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THE PHYSICAL METHOD OF VISUAL DIAGNOSTICS OF FLOW STRUCTURE

ABSTRACT

The article presents results of using the flow structure design equipment, which is based on the method of visual diagnostics of flow structure simulations in the physical models. The changes of radial compressor collector were designed according to distributing of speeds which were exposed by the method of visual diagnostics. The tests results on the stand of "H.Cegielski-Poznan" firm has shown the reduction of noise during work of compressor DA-210 from 96 to 84dB, at the same time the efficiency of work was increase up to 2,3%.

KEYWORDS: visualization, flow structure, hydraulic resistance, modernisation of equipment.

1. INTRODUCTION

Modern ideas about the movement of liquids and gases based on the concept of turbulence. Turbulence is considered to be a complex movement of dissipative media and is associated with chaos [1]. The equations describing the turbulent flow, expect only the averaged parameters of velocity and pressure. The visual diagnostic of flows have a special role in identifying and analyzing the parameters of the equipment. Modern equipment, operation of which is linked to movement of liquids and gases, has a low efficiency due to substantial energy losses in order to overcome hydraulic resistance. Except for substantial energy losses, during movement of liquids and gases, resistance causes noise, vibration and other negative phenomena, too. The visual images characterize the field of hydraulic parameters – speed and pressure, and demonstrate reasons for a poor efficiency.

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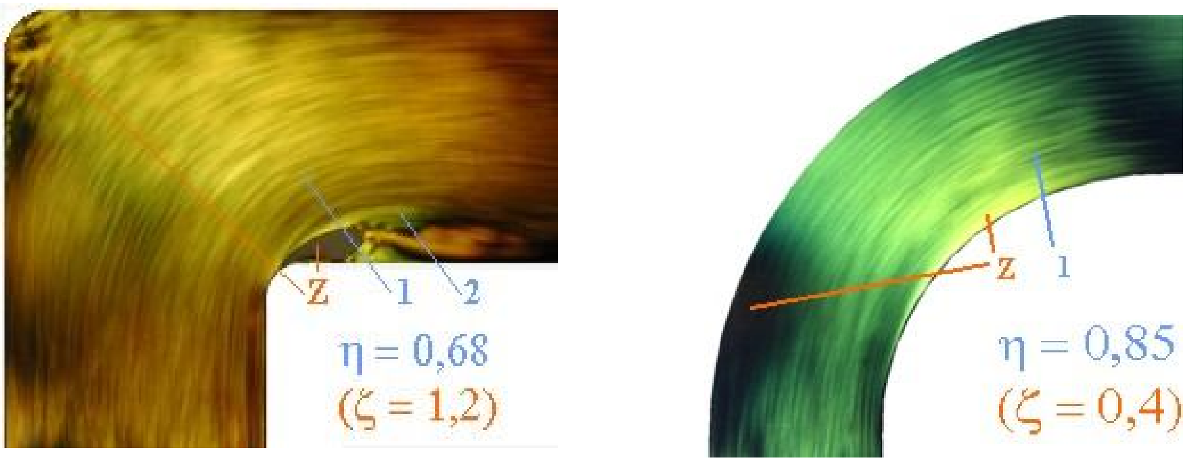
2. METHOD OF VISUAL DIAGNOSTICS OF FLOW STRUCTURE FOR DESIGN OF FLOW PASSAGES

Method of visual diagnostics of flows is shown on the example of designing an optimal flow passage of flow turn by 90°. The examples of modernisation are illustrated by results of visualisation of flow structures in characteristic sections of flow passages. The visual images characterise the field of hydraulic dynamic parameters (speed, pressure) gradients' instance meanings, based on optical density values (intensive white or grey) in every point of the flow. In other words, whilst decoding the field of speed instant meanings, "light areas" characterise positive speed gradients in the point in question and "dark areas" stand for negative speed gradients, whereas the received images enable to judge on the character of speed value changes in every point of the flow [2].

The figure 1 shows the flow structure in a device, which is referred to as "bend" – a turn with equal internal and external corners or radiuses of rounding.



a) "bend" b) "lateral"

Fig. 1. Flow structure in flow turn by 90°.

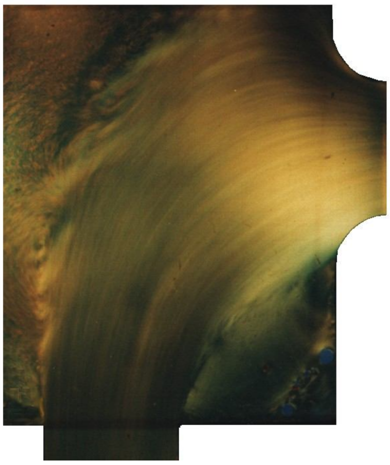
To characterize optimal movement of liquids or gases, let us introduce a term called "hydraulic efficiency of flow passage" - η – applicable to hydraulic or aerodynamic equipment. For this purpose, we use a known meaning of consumption coefficient μ, which can be calculated based on a meaning of hydraulic resistance ζ.

$$\eta = \mu = \frac{1}{\sqrt{1+\zeta}} = \frac{Q_a}{Q_t} \qquad (1)$$

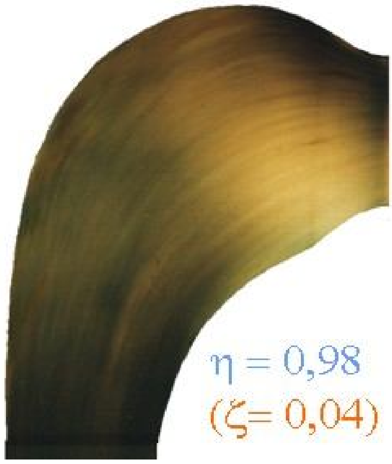
Thus, movement efficiency of liquids and gases in flow passages η can be characterised by a relation of actual consumption Q_a to theoretical consumption Q_t. In case resistance ζ in flow passage are equal to zero, then $Q = Q_t$, in which case the efficiency amounts to η = 1. If the meaning of hydraulic resistance ζ = 1,2, then movement efficiency η of liquids or gases in the "bend" amounts to η = 0,68. The illustrations demonstrate reasons for such a poor efficiency. The dissipated areas, in which the flow comes off the walls Z, are the ones, where energy losses are maximum. The chaotically located transverse structures, presented as the current lines 1, and longitudinal flow structures, presented as homogeneous optical areas 2, do not contribute to an organised movement in the flow passage of the turn.

To improve efficiency of complicated hydraulic systems (pipelines, inlet and outlet elements of pumps, turbines, boilers, etc), the flow turn, known as “lateral”, is used, which is made of radiuses of the same centre (figure 1b). However, the “lateral” also has areas of losses in energy Z, a meaning of its hydraulic resistance ζ = 0,4 and efficiency does not exceed η = 0,85.

The method of visual diagnostics enables to improve significantly the efficiency of movement in the turn [3]. For this purpose, the flow structure of an optically-active liquid is examined in a specially designed model of a so-called “black box” (figure 2a). The flow passage of the “black box” provides for given inlet and outlet dimensions of the channel, taking into consideration radius of the flow turn in flooded space. Specially increased dimensions of flow passage in the “black box”, between the first and last section, enable to turn the flow of liquid in the most optimal way. The obtained image of flow structure in the “black box” gives information to solve the problem of determining optimal limits and geometry of the flow turn (figure 2b).



a) “Black box”



b) “FS-optimal turn”

Fig. 2. Designing of optimal turn by 90°.

In flow passage of the turn by 90°, which is designed using knowledge of flow structure in transverse and longitudinal sections, the transport efficiency of liquids and gases is increased up to η=0,98.

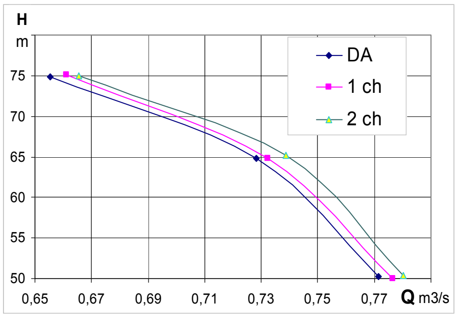
3. RADIAL COMRESSOR MODERNISATION

Modernization of radial compressor collector DA-210 «H.Cegielski-Poznan» firm has been done with the purpose to reduce of noise during its work. The changes of collector flowing part were designed according to distributing of speeds which were exposed by the method of visual diagnostics of flow structure simulations in the physical models of collector.

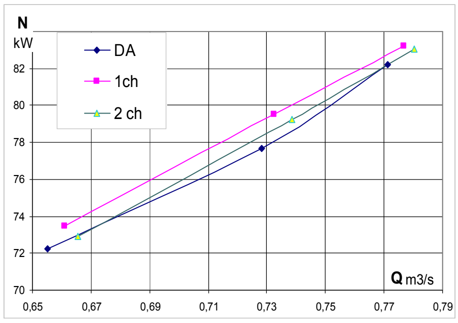
Based on the results of diagnostic phase of the modernization of two streams running of the fan were held: the removal of dissipative zone input plot collector (1 change); replacement of dissipative zones collector using paste (2 change). The tests on the stand of «H.Cegielski-Poznan» firm has shown the reduction of noise during work of compressor DA-210 from 96 to 84 dB, at the same time the efficiency of work was increased up to 2,3%. The test results showed that forms pressure characteristic (figure 3a) and the power characteristics (figure 3b) changed only by reducing the pressure loss.

Each stage of resistance reducing flowing parts makes pressure characteristic P = f (Q) more horizontal. Form of power characteristics has changed from concave (DA-210 characteristic) to a convex (2 change).

Flow providing without division from the walls in flowing part allows solving problems of noise and vibration of working equipment. Flow providing without division from the walls in flowing part allows solving problems of noise and vibration of working equipment.



a) Pressure characteristic P = f (Q).



b) Power characteristic N = f (Q).

Fig. 3. Results of compressor modernization

Carrying out experience of similar reconstructions on the dissipative areas removal shows the substantial diminishing of flowing parts resistances and as fact accordingly increasing of productivity and work efficiency of turbo machinery: turbines, compressors, pumps and modern power engineering technologies.

The method of visual diagnostics has been tested in energy industry, ecological and energy-saving technology, ventilation and air-conditioning, fire engineering and others. The established methods enable to significantly increase and improve energy, acoustic, vibration and other characteristics of various equipment within a short period of time and at minimum expense.

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ZESZYT NAUKOWY POLITECHNIKI RZESZOWSKIEJ Nr 266
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THE POSSIBILITIES OF METAL CONCENTRATION DECREASE IN ACID MINE DRAINAGE

ABSTRACT

Degradation of surface water quality that is in contact with acid mine drainage belongs to the serious environmental problems in Slovak Republic. Mainly abandoned sulphide mines produce AMD with high metal concentrations and low value of the pH (about 3-4) which has negative impact on water ecosystems. Novadays treatment of AMD includes passive and active systems. While passive treatment systems don't require continuous chemical inputs and that take advantage of naturally occurring chemical and biological processes to clean contaminated mine waters, active treatment system involves controlled physical, chemical and biological methods often based on pH increasing and the recovery of precipitate metals from AMD sludge.

The paper presents results of used selected physical-chemical and biological-chemical methods of AMD treatment for aluminium, copper, iron, manganese and zinc removal from acid mine water originated in mine Smolnik in Slovak Republic.

KEYWORDS: acid mine drainage, sorption, selective precipitation, sulphate-reducing bacteria

1. INTRODUCTION

Acid Mine Drainage (AMD) causes the decomposition of the minerals, the devastation of the surrounding environment, the contamination of underground water and water streams by a wide range of elements, including the toxic ones, the penetration of metals into the food chain, etc. The genesis of AMD is conditioned by the existence of autochthonous chemolithotrophic Fe- and S-oxidising bacteria of *Acidithiobacillus* genus. During exploitation, but mainly after the mine closing, sulphide mineral deposits may become potential "natural biogeoreactors" producing AMD and functioning on the principle of biogenous catalysis of chemical oxidation of both primary and secondary sulphide minerals

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by the above-mentioned species of bacteria that live in symbiosis with other species of aerobic and anaerobic bacteria [1,2]. Due to this sulphide-weathering process metal in the water-insoluble sulphide is transformed into water-soluble sulphate.

In Slovak republic there are some localities with existing AMD generation conditions. The most critical values were observed in the abandoned deposit Smolník. The stratiform deposit Smolník belongs to the historical best-known and richest Cu – Fe ore deposits in Slovakia. In 1990 the mining activity at the locality was stopped. The mine was flooded till 1994. In 1994 an ecological collapse occurred, which caused the fish-kill and the global negative influence on the environment. The mine-system represents partly opened geochemical system into which rain and surface water drain. The continuation of AMD generation at the locality of Smolník is not possible to stop and there is no chance for situation self-improvement. It is necessary to respect this situation, monitor the quality of these waters and develop methods for their treatment. That was the reason for starting a systematic monitoring of geochemical development in acid mine drainage in 2004 in order to prepare a prognosis in terms of environmental risk and use of these waters as an atypical source of a wide range of elements.

Methods to prevent AMD production and methods to remediate AMD are both time consuming and expensive. Several methods for treatment of acid drainage exist but only few of them have been applied under commercial-scale conditions [3-5]. Their application depends on geochemical, technical, natural, financial, and other factors. Generally are distinguished two variant strategies for treating AMD: active and passive treatment technologies [4]. The first solution that is the conventional solution is to collect and chemically treat acidified effluents. In the second solution effluents can be routed through natural or constructed wetlands within which microbial communities perform the same function. In the conventional treatment system alkaline materials and other chemicals are added to the AMD to neutralize it and enhance hydroxide precipitation. Each metal in AMD precipitates at specific pH levels. For example, hydroxides of Fe^{3+} precipitate at about pH 3, and of Al^{3+} at pH 3.7 to 4.5. Divalent metal ions precipitate in the alkaline range, Ni^{2+} at about pH 8, Fe^{2+} at pH 8 to 9 and Zn^{2+} at more than pH 9 [6].

Nowadays is pay attention to physical, chemical and biological methods for the selective recovery of metals from AMD. These methods constitute the possibility of the recovery metals in the suitable forms for commercial value development of AMD physical treatment by application of an adsorption process comprised of inorganic chemically active adsorbents to selectively recover of Fe, Cu, Zn, Cd and Pb from AMD without neutralization [7]. Janke and Diebold [8] evaluated the chemical treatment of AMD on the ground of metal recovery from AMD by addition of sulphides followed by oxidation and selective titration. Cu and Zn precipitated as sulphides and Fe, Al, Mn and Mg were recovered as hydroxides. Tabak et al. [9] conducted the biotreatment of AMD by selective sequential precipitation to recover metals as hydroxides and sulphides.

The bases of the biological-chemical methods were the application of sulphate-reducing bacteria (SRB). The basic metabolic process of these bacteria is the anaerobic reduction of sulphates by the formation of hydrogen sulphide reacting in the water with cations of metals forming little soluble sulphides. The process of the heavy metals precipitation by bacterially produced hydrogen sulphide with the combination of the metals precipitation by sodium hydroxide at the various values of AMD pH was investigated. In the literature this methods is named as the selective sequential precipitation (SSP) [9]. All aforementioned methods have been studied in term of the possibility of the metals removal from AMD in a suitable form for additional processing into marketable precipitates and pigments.

The main objective of the present work was to compare and to interpret some chemical and biological-chemical methods to separate metals from AMD out-flowing from the shaft Pech of the deposit Smolník (Slovak republic). The specific objectives of this research can be outlined as follows: to study of Cu, Fe, Al, Zn ions removal from acid mine drainage by adsorption using turf brush PEATSORB - an atypical hydrophobic sorbent that is usually used for oil pollutants removal from surface water; to determine optimal conditions for selected metal removal from AMD by precipitation using NaOH; to develop a several stage process consisting of separate SRB bioreactor system for sulphate-reducing activity and production of biogenic hydrogen sulphide to be used in the metal precipitation and biorecovery system, to separate copper (as copper sulphide), zinc (as zinc sulphide), iron (separate precipitates of ferric hydroxide and ferrous sulphide), aluminium (as aluminium hydroxide) and manganese (as manganese hydroxide), to achieve high recoveries and metal precipitate purities, while producing water was suitable for discharge to the environment.

2. MATERIALS AND METHODS

The acid mine water used in this study was the acidic metal-containing water from the shaft Pech of the flooded deposit of Smolník, Slovak republic. Table 1 shows the average major metals composition of acid mine drainage (pH 3.7).

Table 1. Dissolved major metal concentrations of the AMD sample from the shaft Pech (deposit Smolník, Slovak republic), pH 3.7

Compound	SO_4^{2-}	**Fe**	**Mn**	**Cu**	**Zn**	**Al**
Concentration [mg l^{-1}]	2 938	307	26	5.3	10.8	77

Based on our previous results, where various adsorbents were tested [10], for our study of Cu, Fe, Al, Zn ions removal from acid mine drainage by **adsorption**, turf brush PEATSORB (REO AMOS Slovakia) was used. The dependence of Cu, Fe, Al, Zn concentration decreasing on time (1; 3; 5; 10 min), was investigated under dynamic conditions using turf brush PEATSORB. To intensify the adsorption process, sample of AMD was continuously stirred with 5g of turf brush PEATSORB. In filtrate pH (METTLER TOLEDO) and Cu, Fe, Al, Zn by colorimeter DR 890 (HACH LANGE) was determined.

Test of Cu, Fe, Al, Zn precipitation in AMD was carried out by raw AMD samples of 100 mL, each were titrated to pH end points ranging from 4 to 8 using NaOH (0,5 mol l^{-1}). During titration, the AMD solution was continuously stirred and the pH was monitored. When the preset pH end point was reached, the titrated solution was filtered to precipitated metals removing. The filtrate was used for characterization of Cu, Fe, Al, Zn solubility as a function of pH.

For the biological-chemical experiments the cultures of SRB (genera *Desulfovibrio*) were used which were isolated from a mixed culture obtained from the potable mineral water (Gajdovka spring, the locality Košice-north, Slovakia). The SRB were selected from the mixed cultures grown on plates and in agar shake tubes containing modified Postgate′s medium E [11].The isolation was performed by the modified dilution method [12].

The experiments of the heavy metals selective sequential precipitation from AMD sample was performed in two interconnected reactors with a capacity 1000 mL (the first bioreactor) and 250 mL (the second bioreactor), which operated at the semi-continual conditions. This method contains several process steps and can be divided into these main steps, as well as: - the biological hydrogen sulphide production. In this stage SRB using organic matter (sodium lactate) convert the sulphate to hydrogen sulphide; - the heavy metals precipitation by the bacterial produced hydrogen sulphide. This stage followed after the indication of the bacterial sulphate reduction (i.e. the bacterial production of H_2S). It was carried out the continuous transfer of H_2S by N_2 from the first bioreactor into the second reactor, which was filled by sample of AMD. The bacterially produced hydrogen sulphide in the second bioreactor at the suitable values of pH solution, realized the continuous precipitation of metals; - the heavy metal sulphides separation by the filtration; - the setting pH of the filtrate from previous steps by 1M NaOH (precipitation of metals as hydroxides); - the heavy metal hydroxides separation by the filtration; - the subsequent precipitation of the heavy metals by the bacterial produced hydrogen sulphide. In this stage the filtrate from previous steps was returned into the second reactor and again was submitted to the effect of bacterially produced H_2S. Values of pH for the heavy metals precipitation were assigned on the ground of our previous works and enumerations [13-14].

A turbidimetric method was used to measure the concentration of sulphate ion concentrations. The concentration of metals was determined by atomic absorption spectrometry (AAS) using Spectrometer AA – 30 Varian (Australia) instrument. A glass pH electrode combined with the reference Ag/AgCl electrode was used to measure pH. Digital pH-meter GPRT 144 AGL (Germany) was used. The qualitative analysis of precipitates obtained by biologically produced hydrogen sulphide and by sodium hydroxide was done by energy dispersive spectrometry (EDS) analysis using instruments, which consisted of a scanning electron microscope BS 300 (Tesla, Czechoslovakia) and an X-ray microanalyser EDAX 9100/60 (Philips, Holland). Samples of precipitates were dried and coated with carbon before the EDS analysis.

3. RESULTS AND DISCUSSION

The physical-chemical method

The results of pH measuring in mixture AMD - turf brush depending on time are presented in Figure 1. Influence of adsorption processes on Cu, Fe, Al, Zn concentrations in individual samples are given in figures 2 to 5.

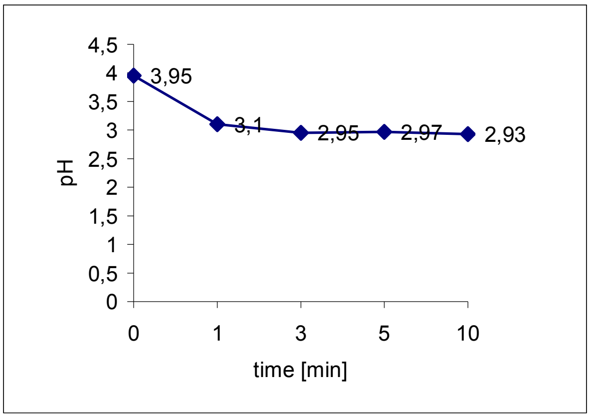

Fig. 1. Dependence of pH change during Cu, Fe, Al, Zn removal from AMD by PEATSORB

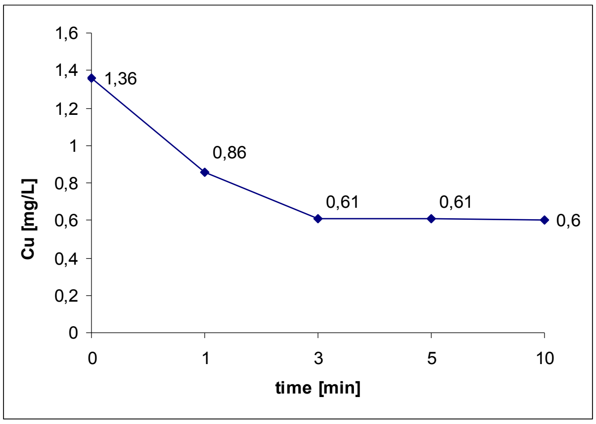

Fig. 2. Dependence of Cu removal from AMD versus adsorption time

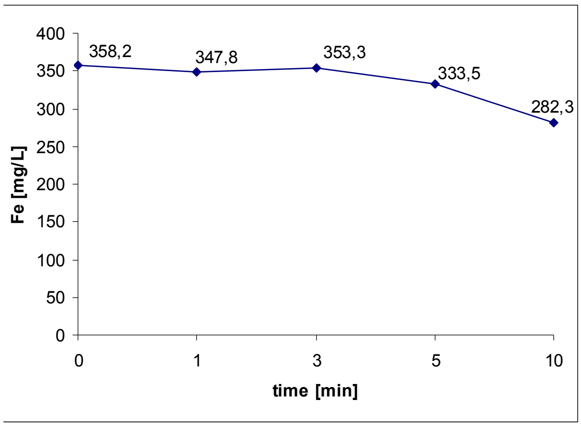

Fig. 3: Dependence of Fe removal from AMD versus adsorption time

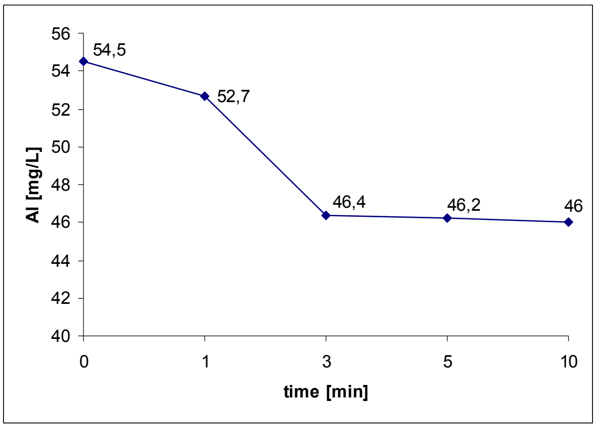

Fig. 4. Dependence of Al removal from AMD versus adsorption time

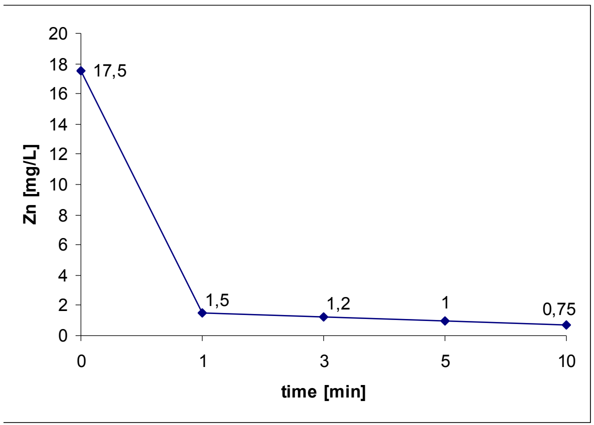

Fig. 5. Dependence of Zn removal from AMD versus adsorption time

From the results follows, that it is possible to decrease the Cu, Fe, Al and Zn concentrations in polluted surface water by physical adsorption. The highest turf brush efficiency was observed for zinc removal, where the decrease of concentration in solution was 95,71 %. Then follows copper (decreasing in AMD about 55,88 %), iron (21,19 %) and aluminium (15,6 %). Based on experimental results we can also state that chosen adsorbent hasn't influenced the pH increasing above 4 (figure 1), which is connected with precipitation of metals.

Precipitation of Cu, Fe, Al and Zn was monitored in dependence on pH change in Table 2.

Table 2 Precipitation of Cu, Fe, Al and Zn in dependence on pH

pH	Cu (mg L^{-1})	Fe (mg L^{-1})	Al (mg L^{-1})	Zn (mg L^{-1})
3,92	1,38	315,5	60,3	6,88
5	0,65	268,8	2,0	6,75
6	<0,02	9,8	<0,1	5,38
7	<0,02	<0,03	<0,1	<0,03
8	<0,02	<0,03	<0,1	<0,03

As it is seen from Table 2, aluminium was precipitated at pH 5 (96,7 %) and at pH 6 was removed 99,9 % of copper and 97 % of iron. Ions of Zn^{2+} were precipitated from AMD at pH 7. Initial assumption about precipitation of followed metals up to pH = 8 has been confirmed.

The biological-chemical method

The operating conditions of the selective sequential precipitation of heavy metals are illustrated in Table 3. The bacterially produced hydrogen sulphide at pH 3.9 (initial pH of AMD), 4.5 and 6.0 was used for the realization of the precipitation of Cu, Zn and Fe respectively (i.e. steps 1., 3. and 5). 1M NaOH as aluminium and manganese hydroxide at pH 6.0 and 9.0 precipitated Al and Mn respectively (i.e. steps 4. and 6.). Fe was precipitated predominantly as hydroxide (steps 2., 4. and 6).

