} / Q'_h < 0{,}15$



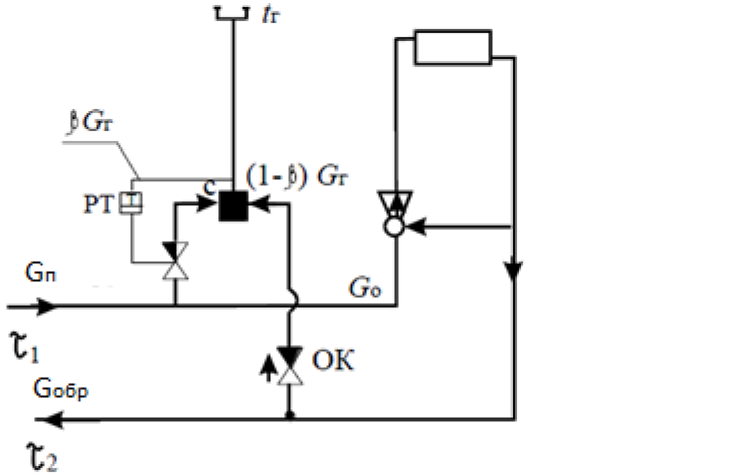


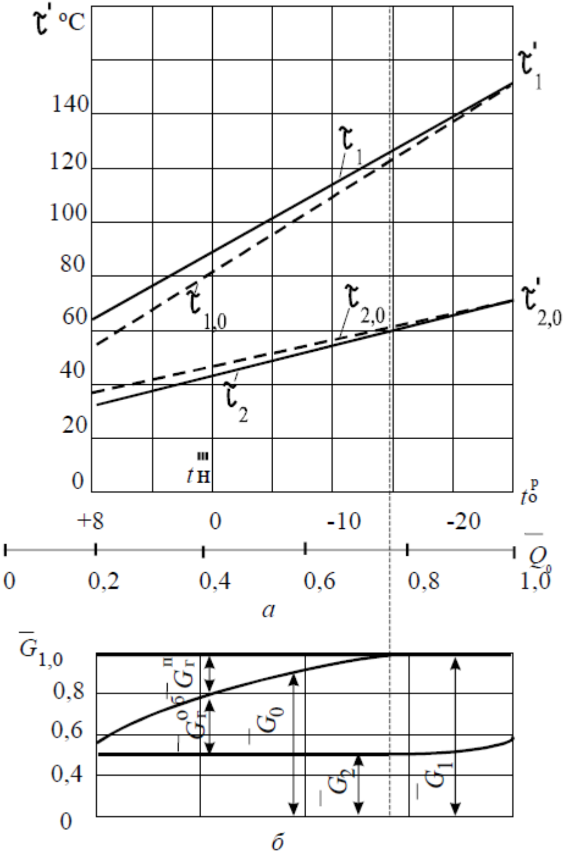
Рис. 4.17. Схема абонентского ввода в открытых системах теплоснабжения при центральном качественном регулировании по отопительной нагрузке: С – смеситель; ОК – обратный клапан

β is a proportion of water from the supply line

0≤β≤1 during heating season

Parameters to be defined: τ'_1, τ'_2

Central regulation of open systems by corrected temperature graph (combined load)



$0{,}15 \le Q_{\text{av. HWS}} / Q'_h \le 0{,}3$

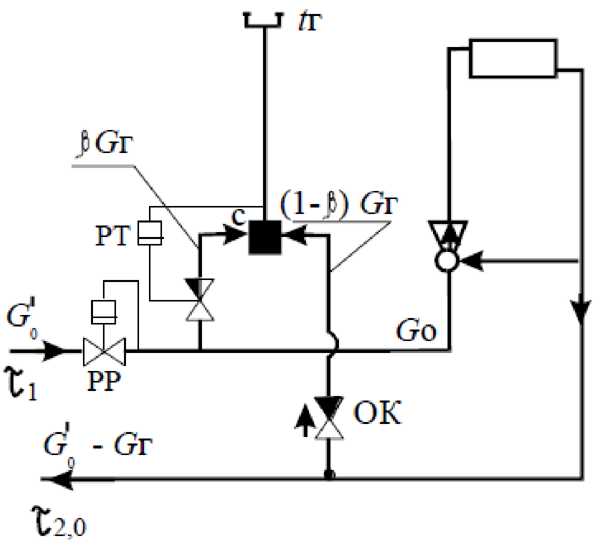


Рис. 4.19. Схема абонентского ввода в открытых, системах теплоснабжения при центральном качественном регулировании по совместной нагрузке отопления и горячего водоснабжения

Parameters to be defined: τ'_1, τ'_2

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The tasks of hydraulic calculation:

1) determination of pipeline diameters;

2) determination of pressure (head) drop;

3) setting the values of pressures (heads) at various points of the network;

4) the coordination of all points of the system under static and dynamic conditions in order to ensure permissible pressures and required heads in the network and subscriber systems.

