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Reliability and Controllability of Systems of Centralized Heat Supply

Key words: *Reliability, system of heat supply, system of heating, system of hot water supply, heat supply networks, temperature mode of premises.*

Annotation: *Features of large systems of the centralized heat supply and questions of reliability of a heat supply are considered at various schemes of automation of heating points. Dependence of heat safety from number of applied means of automation is certain.*

The present stage of development of systems of centralized heat supply is characterized by growth of individual capacity of heat sources, increase in range of transfer of heat energy, growth of diameters of the main pipelines, complication of technological schemes and operating modes. The number of consumers for which breaks in submission of heat are practically inadmissible increases.

The system of centralized heat supply represents complex dynamic system. Its many features are characteristic for other systems of power too. At the same time the system of centralized heat supply possesses also specific features which are necessary for considering at research of its reliability. It is possible to carry to number of the general features of big systems of power: territorial distribution; a continuity of development; non-uniformity of processes of consumption of heat energy; susceptibility to external influences; an opportunity of cascade development of failures, hierarchy; a variety of means of maintenance of reliability; insufficient reliability of the information on parameters and modes of system.

To number of the basic specific features of system of the centralized heat supply concern: localization within the limits of territory of city or industrial center; presence of a small number of large sources of heat; significant inertia of processes of transfer of heat; the complicated conditions of search of a place of failure on transit and main pipelines (3).

In system of the centralized heat supply it is possible to allocate three hierarchical levels (fig. 1):

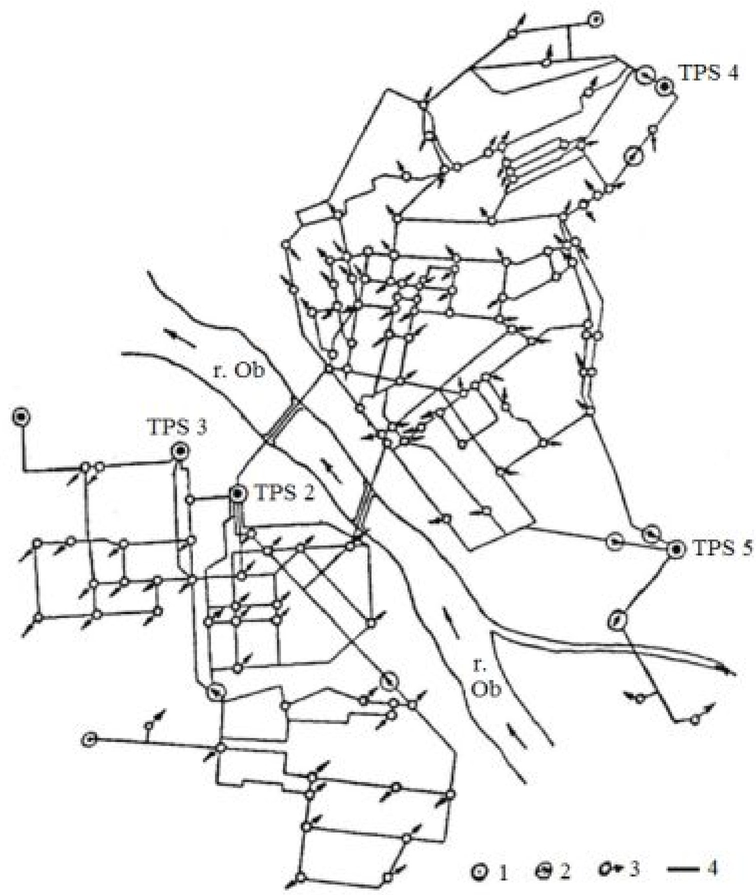

Fig. 1. The scheme of a heat supply of Novosibirsk

1 - Thermal power station (TPS) and the largest regional thermal stations; 2 - pump stations; 3 – heating points and consumers of heat energy; 4 - the main pipelines.

1) The Basic and peak sources of heat, and also transit heat supply networks;

2) The Sources of heat located in areas of heat consumption (regional or central heating points); the city main and distributive pipelines forming ring networks;

3) Deadlock branches from the main pipelines up to consumers - quarter heat supply networks.