Table 3 Summary of 6-steps precipitation process operating conditions

Step	Operating conditions	Product	Proportional representation
1.	Initial pH of AMD - 3.9 Precipitating agent: Bacterially produced H_2S	CuS	99.99%
2.	pH set point - 4.5 Precipitating agent: NaOH	$Fe(OH)_3$ $Al(OH)_3$	19.40% 80.60%
3.	pH set point - 4.5 Precipitating agent: Bacterially produced H_2S	ZnS	99.99%
4.	pH set point - 6.0 Precipitating agent: NaOH	$Al(OH)_3$ $Fe(OH)_3$	30.70% 69.30%
5.	pH set point - 6.0 Precipitating agent: Bacterially produced H_2S	FeS	99.99%
6.	pH set point - 9.0 Precipitating agent: NaOH	$Fe(OH)_2$ $Mn(OH)_2$	94.90% 5.10%

Figure 6 indicates that Cu was precipitated in the form sulphides CuS (step 1. of precipitation process). The element composition of originated precipitates corresponded with this fact. The suspension of precipitates (CuS) was filtered and the pH value of the filtrate was adjusted at 4.5 using 1M NaOH (step 2. of precipitation process). Figure 7 demonstrates that Al and Fe were precipitated in the form of hydroxides. According the proportional representation of originated precipitates under these conditions Al was precipitated predominantly. The filtrate was returned into the second reactor and again was submitted to the effect of the bacterially produced hydrogen sulphide (the subsequent precipitation – step 3. of precipitation process). Figure 8 shows the selective precipitation of Zn. In like manner steps 4. – 6 were realized. Figures 9 - 11 indicate EDS qualitative analysis of precipitates originating at steps 4 – 6. For Fe, Al and Mn the co-precipitation of Fe and Al or Fe and Mn was determined.

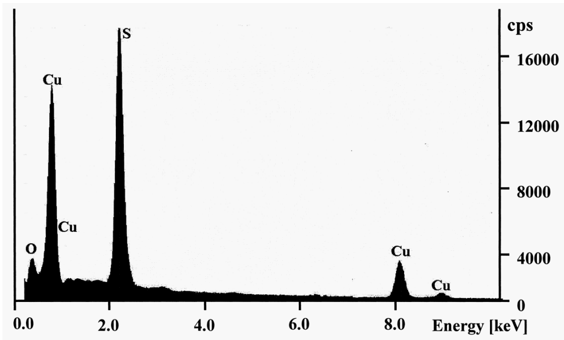

Fig. 6. EDS qualitative analysis of precipitates originating at the precipitation using the bacterially produced hydrogen sulphide by SRB from AMD sample at initial pH of AMD – 3.9 (the selective precipitation of Cu).

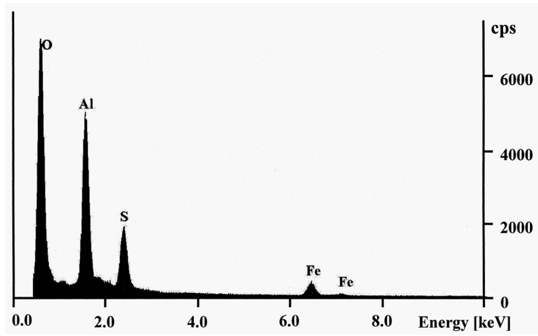

Fig. 7. EDS qualitative analysis of precipitates originating at the precipitation using 1M NaOH from AMD sample at pH 4.5 (the subsequent precipitation - the precipitation of Al and Fe)

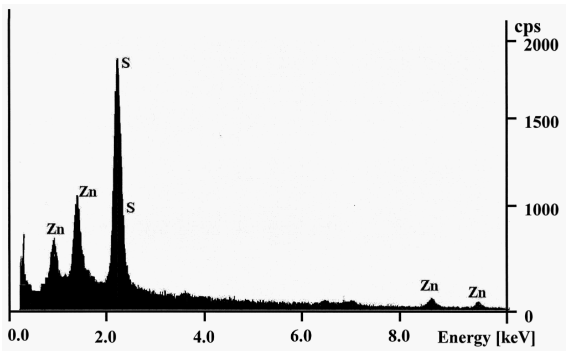

Fig. 8. EDS qualitative analysis of precipitates originating at the precipitation using the biologically produced hydrogen sulphide by SRB from AMD sample at pH 4.5 (the subsequent precipitation - the selective precipitation of Zn)

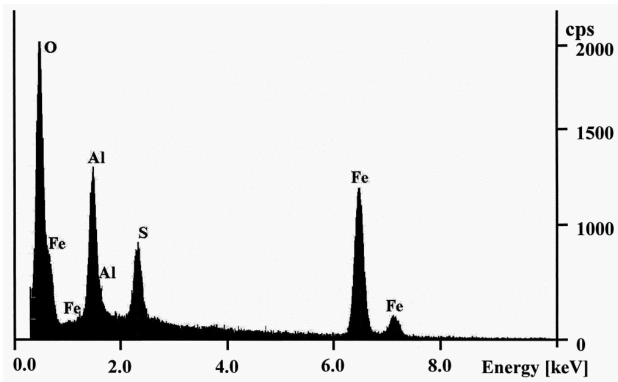

Fig. 9. EDS qualitative analysis of precipitates originating at the precipitation using 1M NaOH from AMD sample at pH 6.0 (the subsequent precipitation - the precipitation of Fe and Al)

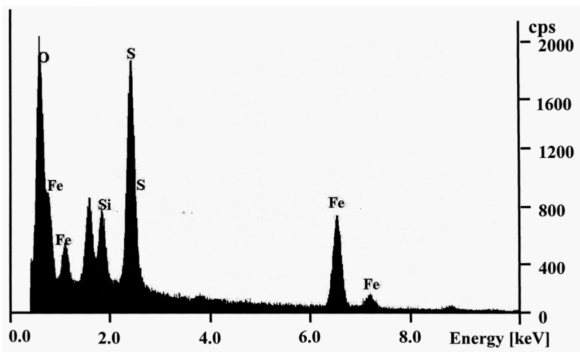

Fig. 10. EDS qualitative analysis of precipitates originating at the precipitation using the biologically produced hydrogen sulphide by SRB from AMD sample at pH 6.0 (the subsequent precipitation - the selective precipitation of Fe)

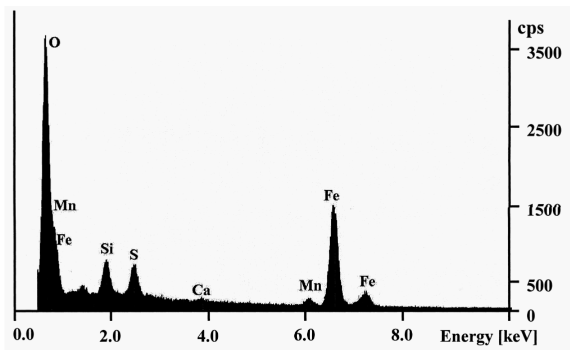

Fig. 11. EDS qualitative analysis of precipitates originating at the precipitation using 1M NaOH from AMD sample at pH 9.0 (the subsequent precipitation - the precipitation of Fe and Mn)

4. CONCLUSION

This work shows the possibility of the natural adsorbent utilization for Cu, Fe, Al and Zn removal from acid mine drainage. Turf brush PEATSORB was the most efficient for zinc removal - decreasing of Zn concentration in AMD was about 95,71 %, then for copper (55,88 %), iron (21,19 %) and aluminium (15,6 %) removal.

The chemical way of metal concentration decrease by precipitation using NaOH was tested, too. Aluminium was precipitated at pH 5 (96,7 %) and at pH 6 was removed 99,9 % of copper and 97 % of iron. Ions of Zn^{2+} were precipitated from AMD at pH 7. Initial assumption about precipitation of followed metals up to pH = 8 has been confirmed.

The study of the selective sequential precipitation and bio recovery of metals of AMD from the deposit of Smolník - shaft Pech was realized by the combination of the metals precipitation by the bacterially produced hydrogen sulphide and the precipitation of metals by sodium hydroxide at the various values of AMD pH. This process is able to sequentially precipitate copper sulphide by H_2S at pH 3,9, zinc sulphide at pH 4,5. The other metal ions (Fe^{2+}, Fe^{3+}, Al^{3+} and Mn^{2+}) were received by precipitation with NaOH as co-precipitates. The selectivity of combined biological – chemical process was 99,9% for Cu (as CuS), Zn (as ZnS).

These results can be used for suggestion of technology for selective metal recovery from acid mine drainage from Smolník.

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Volodymyr V. CHERNYUK [1]

A METHOD OF CALCULATION FOR PRESSURE COLLECTOR-PIPELINES

ABSTRACT

A new method of calculation in which all geometric parameters of the pipeline and all characteristics of the stream are taken into account is suggested for collector pipelines. The results of calculations made by means of obtained formulae practically coincide with experimental data.

KEYWORDS: pressure collector-pipelines, variable mass fluid flow.

1. INTRODUCTION

Enforced streams with discrete joining of fluid along the path take place in water supply (horizontal water collections, ray water intakes, water supply purifying works), amelioration (drainage systems), ventilation (exhaust systems), water lowering (building sites, flooded territories with buildings). The inflow of fluid along the path in collector-pipelines into CP through holes in walls is non-uniform. It increases with the approach to the estuary of CP. Exact hydraulic calculation of pipelines with variable flow rate along the path can be made only by means of theory of variable mass hydraulics [1].

2. ANALYSIS OF THE KNOWN TECHNIQUES OF CP CALCULATION

Differential equation of variable mass fluid flow (DEVMFF) [2, page 18] is the initial equation in CP calculation; for a cylindrical pipeline this equation assumes the form.

$$\frac{\alpha_o(2V - v\cos\beta)dV}{g} + d\left(\frac{p}{\rho g}\right) + \sin\psi \cdot dx + dh_x = 0 \tag{1}$$

where β is the angle between the vector of the main stream velocity $\vec{V}$ inside CP and the vector of the velocity $\vec{v}$ of the joining jet which flows through a hole in the wall into CP; $\sin\psi \cdot dx = dz$ is the geometric head of free cross-sectional area of the stream; ψ is the inclination angle of the axis of CP to the horizon; $dh_x = i_f dx$ are head losses on the friction along the pipeline.

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Series of approaches to integrating DEVMFF [1-10] are suggested. The authors of these works take into account the hydraulic resistance of CP by means of empiric coefficients or assume the hydraulic coefficient of resistance λ to be constant along CP and also assume $\psi = 0^o$ and $\beta = 90^o$. Then, in Equation (1), $sin\psi \cdot dl = 0$, $\alpha_o v \cdot cos\beta \cdot dV / g = 0$ and respectively $m = (v cos\beta)/V = 0$. However, in reality incliner CP ($\psi \neq 0^o$), $m \neq const$ prevail, and the hydraulic resistances of CP increases along CP. Besides, the variables in Equation (1) the authors express in terms of the flow rate $Q_{(x)}$ of the main stream, though the main energetic factor which forms the inflow of fluid into CP is the total operating head. Methods of designing CP in which all the parameters of Equation (1), including variable once a take into account are lacking. If the design variables of perforated pipeline and the hydrodynamic peculiarities of the variable mass stream are taking into account in completely, it leads to considerable miscalculations in designing CP, this reduces the efficiency of their work [9, page 3].

3. AIM OF THE WORK: on the bases of the DEVMFF solution [11] to developed the technique of CP calculation taking into account all geometric parameters of CP and characteristics of the main stream and of joining jets and to test it experimentally.

4. REDUCING THE DEVMFF (1) TO TWO-VARIABLE EQUATIONS

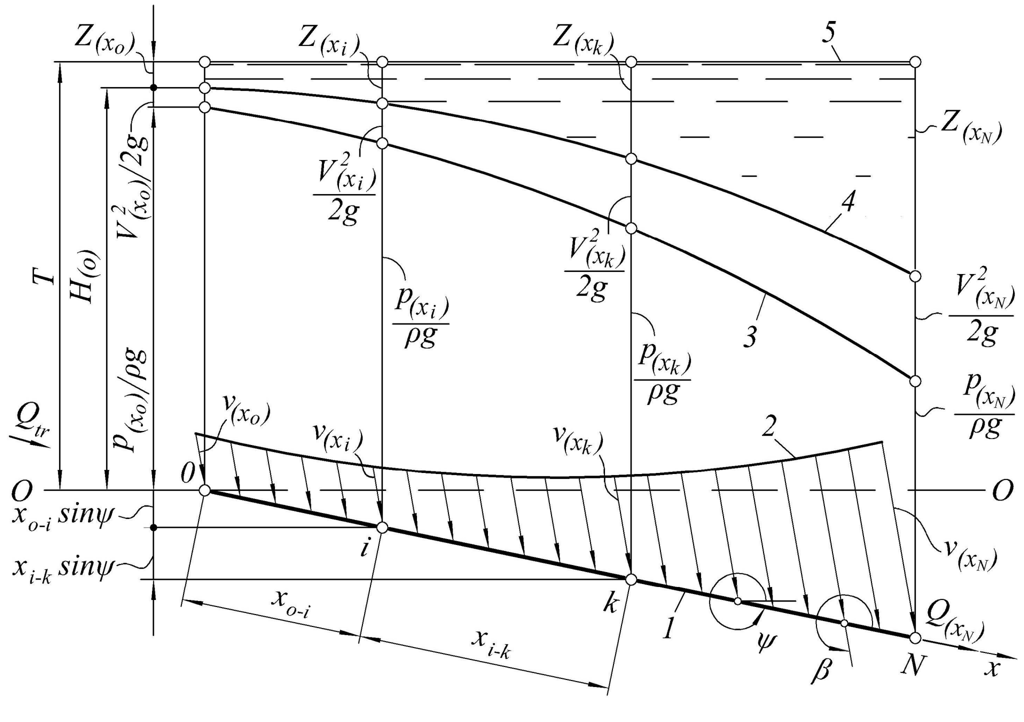


Fig.1. Diagram of CP calculation: 1 – CP; 2 – profile of velocity of joining tributaries; 3 – piezometric curve of stream inside CP; 4 – curve of total head of the same stream; 5 – fluid level outside CP; *x* – axis of CP

The main stream in CP forms by joining individual tributaries to it due to the operating head $Z_{(x)}$. The variables V, dV, v, dp, dh_x, dx in DEVMFF (1) are expressed in terms of the total operation head $Z_{(x)}$ (Fig.1.) and interns of the independent variables x [11]. It the assumed the angle β and ψ wary within $0 \div 360^o$, and the coefficient

$m_{(x)} = v_{(x)} \cos\beta / V_{(x)} \neq const$. As a result, for cylindrical CP a non-linear integro-differential equation of enforced fluid flow with discrete joining of mass along the path in the unknown function $Z_{(x)}$ [11] is obtained:

$$\frac{1}{2g\omega^2 D} d\left[\lambda_{(x)}\left(Q_{tr} + b\int_0^x Z_{(x)}^{1/2} dx\right)^2 x\right] + \frac{(2\alpha_o - \alpha)}{g\omega^2}\left(Q_{tr} + b\int_0^x Z_{(x)}^{1/2} dx\right) bZ_{(x)}^{1/2} dx - \\ - \frac{\alpha_o}{g\omega} ab \cdot \cos\beta \cdot Z_{(x)} dx - dZ_{(x)} + 2\sin\psi \cdot dx = 0, \qquad (2)$$

where D is the inner diameter of CP; ω is its cross-section area; $\lambda_{(x)}$ is the hydraulic coefficient of the friction; Q_{tr} is the transitional flow rate at the intake of CP; $a = \varphi\sqrt{2g}$; φ is the coefficient of velocity; $b = n\mu\omega_o\sqrt{2g}$, $m^{1.5}/s$, $b = const$ on the segment of CP between the neibouring inlet holes; n is the number inlet holes per unit length of CP, m^{-1}; ω_0 is the area of one hole; μ is the coefficients of its flow rate; $Z_{(x)}$ is the total operating head under the action of which the joining jet flows into CP (Fig. 1), $Z_{(x)} = H_o - \left[\left(p_{(x)}/\rho g\right) - x\sin\psi + \left(\alpha V_{(x)}^2/2g\right)\right]$; H_0 is the outside head of CP; $p_{(x)}/\rho g$ is the piezometric head in CP (see Fig. 1) ; α is the coefficient of kinetic energy; α_0 is the coefficient of momentum.

5. SOLUTION OF EQUATION (2)

Due to the absence of transitional flow rate Q_{tr}, laminar flow takes place of the beginning CP. Farther along the stream at a sufficient length of CP, three segments of resistance of turbulent fluid flow zone are situated in sequence: (*a*) of hydraulically smooth pies, of prequadratic resistance of hydraulically rough pies (*b*), of quadratic resistance of hydraulically rough pies (*c*).

From Equation (2), Expression (3) is obtained for calculated flow rates of the fluid which joining the main stream in CP on the segment length *x*. Formula (3) is universal and good for calculating laminar streams and for all the segments of resistance of turbulent fluid flow in CP

$$b\int_0^x Z_{(x)}^{1/2} dx = bZ_{(0)}^{1/2} x + \frac{b^2 x^2}{4g\omega}\left[(2\alpha_o - \alpha)\cdot V_{tr} - \alpha_o v_{(0)} \cos\beta\right] + \\ + \frac{bx}{4Z_{(0)}^{1/2}}\left(\lambda_{(x)} \frac{x}{D}\frac{V_{tr}^2}{2g} + 2\sin\psi \cdot x\right). \qquad (3)$$

6. TECHNIQUE OF CP CALCULATION

The calculating of CP is carried ant in sequence of short segments with the stream. For an inlet cross section of CP, the value total operating head $Z_{(o)}$ inside the CP and the velocity of the stream $V_{(o)}$ are to be determined. The flow rate of the fluid which joining the main stream on the length $x_{(i-k)}$ (see Fig. 1) is calculated according the flowing form:

$$b_{(i-k)}\int_{x_i}^{x_k} Z_{(x)}^{1/2}dx = b_{(i-k)}x_{(i-k)}\left\{Z_{(x_i)}^{1/2} + \frac{b_{(i-k)}x_{(i-k)}}{4g\omega_{(x_i)}}\left[(2\alpha_o - \alpha)\cdot V_{(x_i)} - \alpha_o v_{(x_i)}\cos\beta_{(x_i)}\right] + \right.$$
$$\left. + \frac{1}{4Z_{(x_i)}^{1/2}}\left(\lambda_{(x_i)}\frac{x_{(i-k)}}{D_{(x_i)}}\frac{V_{(x_i)}^2}{2g} + 2x_{(i-k)}\sin\psi_{(x_i)}\right)\right\}. \quad (4)$$

The relation (5) for stepwise calculation of the total operating head $Z_{(x)}$ under the action of with the jet penetrates into CP in the cross-section k is obtained by means of differentiating Expression (3)

$$Z_{(x_k)} = \left\{Z_{(x_i)}^{1/2} + \frac{\kappa\cdot b_{(i-k)}x_{i-k}}{2g\omega_{(x_i)}}\left[(2\alpha_o - \alpha)\cdot V_{(x_i)} - \alpha_o v_{(x_i)}\cos\beta_{(x_i)}\right] + \right.$$
$$\left. + \frac{\kappa}{2Z_{(x_i)}^{1/2}}\left(\lambda_{(x_i)}\frac{x_{(i-k)}}{D_{(x_i)}}\frac{V_{(x_i)}^2}{2g} + 2x_{(i-k)}\sin\psi_{(x_i)}\right)\right\}^2, \quad (5)$$

where in (4) and (5) the subscript x_i indicates that the parameters of equations belong to the beginning of the calculated segment $i-k$ (see Fig. 1); $b_{i-k} = n_{(x_i)}\mu_{(x_i)}\omega_{o(x_i)}\sqrt{2g}$; $V_{(x_i)}$ is the averaged velocity of the main stream in the cross-section x_i of CP; $v_{(x_i)}$ is the velocity of the jet with is joining, $v_{(x_i)} = \varphi_{(x_i)}\sqrt{2gZ_{(x_i)}}$; $\lambda_{(x_i)}$ is the hydraulic coefficient of friction.

For $Re_{(x_i)} \le 2320$ (laminar flow):

$$\lambda_{(x_i)} = 64/Re_{(x_i)}. \quad (6)$$

For $Re_{(x_i)}\left(\Delta_{(x_i)}/D_{(x_i)}\right) < 10$ (segment of hydraulically smooth-pipes of turbulent flow zone):

$$\lambda_{(x_i)} = 0.3164/Re_{(x_i)}^{0.25}. \quad (7)$$

For $10 \le Re_{(x_i)}\left(\Delta_{(x_i)}/D_{(x_i)}\right) \le 500$ (segment of prequadratic resistance of hydraulically rough pipes of turbulent flow zone):

$$\lambda_{(x_i)} = 0.11\left[\Delta_{(x_i)}/D_{(x_i)} + 68/Re_{(x_i)}\right]^{0.25}. \quad (8)$$

For $Re_{(x_i)}\left(\Delta_{(x_i)}/D_{(x_i)}\right) > 500$ (segment of quadratic resistance of hydraulically rough pipes of turbulent flow zone):

$$\lambda_{(x_i)} = 0.11\left(\Delta_{(x_i)}/D_{(x_i)}\right)^{0.25}. \quad (9)$$

The value of Reynolds' criterion for the main stream in CP is determined according to the formula

$$Re_{(x_i)} = Q_{(x_i)}D_{(x_i)}/\omega_{(x_i)}v_{(x_i)}, \quad (10)$$

where $v_{(x_i)}$ is the kinematic viscosity.

Substitution of $y = Ax + Bx^2$ for $y = \int_o^x Z_{(x)}^{1/2} dx$ in solving Equation (2) has let to the introduction of the empiric coefficient κ into the calculation formula (5). In order to determine values of the coefficient κ, results of experimental investigations of CP with D = 46.3 *mm* [12] were used. For example, at the relative pitch of inlet nozzles l_{hole}/D = $4.32 \div 12.95$ and in the absence of transitional flow rate ($Q_{tr} = 0$) the coefficient κ = 1.65. For l_{hole}/D = $12.95 \div 43.2$ and $Q_{tr} = 0$, the coefficient κ with approximation truth R^2 = 0,9684 $\kappa = 0.029(l_{hole}/D) + 1.2797$. In the presence transitional flow rate ($Q_{tr} \neq 0$) at the intake of CP, this Q_{tr}, whim in V.A. Voloshchuk's experiments was with $(2 \div 6) \cdot 10^{-4}\ m^3/s$, for relative pitch of inlet nozzles l_{hole}/D = $8.64 \div 17.27$, the value of the coefficient $\kappa \approx 1.54$.

Coefficients of the flow rate inlet-hole or of inlet-nozzle $\mu_{(x_i)} = f(\mathrm{Re}_{hole_{(x_i)}}, l/d)$ where l is the thickness of CP wall or the length of inlet nozzle; d is the diameter of inlet-hole or of inlet nozzle; $Re_{hole(x_i)}$ is the Reynolds' number for the jet which flows through inlet-hole or through inlet-nozzle in the cross-section x_i of CP, $Re_{hole(x_i)} = f(Z_{(x_i)})$. For example, for a cylindrical inlet-nozzle at $Fr_{(x_i)}$>10, $We_{(x_i)}$>200, for perfect total compression and sharp inlet edges the value of the coefficient $\mu(x_i)$ can be calculated by means of empiric formulae obtained by formulae from [13, pages 68-71]. One of these relations for the ratios: $l/d = 1\ldots1.5$, $\mathrm{Re}_{theor_{(x_i)}} = l/d = 1\ldots1.5$, $Re_{th(x_i)} = 10^3\ldots10^5$ or $l/d = 2\ldots5$, $Re_{th(x_i)} = 50\ldots15 \cdot 10^4$, or $l/d = 10\ldots50$, $Re_{th(x_i)} = 80\ldots15 \cdot 10^4$ is of the form [13, page 69]

$$\mu_{(x_i)} = 1/\left(1.23 + 58 \cdot l/Re_{th(x_i)}\, d\right). \tag{11}$$

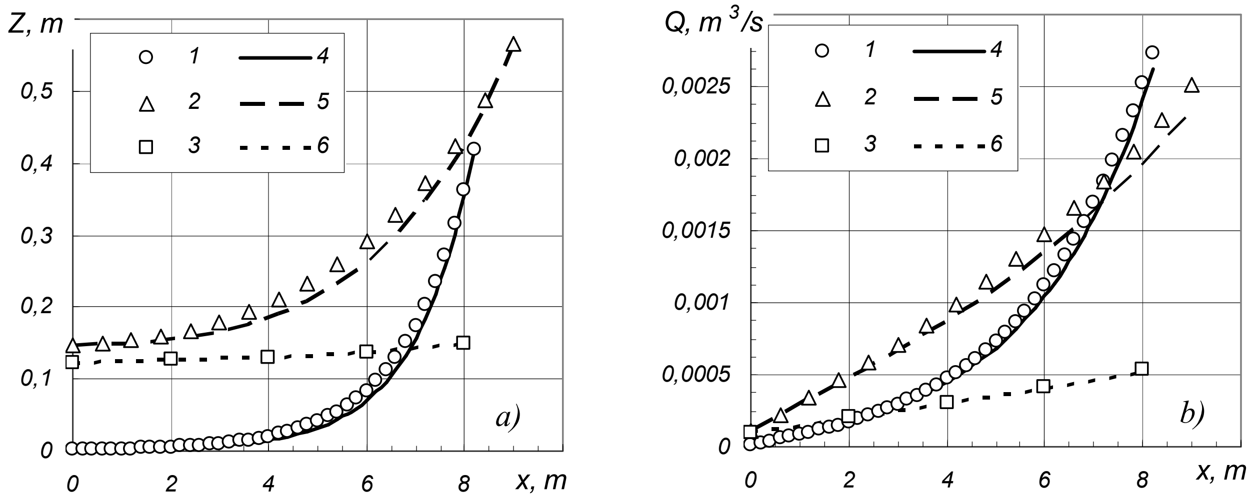
where $Re_{th(x_i)} = \sqrt{2gZ_{(x_i)}} \cdot d/\nu$ is the Reynolds' number for joining jet at a "theoretical velocity of running in" $\sqrt{2gZ_{(x_i)}}$ [13, page 61].