Main dependencies for calculation

Bernoulli's equation

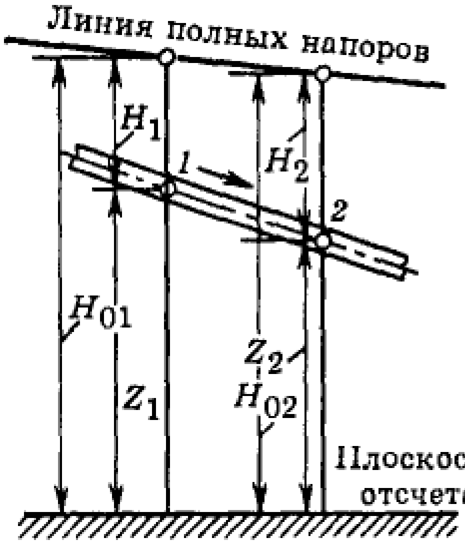


Рис. 5.4. Схема движения жидкости по трубопроводу

$$Z_1 g + \frac{w_1^2}{2} + \frac{p_1}{\rho} = Z_2 g + \frac{w_2^2}{2} + \frac{p_2}{\rho} + \frac{\delta p}{\rho},$$

specific energy of height

specific kinetic energy

specific potential energy

specific loss of potential energy

Z_1 and Z_2 are geometrical heights; w_1 and w_2 are fluid velocities; p_1 and p_2 are pressures measured at the level of the pipeline axis; δp is pressure drop across the section 1-2; γ is specific gravity of liquid.

Head: $$H_0 = Z + \frac{w^2}{2g} + \frac{p}{\gamma} = Z + \frac{w^2}{2g} + H,$$

piezometer head

$$\boxed{H_0 = Z + p/\gamma = Z + H,}$$

Drop pressure in a pipeline:

$$\boxed{\Delta p = \Delta p_{lin} + \Delta p_{loc}}$$

Δp_{lin} is a linear drop pressure;

Δp_{loc} is a drop pressure in local resistances.

or

$$\Delta P = R l_{spec}$$

Specific length of pipeline: $l_{spec} = l + l_{eq}$, l is pipeline length according to plan, m;

Equivalent length of local resistances: $l_э = \sum \xi \dfrac{D_i}{\lambda}$, м,

$\sum \xi$ is sum of local resistance coefficients; D_i is inner diameter; λ is a coefficient of hydraulic friction;

Specific pressure losses on friction: $R = 6.27 \cdot 10^{-8} \lambda \dfrac{G_i^2}{D_i^5 \rho}, Pa/m$

G_i is total estimated flow of network water in two-pipe heating networks of open and closed heat supply systems, kg/h.

Inner diameter: $D_i = \sqrt[5]{\dfrac{6,27 \ 10^{-8} \lambda \ G_i^2}{R \ \rho}}$, м.

Coefficient of hydraulic friction: $\lambda = 0,11 \left(\dfrac{k_э}{D_i} + \dfrac{68}{Re} \right)^{0,25}$,

Constructive hydraulic calculation of a two-pipe water network

Purpose: to define diameters of the pipeline sections of the network, head losses in sections and the pressure of network pumps.

Recommended to take the value of specific linear pressure loss:

- for main pipelines - $\Delta P \leq 80$ Pa/m;
- distribution network and branches to buildings $\Delta P = 150 \div 300$ Pa/m.

Hydraulic calculation is carried out in the following sequence:

1. To draw the calculation scheme of the heat network, to number sections of the network with lengths and calculated water flow rates.
2. To select the general main pipeline (calculated).
3. Using total estimated flow of network water to choose from the nomogram or table standard diameter of the pipeline corresponding to the permissible values of the specific linear pressure or head losses (ΔP_l). The value of ΔP_l corresponding to standard diameter is written.
4. To start hydraulic calculation from the last section. To choose types of fittings and other additional equipment for each section.
5. To calculate equivalent length of local resistances depending on the nature of the resistance and the diameter of the pipeline.
6. To calculate pressure or head loss on the calculated section.