Research problems of reliability are solved on each of these levels.

Reliability of systems of a heat supply includes: non-failure operation, durability, maintainability. Tasks of increase of reliability are: optimization of the plan of repairs of the capital equipment, development of modes and plans of operation in emergencies.

To provide consumers with heat in necessary quantity of demanded quality - means to maintain settlement temperature of air in heated premises and a variable production schemes of hot water supply.

Consequences of refusals depend mainly on duration of infringement of submission of heat, its depth, from temperature of external air and other climatic conditions.

From the point of view of reliability and safety of a heat supply dangerous are refusals of pumps, regulators of temperature, the pressure leading emergencies - to switching-off of consumers from a source of heat.

Automation of regulation of a hydraulic mode and protection in heating points depends on the scheme of connection of consumers to the heat network, the accepted schedule of regulation of heat, a ratio of heat loadings on heating and hot water supply, conformity of parameters of a hydraulic mode of a heat network on input in heating points to demanded parameters of a hydraulic mode of local systems. At a deviation of parameters of modes of a heat supply network from demanded for normal work of heating points with dependent connection of systems of heating (fig. 2, tab. 1), are applied additional means of automation (fig. 3).

Application of the pump blocks, the regulating equipment with the electric drive brings an additional element in traditional system of automation - a source of the electric power that changes a parameter of reliability.

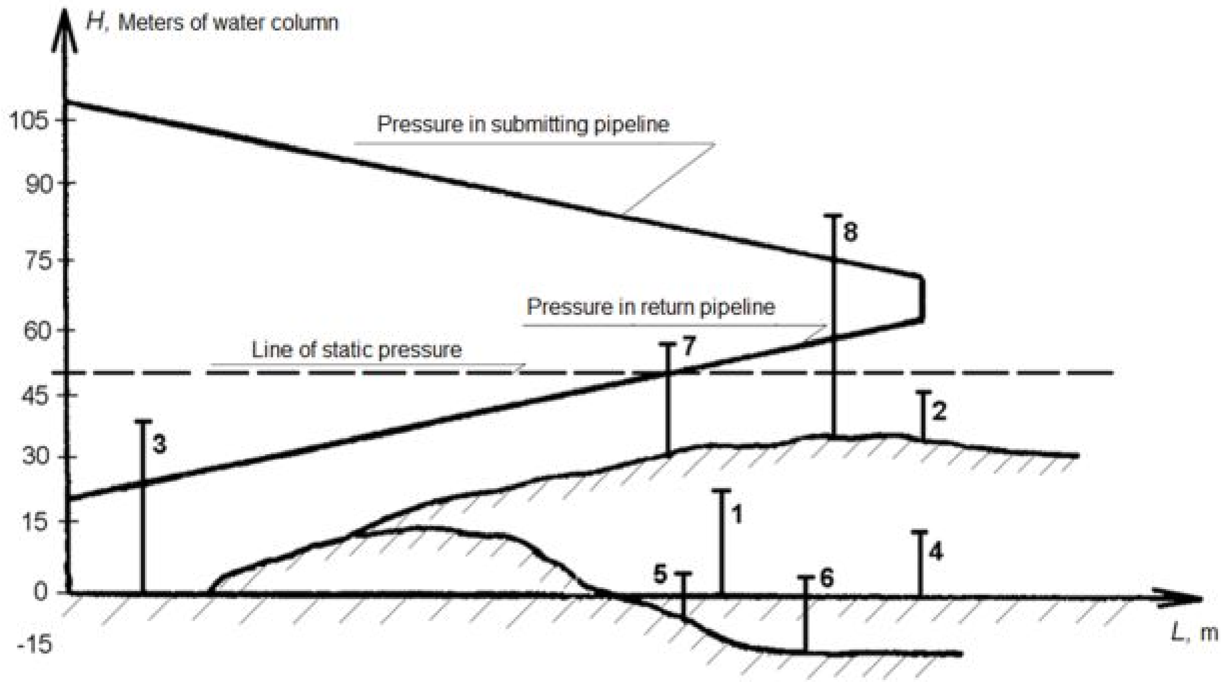

Fig. 2. *The scheme of pressures in a heat supply network*

Table 1

Additional actions of automation in heating points with dependent connection of system of heating at a deviation of parameters of modes of heat supply network from demanded for normal work of heating points