At the first inlet hole in the cross-section $x = 0$ of CP (Fig.1), the total operating head under the action of which the jet flows into CP $Z_{(x)} = Z_{(0)}$. In the absence of transitional flow rate ($Q_{tr} = 0$), the value of $Z_{(0)}$ should be set, for example $Z_{(0)} = 10^{-2} \cdot H_{(0)}$. The flow rate in the cross-section x_i is calculated according to the formula (4). Then, the operating head $Z_{(x_i)}$ at the end of the calculated segment $0 - i$ is determined according to the formula (5). The calculation should be made along the stream in all the intermediate segments up to the cross-section *N*. For each segment, the values of $Q_{(x_i)}$ and of $Z_{(x_i)}$ are to be determined. It is expedient to take the lengths of the calculated segments $x_{(i-k)}$ equal the lengths l_{hole} between the neighbouring inlet holes.

7. COMPARISION OF CALCULATION WITH EXPERIMENTAL DATA

The values of the total operating head $Z_{(x)}$ and flow rates $Q_{(x)}$ inside CP with are calculated according to formulae (4)-(11) both in the pressure and the absence of transitional flow rates Q_{tr} are in good agreement with the experimental data [12] (Fig. 2).

Fig. 2. Total the total operating head (*a*) and flow rates of water (*b*) in CP with different values of l_{hole}/D and of $Z_{(o)}$ (in *meters*): 4.32 and 0.0026 (1, 4); 12.95 and 0.1481 (2, 5); 43.19 and 0.2845 (3, 6); 1-3 experimental data [12]; 4-6 – results calculations according to the formulae (4)-(11); $D = 46.3\ mm$; $Q_{tr} = 0$; $\varphi = 90^o$; $\psi = 0^o$



8. CONCLUSIONS

A new approach to solving the differential equation of variable mass fluid flow is suggested. It consists in expressing all the variables of DEVMFF in terms of the total operating head $Z_{(x)}$ in CP. The influence of or variable magnitudes of all geometric parameters of CP, of kinematic and dynamic characteristics of the main stream and those of tributaries, including the angle $\beta_{(x)}$ of the joining of tributaries, the angle $\psi_{(x)}$ of the inclination of CP axis to horizon as well as the change of modes of flow and laws of hydraulic resistance along the stream. The deduced relations are good for designing long, short, and inclined CP even when tributaries join the stream not at right angles $\beta_{(x)}$. The calculation is made in short segments along the stream. The results calculated according the suggested technique practically coincides with the experimental data.

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EXPERIMENTAL VERIFICATION OF A NEW METHOD OF CALCULATION FOR PRESSURE DISTRIBUTIVE PIPELINES

ABSTRACT

In comparison with all the known methods of calculation for pressure distributive pipelines (PDP), those developed by Chernyuk,V.V. proved to most exactly agree with results of experiments. Calculated by this technique values of flow rate and of heads of fluid inside PDP practically coincide with experimental data.

KEYWORDS: pressure distributive pipelines, variable mass fluid flow.

1. INTRODUCTION

Pressure pipelines with discrete fluid dispensation along the path are used in different branches of economic activity of the human: irrigation (drip, subsurface, surface); ventilation (discharge systems); metallurgic industry (cooling systems); water transport (distributive lock-feed piping systems and those of large dry docks); water supply and water drainage (distributive pipe systems of purification works, dispersed discharge of sewage) and others. There are different techniques of calculation for pressure distributive pipelines (PDP).

The most perfect of them are based on differential equation of variable mass fluid flow (DEVMFF) [1]. The creator of the theory of motion of variable mass bodies is prof. Meschersky,I.V. (1897). In 1928, prof. Makkaveev,I.V. for the first time deduced the general DEVMFF. In 1937, prof. Nen'ko,Ya.T. obtained the DEVMFF for total stream of fluid and applied it to problems of calculating perforated PDP [2]. For cylindrical PDP DEVMFF is of the form [3]:

$$\frac{\alpha_0(v\cos\varphi - 2V)\cdot dV}{g} + \frac{dp}{\rho g} + \sin\psi \cdot dx + dh_x = 0\,, \tag{1}$$

where V is the average velocity of the main stream; v is the same for the flow of an outlet jet; p is the pressure inside PDP; $\sin\psi \cdot dx = dz$ is the geometric head; $dh_x = i_f dx$ is the loss of head along PDP; φ is the angle between the vectors $\vec{v}$ and $\vec{V}$; ψ is the angle of the inclination to horizon (Fig. 1).

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In the existing methods, some variables of DEVMFF are expressed in terms of the main flow $Q_{(x)}$, and the angle $\psi_{(x)}$ of inclination to horizon and is the angle $\varphi_{(X)}$ between the axis of PDP and the direction of outlet jets are neglected. Besides, in the known methods, the magnitude of the friction factor $\lambda_{(x)}$ of PDP and that of the coefficient of the flow rate $\mu_{(x)}$ of outlets (nozzles) are assumed to be constant along the PDP. The non-complete taking into account of design variables of a perforated pipeline and that of hydrodynamic peculiarities of variable mass flow lead to considerable miscalculations [4].

2. TECHNIQUE OF PDP CALCULATION SUGGESTED BY CHERNYUK,V.V. [3]

Doc. Chernyuk,V.V. has suggested a new approach to solving DEVMFF for PDP [3]. It consists in expressing all the variables of DEVMFF in terms of the total operation head $H_{(x)}$ in the PDP. The calculation of PDP made by means of the relations obtained from the solution of DEVMFF practically coincides with the experimental data. The influence of constant or variable magnitudes of all the geometric parameters of PDP, those of kinematic and dynamic characteristics of the main stream and of outlet jets, including the angle $\varphi_{(x)}$ of jet outlets, the angle $\psi_{(x)}$ of inclination, and the change in modes of flow and in laws of resistance along the PDP are taken into account. The deduced relations are good for designing long, intermediate, short, horizontal and inclined PDP. According to the technique suggested by Chernyuk,V.V. [3], the flow rate $b\int_{x_i}^{x_k} H_{(x)}^{1/2}dx$ of the fluid which is dispensed from PDP in its segment $i-k$ whose length x_{i-k} is calculated by means of Equation (2);

$$b_{(i-k)}\int_{x_i}^{x_k} H_{(x)}^{1/2}dx = b_{(i-k)}x_{(i-k)}\left\{H_{(x_i)}^{1/2} + \frac{b_{(i-k)}x_{(i-k)}}{4g\omega_{(x_i)}}\left[\left(2\alpha_o + \alpha\cos\varphi_{(x_i)}\right)V_{(x_i)} - \alpha_o v_{(x_i)}\cos\varphi_{(x_i)}\right] + \right.$$
$$\left. + \frac{1}{4H_{(x_i)}^{1/2}}\left(\lambda_{(x_i)}\frac{x_{(i-k)}}{D_{(x_i)}}\frac{V_{(x_i)}^2}{2g} + 2x_{(i-k)}\sin\psi_{(x_i)}\right)\right\}. \tag{2}$$

The calculation of PDP is made against the stream. The lengths of the segments are taken to be equal to the distances between outlets (nozzles) l_{hole}. The values of total heads are determined according to Formula (3);

$$H_{(x_k)} = \left\{H_{(x_i)}^{1/2} + \frac{\kappa\cdot b_{i-k}x_{i-k}}{2g\omega_{(x_i)}}\times\left[\left(2\alpha_o + \alpha\cos\varphi_{(x_i)}\right)V_{(x_i)} - \alpha_o v_{(x_i)}\cos\varphi_{(x_i)}\right] + \right.$$
$$\left. + \frac{\kappa}{2H_{(x_i)}^{1/2}}\left(\frac{\lambda_{(x_i)}x_{i-k}}{D_{(x_i)}}\frac{V_{(x_i)}^2}{2g} + 2x_{i-k}\sin\psi_{(x_i)}\right)\right\}^2, \tag{3}$$

where $V_{(x_i)}$ is the average velocity of the main stream in the cross-section x_i of PDP (Fig. 1); $v_{(x_i)}$ is the velocity of outlet jet; $b = n\mu\omega_o\sqrt{2g} = const$, $m^{1.5}/s$; $\omega_o = \pi d^2/4$ is the area of the outlet hole (nozzle); d is its diameter; n is the number of holes per unit length of PDP, m^{-1}; D is the inner diameter of PDP.

Friction factor $\lambda_{(x)}$ for PDP is calculated according to the formulae for $Re_{(x_i)} \le 2320$ (laminar flow):

$$\lambda_{(x_i)} = \frac{64}{Re_{(x_i)}}; \tag{4}$$

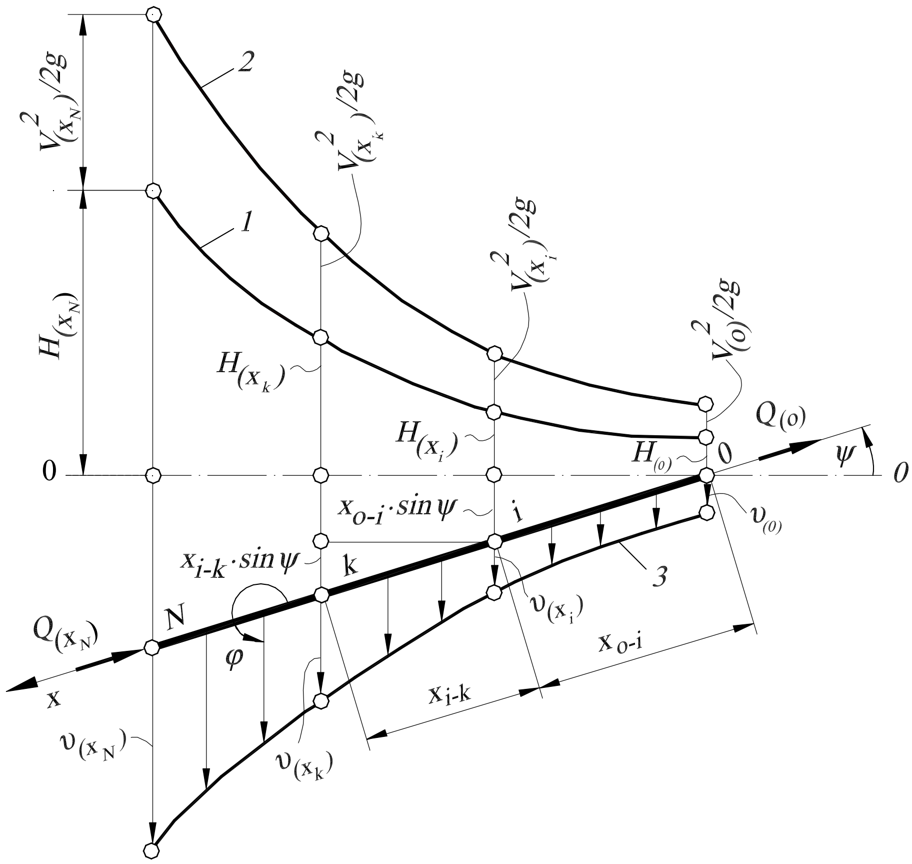

Fig.1. Schematic diagram of PDP calculation against the stream; 1 – curve of piezometric head; 2 – curve of total head; 3 – profile of average velocity of running out jets; x – axis of PDP

for $Re_{(x_i)}\dfrac{\Delta_{(x_i)}}{D_{(x_i)}}<10$ ("smooth-pipe" turbulent flow):

$$\lambda_{(x_i)}=\frac{0.3164}{Re_{(x_i)}^{0.25}}; \tag{5}$$

for $10\le Re_{(x_i)}\dfrac{\Delta_{(x_i)}}{D_{(x_i)}}\le 500$ (transitional turbulent flow):

$$\lambda_{(x_i)}=0.11\left[\frac{\Delta_{(x_i)}}{D_{(x_i)}}+\frac{68}{Re_{(x_i)}}\right]^{0.25}; \tag{6}$$

for $Re_{(x_i)}\dfrac{\Delta_{(x_i)}}{D_{(x_i)}}>500$ ("rough-pipe" turbulent flow):

$$\lambda_{(x_i)}=0.11\left(\frac{\Delta_{(x_i)}}{D_{(x_i)}}\right)^{0.25}; \tag{7}$$

and the value of Reynolds' number for the main stream in PDP is determined according to the formula

$$Re_{(x_i)}=\frac{Q_{(x_i)}D_{(x_i)}}{\omega_{(x_i)}\nu_{(x_i)}}; \tag{8}$$

where $\nu_{(x_i)}$ is the kinematic viscosity; $v_{(x_i)}$ is the velocity of jet; φ is the coefficient of velocity; $\varphi_{(x_i)}$ and $\psi_{(x_i)}$ are the angles, the reference is made counterclockwise as it shown in Fig.1.

Coefficients of flow rate outlet-hole or of outlet-nozzle $\mu_{(x_i)} = f(\mathrm{Re}_{hole_{(x_i)}}, l/d)$ where l is the thickness of PDP wall or the length of outlet nozzle; d is the diameter of outlet-hole or of outlet nozzle; $\mathrm{Re}_{hole_{(x_i)}}$ is the Reynolds' number for the jet which flows through outlet-hole or through outlet-nozzle in the cross-section x_i of PDP, $\mathrm{Re}_{holer_{(x_i)}} = f(H_{(x_i)})$. For example, for a cylindrical outlet-nozzle at $Fr_{(x_i)}$>10, $We_{(x_i)}$>200, for perfect total compression and sharp inlet edges the value of the coefficient $\mu_{(x_i)}$ can be calculated by means of empiric formulae obtained by formulae from [5, pages 68-71]. One of these relations for the ratios: $l/d = 1\ldots1.5$, $\mathrm{Re}_{theor_{(x_i)}} = 10^3...10^5$ or $l/d = 2\ldots5$, $\mathrm{Re}_{theor_{(x_i)}} = 50...15 \cdot 10^4$ or $l/d = 10\ldots50$, $\mathrm{Re}_{theor_{(x_i)}} = 80...15 \cdot 10^4$ is of the form [5, page 69];

$$\mu_{(x_i)} = \frac{1}{1.23 + \dfrac{58 \cdot l}{\mathrm{Re}_{theor_{(x_i)}} d}}; \tag{9}$$

where $\mathrm{Re}_{theor_{(x_i)}} = \sqrt{2gH_{(x_i)}} \cdot d / \nu$ is the Reynolds' number for a jet at a "theoretical velocity of running out" [5, page 61].

At the estuary of the PDP in the cross-section $x = 0$ (Fig. 1) the flow rate equals the transitive one $Q_{(0)} = Q_{tr}$, and the operating head $H_{(x)} = H_{(0)}$. The latter is calculated by the formula $q_{(0)} = \mu\omega_o\sqrt{2gH_{(0)}}$; the value of the flow rate $q_{(0)}$ through the last outlet-hole which is to be realized should be substituted into this formula.

3. AIM OF THE PAPER

To experimental test the technique of calculation for PDP developed by Chernyuk,V.V. [3] on the basis of the new approach to solving DEVMFF for PDP are determined according to Formula (1)

4. EXPERIMENTAL PROCEDURE

The investigations were carried out on an experimental PDP whose diameter D = 8.21 mm, the water was supplied by gravitation [6]. The material of the pipes was stainless steel. The pipes were joined by flanges.

In the network of experimental PDP, holes with diameter of 3.2 mm were drilled along a generatrix; coaxially to them, water outlets whose lengths was 25 mm and the inner diameter d = 3.2 mm were welded to the wall. They were situated with the interval multiple of 10d. Depending on the purpose, these outlets were used for dispensation along the path or they served as unions to which rubber pulse tubes where connected to join with piezometers (Fig. 2). For convince in reading the schematic diagrams, unions in the diagram (Fig. 2) a directed upward, and water outlets are oriented downward, as it really was. The inner diameter of rubber pulse tubes is 8 mm. Heads were measured by piezometers correct to 0.5 mm. The operating head in the experimental PDP was 3740 mm when the valve *11* at its end was closed (Fig. 2). Head tank *2* which has an overflow wall ensured constant head in the experimental PDP, constant flow rate; and it prevented pulsations.

The nozzle to pipe cross-section ratio of PDP was calculated according to the formula [7, page 30]:

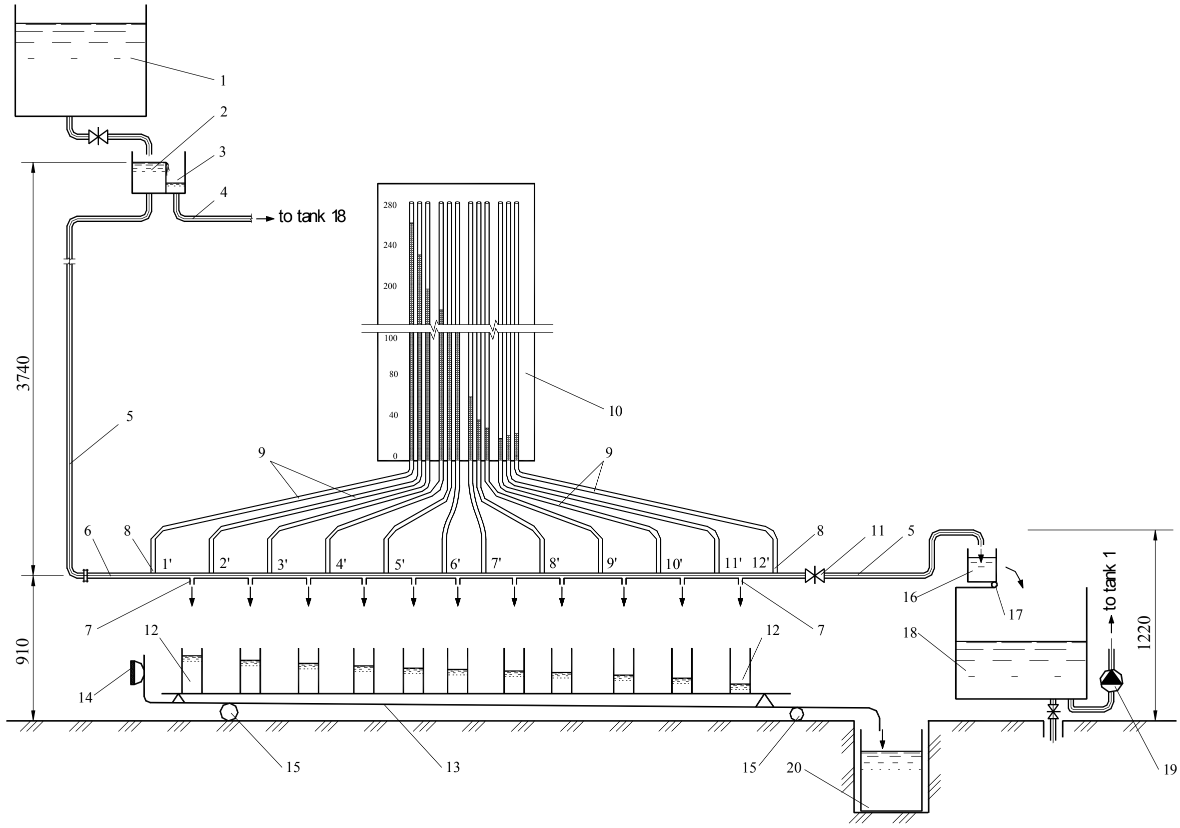

Fig. 2. Schematic diagram of experimental setup: 1 – tank; 2 – head tank; 3 – overflow tank; 4 – overflow pipe; 5 – supply pipe; 6 – experimental PDP; 7 – water outlets; 8 – unions; 9 – rubber pulse tubes; 10 – board of piezometers; 11 – valve; 12 – measuring vessels; 13 – movable trough; 14 – handle; 15 – rolling bearings; 16 – measuring tank; 17 – hinge; 18 – receiving tank; 19 – pump; 20 – water collecting tank; 1`–12` – numeration of unions (dimensions are given in mm)

$$f = \frac{n \cdot \omega}{\Omega} , \tag{8}$$

where ω is the area of the cross-section of water inlet nozzle, $\omega = \frac{\pi d^2}{4}$; n is the number of water inlet nozzles in the whole PDP; Ω is the area of the cross-section of the experimental PDP, $\Omega = \frac{\pi D^2}{4}$.

The non-homogeneity of the water dispensation along the path from the PDP is calculated like this [7, page 32]:

$$\eta = \frac{q_{beginning}}{q_{end}} , \tag{9}$$

where $q_{beginning}$, q_{end} are flow rates through the first and the last water inlet nozzles of PDP respectively.

The flow rates q of water through the nozzles where determined in terms of volume with a help of the measuring vessels *12* (Fig.2).

The relative change of non-homogeneity in the dispensation of water along the path is caused by the inclination of PDP compared to its zero inclination under other analogical conditions is

$$\frac{\Delta\eta}{\eta} = 1 - \frac{\eta_\psi}{\eta_o} \cdot 100\% \ , \qquad (10)$$

where subscripts ψ and 0 denote the water flow in PDP with inclination to horizon at the angle of $\psi \neq 0$ and $\psi = 0$ respectively.

The flow rate at the end of PDP (Fig. 1)

$$Q_{\text{beginning}} = Q_{(xN)} = \Sigma q + Q_{tr} \ , \qquad (11)$$

where Q_{tr} is the transitional flow rate at the end of PDP which was also determined in terms of volume with a help of the measuring tank *16* (Fig.2) according to Fig. 1, $Q_{tr} = Q_{(o)}$.

5. COMPARISON OF PDP CALCULATION TECHNIQUE [3] WITH EXPERIMENTAL DATA

PDP of intermediate lengths were investigated with eleven (Fig. 3a) and with eight (Fig.3b) water inlet nozzles whose nozzle to pipe cross-section ratio f = 1.469 and 1.215 and whose operating length L = 2644 mm and 1276 mm respectively.

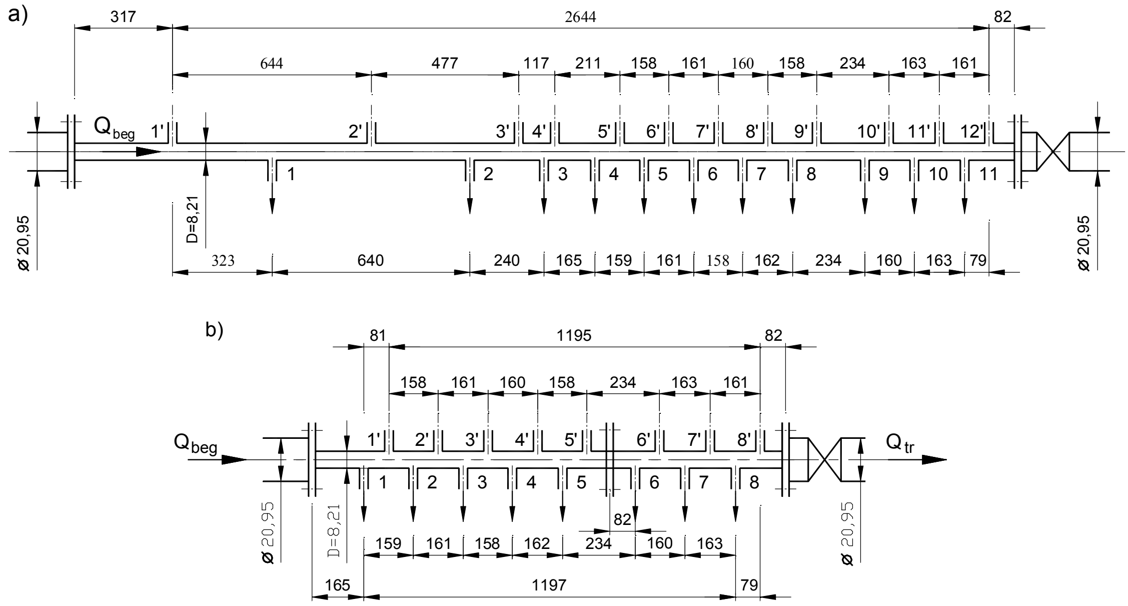

Fig. 3. Schematic diagram of experimental PDP whose f = 1.469 (a) and 1.215 (b): 1-11 – water inlet nozzles; 1`–12` – unions for connecting rubber pulse tubes; $Q_{\text{beginning}}$ – flow rate at beginning of PDP; Q_{tr} – transitional flow rate (dimensions are given in mm)

During investigation on PDP with f = 1.469, the transitional flow rate in the cross-section 0 (Fig. 1) was absence, and the head $H_{(0)}$ = 0.104 m. With this, the non-homogeneity of the water dispensation along the path from PDP was η = 2.77 (Fig. 4).

The investigation on PDP with f = 1.469 (Fig. 6) were carried out under its different inclinations according to the schematic diagram given in Fig.5, at the absence ($Q_{tr} \neq 0$) and presence ($Q_{tr} = Q_{(o)} = 0$) of transitional flow rate in the cross-section 0 (Fig. 1).

According to Fig. 6, the non-homogeneity η of water dispensation along the path from PDP is shown in Table 1.