7. At the end of calculation of each section, total loss of pressure (head) in the main (calculated) line heat network is calculated.

$$\Delta P_s^c = \sum_1^n \Delta P_{sect}, Pa \qquad \Delta H_s^c = \sum_1^n \Delta h_{sect}, m\,H_2O$$

No	Water flow rate	Section length, m			Diameter	Velocity of water	Specific losses	Losses on the section	Head losses
		According to plan	Equivalent length	Specific length					
	G, t/hour	l, m	l_{eq}, m	l_{spec}, m	D, m	w, m/s	Δp_l, Pa/m	ΔP, Pa	Δh, m H_2O
General main pipeline (calculated)									
1									
2									
3									
								ΣΔP	ΣΔh
Branch I									
								ΣΔP	ΣΔh
Branch II									

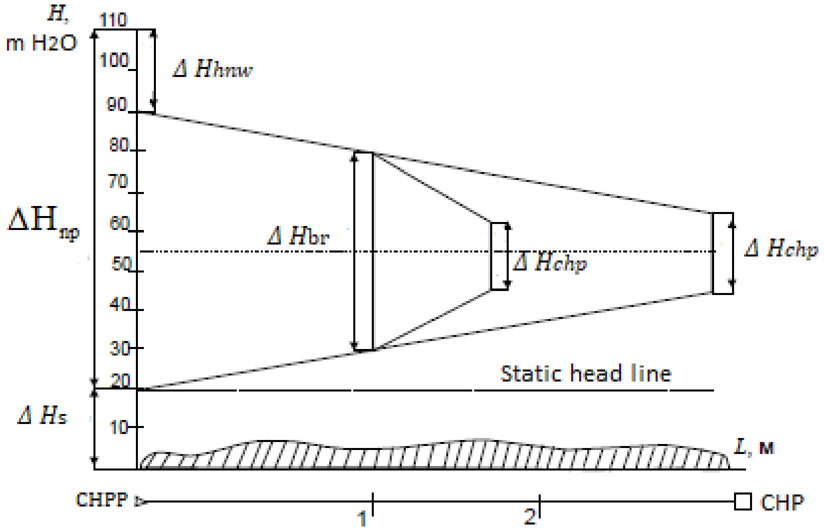
8. To calculate necessary available head of network pumps

$$\Delta H_{np} = \Delta H_{hnw} + \Delta H_s^c + \Delta H_{chp}, m\,H_2O$$

ΔH_{hnw} is head losses in heaters of network water, accepted 15-20 m H_2O

ΔH_{chp} is available head on Central Heat Points , accepted 20-25 m H_2O

Construction of piezometer graph



L, м			
G, kg/s			
D, мм			
Δh, м			

1. To put on the sucking height ΔH_s of the network pumps, can be accepted within 15-30 m of water;
2. To put on the head of the network pumps ΔH_{np} nd the head losses in heaters of network water ΔH_{hnw} (accepted 15-20 m H_2O);
3. To construct head lines in the flow and return lines of the main pipeline;
4. To choose the value of static pressure.

Verification hydraulic calculation of two-pipe water network

<u>The purpose:</u> determination of pressure losses on the sections of the pipelines of a two-pipe water network and the available heads at the heat inputs of consumers. The methodology is designed for the current network (known pipeline diameters and coolant flow rates across sections).

A design diagram of the heat network is drawn up, with the lengths and diameters of the pipelines, local resistances and design coolant flow rates on all sections of the network.

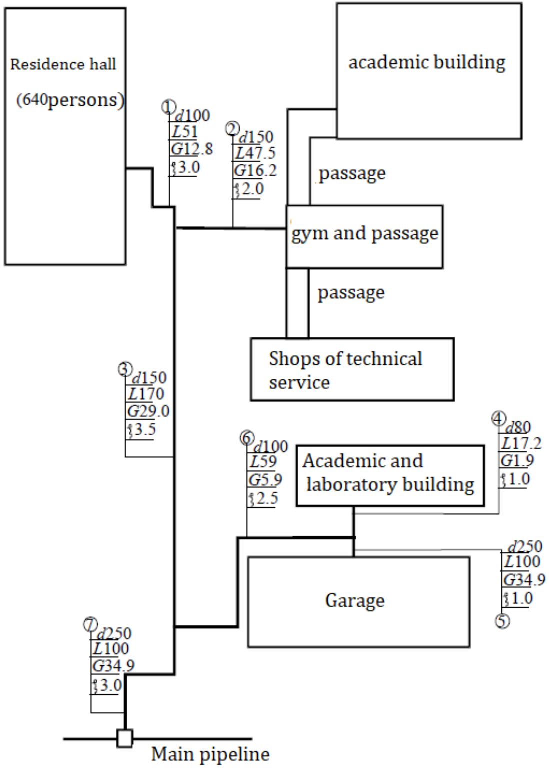


Рис. 6.2. Внутриквартальная схема двухтрубной теплосети в однолинейном изображении

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THANK FOR YOUR ATTENTION!