Character of a deviation of modes of heat supply network			Actions on maintenance normal work of consumers	
Condition of a deviation	Probable consequences (infringements)	№ of consumer	The list of additional elements in scheme of heating point and its automation	The scheme of automation
$\Delta h < \Delta h_s$ (*s* – settlement)	The demanded charge of water at the subscriber is not provided	2	Pumping up pumps on return (or submitting) or replacement of the mechanical device of mixture to pump	Figures 2.27*a*, 2.27*b*
$H_h < h_{ls}$ (*h* – heating; *ls* – local system)	There is no filling with water of local system, plums of water from it	3	Regulator of pressure on a return line	Figure 2.27*c*
$P_h > P_{adm}$ $\Delta h < \Delta h_s$ (*adm* – admissible)	Destruction of heating devices, the charge in local system is not provided	4	The dependent scheme of connection of heating with the pump on a return line	Figure 2.27*d*
			The independent scheme of connection of heating	Figure 2.27*з*
$H_{st} > H_{adm}$ (*st* – static pressure)	Destruction of heating devices at a stop of pumping up pumps	5	The dependent scheme of connection of heating with the cutting valve on the submitting pipeline both the safety and return valve on the return pipeline	Figure 2.27*∂*
			The independent scheme of connection of heating	Figure 2.27*h*
$P_h > P_{adm}$ $P_{st} > P_{adm}$	Destruction of heating devices	6	Pumping up pumps, regulator of pressure on submitting and return pipeline	Figure 2.27*a*
$H_h < h_{ls}$ $H_{st} < h_{ls}$	There is no gulf of local system, plums of water from it	7	Regulator of pressure on return line and the return valve (or a regulator of pressure) on submitting pipeline	Figure 2.27*f*
$H_s < h_{ls}$	Boiling up of water in the top points of system of heating	8	The dependent scheme of connection of system of heating with pumping up pumps on submitting pipeline and a regulator of pressure on a return pipeline	Figure 2.27*g*
			The independent scheme of connection of heating	Figure 2.27*h*