Table 1. Non-homogeneity of water dispensation from PDP along the path

Angle of inclination to horizon $\psi_{(x)}$, agree	$Q_{tr} \neq 0$		$Q_{tr} = 0$	
	η	$\Delta\eta/\eta$, %	η	$\Delta\eta/\eta$, %
0	1.671	—	1.867	—
5.3	1.945	–16.4	2.291	–22.7
354.7	1.622	2.9	1.692	9.4

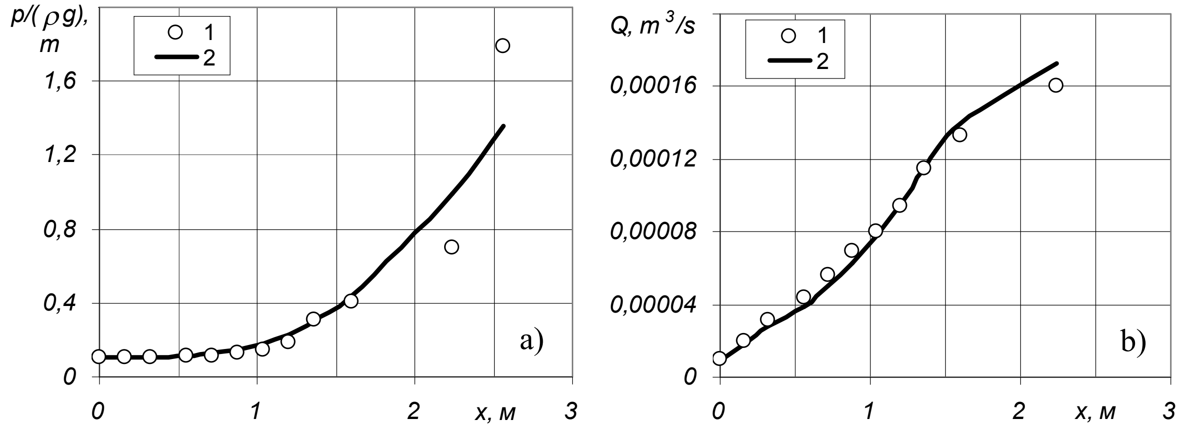

Fig. 4. Comparison of results for PDP whose *f = 1.469*:
a – piezometric head inside PDP; b – flow rate inside PDP;
1 – experimental data; 2 – calculation according to the formulae (2)–(7);
x-axis is directed against the stream [9]

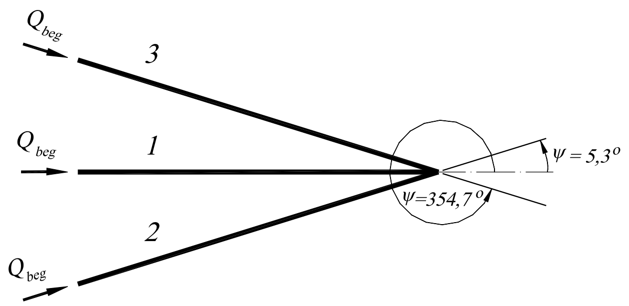

Fig. 5. Schematic diagram of inclined PDP:
1 – zero inclination (ψ = 0°); 2 – descending of pipe along the flow (ψ = 5.3°); 3 – ascending of pipe along the flow (ψ = 354.7°)

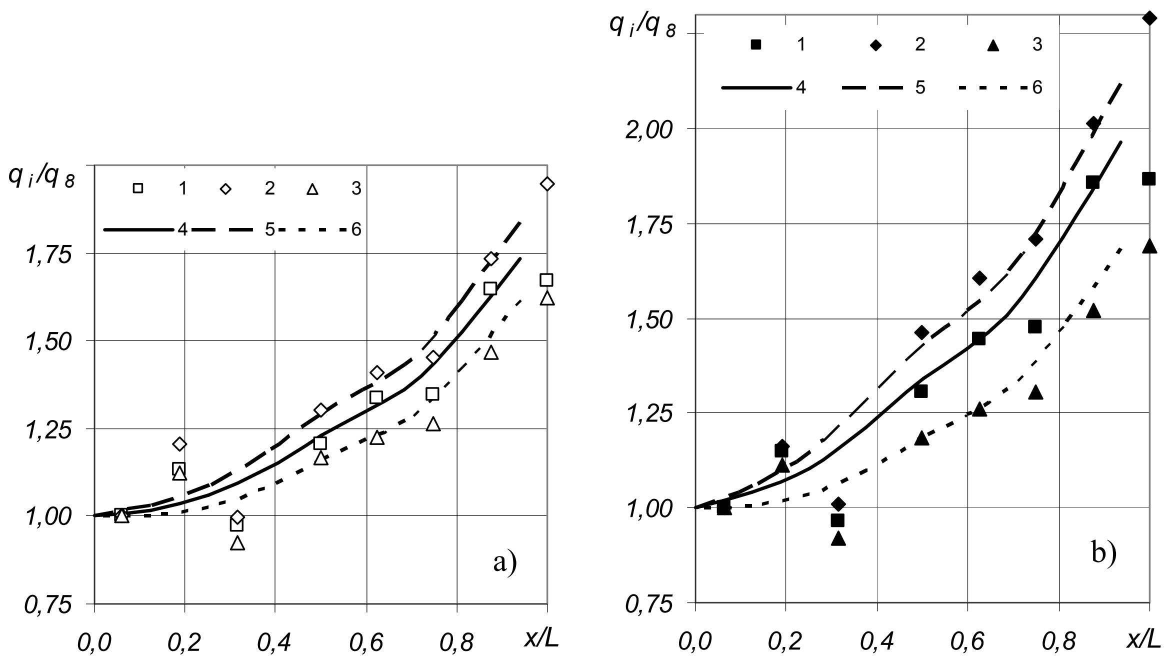

Fig. 6. Relative variation of water dispensation along the stream for PDP with f = 1.215 for $Q_{tr} = Q_{(o)} = 0$ (a) and $Q_{tr} \neq 0$ (b): 1-3 – experimental data; 4-6 – calculation according to the formulae (2)–(7); 1, 4 – ψ = 0°; 2, 5 – ψ = 5.3°; 3, 6 – ψ = 354.7°;
L – operating length of PDP; x-axis is directed against the stream

Thus, the least non-homogeneity of water dispensation from PDP along the path is observed under ascending of pipe along the flow ($\psi = 354.7^{o}$), and the greatest one under descending of pipe along the flow ($\psi = 5.3^{o}$). The presence of transitional flow rate ($Q_{tr} \neq 0$) lessens the non-homogeneity of water dispensation from PDP along the path. This can be seen from our calculation and is confirmed by experiments (Fig. 6, Table 1).

6. CONCLUSIONS

The method of calculation for pressure distributive pipelines (PDP) [3] is good for calculations horizontal, ascending, and descending of PDP; this is confirmed by experiments. The values of heads, of flow rates of water inside PDP and of the water dispensation along the path which are calculated according to the formulae (2)–(7) practically coincide with the experimental data.

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FORMING THE DELIVERY JETS OF DIFFERENT DECAY RATE

ABSTRACT

Modern air distributive devices allow to form the different types of stream with parameters that can differ and by fading rates. Among the wide variety of air distributor devices, on principle of action will consider a few especially interesting.

All transferred methods provide the necessary method of serve of air in every concrete case, what provide the normative parameters of ventilation. The construction of air distributive which will unite all higher marked stream depending on requirements to organization of ventilation is offered.

KEYWORDS: air distributive device, air jet, velocity, temperature.

1. INTRODUCTION

Jet flows are one of the main factors that form parameters of air environment in buildings of different purpose. According to the working condition of apartment, that can be changed in course of time, the necessity to provide the air supply with the jets of different parameters (long-ranged, fast decayed etc.) appears.

Existing constructions of air diffusers, as a rule, supply air into the apartment by means of one type of jets [1, 3, 4]: packaged, flat, windmilled, twisted. If the working conditions of apartment were changed and accordingly it is necessary to change a scheme of air supply, exchange of air diffuser is providing.

While planning the system of air diffuser the peculiarities of forming of delivery jets should be taken into consideration, as they allow to get the jet with the necessary parameters, and this in its way will provide the increasing of efficiency and economy of air diffuser systems, air-heating and air-conditioning.

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2. THEORETICAL BASIS

It is offered the air terminal device, (Fig. 1) which would form the jets of different types and provide parameters of microclimate depending on the demands to the organization of air change in apartment. Air diffuser consists of body, in which there is an aperture, near which the curvilinear surface in form of flexible sheet is movably fastened (Fig. 1a). Air diffuser works in the following way: the air jet for distribution moves into box, out of which it goes through the air slot and is divided by the curvilinear surface into two jets. Providing the curvilinear surface is placed in the extreme position joining the upper or lower part of the box, the jet, which is laid on the curvilinear surface with the change of the trajectory of motion which depends on the curvature of the last, is forming. In case of arrangement of curvilinear surface in the centre of the slot or with displacement, two jets are forming, with the possibility to regulate their parameters and decay rate. While the transformation of the curvilinear surface into the flat state, the packaged jet with the low coefficient of local resistance is forming.

Half-limited jets on the prominent and concave surfaces are one of the types of curvilinear flows. In a difference from axial section, smooth of the prominent surface or concave surface is entailed by appearing of crosscut pressure gradient, that is the static pressure in the middle of the boundary layer is constant. This is one of the main peculiarities of flows around curvilinear surfaces. Under the influence of crosscut pressure gradient, takes place the transformation of speed profile and temperature in boundary layer: around the prominent surface becomes less filled up then during the axial flow and around concave it is more filled up. The thickness of boundary layer also changes. The degree of completion of speed profile and temperature is determined by the value of curvature parameter δ / R_U, and also by other affecting factors (pressure gradient, external turbulence).

During the flow of jet around the curvilinear surface just as during the flow around flat wall, there can be singled out initial and main parts of movement (Fig. 2). On the initial part with the length $x_н$ takes place the reconstruction of speed profile from equal on the entrance of profile corresponding to the curve with maximum. For-and-aft component of speed reaches its maximal value on the boundary of wall area with the thickness $\boldsymbol{\delta_m}$. The reconstruction of speed profile on the prominent surface occurs more slowly, then on the flat one, and on the concave – more quickly. That is why the length of initial part on the prominent surface is bigger, and on the concave one – smaller, then in the jet on the flat surface. The development of the jet around the prominent surface is examined in works [1. 6.] For the description of the length of the initial part of jet movement around concave surface the following dependence is advised [2]:

$$\boldsymbol{x_н / s = 42\ [\ 100\ s\ /\ |\ R_w\ |\ ]^{-0,65}}, \tag{1}$$

where: $\boldsymbol{x}$ – position data of the point of jet separation, **s** – width of jet blowing slot; $\mathbf{R_w}$ - radius of surface curvature.

In the initial section the width of the wall boundary layer $\boldsymbol{\delta_m}$ can be considered equal 0,5s. With the advancement and reconstruction of jet takes place the displacement of the maximum of the fore-and-aft speed component to the wall. Decrease of the thickness of wall boundary layer on the initial part of jet movement around concave surface happens according to the exponential law:

$$\boldsymbol{\delta_m / s = 0,5\ \exp\ (-0,023\ x\ /\ |\ R_w\ |\ )}, \tag{2}$$

where: $\boldsymbol{\delta_m}$ – the width of the wall boundary layer.

Fore-and aft curvature makes an essential influence on the characteristics of wall jet also on its main part of movement. On the prominent surface the thickness of jet increases in comparison with the flat surface, on the concave – decreases (Fig. 2). Change of the thickness of jet occurs in such way that correlation between the thickness of wall layer $\boldsymbol{\delta}_m$ and half-width of the jet **b** remains constant.

The rate of decrease of maximal value of fore-and-aft speed on the prominent surface is higher, and on the concave – lower then it is on the flat wall.

In the half-limited jet the different forms of boundary level are combined: wall and jet. The speed profile in wall area of jet ($y < \delta_m$) can be described by the sedate profile like:

$$\mathbf{U/U_m = (y / \delta_m)^{1/n}} . \quad (3)$$

where: U - friction velocity (speed) , m/s;

Under the influence of curvature the completion of speed profile changes. On the prominent surface it is smaller, and on the concave it is bigger, then on the flat one. In accordance to this the value of index of power in formula also changes Eqn3. On the prominent surface the value **n** decreases, and on the concave – increases together with the increase on curvature parameter.

It is recommended in work [2] to describe the change of the speed in wall are in dependence with the curvature with the help of formulas:

a) For the prominent surface $\mathbf{n/n_o = 1 - 1.7\ (\delta_m / R_w)^{0.31}}$

For the flat surface $\mathbf{n = 7.12}$

b) For the concave surface $\mathbf{n/n_o = 1 - 2.69\ (\delta_m / |R_w|)^{0.65}}$

where: $\mathbf{n_o} \sim 7$ – corresponds to the flat boundary layer, in our case it is the initial part of jet flow forming. Indices **n** and $\mathbf{n_o}$ are the functions of the geometrical parameter of similarity $\mathbf{\delta_m / R_w}$. Above mentioned dependences of calculation of the value **n** were received on the basis of the experiments. They give enough close results and in major correspond to the physics of the process, as they reflect nonlinear character of the curvature influence. Similar, but more general researches of dependence of the value n from curvature were held by Wottendorf [8] on the prominent and concave surface, their results were close to above worded.

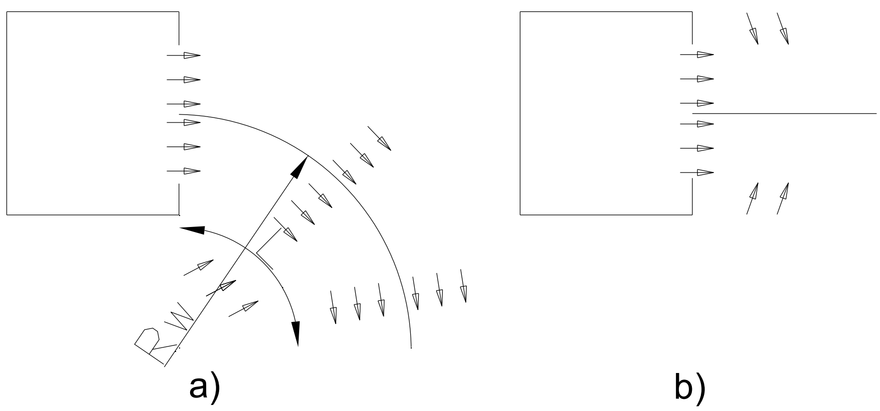

Fig. 1. Scheme of the offered air terminal device: a) with the curvilinear sheet; b) flat surface;

In jet are of flow ($y > \delta_m$) independently from surface curvature, the speed profile is described by the hyperbolic dependence:

$$U/U_m = ch^{-2}\,[0{,}882\,(\,y - \delta_m\,)\,/\,(\,b - \delta_m\,)], \tag{4}$$

which is also true for halflimited jet on the flat surface. Safe of profile form is explained by that fact that under the influence of the curvature values U_m, δ_m and b are changed in a such way that it is not influences the relative form of speed distribution.

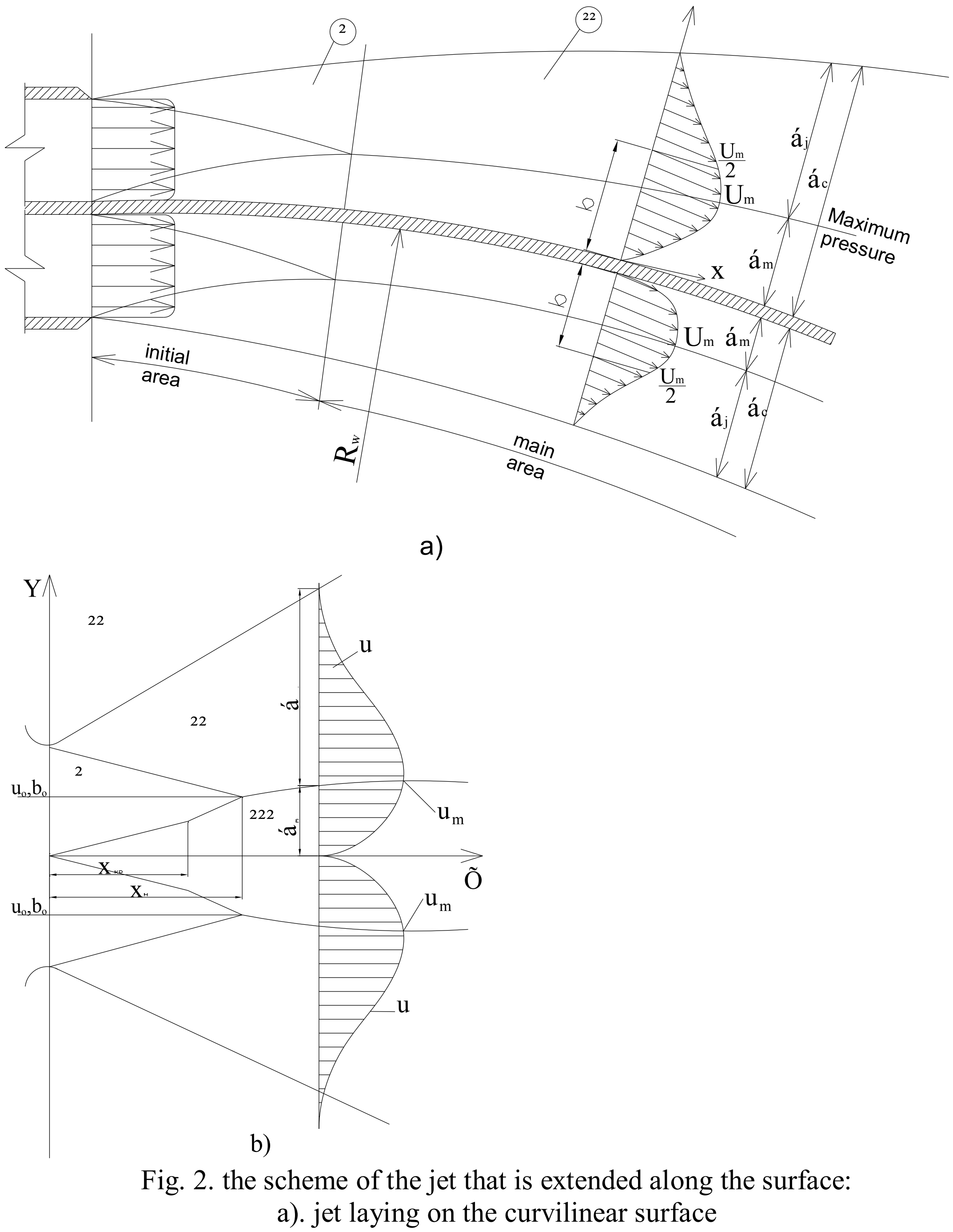

Fig. 2. the scheme of the jet that is extended along the surface:
a). jet laying on the curvilinear surface
b). jet laying on the flat surface

Jet flows are calculated by means of experimental dependence, and their theoretical description is complicated, that is why one of the main principles of theoretical methods of jet flow calculation is substitution of present flow with the established flow, that is averaged in time, in which there no pulsing and eddies.

3. COMPUTER SIMULATION

Computer simulation of jet flow was held on the exit from air diffuser on the curvilinear surface (Fig. 3) and flat one (Fig. 4). The graphic model of jets of the offered air terminal device was build up in Solid Works, development of the jet flow along the curved attachment (Fig. 3) and straight flat attachment (Fig 4). It is shown the result of modeling providing the correlation of consumption of the jets laying on the curved attachment $L_{вып}/L_{вог}$ = 1/3 and on the flat one in the correlation 1/1. in future it is planned the confirmation with the results of the physic experiment.

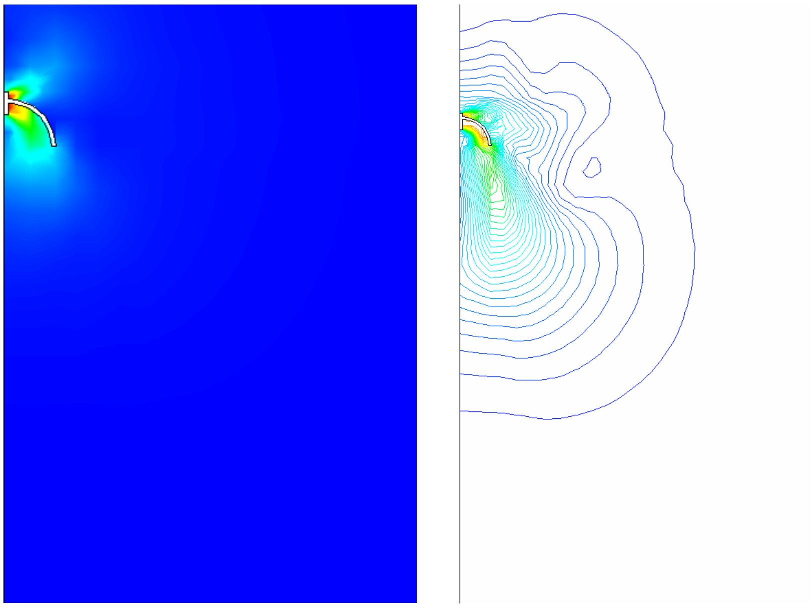

Fig. 3 Computer simulation of the jet flows on the exit from air diffuser on the curvilinear surface made in Solid Works

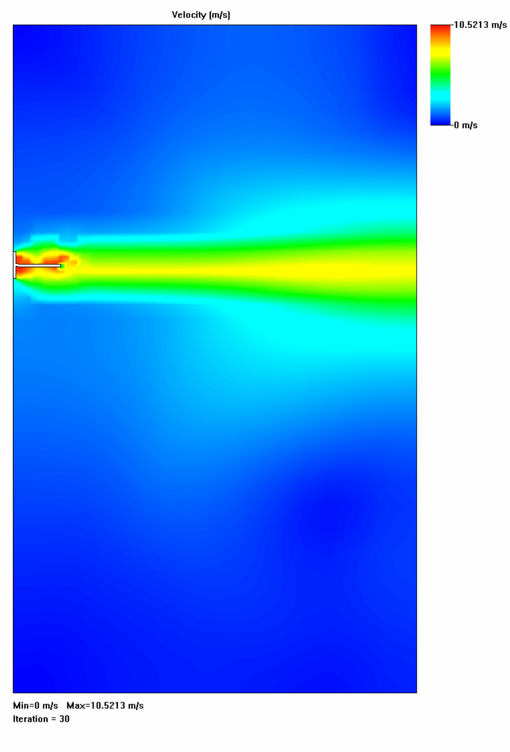

Fig. 4. Computer simulation of the jet flows on the exit form air diffuser device on the flat surface

CONCLUSIONS

Above were examined the theoretical bases of forming the jets of different decay rate while laying on the curve surface with the different degree of curvature.

It was proposed the air diffuser device, which allows creating the jet flows with the different decay rate, and also in the same time forming several jet flows of different type. This allows to provide for every particular apartment the most efficient way of air change organization, to maintain normative parameters of air environment with the least air change. Low airflow resistance of air diffuser leads to the decrease of energy consumption for air travel in the systems of ventilation and air-conditioning.

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AN EMISSION OF THE METHYLATED MERCURY COMPOUNDS FROM THE CLOSED LANDFILLS AND THEIR IDENTIFICATION WITH USE OF THE SPECTRAL ANALYSIS METHODS

ABSTRACT

The municipal or industrial closed landfills are the source of numerous volatile compounds containing the methylated mercury. The landfills are actually the bioreactors where several methylated mercury compounds are generated. These compounds are emitted to our atmosphere as the landfill gas. An analysis shows that dimethyl mercury is the most frequently occurring product emitted in landfills gas. Chemical assignment of the methylated mercury compounds involves very advanced analytical methods. It seems that spectral analysis can give the exact identification of the investigated compounds. The gas samples gotten from landfills we excited in an electric discharge to receive an emission spectrum of the compounds occurring in our samples. The registered spectra were analyzed using the spectral catalogues.

KEYWORDS: landfill, mercury, biomethylation, wastes.

1. INTRODUCTION

The industrial wastes with the mercury compounds were accumulated at the municipal landfills by that legal regulation time of. In the sixth decade of twenty century the discharge tubes of served types (sodium, mercury, fluorescent lamp) was applied for an advertising. Operating costs are very low and the operating parameters are very high for this lamps. Because of it, the lamps of these types were taken a full advantage. Used lamps and the spoilage in a manufacturing process produced the large amount of wastes containing the mercury additionally blowing-up by the used batteries, the latex points, are the insecticide stores on the areas of municipal landfills.

Actually the research works and the standard establishments connected with a mercury dissipation are focused on the carbon combustions effects, geological background etc. The landfills are investigated taking into account their leachates, but disregarding their unknown source of emission of methylated mercury or other heavy metals.

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Existing and constructed now, landfills are the bioreactors based on the bioremediatire and physicochemical process. In there, pollutions are formed in liquid or gaseous state which cannot be predicted on a basis of our actual knowledge. Some of these process are recognized much better in the or in the bottoms than in landfills. Biomethylation of mercury belongs to such process. We can expect in a deposit of communal wastes and also industrial wastes the methylation process which take a place as a result of an alkyl groups binding with the mercury by a participation of the microorganisms creating several methylated mercury compounds. These species are incomparable toxic then the metallic mercury. The toxicity of these compounds is not sufficiently recognized yet, but a fact of Prof. Karen E. Wetterhahn (1948-1997) dead confirms its danger quite sufficiently [1].

2. ACTUAL STATE OF THE RESEARCH PROJECTS CONCERNING THE MERCURY COMPOUNDS EMITED FROM LANDFILLS

Prof. S.E. Lindberg and his group [2] confirmed the proposed thesis by the end of the ninth decade of twenty century [3], that the municipal and industrial waste landfills act as bioreactors for methylated mercury compounds. During the investigations of the active waste landfills at South Florida (1997) [4], a high concentration of the gaseous mercury was discovered in the samples of the landfill gas (LFG) at a range of 30-1800ng/m^3. Further investigations realized at Brevard Country landfill [5] give a concentration of the total gaseous mercury (TGM) as elemental version (Hg^0) and such form of an occurring mercury was determined for the first time in a landfill gas. The gaseous mercury compounds were identified at the level of ng/m^3. Taking into account very high toxicity of these compounds, it appeared that a repetition of the investigations in other landfills are quite reasonable. In a consequence such investigation were performed for nine municipal landfills in United States of America to determine a concentration of a total gaseous mercury as well as the methylated mercury during a period of time 1999-2002. Elemental mercury appears the concentration on a level of µg/m^3 , while the methylated mercury compounds are at range of ng/m^3 . It exhibits that dimethyl mercury (DMM) is a predominant organic compound with a concentration reaching level of 100ng/m^3, while monomethyl mercury (MMM) ranged to 40ng/m^3 [2].

The landfill gas sampling was performed at the closed and opened areas of the given landfill using the suitable accumulating system. For instance at Florida region the samples was taken from two installation systems accumulating a landfill gas from closed area and opened area where the storing process is of the range of 10000m^3/day. For others investigated landfills this values were of the range from 7000 to 50000m^3/day.

Elemental mercury and the compounds containing mercury were classified as the stables compounds which are bioaccumulative toxins (PBTs – persistent bioaccumulative toxins). Washington State Department of Ecology made some efforts to set a limit for bioaccumulative toxins in environment. Department proposed the searching of the mercury emission from several landfills in Washington State to establish a quantity of this emission. On May and June 2003 the samples was taken from eight landfills situated in the region of Washington State. These samples gotten by Frontier Geosciences Inc. Laboratory was analyzed to determine a concentration of the elemental mercury and dimethyl mercury. Additionally in each landfill the investigation of an emission of elemental mercury was performed using the field equipment. The results are listed in Tab.1

Tab.1 Results of landfill gas research executed for Washington State Department of Ecology

Sample assignment	Elemental mercury [ng/cm^3]	Dimethyl mercury [ng/cm^3]	Participation of dimethyl mercury in elemental mercury [%]
Site #1 A	16.5	9.5	57.6
Site #1 B	73.8	27.7	37.5
Site #2	1175.6	10.5	0.9
Site #5	94.4	7.1	7.5
Site #6 A	334.5	23.2	6.9
Site #6 B	126.9	26.4	20.8
Site #7	8011.9	46.1	0.6
Site #8	252.6	28.8	11.4

Sampling of dimethyl mercury was performed by pulling of the landfill gas trough a trap containing an adsorbent bed of the Carbotrap^{TM} (10 cm length , 0,4 cm of diameter). Concentration of dimethyl mercury was determined by the thermal-desorption, gas-chromatography and by the atomic fluorescence spectroscopy (TD – GC – CVAFS). Method applied for determination of a total gaseous mercury is described in the article [5] given by Lindberg. For an assignment of the metallic mercury, the apparatus Lumex RA915+ was used. This analyzer is based on the atomic absorption spectroscopy using 253,7 nm spectral line absorbed by atomic mercury. Its limit of detection is of a range 2ng/m^3 which is achieved by an application of the multipath absorption cell with the length path of 10 m. Selectivity of this method is extended by an application of Zeeman effect. An assignment of elemental mercury by the application of Lumex RA915+ apparatus is one of the best method for analysis in the landfills.

3. THE RESEARCH WORKS REALISED AT POLISH LANDFILLS

The Department of Geotechnics and Hydraulic Engineering in collaboration with Department Mathematics and Applied Physics at the Rzeszow University of Technology elaborated the method of an assignment for the gaseous compounds of mercury which is based on spectral analysis. The samples of the landfill gas was gotten at a landfill close to Rzeszow city and investigated in The Laboratory of Molecular and Atomic Physics at Faculty of Physics. The performed analysis confirmed the occurrence of the methylated mercury compounds.

3.1. Proving ground

Rzeszow city is situated in Przedkarpacka glacial volley, where is also analyzed landfill, and this depression area was created by postglacial waters erosion. This depression was filled up by the Pleistocene Holocene deposits. A depression is bounded by Rzeszow foot-hills which is ascending over Depression and it consists of height covered by the loess layers. The analyzed landfill, closed from several years, is situated in the open cast working for the brickyard previously. An exploratory drilling performed for this brickyard exhibits that at 7,5 m depth of the silty clay deposits here, and it was exploited by the brickyard. Under these clays, here are the layers of the bank-run gravel with boulders. The depth of these strata attains 5m, and their range is unknown. The bottom is also doubtful as a geological barrier. This landfill has not any additional packing and its exploitation was ended 1990. During this exploitation about 2 621 550 m^3 of the municipal and industrial wastes was deposed from

Rzeszow city. The surface of this landfill is about 3 ha. The cullet from RZLW- Polam Factory at Rzeszow was deposed here in quantity of 6700kg , which is 67% of the wastes from this factory. Assuming the lowest evaluation of mercury content in these wastes, we can evaluate that from this factory 4000kg of metallic mercury was deposed a quantity of 2680 kg on this landfill. Other evaluation give a quantity of 10 000kg or even more. An exact estimation of the mercury deposit here is rather impossible and the most frequently it says that this deposit contains 4000 kg of mercury. Because of it this landfill became a special subject of investigation by Department of Geotechnics and Hydraulic Engineering at Rzeszow University of Technology from over ten years [8,9,10].

3.2. Sampling

The investigated landfill is equipped with the ventilation ducts which carry away the landfill gas. These ducts are made of the steel tubes with a diameter of 51 mm, and placed – in a concrete cylindrical key with a diameter of 60 cm. This key is ended with horizontal bottom from which the ducts are standing out.

Such ventilation system allows to perform a sampling of the landfill gas. Our method consists in putting on, the glass petticoat on the key bottom, covering the ventilation duct carring away the landfill gas. This glass petticoat has a side output with a rubber hose closed by the clip. We placed our petticoat on the key bottom for an accumulation of the landfill gas for one hour.

We applied the glass tanks with two vacuum cocks: input and output to get the gas samples. Before a sampling process our glass tanks were pumped by the vacuum system during two weeks. This preparation treatment consist in an achievement the vacuum of a range 10^{-4} Tr every day. In two weeks we just received a stable vacuum state of a range $5*10^{-4}$ Tr in our tanks. So prepared tank we just connected with rubber hose situated at the glass petticoat accumulating the landfill gas. Next using an input cock we let in the landfill gas to our tank. Gotten sample was tested at Molecular and Atomic Physics Laboratory in Rzeszow University of Technology.

3.3. Excitation of a gas emission radiation

The tank with landfill gas was installed at the vacuum system. In the way of convenient treatment of our tank of the landfill gas was introduced to Geissler type discharge lamp equipped with small container to have some reserve of the investigated gas for experimental several tests. This lamp allows to excite electrically the investigated gas. Using our discharge lamp we can realize an electric discharge of 0,5 to 3,0 kW power. Such range of an electric discharge give a possibility of the experimental condition choice for very diversified research projects. Also our lamp is equipped with quarts window which allow to make the exposition in the spectral range visible and UV region up to 200 nm.

In our experimental procedure we performed by the electric discharge with a intensity currant of 0,3 A from this simple phase transformer controlled with autotransformer. An exposition time was about 10 minutes. The pressure of the landfill gas in Geissler lamp was about 5 Tr. The electric discharge during an exposition was rather stable.

3.4. The conditions of spectral resolution

The registration of a spectrum given by landfill gas was performed using PGS-2 spectrograph (Carl Zeiss- Jena GmBh). The spectrum was registered in the first spectral order of standard diffraction grating (651,5 lines/mm) with a reciprocal dispersion of the range

7,4Å/mm. A registration was realized on the plates UV-1. Spectral calibration of plates was made using standard scale of PGS-2 instrument.

The explored spectral region was at the range 230-250 nm. According to Herzberg monography in this spectral region the band systems occurring here, are emitted by dimethyl mercury molecule. The registered spectra confirmed an occurrence of the diffuse band systems. The resolution of band spectra was sufficiently enough to confirm the emission by dimethyl mercury.

3.5. Conclusion

The structure of dimethyl mercury spectrum was studied by many investigator. In the infrared spectral region several research works was published by M. Bochmann and all [12] also Bribes [13] and J. Minch , L. Nemes [14] elaborated some particular spectra. Very significant article concerning this molecule in ultraviolet region was published by Thompson [15] from Oxford University. In this report one can find a vibrational spectral structure with vibrational assignment in our molecule. In our samples we just observed the bands mentioned by these investigators. Taking into account the importance of an emission of dimethyl mercury to the atmosphere it is quite comprehensible that the farther investigations must be undertaken.

4. SUMMARY

In spite of a fact that at greater number of the landfills the landfill gas is taken and combusted, bringing a decomposition of the organic mercury compounds and a winning a metallic mercury which is less toxic, the dissipated gas is still an important anthropogenic source of the methylated mercury to the atmosphere.

European Union directions concerning the exploitation process of the landfill order the utilization of the landfill gas. The most frequently in Poland the landfill gas created in the bioremediation process are dissipated to atmosphere. It proposes to perform the investigation all closed landfills in area of Poland using the methods described here. These landfills which occurs as an emitter of the organic mercury must be isolated from its hydrogeological environment using the methods proposed previously [16, 17]. The landfill gas containing an organic mercury must be combusted with an emission control or stored in the special containers. Such stored gas can be transported and used for energy production.

The research works and analysis guided by Rzeszow University of Technology connected with an assignment of the mercury compounds are monitored by the members of the Committee of Civil Engineering of Polish Academy of Sciences. They accept with full respect our trials and also the proposal of an active research project on the area of Poland for monitoring of the closed landfills with mercury compounds.

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USING NUCLEAR POWER AS ALTERNATIVE SOURCE

ABSTRACT

Paper represents perspectives for wider usage of nuclear power as one of the alternative sources. Paper studies nuclear reactions and their general principles, classification of various radioactive isotopes and chain reactions.

Here are given calculations of thermal power, radioactive products power, changes of neutron current in reactor and irregularity factor of neutron current.

Power reactors are classified: by neutron energy that initiates decomposition reaction as thermal reactors and speed ones; by usage of fuel as multiply reactors and converters; by their structure as heterogeneous and homogeneous reactors; by cooling and moderating types as water, heavy water, water-graphite, gas, channel and complex reactors.

KEYWORDS: nuclear power, radioactive isotopes, neutron energy.

1. INTRODUCTION

A nuclear reaction is the process in which two nuclei or nuclear particles collide to produce products different from the initial particles. Many kinds of nuclear reactions occur in response to the absorption of particles such as neutrons or protons. Other types of reactions may involve the absorption of gamma rays or the scattering of gamma rays. Each of the elements has definite quantity of isotopes. Some of them are stable and natural, others even are initially unstable. Such unstable isotopes are named radioactive and can be artificially produced in nuclear reactions.

2. NUCLEAR REACTIONS, BASIC TERMS

In laboratory conditions nuclear reactions occur due to bombarding a target substance by a fast particles beam. Bombarding particle and target may collide producing such effects as elastic and inelastic collision and nuclear reaction.
If the particles collide and separate without changing, the process is called an elastic collision rather than a reaction. Inelastic collision produce particle identical to bombarding one but nuclei remain excited. Nuclear reaction is interaction which changes internal properties and

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composition of the target nuclei and produces a new particle [1]. Various radioactive elements emissions are shown in fig. 1.

Their fission produces new isotopes as their products.

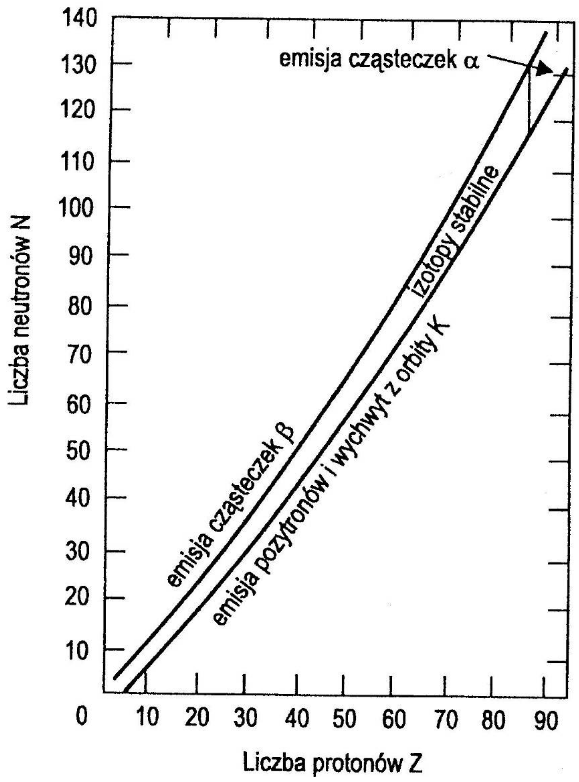

Fig.1. Fission type relations in functions Z and N

If fission produces a stable isotope it isn't to be further split. All unstable isotopes will have further decay until they reach stability. In this way initially radioactive isotopes create chains of product isotopes leading to stable one.

3. NUCLEAR REACTORS, CHAIN REACTION

The thermal neutron having 0.03 MeV energy produces about 200 MeV. Significant, that this process is followed by emission of neutrons capable to produce further nucleus fission. One neutron initiates chain fission in which number of nucleus involved into fission will rise rapidly. This fission is unlike natural nuclear reactions in which one particle collides with one nucleus and then reaction stops.

To maintain chain reaction each nucleus fission should emit one neutron that would cause further nucleus decay.

Every nuclear reactor should have thermal power calculated. The reactor core generates heat in a number of ways: the kinetic energy of fission products is converted to thermal energy when these nuclei collide with nearby atoms; some of the gamma rays produced during fission are absorbed by the reactor in the form of heat; heat produced by the radioactive decay of fission products and materials that have been activated by neutron absorption [1].

Figure 2 illustrates neutron emission changes in reactor.

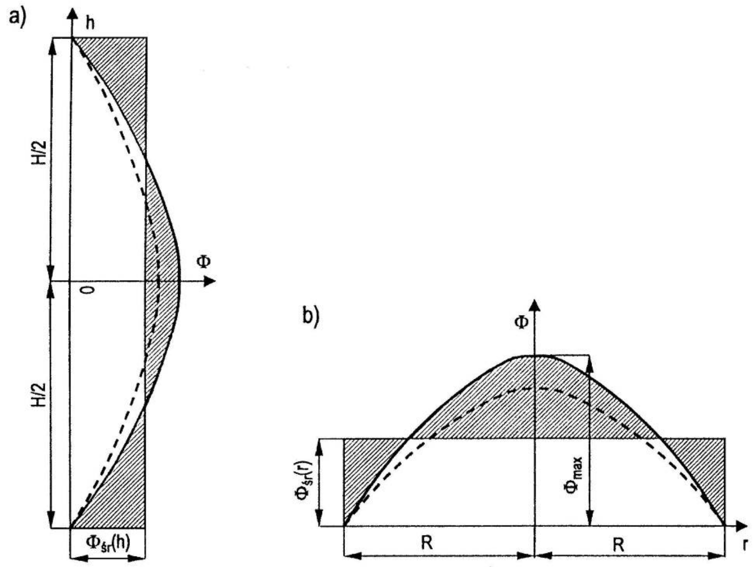

Fig. 2. Scheme of neutron emission changes in reactor [1]

Neutron emission irregularity factor can be found as:

$$K_h = \frac{\Phi_{\max}}{\Phi_{sr}(h)} = \frac{\Phi_{\max}}{\frac{1}{H}\int_{-H/2}^{H/2} \Phi_{\max}\cos(\frac{\pi h}{H})dH} = \frac{\pi}{2} = 1{,}57 \quad (1)$$

Thermal power is proportional to neutron stream. Its irregularity causes irregularity of generated power.

4. NUCLEAR REACTORS CLASSIFICATION

Nuclear reactors are classified by several methods:

- fission reactors can be divided roughly into two classes, depending on the energy of the neutrons that are used to sustain the fission chain reaction:
- a) thermal reactors use slow or thermal neutrons. Most power reactors are of this type.
- b) fast neutron reactors use fast neutrons to sustain the fission chain reaction at more than 0.1 MWt energy.
- Classification by use of fuel:
- a) multiplying reactors whose conversion coefficient equals 1.5 and higher. Such reactors use fast neutrons;
- b) converter reactors, whose conversion coefficient ranges within 1..1.1.
- Classification by structure:
- a) heterogeneous reactors in which fuel is separated from moderator;
- b) homogeneous reactors in which fuel and moderator make homogeneous structure.
- Classification by coolant and moderator:
- a) light water reactors use ordinary water to moderate and cool the reactors;
- b) heavy water reactors use heavy water as a neutron moderator;

- c) water-graphite reactors use light water as a coolant and graphite as a moderator;
- d) liquid metal cooled reactors are cooled by liquid Na;
- e) gas cooled reactors are cooled by a circulating inert gas, usually helium. Nitrogen and carbon dioxide have also been used. Graphite is used as a moderator;
- f) organic substance cooled reactors use organic moderator and molten salt coolant.
- Classification by design:
- a) channel reactors;
- b) assembled reactors.

Further studying will be focused in the most widely used reactors.

4.1. Single-loop cycle channel reactors

Single-loop systems use single-loop boiling water reactors. An example of single-loop cycle reactors is shown in fig. 3.

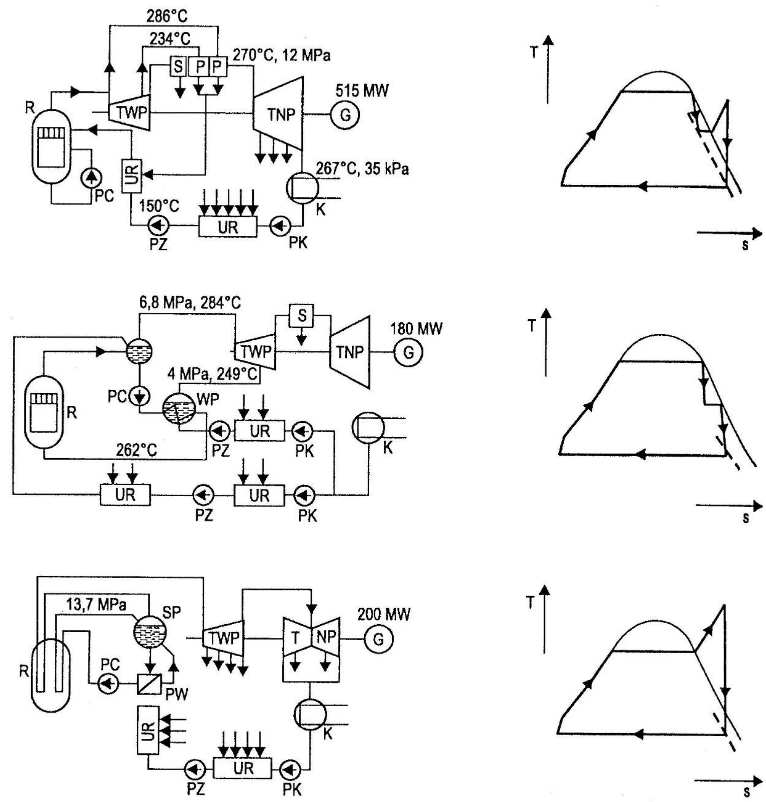

Fig. 3. Single-loop cycle boiling water reactor containment structure
R – reactor; PC – cycling pump; S – water separator; P – steam collector;
SP – steam separator; PW – water boiler; G – generator [2]

Besides single-loop cycle boiling water reactor, single-loop cycle graphite channel reactors called as high power channel reactor ("Reaktor Bolshoy Moshchnosti" RBM) are used. Such reactors use light water as a coolant.

4.2. Two-loop cycle reactors

Pressurized water reactor (PWR) or gas-graphite reactor (GGR) and advanced gas cooled reactor (AGR) are the most frequently used two-loop cycle reactors. Schemes of such reactors are represented in fig. 4.

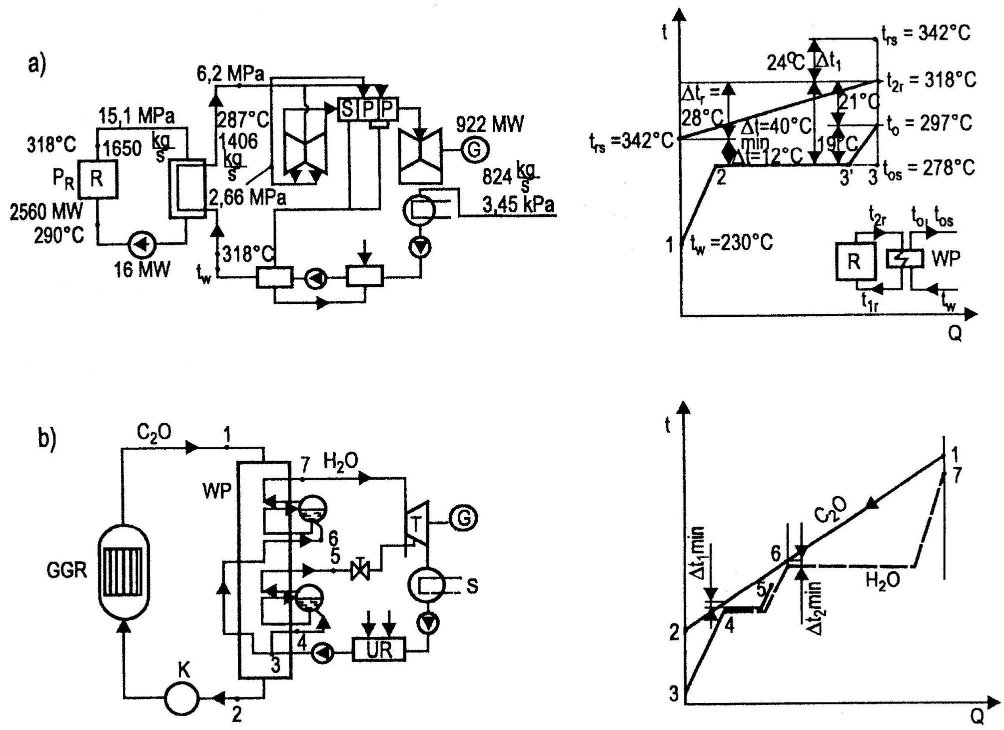

Fig. 4. Schemes of two-loop cycle reactors PWR and GGR [2]

Thermodynamic loss is reduced due to additional sections in which two steam streams having different pressure are generated. Pressurized water reactor is referred to as neutron one using fuel mixture of U^{238} and U^{235} enriched of 1.6..3.6% U^{235}, made as rods and fuel cassettes [2].

4.3. Three-loop cycle reactors

Three-loop cycle reactors use liquid metal as coolant. An example of such reactor is represented in fig. 5.

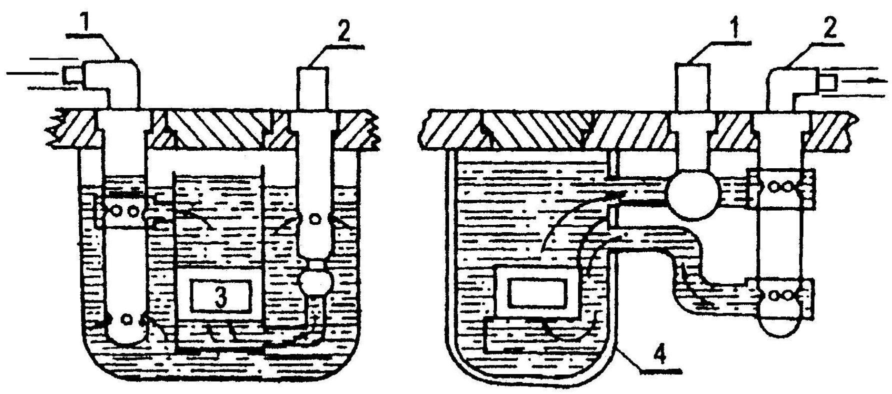

Fig. 5. Scheme of three-loop cycle reactor with liquid metal coolant [2]

Two types of three-loop cycle reactors are generally used, those are: pool-type reactors and tube-type reactors. They differ by the structure of the primary and secondary loops (fig. 5). The primary loop is cycled inside the reactor corp. Operation of such reactor consists in the following: after completing heat absorption in active zone the liquid sodium moves to the moderator installed right in the reactor corp.

Multiplying reactors (fast neutron reactors) don't have moderator. Neutrons initiate nuclear reaction in the fuel and have 0.1…1 MeV energy. In such type reactors burning nuclear fuel goes along with creating new one. Effectiveness of this process which is called "multiplying process" can be estimated by the relation:

$$C = \frac{N_{RK}}{N_{RW}},$$

where N_{RK} - quantity of split nuclei generated due to conversion; N_{RW} - quantity of lost split nuclei.

Density of power generated through multiplying reactors is quite high in the limits 500…1000 MW/m^3, thanks to what they may have a small size. Incidentally, thermal reactors' efficiency of using uranium fuel reaches only 1 %, but multiplying reactors reach 80 %. That makes them very effective in use for the next few hundreds years.

Thus, represented paper is intended to show which nuclear reactors are the most effective today, which reactors are most frequently used and will be in the nearest future. Also we are determined that future power industry will be promoted by innovative sources of power including nuclear power.

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APPLICATION of PIGFARMS RADIATION HEATING SYSTEMS

ABSTRACT

In this article the followin results of the investigation are shown: infrared heater's work with outlet in changing it's heating power and the quantity of exhaust air. The results of investigations can be used for projection of heating systems of pigfarms.

KEYWORDS: infrared heating, infrared heater, heating power, convection component.

1. ACTUALITY WORK

Proposed pigfarm heating system includes: infrared heater, heating mat located at the piglet area and wall heating panel located at the pig area. The object of investigation was only one component of the presented system – infrared heater.

For this reason experimental setup was built, fig. 1, which included infrared heater 4, air pipe 2, outlet 3 and connected to it ventilator 1.

With the help of outlet air and convection component of heat energy is selected from infrared heater.

When we find this component we can save part of heat, which then can be used for heat carrying medium heating.

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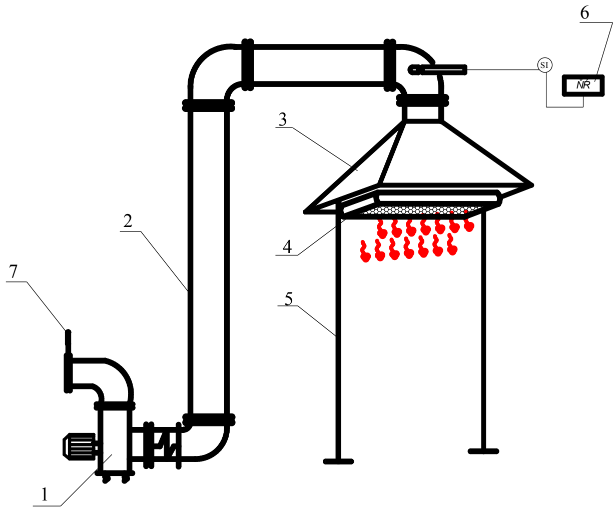

Fig.1. Experimental setup
1 – ventilator; 2 – air pipe; 3 – outlet; 4 – infrared heater; 5 –support; 6 – hot wire anemometer, 7 - damper.

2. PLANNING OF EXPERIMENT

On the value of quantity heat ΔQ, Wt, had an influence of heating power infrared heater Q, Wt, and quantity of exhaust air L, m^3/hr. This values was input parameter planning experiment.

Output parameter – quantity heat ΔQ, Wt.

Province definition inputs parameter:

Q = [400…1200] Wt, L =[700…880] m^3/hr.

Amount experiments found with dependence:

$$N = P^K \tag{1}$$

Where P – number levels factors ($P = 2$);

K – number factors ($K = 2$).

Тоді: $N = 2^2 = 4$ - number experiments.

Equation regressions:

$$y = b_0 x_0 + b_1 x_1 + b_2 x_2 + b_{12} x_1 x_2 \tag{2}$$

Where: b_0, b_1, b_2, b_{12} – coefficients, which found of method the least squares.

In results of calculation coefficients equation regressions was receive formula:

$$y_1 = 187{,}13 + 160{,}38 x_1 + 21{,}28 x_2 + 18{,}23 x_1 x_2 . \tag{3}$$

We can conclude that most on a value У, that on quantity heat influence heating power infrared heater.

Equation regressions come into effect according to 400 Wt≤ X_1 ≤ ≤1200Wt , 700 m^3/hr ≤ X_2 ≤ 880 m^3/hr.

3. CONSTRUCTION OF CHART

For the receipt of high-quality picture of dependence of quantity heat from heating power infrared heater and quantity of exhaust air was construction of chart, fig.2.