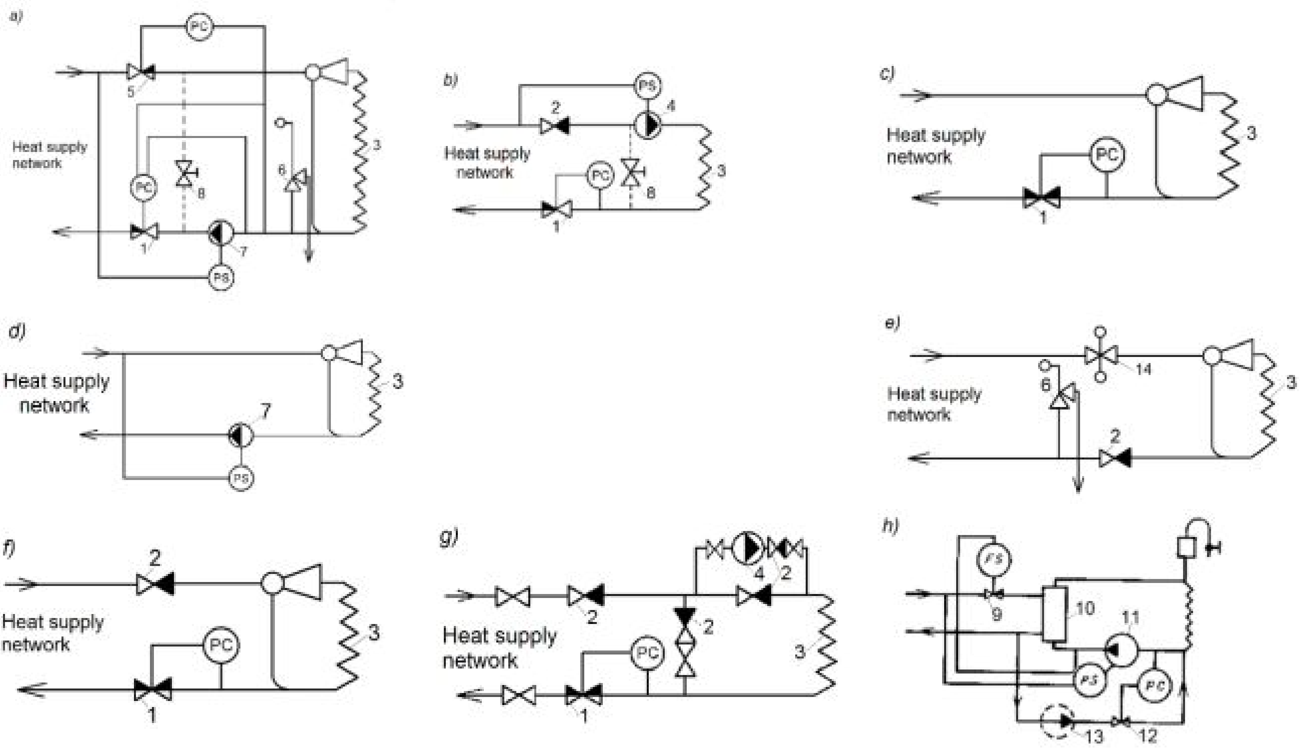

Fig. 3. Additional means of automation in heating points

1 – the regulator of pressure; 2 - the return valve; 3 - the consumer; 4 - the pumping up pump; 5 - the regulator of pressure; 6 - the safety valve; 7 - the pump; 8 - the cross pipe with the valve; 9 - the valve of pressure; 10 - the water heater of heating; 11 - pumps of heating; 12 - the regulator of pressure « after itself »; 13 - pumps; 14 - the cutting valve.

For an estimation of reliability of automation systems in a heat supply two main parameters of reliability are used: the first - $R_{ст}(\theta)$ has likelihood structure, depends on the scheme and of number of elements of automation system and the second, determined - factor of the limited submission of the heat-carrier, K_l. At failures of a building are completely disconnected from the heat supply network, then $K_l = 0$. Considering, that refusals are rare events and duration of standing of settlement external temperatures $t_{os}^{Б}$ is insignificant, it is possible to admit decrease in temperature indoors up to critical

t_i^{min}=12 °C at $t_{os} \leq t_{os}^{Б}$ (1).

Then, the temperature of internal air which will be through τ hours after failure can be determined under the formula:

$$t_{в} = t_{н} + (t_{вр} - t_{н}) \cdot e^{-\tau/\beta}, \qquad (1)$$

here β – the factor of accumulation, for modern buildings makes 35-45 hours, (1).

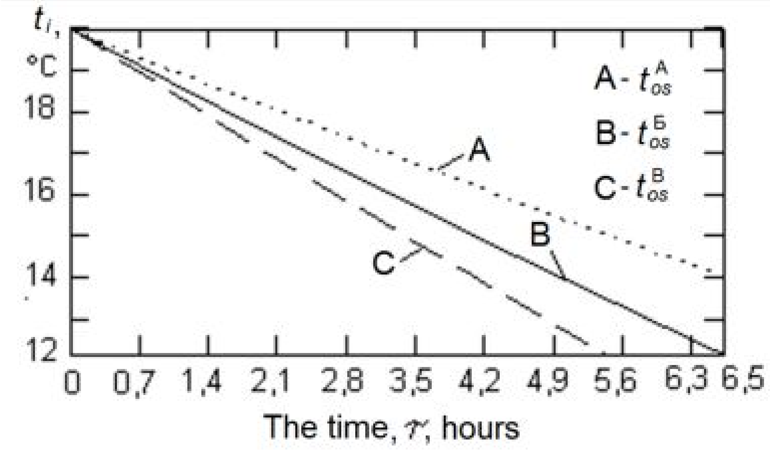

Fig. 4. Cooling of a premise at failure

For example, for a residential building in Novosibirsk, at t_i=20 °C (internal temperature), t_{os}= $t_{os}^{Б}$ = –37 °C (outside temperature) и β = 45 hours, the temperature of internal air in case of failure will lower up to 12 °C in time τ = 6,5 hours (fig. 4).
The probability *m* refusals during the heating period can be determined under Pawson's law (form. 2), (1), where ω - parameter of a stream of refusals:

$$P_m(\theta) = \frac{(\omega\theta)^m}{m!} e^{-\omega\theta}. \qquad (2)$$

Duration of the heating period for of Novosibirsk makes 221 days (τ=5304 hours). The maximal value of this function for conditions of Novosibirsk (θ=5304/8400 = 0,631; 8400 hours - the operating time of system of a heat supply within a year) at P_m=0 is reached at ω=1,612 year $^{-1}$ that has allowed to estimate probability of refusals for the heating period (2), fig. 5.

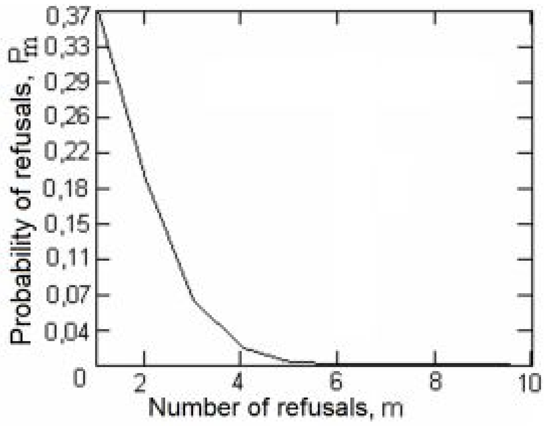

Fig. 5. Probability of number of refusals for the heating period

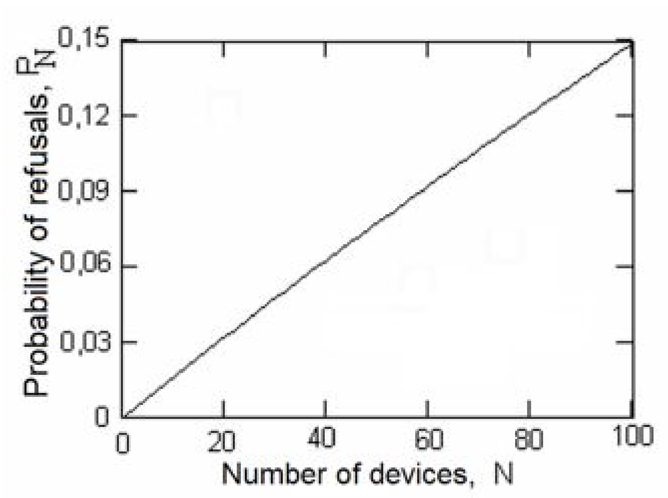

Fig. 6. Dependence of probability of refusals on number of devices of automation

During time 2τ heat balance of a premise necessary for restoration it is possible to determine probability of occurrence of repeated refusal under the (formula 3), where T=2τ /8400.

$$P_{1,2}(\theta) = (1 - e^{-\omega\theta})(1 - e^{-\omega \mathrm{T}}), \qquad (3)$$

According to the theory of probability, probability of approach even one of independent events (refusal any of elements of the automation, leading failure, is determined under the formula

$$P_N(\theta, \mathrm{T}) = 1 - q^N = 1 - \left(1 - P_{1,2}(\theta)\right)^N, \qquad (4)$$

Where q - probability of opposite event;

N - number of devices of automation.

Dependence of probability of repeated refusal on number of means of automation in time 2τ from the beginning of failure is presented on fig. 6.

Conclusions.

Creation of the computer network operating from uniform server work of all equipment and automation of system of a heat supply, capable to conduct exact calculation and regulation of all operating modes of heat supply networks is perspective. Application of means of program regulation of parameters of heat supply causes additional requirements to reliability of operating and operated systems. Work of the equipment providing hydraulic protection and heat safety in an independent mode that increases number of means of automation is necessary. Therefore, at a difficult lay of land when additional means of automation are required can appear more reliable to use the independent scheme of connection of system of heating and the simple scheme of regulation using energy of a stream of the heat-carrier.

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