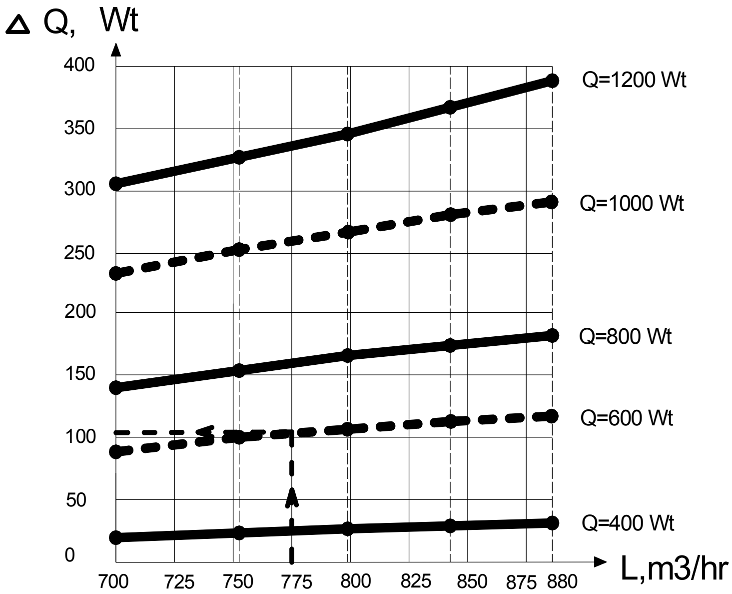

Fig.2. Chart of dependence of quantity heat ΔQ ,Wt from heating power infrared heater Q,Wt and quantity of exhaust air, L ,m^3/hr.

After the construction of chart for a двофакторної function approximation was conducted, that searching for a empiric formula which describes the conduct of this function with three variables :

$$\Delta Q = 12{,}5 - 78{,}12 \cdot (Q - 0{,}8)^2 + L \cdot (0{,}5 \cdot Q - 0{,}18)\ \text{,Wt} \tag{4}$$

4. CONCLUSION

In this article graphic and analytical formulas were received, which help to find convection component of heat energy from infrared heater. It shows dependence of quantity heat from heating power infrared heater and quantity of exhaust air.

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UTILIZATION OF REFINED ATMOSPHERIC SEWAGE IN TECHNICAL WATER SUPPLY OF A KNITTING FACTORY

ABSTRACT

The results of experimental investigation as to determination optimal dose of the coagulant $Al_2(SO_4)_3$ for the cleaning the atmospheric sewage are represented in the article.
KEYWORDS: optimal dose, coagulant, atmospheric sewage.

1. MAIN PROBLEM

We suggest enterprises to use cleaned atmospheric sewage for the technical demands of the knitting factories because of the water rate increasing. The requirements for the quality of the technologic water of knitting factory are directed at the table 1.

Table 1. Quality standards of technical water for knitting factory [1]

Index	Concentration of suspended material, mg/dm^3	pH	General solidity, mg-ekv/dm^3	General alkalinity, mg-ekv/dm^3	Fe_{gen}, mg/dm^3	Permanent oxidability, mgO_2/dm^3	Colouration, deg
Value	not greater than 8	6,5–8,5	7	7	0,1	10	<25

Atmospheric sewage waters (SW) are mainly polluted with suspended material (SM) and petroleum derivatives [2, 3]. The offered units for refining such waters consist of divider (oil remover) and reservoir-storage. They are able to reduce the concentration of SM to 12 mg/dm^3. However refined atmospheric SW could not be used for the technological necessities of knitting factories, as the content of SM exceeds permissible 8 mg/dm^3. The concentration

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of suspended material can be declined with the coagulation process. We offer to place blender in the reservoir-storage, which solution of coagulant will be inputted.

2. EXPERINMENTAL RESEARCH

Subject of research – determination the capability of using the refined atmospheric SW in engineering water-supply of industrial enterprises by the experimental way (knitting factory, for example).

Object of research:

1. Experimental determination of dependence an optimum dose of coagulant $Al_2(SO_4)_3$ on the output concentration of SM in the surface drainage.
2. Experimental determination of dependence the pH variation from a dose of coagulant $Al_2(SO_4)_3$ and the output concentration of SM during the refining of model solutions.
3. Checking the gained experimental dependences in a process of refining atmospheric SW.
4. Determination the specific value of the coagulant $Al_2(SO_4)_3 \cdot 18H_2O$ for the refining the atmospheric SW.

The optimal dose of coagulant has been determined by the experimental way in the laboratory condition with the standard method [4]. Examined water was poured in the measuring cylinder (the volume of which is 1 dm^3) up to the marker. After this different amount of 1 percent sulfate aluminum solution $Al_2(SO_4)_3$ (in milliliters) was added in the cylinder, on the assumption that it different doses would be gotten, which included suggested optimal dose.

Having added coagulant to the water the cylinder content has been intensively mixed with a glass stick for 15–20 s. and then continued to mix gradually and carefully (one stick turn in 3–4 s.) for 15 m. Slowly mixing is favorable for the formation of the coagulant flakes. After this cylinders were left in a quit for 30 m. and were observed visually for the flakes formation and compression. 200 ml of water from the top layer was taken from every cylinder after 30 m. (by the instrumentality of a siphon), without roiling the water. The concentration of SM was determined in the selected proof of water.

The concentration of SM was determined by the photocolometrical method. The coefficient of the transparency of the water proof was determined by the instrumentality of the photoelectrocolorimeter (КФК–2МП label). The concentration of SM in the water proof was determined for the calibration curve according to the transparency coefficient [5]. pH variation of water was defined by the instrumentality of universal ionometer, ЭВ-74.

3. THE RESULTS OF EXPERINMENTAL RESEARCH

4 series of research (refining the model solution with the outputted concentration of SM (C_{en}) 12, 30, 50, and 100 mg/dm^3) were conducted. Model solutions were prepared by addition definite volume of working solution with earthy pieces in the distilled water, which have hydraulic fineness less than 0,05 mm/s.

During the researching were refined: temperature (t), finite value of concentration SM (C_{ex}) and pH (pH_{ex}) of model solution and different doses of coagulant (D_k). The results of experimental research are shown in the tables 2–5 in the fig. 1–2. The results of the static processing of getting data affirmed about the authenticity of getting results.

Table 2. The results of experimental research, clearing of the model solution with the outputted concentration SM C_{en} = 12 mg/dm^3*

№of a cylinder	I		II		III		IV	
Volume of the coagulant V_c, ml	0,1		0,2		0,3		0,5	
A coagulant dose D_k, mg/dm^3	1		2		3		5	
The optical transmission coefficient, τ	85,39	85,39	85,19	85,05	86,2	86,78	88,78	89,21
Final concentration SM C_{ex}, mg/dm^3	8,5	8,5	8,15	8,05	7,4	6,6	3,3	2,7
Mean value C'_{ex}, mg/dm^3	8,5		8,1		7,0		3,0	
pH_{ex}	5,28	5,24	5,15	5,03	4,93	4,87	4,57	4,52
Mean value pH'_{ex}	5,26		5,09		4,89		4,55	

*) t = 18,2°C; pH_{en} (of distilled water) = 5,84; pH_{ex} (of model solution) = 7,0.

Table 3. The results of experimental research, clearing of the model solution with the outputted concentration SM C_{en} = 30 mg/dm^3*

№of a cylinder	I		II		III		IV		V	
Volume of the coagulant V_c, ml	2,5		5,0		7,5		10,0		15,0	
A coagulant dose D_k, mg/dm^3	25		50		75		100		150	
The optical transmission coefficient, τ	82,28	84,97	85,48	85,02	87,09	86,43	87,50	88,03	88,66	88,96
Final concentration SM C_{ex}, mg/dm^3	10,1	10	8,6	9,04	6,1	6,9	5,3	4,7	3,7	3,1
Mean value C'_{ex}, mg/dm^3	10,05		9,0		6,5		5,0		3,4	
pH_{ex}	4,57	4,53	4,22	4,38	4,11	4,19	4,05	3,91	3,82	3,92
Mean value pH'_{ex}	4,55		4,25		4,15		3,98		3,75	

*) t = 17,0°C; pH_{en} (of distilled water) = 5,55; pH_{en} (of model solution) = 6,31.

Table 4. The results of experimental research, clearing of the model solution with the outputted concentration SM C_{en} = 50 mg/dm^3*

№of a cylinder	I		II		III		IV		V	
Volume of the coagulant V_c, ml	10		15		17,5		20		25	
A coagulant dose D_k, mg/dm^3	100		150		175		200		250	
The optical transmission coefficient, τ	80,15	81,19	87,34	84,19	85,39	85,39	86,43	82,0	82,38	82,74
Final concentration SM C_{ex}, mg/dm^3	17,2	15,8	11,5	10,9	8,5	8,5	6,9	6,1	5,8	5,2
Mean value C'_{ex}, mg/dm^3	16,5		11,2		8,5		6,5		5,5	
pH_{ex}	4,0	3,92	3,84	3,83	3,77	3,77	3,86	3,56	3,65	3,51
Mean value pH'_{ex}	3,96		3,84		3,77		3,71		3,58	

*) t =18°C; pH_{en} (of distilled water) = 5,84; pH_{en} (of model solution) = 7,0.

Table 5. The results of experimental research, clearing of the model solution with the outputted concentration SM C_{en} = 100 mg/dm^3*

№of a cylinder	I		II		III		IV		V	
Volume of the coagulant V_c, ml	15		20		25		30		35	
A coagulant dose D_k, mg/dm^3	150		200		250		300		350	
The optical transmission coefficient, τ	76,22	76,63	77,69	79,42	80,83	81,48	87,29	86,34	87,49	88,23
Final concentration SM C_{ex}, mg/dm^3	26,4	23,0	21,2	18,4	16,9	15,5	7,6	6,4	5,9	4,1
Mean value C'_{ex}, mg/dm^3	23,2		19,8		16,2		7,0		5,0	
pH_{ex}	3,75	3,73	3,70	3,56	3,57	3,47	3,46	3,4	3,4	3,28
Mean value pH'_{ex}	3,74		3,63		3,52		3,43		3,34	

*) t = 17,5°C; pH_{en} (of distilled water) = 5,84; pH_{en} (of model solution) = 7,0.

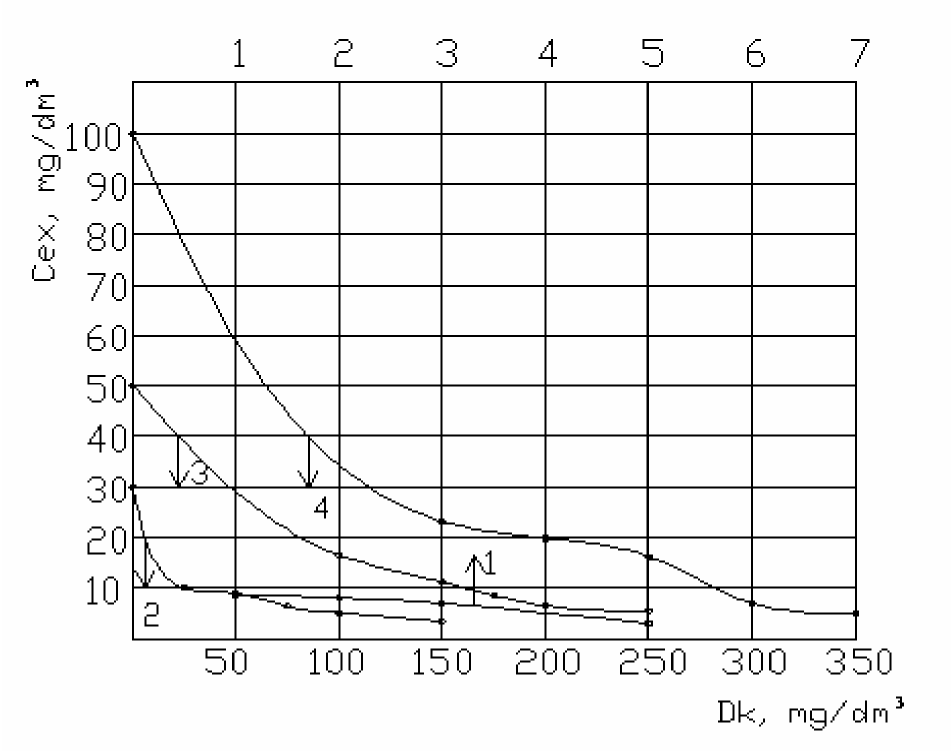

Fig. 1. Dependence of the concentration of suspended materials in model solution C_{ex} from the coagulant dose D_k in different values C_{en}, mg/dm^3: 1 – 12; 2 – 30; 3 – 50; 4 – 100

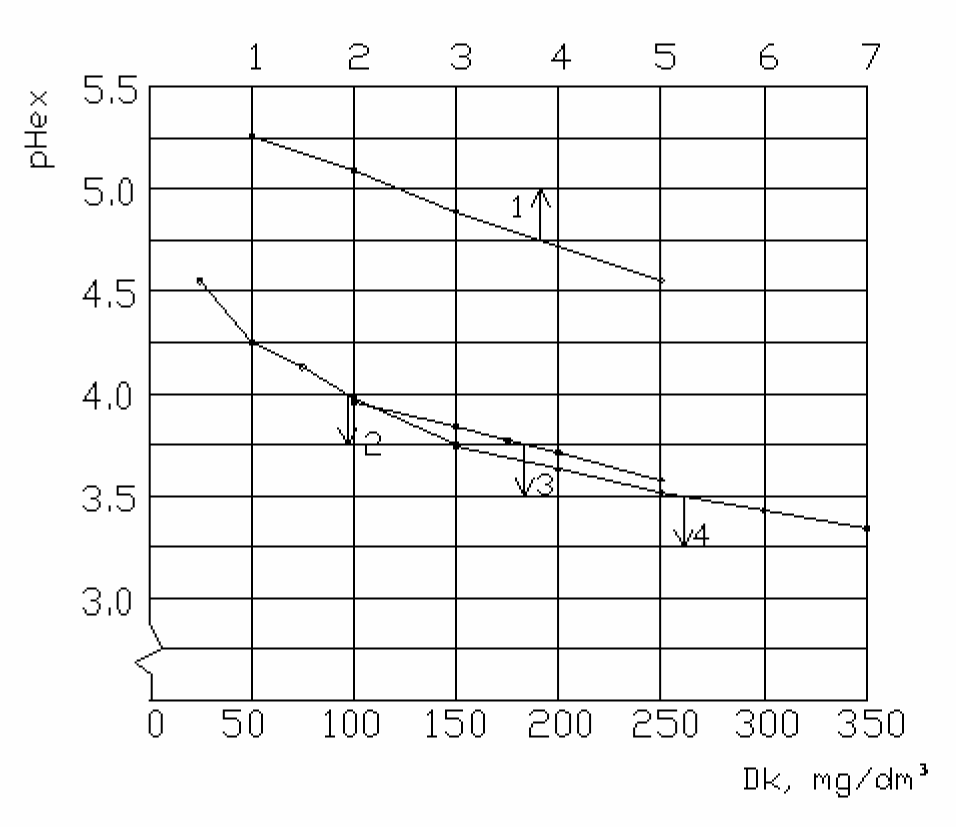

Fig. 2. Dependence of pH_{ex} of model solution from the coagulant dose D_k in different values C_{en}, mg/dm^3: 1 – 12; 2 – 30; 3 – 50; 4 – 100

As a result the experimental dependence of optimal coagulant $Al_2(SO_4)_3$ dose was gotten in a research process of clearing the model solution from the initial concentration of SM (fig. 3).

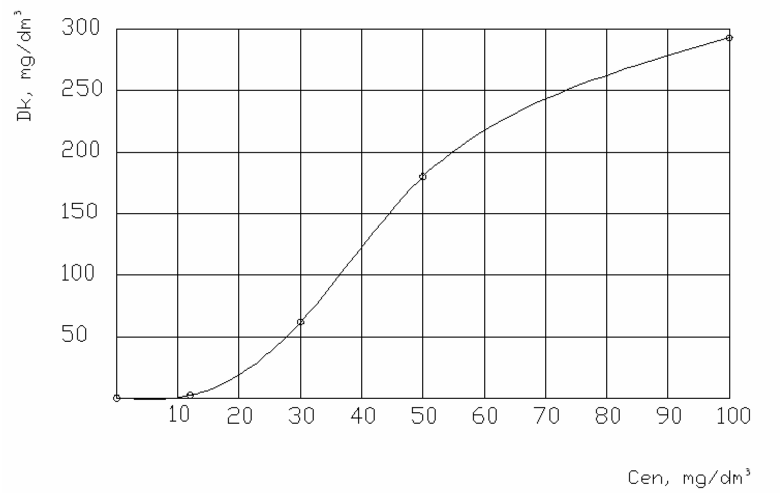

Fig. 3. The experimental dependence of optimal coagulant dose $Al_2(SO_4)_3$ (D_k) from the outputted concentration of the suspended materials (C_{en}) in the model solution

Graphic dependence is described by the equation:

$$D_k = \frac{a}{(1+e^{b-cC_{en}})^{1/d}}, \tag{1}$$

where a = 302,39477; b = 0,11807958; c = 0,059241642; d = 0,11149177.

Atmospheric sewages are chosen for the examination of the received dependence from the waterproof surface of a town. The concentration of SM in a rainy water was C_{en} = 86,8 mg/dm^3 after the previous sedimentation. The optimal dose of coagulant is D_k = 285,12 mg/dm^3 acording to a fig. 3. After the coagulation of impurity substance of atmosphere SW the contents of SM in it has declined to 7,98 mg/dm^3, and pH to 4,32 (fig. 4,5).

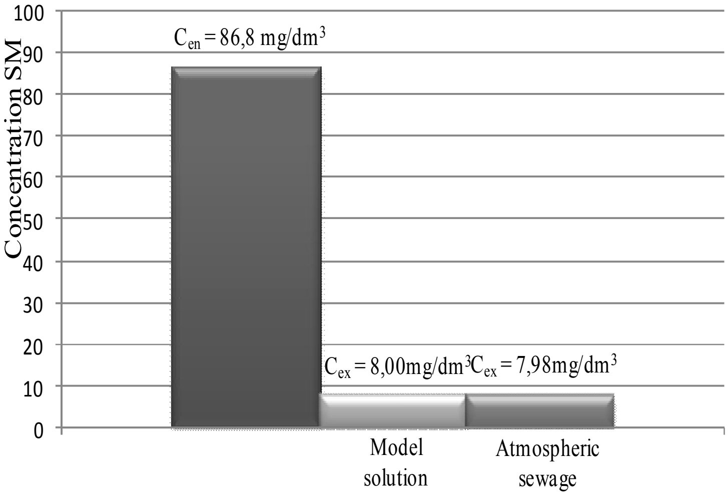

Fig. 4. The concentration change of suspended materials in the coagulation process of the model solution and atmospheric sewage

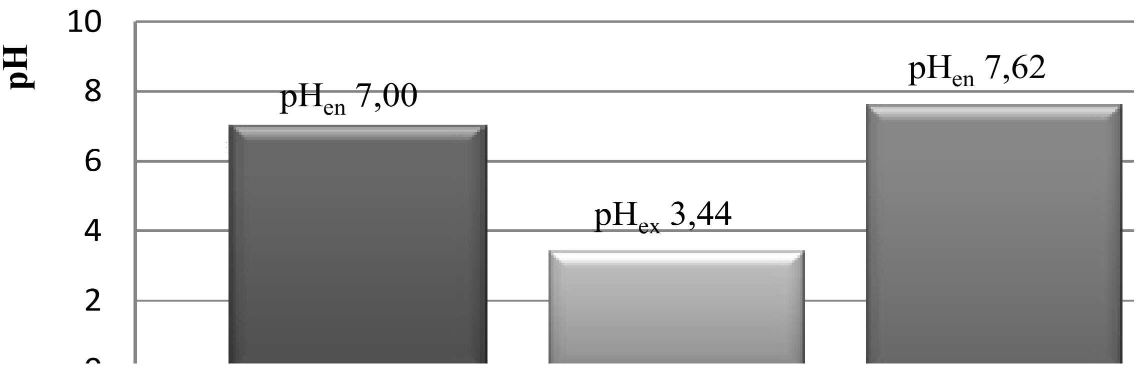

Fig. 5. The pH change in the coagulation process of the model solution and atmospheric sewage from C_{en} = 86,6 mg/dm^3

The value of 1 gm of the coagulant $Al_2(SO_4)_3 \cdot 18H_2O$ (from November 2008) is 11,10 UAN. 4,1 g of coagulant $Al_2(SO_4)_3 \cdot 18H_2O$ is needed for the coagulation of 1 m^3 of rainy water with a contents of SM C_{en} = 12 mg/dm^3, and so 0,046 UAN. Suitably from the C_{en} = 100 mg/dm^3 for the water is needed 574,47 g $Al_2(SO_4)_3 \cdot 18H_2O$ – 6,377 UAN/m^3.

4. CONCLUSIONS

1. The possibility of usage polished effluent in technical water supply of knitting factory is proved.
2. The experimental dependence of optimal dose of coagulant $Al_2(SO_4)_3$ from the initial concentration of SM model solution is determined, is described by the equation (1).
3. The experimental dependence of the pH changing from a dose of the coagulant $Al_2(SO_4)_3$ in a model solution is determined. Was founded out that pH_{ex} of model solution has declined within from 5,07 to 3,44 in the period of coagulation SM accordingly with the increase of optimal dose of coagulant from 2,1 to 294,6 mg/dm^3.
4. The possibility of usage the experimental dependence was proved during the atmosphere sewage depuration.
5. Specific value of coagulant $Al_2(SO_4)_3 \cdot 18H_2O$ is (depending on concentration of SM in rainy waters):
   - for C_{en} = 12 mg/dm^3 – 0,046 UAN/m^3;
   - for C_{en} = 100 mg/dm^3 – 6,377 UAN/m^3.

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EMERGENCY EVENTS IN WATER SUPPLY SYSTEM IN POLAND

ABSTRACT

In the thesis emergency events in polish Water Supply System (WSS) were presented. Three kinds of emergency events were distinguished on account of main premises which caused them: technical (T), human (H) and environmental (E). Also emergency events ensuing as a result of cooperating of the factors mentioned above were distinguished. A model of the probability of the appearance of emergency events in Water Supply System as a result of occurring and cooperating of the three factors: technical (T), human (H) and environmental (E) was displayed.

KEYWORDS: emergency events, Water Supply System (WSS), the probability of the appearance of emergency events

1. INTRODUCTION

The permanent and long-lasting development of the civilization influences the growth of the threat of the appearance of breakdowns connected with the functioning of Water Supply System. Act [1] determines a technical emergency as violent, unpredictable damage or destruction of a building object, the technical device or the system of technical devices, causing the break at using them or loss of their properties. The appearance of the emergency causes a certain amount number of damage. It can cause the threat of health and people's lives, degradation of the environment or also considerable economic losses. The distinctive features of events connected with emergencies are their uniqueness, the randomization, the pluricausality and diversity of direct effects [2]. In thesis [3,4,5] scripts of proceedings and problems in the case of appearing of emergency events in Water Supply System were analyzed. In thesis [6] a review of 619 waterborne disease outbreaks were reported, which appeared from 1971 to 1998 in the USA. The main causes of their appearance were: inadequate water treatment (44.1%), pollution of surface waters and groundwaters (29.7%), chemical and microbial contaminants entering the distribution system (18.3%).

In the paper the analysis of the chosen events connected with the lack of the delivery of drinking water in the appropriate amount and qualities, which appeared from 1998 to 2009 was presented.

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2. FACTORS CAUSING THE EMERGENCY EVENTS

A lot of factors overlap causing the appearance of events connected with the lack of the delivery of drinking water. Among them there are three elements necessarily connected with the development of the civilization and being its inevitable consequence: human-technique-environment (H-T-E) [7]:

a) technical factors:
   - damaging the main pipe during the redevelopment of the street, Wrocław (29.05.08),
   - bad technical condition of Water Treatment Plant (WTP), Nisko (19.03-27.03.08, 4.07-6.07.08, 18.09-21.09.08),
   - the failure of the main pipe because of the corrosion and bad technical condition, Wrocław (12.05-14.05.08),
   - the failure of the main pipe because of too high pressure, Wrocław (31.07.08),
   - the failure of the main pipe because of the effect of using up the material, Szczecin (3.01.09).

b) human factors:
   - the acts of vandalism, devastation of the wire linking the main well with the compensatory container, Strzyżów (15.10.98),
   - leaks of petroleum-derived substances from machines to the river Wisłok, Babica (31.08.98),
   - poisoning leaks from production plants to the water supply system, Wiele (10.11.98),
   - the mistake of the operator, the secondary water pollution, Tarnobrzeg (16.06-03.07.08).

c) environmental factors:
   - long-term and abundant falls, increasing the infiltration of pollutants into the water intake, Jabłonna (25-29.09.08), Pleszew (19-30.03.07),
   - polluting the water intake as a result of ducking in the vicinity of water treatment plant, Płoty (14-15.04.08),
   - destroying the pipeline supplying water from the well to water treatment plant as by moving aside escarpments as a result of the flood, Dąbrówka near Łańcut (31.07-8.08.04),
   - the low water level in Wisłok, Rzeszów (28.11-3.12.05).

Emergency events in water supply system can act as a result of cooperating of the factors mentioned above, that is T-H, H-E, H-E and as a result of occurring of all factors T-H-E. The purpose of the thesis is the analysis of emergency events in water supply system and, on this base, working out the model of threats appearing in the arrangement of H-T-E.

3. EMERGENCY EVENTS IN WATER SUPPLY SYSTEM

3.1. Emergency events in Water Supply System with the participation of the technical factor

In 2008 in the Water Supply System of Nisko (prov. Podkarpacie) a bacterium of the group of cola appeared three times [7]. The first contamination took place in the period of Easter at the turn of March and April. The test examining of water, done on 19 March 2008 by the Sanitary National County Inspector in Nisko demonstrated bacteria groups of cola in the number exceeding permissible norms. Townspeople were notified about the threat on 21 March by the announcement issued by State Sanitary Inspectorate in Nisko. The State Sanitary Inspectorate appealed, that until getting positive results are achieved and the confirming announcement of the usefulness of water for the consumption is issued, people with the weakened resistance, parents of babies and small children should be particularly careful during using water from waterworks. Sanitary Inspectorate stated that the water was fit for drinking after prior boiling. The Municipal Council performed round-the-clock duty providing supplies of water. In the announcement from 24 March the State Sanitary Inspectorate announced that the disinfection of water was bringing effects, the bacteria of the group of cola was detected only in two of nine taken tests of water. He announced that till the time of getting positive results concerning the whole Water Supply System boiled water should be used on 27 of March, because of persistent contamination of bacteria Coli, recessionary headquarters decided to import successive supplies of drinking water (1.2 thousand of fivelitre bottles). Community councils of individual districts of the city dealt with distribution of water. In order to keep townspeople informed, the magistrate hung leaflets on every housing estate. In the next announcement of 29 March a Sanitary National County Inspector, basing on research of tests from the water supply system of 27 March, announced the usefulness of drinking water from the Water Supply System. The Municipal Council announced implementing the collateral security on the water treatment plant, permanent chlorinating water, constant monitoring, using saturated mats with chlorine. For this reason the Municipal Council concluded for raising water rates for about 20%. The council took the 10% discount in the water rate from the day on which the contamination occurred. The consumers had to set the application in order to get it. The next announcement about not-using water from the network appeared on 4 July. The Sanitary Inspector collected tap water in the newly opened butcher's shop for routine control. In the taken sample the bacteria of the group of cola were stated in number of 10 [cfu] in 100 ml of water at acceptable number 0. On 6 July Sanitary Inspector cancelled the announcement from 4 July, on the basis of tests of water taken in the place where microbiological polluting with bacteria the group of cola appeared, and in different points of the water supply system located in different parts of the city. The next pollution of water with the bacteria of the group of cola occurred 18-21.09. Sanitary County Inspector in Nisko announced, that if by the end of the year the technical condition of the water treatment plant doesn't improve, he will begin execution proceedings. The problem of water in Nisko appears extremely often. Exceeding the norms of contents of the manganese, nickel, iron, the colour and turbidity, contaminating water with bacteria of the group of cola occurs very often. The authorities of Nisko don't have money for the modernization of the water treatment plant. They consider a solution of resigning from their own water intake and connecting water supply systems to the network of Stalowa Wola network. Such a solution would allow avoiding building a water treatment plant.

On 29 May 2008, as a result of a failure of a water pipe, which took place in Wrocław, half of townspeople were deprived of water for about 12 hours. During the reconstruction of the Krakowska street construction workers damaged the water main. At first, two main pumps providing the city with water were excluded and its pressure was lowered in the whole Wrocław. Later, it turned out that one of the pumps could be included. The second pump didn't function through the whole time of repairing the main pipe therefore, mainly inhabitants of southern districts of the city lacked water. Water gushed out under the very high pressure tearing the huge hole in the ground, flooding the street and nearby allotments. On the same pipe line a failure took place two weeks earlier, because of the corrosion, since this wire still remembers prewar times. It was the only active pipe line at that time since remaining pipelines were subjected to the renovation.

3.2. Emergency events in Water Supply System with the participation of the environmental factor

On 25 of September of 2008 1.5 thousand of inhabitants of the administrative district Jabłonna (prov. Lublin) were deprived of drinking water supply [7]. In the water intake in Piotrków Sanitary Inspectorate detected the presence of the bacterium of the group of cola. Authorities of the administrative district delivered water to inhabitants by water carts. Sanitary Inspectorate closed the canteen in the School in Piotrków and the bar. They introduced restrictions on the sale of non-packaged goods and bread in seven shops. On 29 September the Sanitary Inspectorate conditionally let water to be drunk after previous boiling and on 3 October he allowed drinking it. As the reason for contaminating prolonged falls were given which caused getting of bacterium to the water intake.

On 14 April of 2008 four thousand inhabitants of the Płot administrative district in the province zachodniopomorskie were devoid of water, as a result of the river pouring out in the area of the water treatment plant. The Sanitary-Epidemiological Station in Gryfice issued the announcement, in which they stated the unfitness of water for consumption, but only for economic purposes. 5 water carts in individual sectors systematically supplied inhabitants, and for older and disabled people the worker of PCK and Caritas delivered water in bottles. A permanent point of providing water was appointed. For the purpose of appropriate informing the society, leaflets were being distributed as well as advertisements were being pasted up. In the afternoon on 15 April the Sanitary Inspectorate announced, that water is fit for consumption.

3.3. Emergency event in Water Supply System with the participation of the human factor

An example of the emergency event, on which the mistake of the operator had the influence was a water pollution in the water supply system in Tarnobrzeg [7]. At the turn of June and July 2003 in the water network supplying 50 thousand inhabitants of the bacterium of group of cola were detected. Quality tests on 12 and 13 June, showed that in 100 cm^3 of water were 99 of bacterium of group of cola. The townspeople were notified about the threat on 16 June with two announcements. The County Health Inspector forbade drinking water, until further notice, while the Enterprise of Public Utilities claimed that water was appropriate for drinking after earlier boiling. It caused the information chaos. In the city panic broke out, people found out about polluted water through „the grapevine”. The cause of the pollution was phosphate preparation which was supposed to improve the network. Inaccurate rinsing out the network caused contamination. In the announcement from 3 July, the National County Sanitary Inspectorate stated that the water was appropriate for drinking after earlier boiling.

3.4 Emergency events in Water Supply System as a result of cooperating of the technical and the human factors

Emergency events ensuing as a result of cooperating of the technical and the human factors are brewing up every single time, when the operator of the technological process of treating water, doesn't correct doses of reagents and the quality of water periodically doesn't correspond with requirements of the standard or technological parameters of the functioning of devices. Every single time it is connected with an error of the operator in the process of treating water.

3.5. Emergency event in Water Supply System as a result of cooperating of the human and environmental factors

On August 1998 a pollution of petroleum-derived in the form of the oil film of the river Wisłoka appeared in the area of the place Wyżne and Babica [7]. The moving oil stain spread on the length of about 4 km. An unchecked leak of fuel from the container was the reason for polluting the river of one of diggers working at the renovation of a road bridge in Wyżne. Rescue action performed by fire brigade consisted in removing the pollution by setting up 4 dams against outspreading the oil (directly before the water intake for the city of Rzeszów in Zwięczyca). Barriers served their purpose and oil didn't penetrate the area of the water intake for Rzeszów.

3.6. Emergency event in Water Supply System as a result of cooperating of the technical and environmental factors

On January 2009 low temperature caused the sequence of breakdowns appearing on networks, as it took place in Szczecin (3.01) [7]. The breakdown appeared in the place in which material was used up, it appeared on the main pipe ∅300. Removing the waterworks breakdown took over ten hours. The part of the street, in which the breakdown appeared, was closed. The movement of trams and cars was suspended. Substitute transport was started. On the place a delivery of water was guaranteed - it was delivered by a water cart. The majority of inhabitants got bottles of waters in nearby shops.

3.7. Emergency events in Water Supply System as a result of cooperating of the technical, the human and environmental factors

On 17 February 2006 the National County Health Inspector in Krosno informed that in tests examining of water from the network Krosno - Iskrzynia was stated a presence of the bacteria of the group Clostridium [7]. These bacteria reduce sulphates, potentially pathogenic. Production of water in the water intake Iskrzynia was limited, increasing the amount of water from remaining water intakes, in which this bacterium wasn't detected, i.e. of Sieniawa and Szczepańcowa. Fire brigades made a number of holes in the ice lid of taking hold of the container, causing the oxygenation of water. A disinfection of the entire technological line was carried out. It caused deficiency in water in night hours (around 17 on 18 February) and periodic deficiencies on Saturday (18.02.). Restoring the cleanness of water required norms lasted over the week. The factor influencing the appearance of the bacteria Clostridium is a great changeability of parameters of water having the close relationship with weather conditions and the season: low level of the river (28.11-3.12.05 Rzeszów) or as in the case of Krosno, when the river was ice-bound.

On Wednesday 10 September 2008 in Gołdap (prov. Warmian-Mazurian) and in nine local villages a 10-days pollution of water in the water supply system took place. The State Sanitary Inspectorate detected trichloroethane and tetrachloroethane, which exceeded norms seven times during routine investigations in the water network supplying 16 thousand inhabitants. Both chemical factors consumed in exceeded doses can be harmful to health, they are used as a solvent, to numerous syntheses in the organic chemistry for degreasing metal, they are also used in laundries. They are poorly water-soluble toxic liquids, demonstrating strong carcinogenic action. The tests examining of water to contents of these chemical compound were taken on 18.08.2008, whereas research to the local Sanitary Inspectorate was delivered on 10.09.2008. On Wednesday afternoon the mayor of Gołdap called the critical staff, which after getting investigations from the State Sanitary Inspectorate began informing inhabitants.

After the message about contaminated water inhabitants started wholesale buying water and drinks from shops. Gołdap is supplied with water from around five intakes. In connection with stated contaminating water on 12.09.2008 tests examining of water were picked up from all urban wells and extra seven points. As a matter of urgency they were investigated by the laboratory in Białystok. This investigation showed that water was contaminated with chemical compounds in two intakes. The drinkable water was inserted from clean wells into the net but time to rinse out the water supply system was needed. The Mayor of Gołdap admitted that it wasn't obvious how long water with exceeded doses of trichloroethane and tetrachloroethane flew in networks. He announced that the last investigations could be carried out the year before. The State Sanitary Inspectorate wasn't able to show reasons of contamination. A district prosecutor's office in Olecko dealt with contamination. The district prosecutor's office in Olsztyn announced that a suspicion of committing the consisting crime was occurring by the health hazard of many people, for which the punishment of imprisoning is threatening of about 10 years. For dwellers of Gołdap and local villages water was provided - it was being delivered by water carts. The ban on drinking water applied till 19 September. The water supply system in Gołdapia was systematically controlled by the public health after the next days. A reason for contamination water in Gołdapia was probably containers after an old dry-cleaner. The District prosecutor's office in Olecko found one of the two containers, in which substances were kept, used as solvents. A dry-cleaner was closed 15 years ago. It was in surroundings of the two intakes with contaminated water. Afterwards two metal containers were left. One of them was found by a prosecutor's office. The ground in the vicinity of the container gave off the similar smell to solvent adhesive, samples of the ground were handed over for analysis.

4. THE MODEL OF THE PROBABILITY OF APPEARANCE DANGERS IN THE CONFIGURATION T-H-E

The model was drawn up on the basis of data from points 2 and 3. Emergency events in the water supply system can appear as a result of three factors: T – technical, H – human, E – environmental: Fig. 1.

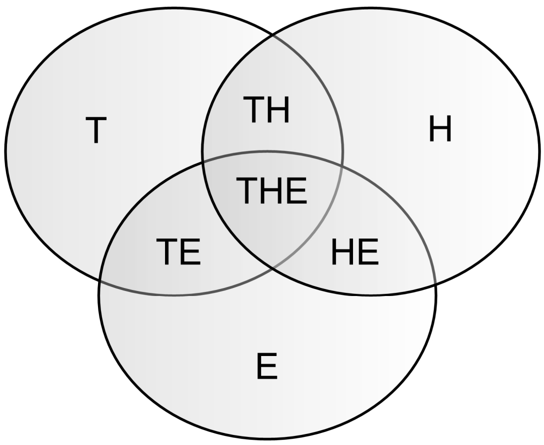

Fig. 1. Illustration of the interdependence of occurring the emergency events in the water supply system: T – technical factor, H – human factor, E – environmental factor

It is possible to assign to every of causes mentioned above, probability of the appearance of the undesirable event P(T), P(H), P(E).

The probability of the emergency event with the participation T-H-E is appointed by the relation:

$$P(T\text{-}H\text{-}E) = P(T) \cdot P(H) \cdot P(E) \qquad (1)$$

The probability of the emergency event with the T-H participation in the T-H-E arrangement is estimated as follows:

$$P(T\text{-}H) = P(T) \cdot P(H) - P(T) \cdot P(H) \cdot P(E) \qquad (2)$$

The probability of the emergency event with the H-E participation in the T-H-E arrangement is estimated as follows:

$$P(H\text{-}E) = P(H) \cdot P(E) - P(T) \cdot P(H) \cdot P(E) \qquad (3)$$

The probability of the emergency event with the T-E participation in the T-H-E arrangement is estimated as follows:

$$P(T\text{-}E) = P(T) \cdot P(E) - P(T) \cdot P(H) \cdot P(E) \qquad (4)$$

Summary probability with the T-H-E participation is possible to estimate as follows:

$$P(T\text{-}H\text{-}E) = P(T) + P(E) + P(H) - P(T) \cdot P(E) - P(T) \cdot P(H) - P(H) \cdot P(E) + P(T) \cdot P(E) \cdot P(H) \qquad (5)$$

5. CONCLUSIONS

The development of methods connected with the analysis and the assessment of the risk is observed, of which essential elements are cost estimation of losses and of preventive protection from failure appearance. The main causes of emergency events in the water supply system are: improper technical condition of pipelines, devices, objects, errors connected with managing and the work of the operator, sanitary-hydrobiological conditions in the source of water and secondary pollutant in the water networks. Applied methods of the protection and securities in WSS don't protect recipients from obtaining water in the full dimension. Guaranteeing the constant delivery of water from waterworks requires having tested procedures of acting in case of among others, emergency events in WSS.

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INCREASE OF THE OVERALL PERFORMANCE OF INFRA-RED HEATING SYSTEMS OF THE HEN HOUSES PREMISES

ABSTRACT

The schedules of air speeds of movement field's distribution at job of heating device for heating premises of hen houses are presented. The results of investigations can be used at designing infrared heating on industrial objects.

KEYWORDS: infrared heating, air temperature, bird's finding zone, exhaust outlet.

1. INTRODUCTION

Premises of agricultural complexes are characterized by big area and height. In such big premises using of infra-red heating systems is expedient. Heating engineers' microclimate in bottom zone of hen houses asserts that it is important to provide. Systems of infra-red heating can make it. Even the ideal air system of heating can not provide the necessary temperature of internal air in a bird's finding zone. It means that air convection decreases in a direction of the floor. The most part of heat reaches to the floor at radiating heating [1].

For prevention of gathering gas combustion products it is necessary to equip a premise of hen house by forced-air and exhaust ventilation. Using the combined infra-red heaters equipped by exhaust outlets, will allow eliminating an opportunity of hit carbonic gas and other products of combustion in a bird's finding zone.

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2. THE LAST RESEARCHES AND PUBLICATIONS ANALYSIS

Big attention among all providing systems of microclimate is allocated highly effective and energy-saving systems of heating and ventilation. Therefore researches of system which united an infra-red radiator for local heating and an exhaust outlet for removal of harmful gases from top part of a bird's finding zone were carried out. Universality of given design shows association of local system exhaust ventilation with system of infra-red heating.

In details design of the heating device is described in [2]. It provides localization and removal of polluted air and increase of efficiency heating the bird's finding zone. Heating device is also known with a radiating grid surface [3]. Lack of this heating device is that it has no an exhaust outlet and intended for job on open air. Other heating device [4] contains an infra-red heater which consists of ceramic plate and reflector installed above it. But this heater does not carry out localization and removal of polluted air.

3. THE PURPOSE AND RESEARCH PROBLEMS

The purpose of carrying out the given research is construction of a speed's field distribution in an operative range of an exhaust outlet at using the heating equipment.

4. TECHNIQUE OF RESEARCHES CARRYING OUT

On fig.1 it is represented scheme of heating device.

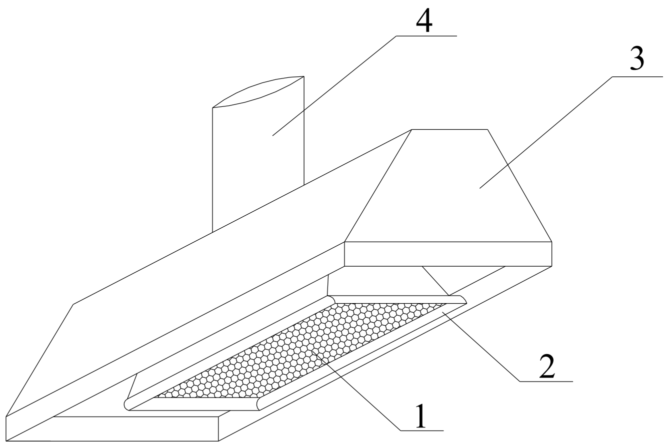


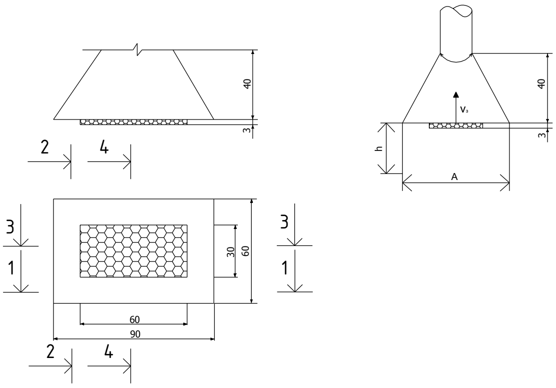
Fig.1. Scheme of experimental installation
1 - ceramic plate; 2 - reflector; 3 - exhaust umbrella; 4 - exhaust branch pipe.

Given heating device contains an infra-red heater that consists of rectangular ceramic plate 1, reflector 2 made from a mirror metal leaf, the exhaust outlet 3 placed above infra-red heater, and exhaust branch pipe 4 for connection to air pipe.

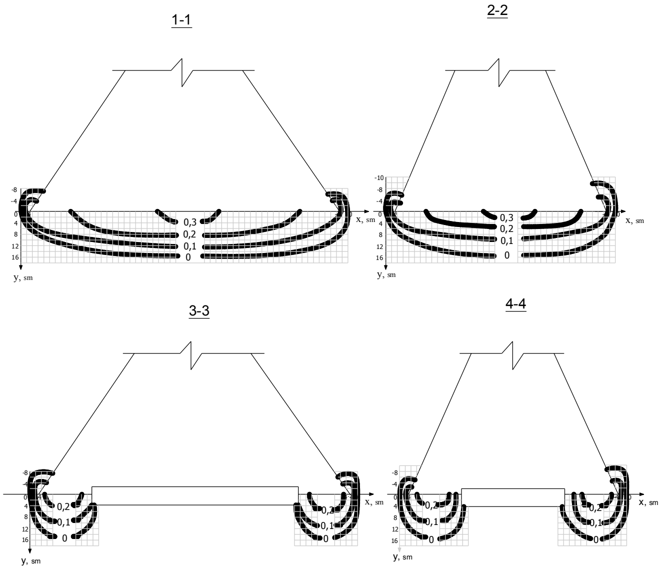
After inclusion of the heating device from a surface of a rectangular ceramic plate 1 there is a thermal streams radiation. Thus by means of reflector 2 made from mirror metal leaf, thermal beams go to bird's finding zone. Simultaneously with heating, exhaust outlet 3 polluted air is localized and leaves through exhaust branch pipe 4, which connected with air pipe.

For example of experimental installation job of system of infra-red heating in a combination to local exhaust ventilation is shown. Establishment of such system in premises will allow providing sufficient microclimate at simultaneous heating objects and removals of share warm air from the top part of a bird's finding zone, with an opportunity of its further recycling.

As a result of researches it has been certain outlet's speed of soak up and its actions zone in places of characteristic sections. The results of experiment are presented in graphic kind and presented on fig. 2, a, b.



a)



b)

Fig.2. Design features of heating device:
a – place of characteristic sections for research of air mobility;
b – schedules speeds of an exhaust outlet in cross-section sections 1-1, 2-2, 3-3, 4-4;
$v_з$ - air speed of soak in an aperture of an outlet; h - vertical distance from the bottom side of a soaking up aperture of an umbrella up to a surface a pollution source, m;
A - the smallest side of an outlet, m.

Character of speeds field distribution in an operative range of an exhaust outlet enables to draw a conclusion, that the given design can localize a convection component of an infra-red radiator and to utilize heat from exhaust air. Thus most the component of such system improves energy-saving, except for it with exhaust air will be partial removal of gas pollution is spent.

5. CONCLUSION

As a result of the spent researches graphic distribution of a speeds field in an operative range of an exhaust umbrella has been received.

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WATER STORAGE TANK CAPACITY INFLUENCE ON DRINKING WATER SAFETY

ABSTRACT

Recently a problem of municipal systems safety became on of the most important. Safety can be defined as a probability that there is no threats for human's life, health or extremely high financial costs. Loss of safety usually results from raw water quality or insufficient treatment. Usually it is reduced by monitoring of raw water or during the treatment process. Important role can have water storage tanks which end treatment process. They reduce pollutant concentration by thinning it down and extend time, when safe water is delivered to water network. In the paper mathematical model of thinning down the pollutant was shown. It makes possible to calculate time of thinning down to get water indicator values recognized as safe for human's health. The method was shown by computational examples for Fe removing process. The tank's safety role lies in reducing pollutant's concentration and extending time necessary for water supply system's operator for actions to reduce pollutant's influence on water consumers, like closing valves or modify the treatment processes.

KEYWORDS: safety, reliability, drinking water, water storage tank, contamination

1. INTRODUCTION

Safety is usually defined as a probability that there is no threats for humans health (life) or extremely high financial costs [1, 2, 3, 4, 5]. The measurements of security are: probability, threat, vulnerability, and consequence [1, 2, 5]. Safety management consist of four phases shown on fig. 1 [6]. The most important is time necessary to make an effort to head towards minimize the consequences [7].

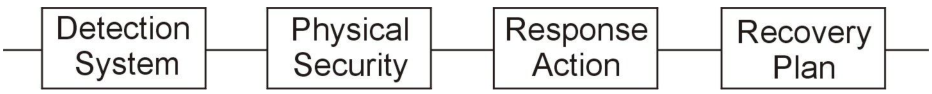

Fig. 1. Functional block diagram [6].

One of the main causes of safety unreliability is bad quality of raw water caused by anthropogenic pollutions. Loss of safety risk can be reduced by raw water quality monitoring,

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monitoring during water treatment and flexibility of the treatment [8, 9, 10, 11, 12, 13]. It can be reduced by treated water storage tanks capacity as well. Water storage tanks have different functions in water supply system. One of them, especially for water tanks at the end of the treatment process, is providing sufficient time for disinfection, others are: water retention for peak water demand, failures and fire demand. Water capacity is favourable because of two reasons: it can reduce contamination concentration and give water supply system's operator some more time for operations to reduce it's influence on water consumers [1,2, 7].

The aim of this work is to describe the tank's advantages mentioned above. The work contains a mathematical model of thinning a contamination down which can be used for time of thinning calculation. It is useful both for incidental man-made pollutions and compounds that naturally exist in raw water. The second case was explained on the example of iron filters failure.

2. IRON SEPARATORS FAILURE

Iron separation process is realized by filters, some of them (basic elements) are designed for reducing iron concentration to standard values, others are reserved in case of failure or operation downtime like separator cleaning or renovation. Basic elements are able reduce Fe concentration to the standard value with operating capacity needed for water demand covering (usually maximum daily demand Q_{dmax}). Usually during the operation all the filters work, so they can reduce Fe concentration below the standard value because effectiveness of the process depends on filtration velocity. Furthermore Fe reducing is used usually in smaller water supply systems - rural or group water mains and not big urban mains, where discrepancy between an average Q_{dav} and maximum Q_{dmax} daily demand is relatively high (relatively high daily unequal index N_d value [14]). So water treatment plant which provides drinking water quality when water demand is Q_{dmax} during Q_{dav} allows to get the water with lower values of Fe concentration. Thus in water storage tanks there is capacity of water V_R with it's quality higher than required by standards. Thanks to this it is possible to temporary overload the filters and deliver to the tank higher Fe concentration and using an effect of thinning down.

The relationship described above on the example of Fe reducing can be extended into other water quality indicators if mathematical relations between concentration reducing and water treatment parameters are known. For anthropogenic pollutions initial concentration in the reservoir can be assumed 0. As a safe value of an indicator like no-observed-effect-level (NOEL) or lovest-observed-adverse-effect-level (LOAEL) according to WHO guidelines [15] or [16] can be assumed.

3. MATHEMATICAL MODEL OF THINNING IN THE STORAGE TANK

There is n basic elements (filters) and m reserved ones. Number of basic elements enables to receive Fe concentration according to the standards, what means that filtration velocity when water demand is Q_{dmax} includes in values allowing to get Fe concentration in treated water for example $c_{Fetr} \leq 0,2$ gFe/m^3. If the water is filtered by all m+n filters filtration velocity is lower so Fe concentration in the reservoir c_{FeR} is lower than required. Thus if it is necessary to turn off more than m filters it is possible to overload working filters to get the filtration velocity which results Fe concentration $c_{Fek} > 0,2$ gFe/m^3. Such an overload can be made until $c_{FeR} = 0,2$ gFe/m^3.

The symbols used below:

k – number of not working filters; $k > m$,

c_{Fe0} – Fe concentration in raw water; g/m^3,

c_{Fetr} – Fe concentration standard value in drinking water; $c_{Fetr} = 0{,}2$ g/m^3,
c_{FeR} - Fe concentration in the storage tank, $c_{FeZb} \le c_{FeUz}$; g/m^3,
c_{Fek} - Fe concentration in filtered water when m+n-k filters work; g/m^3,
V_R – water capacity in the storage tank; m^3,
Q – flow rate of water piped away from the reservoir to water network; m^3/s,
t – time; s.

Calculating a relationship between Fe concentration in time and a number of working filters was made under assumed conditions:

- filters capacity and flow velocity of water piped away from the tank are equal, water capacity in the reservoir is constant,
- water inflowing into the tank is instantly mixing with the water inside.

Let x(t) be Fe load in the tank in time t.
$x(t_0 = 0)$ Fe load in the tank when k filters is turned off:

$$x(t_0) = V_R \cdot c_{FeR} \tag{1}$$

Inflowing Fe load when k>m x_{in}:

$$x_{in} = c_{Fek} \cdot Q \tag{2}$$

Outflowing Fe load x_{out} is:

$$x_{out} = Q \cdot \frac{x(t)}{V_R} \tag{3}$$

x'(t) – change of Fe load velocity in the reservoir is:

$$x'(t) = c_{Fek} \cdot Q - Q \cdot \frac{x(t)}{V_R} \tag{4}$$

Equation (4) is non-homogeneus linear equation, it's solution is sum of general integral of homogeneus equation (GIHE) and particular integral of non-homogeneus equation (PINE).

$$\frac{dx}{dt} = -\frac{Q}{V_R}x \tag{5}$$

$$\int \frac{dx}{x} = \int -\frac{Q}{V_R}dt$$

$$\ln|x| = -\frac{Q}{V_R}t + C_1$$

$$x(t) = e^{C_1} e^{-\frac{Q}{V_U}t} = Ce^{-\frac{Q}{V_U}t} \quad \text{(GIHE)} \tag{6}$$

Using expectation method (CINE) is:

$$x(t) = A$$

$$x'(t) = 0$$

$$\frac{Q}{V_R} x(t) = c_{Fek} \cdot Q$$

$$x(t) = c_{Fek} \cdot V_R \qquad \text{(PINE)} \tag{7}$$

Finally the solution of (Eqn. 4) is:

$$x(t) = C \cdot e^{-\frac{Q}{V_R}t} + c_{Fek} \cdot V_R \tag{8}$$

Using (Eqn. 1):

$$x(t_0 = 0) = C \cdot e^{-\frac{Q}{V_R}t} + c_{Fek} \cdot V_R = c_{FeR} \cdot V_R \tag{9}$$

Thus:

$$C = V_R \cdot (c_{FeR} - c_{Fek}) \tag{10}$$

The relationship between Fe load and time x(t) is:

$$x(t) = V_R \cdot (c_{FeR} - c_{Fek}) \cdot e^{-\frac{Q}{V_R}t} + c_{Fek} \cdot V_R \tag{11}$$

Fe concentration in time $c_{Fe}(t)$:

$$c_{Fe}(t) = (c_{FeR} - c_{Fek}) \cdot e^{-\frac{Q}{V_R}t} + c_{Fek} \tag{12}$$

Equation 12 was shown on fig. 2.

Assuming as the most important quality of treated water, using (Eqn. 12) T_{nmax} when m+n-k filters work can be calculated as shown on fig. 1, or if the time when k filters are turned off (for example when time of filters restoration is assumed), it is possible to find maximum number k. Similarly if relationships describing other contaminations removing are known it is possible to estimate T_{nmax} or k.

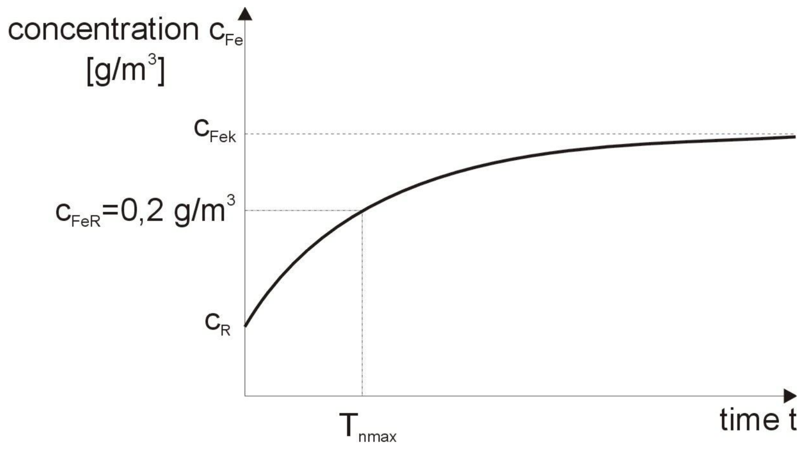

Fig. 2. The relationship between an average Fe concentration and time according to (Eqn. 12), T_{nmax} - is time, when c_{Fe}

Using generalized availability factor [17] allows to calculate water shortage. When it is necessary to reduce capacity piped to water network from Q to Q_f during $T_n > T_{nmax} + T_{Re}$ water shortage is:

$$N = \int_{T_n - T_{n\,max} - T_{Re}}^{T_n} Q(t)dt - Q_f \tag{13}$$

where:

T_{nmax} - time, when the filters capacity is Q,

T_{Re} – is time of the storage tank emptying.

Equation above shows that the water capacity collected in the storage tank extend safe water providing time because both thinning down and after it reservoir emptying time, so increase reliability of water providing.

The mathematical model shown above is theoretical, it's application to a certain storage tanks should be confirmed empirically. It is necessary to take into consideration flow velocity distribution inside the reservoir, which depends among other things on reservoir's construction, it's shape, location of inlet and outlet. But it allows to estimate maximum time, when the quality of treated water is lower than standards or clinically tested safe values without negative consequences for water consumers.

4. COMPUTATIONAL EXAMPLE

Water treatment plant was designed for providing maximum daily demand Q_{dmax} = 3500 m^3/d, average daily demand $Q_{śr}$ = 2500 m^3/d, so daily unequal index is N_d = 1,4, Fe concentration in raw water c_{Fe0} = 2,3 g/m^3, water temperature temp = 10 ºC, pH index 7,0. Deferrization is running by 6 filters, which diameter is 3 m – F = 7,07 m^2 (including 1 reserved filter), filtration filling height L = 1m, average filling diameter d_{av}=1 mm. Clean water reservoir capacity is $V_{Rmax} = 1000\ m^3$, in moment of failure filled in 70% - $V_R = 700\ m^3$.

An effect of Fe removing depends on quality of raw water, filling material, and filtration velocity, for example estimated by Kittner's equation. Filtration velocity v_f shows equation [18]:

$$v_f = 0{,}7 \cdot \left[(3{,}0pH - 18{,}6) \frac{temp^{0,8} \cdot L}{d_{av} \cdot c_{Fe0}^{0,1} \cdot \ln \frac{c_{Fe0}}{c_{Fek}}} \right]^{1,28} \qquad (14)$$

where:

c_{Fe0}, c_{Fek} – Fe concentration before and after filtration; g/m^3.

Calculations were carried out for failure of 3 filters in two cases:

- case 1: failure during Q_{dmax},
- case 2: failure during Q_{dav}.

Case 1

When all the filters work:

$$v_f = \frac{Q_{d\max}}{24 \cdot 6 \cdot F} = 3{,}44\ \text{m/h},$$

According to (Eqn. 13):

$$c_{FeR} = 0{,}11\, g/m^3,$$

$$v_{fk} = \frac{Q_{d\max}}{24 \cdot 3 \cdot F} = 6{,}88\ \text{m/h},$$

$$c_{Fetr} = 0{,}22\, g/m^3,$$

$$c_{Fe}(t) = 0{,}22 - 0{,}11 \cdot e^{-0{,}000058t} \quad \text{(Eqn. 12)}$$

Thus time till $c_{Fe} = 0{,}2\ g/m^3$ is 8,2 h.

Case 2

When all the filters work:

$$v_f = \frac{Q_{dav}}{24 \cdot 6 \cdot F} = 2{,}46\ \text{m/h},$$

According to (Eqn. 13):

$$c_{FeZb} = 0{,}01\, g/m^3,$$

$$v_{fk} = \frac{Q_{dav}}{24 \cdot 3 \cdot F} = 4{,}91\ \text{m/h},$$

$$c_{Fek} = 0{,}12\, g/m^3,$$

In this case water treatment plant works correctly - Fe concentration is lower than standard value.

5. SUMMARY

The main goal of this work was to point storage tanks influence on safety of water supply. Thinning pollutants down the reservoir allows to reduce contamination's concentration, extend time necessary to detect the contamination and finally to make activities allowing to remove it or to protect water consumers against it. The method of estimating time T_{nmax}, when the storage tank allows to reduce pollutant concentration to safe value was shown. It can be applied both for contaminations that naturally exist in raw water and anthropogenic ones or to estimate maximum time of disinfection facilities failure removal. Assumed conditions: filters capacity and flow velocity of water piped away from the reservoir are equal, water capacity in the reservoir is constant and water inflow into the reservoir is instantly mixing with the water in it, cause estimated value T_{nmax} according to (Eqn. 12) higher than real. For a certain water reservoirs it should be confirmed empirically. As it was shown reservoirs can reduce loss of safety probability.

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AIR DISTRIBUTION BY OPPOSED NON-COAXIAL NON-ISOTHERMAL ROUND AIR JETS

ABSTRACT

In this article results of experimental investigations of air supply into the room by air distribution device with interaction of opposed non-coaxial air jets for creation more intensive turbulization air flow in the room are presented. Experimental investigations in order to composed matrix have been carried out; graphycal and analytical calculation dependences have been obtained as well 3-factor chart has been designed. Obtained results of these investigations give possibility to realize engineer calculations of air distribution with interaction of opposed non-coaxial air jets.

KEYWORDS: opposed, non-coaxial, air jet, velocity, temperature.

1. INTRODUCTION

Person's health and efficiency depends on hygiene and sanitary features of working area's microclimate. Physical state of working area's air environment depends on temperature, moisture, air velocity, dust content, and so on. Air velocity has considerable effect on comfort conditions, and also initial turbulization of incoming air on its outlet from nozzle [1-9].

One of the most efficient way of air distribution in the working area is supply of incoming air from the air distribution devices with high intensity (velocity V and exceed temperature Δt) of incoming air parameter's falling at the expense of using an interaction of opposed supply air jets.

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2. LATEST RESEARCH AND PUBLICATIONS REVIEW

One of the most rational way of air distribution is submission of coming air directly in a room serviced area. For this purpose air distribution devices with high intensity of falling of parameters (velocity *V* and temperature *t*) of incoming air are used . As characteristic property of such incoming air jet there is its higher turbulency in comparison with common air jets.

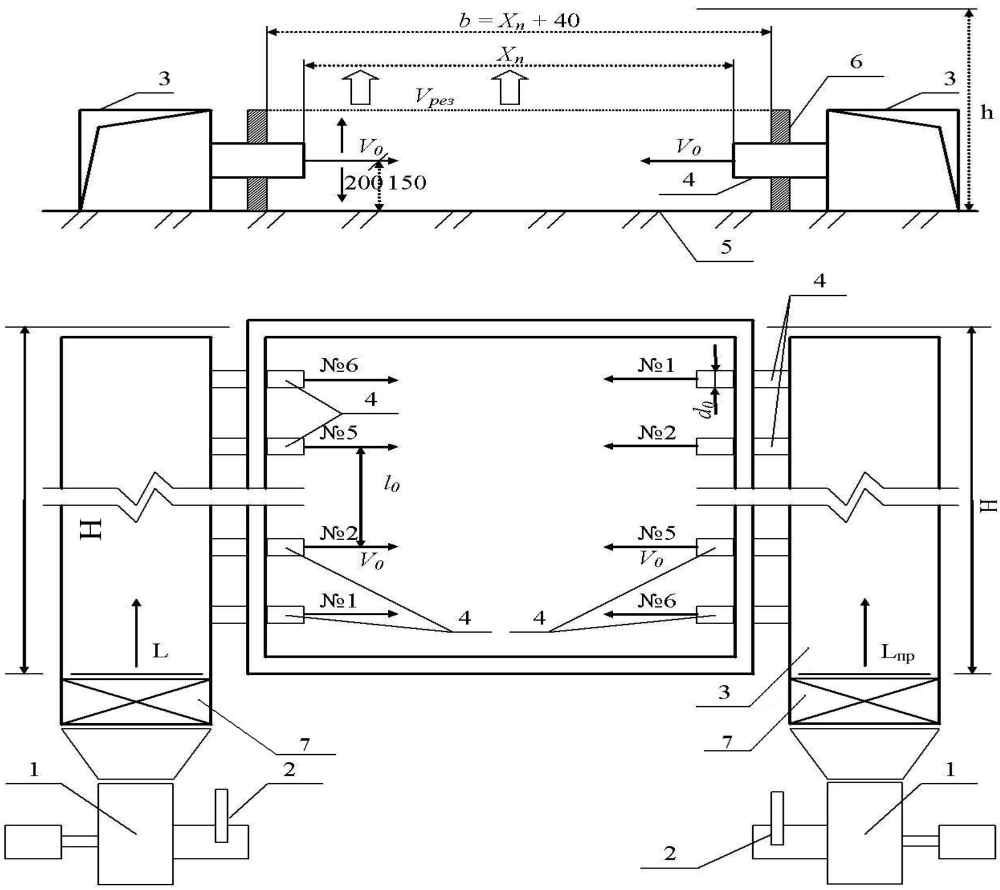


Fig. 1. Scheme of experimental installation:
1 – ventilator; 2 – damper; 3 – air duct a x b = 350 x 350 mm;
4 –air supply nozzles d_o = 50 mm and their numbers (1÷6); 5 – base stand;
6 – constructive part of air distribution device; 7 – air-heater (air-cooler);
h – distance from the flat area of the specific fields of velocities.

In this work we consider aspect of raising effect from air distribution in the working area at the expense of achievement high intensity of falling of parameters of the total air flow during air supply by the air distribution device with interaction of opposed non-coaxial air jets. It is also considered the effect of interaction of opposed non-coaxial air jets, which leak from the nozzle in due conditions Fig.1.

As a result of interaction of air jets is created total air flow, which is directly applied in the working area. The principal concern in this work is to investigate relation between air supply device characteristics and total air flow in dependence of air jets interaction.

3. FORMULATION THE ARTICLE'S PURPOSE

The purpose of this work is to study the character of total air flow spreading, to determine and optimize correlation among geometric characteristics of the air distribution device, and also the intensity of velocity falling V and exceed temperature Δt extinction of the total air flow for various cases of interaction among opposed non-coaxial air flows, namely: in view of various values of running data (h and x), distance relationship between opposed jets axes (l_o), distance between opposite nozzles ($X_п$).

4. PRESENTATION OF THE MAIN MATERIAL

Experimental research has been carried out on the installation, that is presented on fig. 1, under such conditions and simplifications: jets are non-isothermic; research was conducted with heated, and cooled jets; air supply nozzles – branch tube with coefficient of velocity falling m = 6,8; their diameter was constant and was equaled to d_o = 50mm; linear dimension of air ducts didn't change and was equaled to H = 1,5 m; the distance between axes of nozzles l_o was running and equaled to: l_{o1} = 100 mm = 2d_o; l_{o2} = 150 mm = 3d_o; l_{o3} =200 mm = 4d_o; the stretch of opposed jets $X_п$, was running and equaled to: $X_{п1}$ = 0,6m = 12 d_o; $X_{п2}$ = 0,8m = 16 d_o; $X_{п3}$ = 1,0m = 20 d_o; $X_{п4}$ = 1,2m = 24 d_o; relation of air flow rates that interact $\overline{L} = L_l / L_r$, did not change, at that $L_l = L_r$; initial velocity of air in nozzles for supply was in the range of: V = 5 –15 m/s.

The gaugings of air flow velocity V were carried out by thermal electric anemometer testo-405 with using coordinate grid of 5 x 5 sm.

For realization of experimental investigations 3 - factor chart has been design taking into account the effect of factor interaction, at that was accepted linear mathematical model [10]. As the starting point were taken such values Fig.1 : x_1 = h / H – relative vertical running data; $x_2 = X / X_п$ – relative horizontal running data (Xп – distance between air ducts); $x_3 = l_o / d_o$ – relative distance between nozzles axes.

As optimization parameters y_1 and y_2 there were: $\overline{V}_h = V_h / V_0$ is relative velocity of air motion in the room, where V_h is running velocity of total airflow in the calculated air distribution device flat area, and V_0 is initial velocity; $\Delta\overline{t}_h = \Delta t_h / \Delta t_0$ is relative exceed air temperature in the room , where Δt_h is running exceed temperature of total airflow in the calculated air distribution device flat area , and Δt_0 is initial exceed temperature (at the output of nozzle).

Consequently, we need to establish functional dependences $\overline{V}_h = f_1(x_1; x_2; x_3)$ and $\Delta\overline{t}_h = f_2(x_1; x_2; x_3)$.

Regression equations are next:

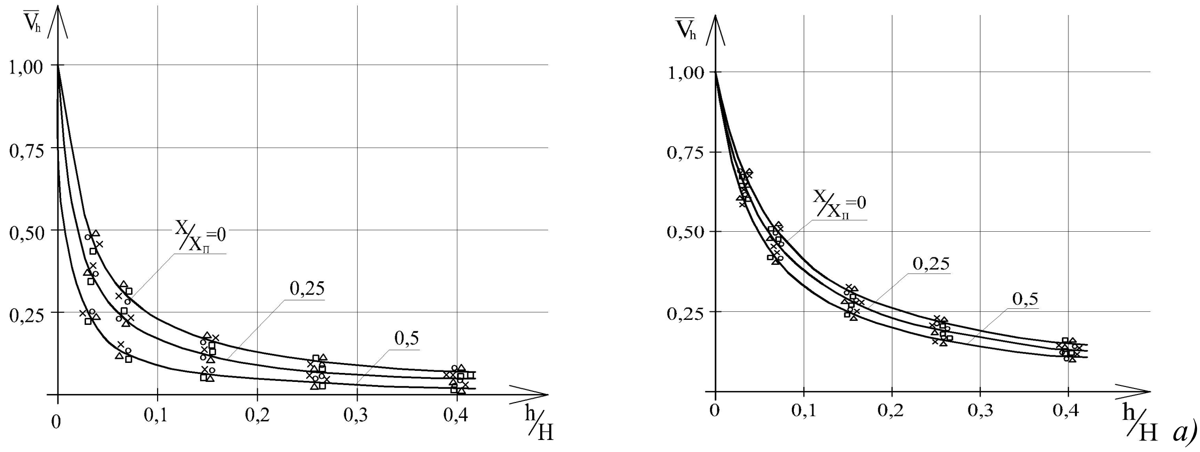
$$\overline{V_h} = 0,488 - 0,295x_1 - 0,113x_2 + 0,075x_3 + 0,005x_1x_2 - 0,023x_1x_3 - 0,010x_2x_3 - 0,008x_1x_2x_3 \quad (1)$$

$$\Delta\overline{t_h} = 0,343 - 0,215x_1 - 0,075x_2 + 0,055x_3 + 0,003x_1x_2 - 0,018x_1x_3 - 0,008x_2x_3 - 0,005x_1x_2x_3 \quad (2)$$

On the ground of the analysis of regression coefficients Eqn.1, Eqn.2 we can assert:

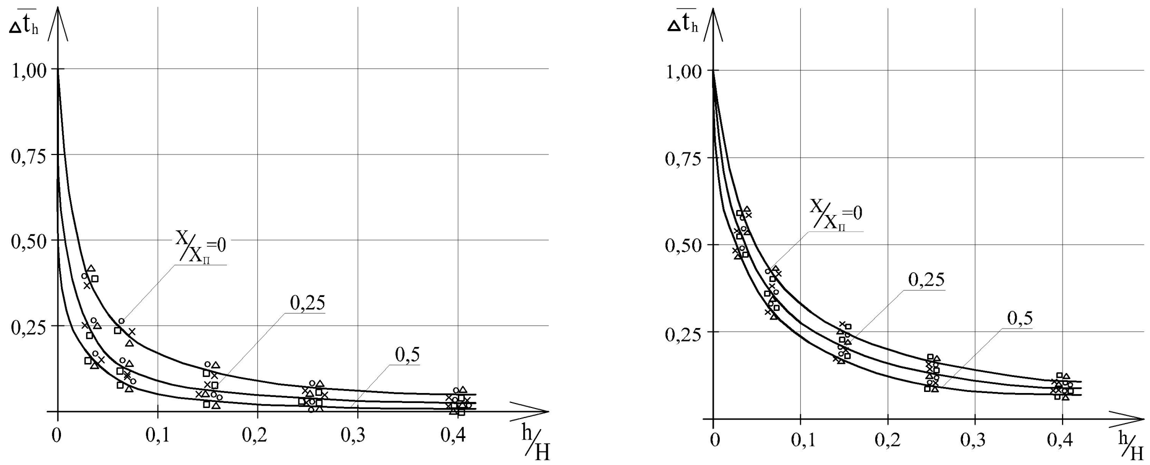
- the profound effect on behavior of response function reveals factor x_1 (relative vertical coordinate h / H), but factors: x_2 (relative horizontal coordinate $x / X_п$), x_3 (relative distance between axes of the nozzles) – does not have considerable influence;

- numeric increase of the relative distance between axes of the nozzles results in increasing response function, but increase of relative coordinates (vertical and horizontal) result in to its decrease. This means, that in order to increase the intensity of velocity $\overline{V}_h$ and exceed temperature $\Delta\bar{t}_h$ extinction of the total air flow it is necessary to increase distance from air supply nozzles to the flat working area, but distance between axes of the nozzles and relation of flow rate – decrease.



a) $l_0 / d_0 = 2$ b) $l_0 / d_0 = 4$

Fig. 2. Chart for determination of air velocity in the room $\overline{V}_h$



a) $l_0 / d_0 = 2$ b) $l_0 / d_0 = 4$

Fig. 3. Chart for determination of air exceed temperarure in the room $\Delta\bar{t}_h$

As a consequence of maximal decreasing of the distance between axes of the nozzles the flat flow with a number of compact ones has been created.

As a result of experimental research charts have been designed Fig.2, Fig.3.

On the basis of presented charts analytic equation has been obtained Eqn.3:

$$\overline{V} = \frac{-0{,}01 + 0{,}01\frac{l}{d} - 0{,}04\frac{x}{Xn}}{\frac{h}{H} - 0{,}01 + 0{,}01\frac{l}{d} - 0{,}04\frac{x}{Xn}} \qquad (3),$$

and we have also made an attempt to construct universal chart Fig.4, in which all the values that we have viewed are united on the common figure: $\overline{V}_h$; h / H; $x / X_п$; l_0 / d_0.
In accordance with experimental findings, the optimal linear relations to take sufficiently high intensity of velocity extinction of the resulting air flow, that is minimal values $\overline{V}_h$, are: h / H = 0,40 ; $x / X_п$ = 0,5 ; $l_o / d_o = 2$. At that the effect of using opposed non-coaxial jets will be highest possible. It is evidence of expediency to substitute compact jets for flat ones.

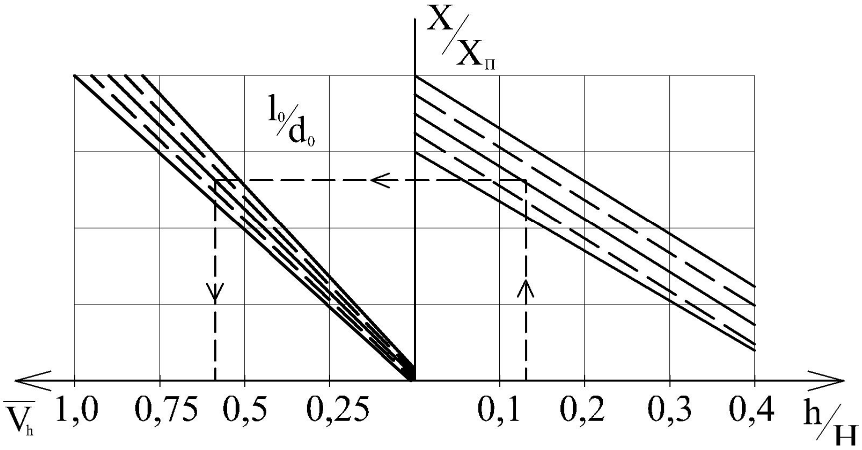


Fig. 4. Chart for determination air velocity in the room $\overline{V}_h$

5. CONCLUSIONS

On base obtained results we assert:

- geometric and flow rate data of air distribution device is determined and optimized for different cases of opposed non-coaxial air jets interaction, namely: at different distance from air outlets to serviced area surface x/X_p and h/H, and also distance between axes of cylinder nozzles (l_o / d_o);
- transfer from compact air jets that interact to flat air jets is recommended.

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RISE OF USE EFFECTIVENESS OF SOLAR ENERGY IN ANNUAL SOLAR SYSTEMS

ABSTRACT

This article coves the results of investigation of solar radiation incoming on the heliocollectors. Dependence between the amount of discreet orientations of the solar collector and efficiency of work of its system has been established. The results of the experimental researches of one constant and four variable orientations of the collector on the Sun are given.

KEYWORDS: solar collector, solar energetic, discrete orientation.

1. PUTTING OF THE PROBLEM

System of supplying solar heat is one of the most perspective themes in solar energetic. Despite the great variety of solar systems, practically each of them has three main elements: energy receiving system (solar collectors), energy transferring set (heat carrying medium) and energy using system (system of supplying warm water, heating, etc).Accumulator of heat and extra source of energy can also be added. The efficiency of using solar energy coming from the sun depends on the right and coordinated function of these mentioned systems in complex and each systems alone.

Maximum receiving of energy by surface of a solar collector which corresponds to the highest efficiency and the most effective use of solar energy is reached by the way of putting the surface into the position, perpendicular to the falling sunrays.

The discreet reorientation of the collector gives rather a big gain of received energy comparing with energy that could come from the constant collector.

However it is unknown how many times per day collectors must be moved in order that the expenses for reorientation could be minimum and received amount of energy could be maximum.

So, the task is to find a simple and economical method of orientation of solar collectors, due to which one could get maximum possible amount of solar energy.

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2. SURVEY OF THE LATEST RESEARCHES AND PUBLICATIONS

A lot of works [1; 3; 4] are devoted to finding the best angles of slope of the collector to the horizon and azimuth of turning at which the greatest amount of solar energy will come. Everyone states that about 40% more energy comes from the collectors that change their angles of position than from the constant collectors [2].

Daily change of the position of the angles of the collector cannot be necessarily constant but periodical too. So, a solar device is put in the best, for a given period of work, position and the collector of solar energy allows changing orientation by hand several times per day [5;6].

The idea of a "half follow" collector was suggested in the work [7]. The collector axle was bent to the horizon under the angle which is the best for any month. For twenty-four hours collector is moved around its axle every 30 minutes. As a result the collector received amount of energy which equals to amount of energy which would come on a constant regular moving collector and much more bigger amount of energy than on a constant.

All investigations show that daily reorientation of the collector gives rather a big gain of a received energy comparing to the energy that would come from a constant collector.

3. THE AIM AND TASKS OF RESEARCHES

Finding the best amount of turning of the solar collector at its discreet orientation for different regions of placing solar device from the point of its economical and energetic efficiency.

4. DESCRIPTION OF EXPERIMENTAL DEVICE

Device consists of two standard solar collectors, a tank for heat carrying, pipelines and hoses, control accessories Fig. 1.

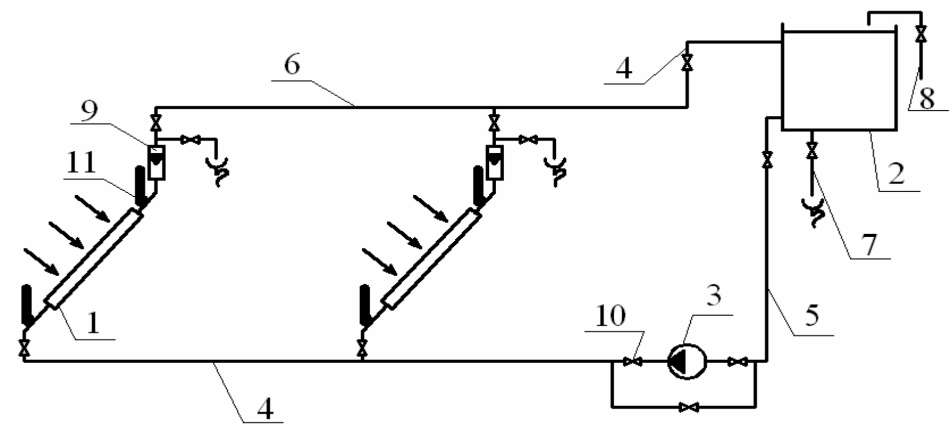

Fig. 1. Principle chart research plant

1. Solar collector. 2. Tank for heat – carrying agent. 3. Circulating pump. 4. Distributive tubing. 5. Supply tubing. 6. Reverse tubing. 7. Interflow tubing. 8. Tubing of cold water. 9. Measurer of liquid. 10. Control accessories. 11. Mercurial thermometer.

The general radiation on the horizontal surface was measured by a thermoelectric albidometer and the direct radiation on the perpendicular to the rays surface-by thermoelectric acidometer. All solar collectors are put in the best given surfaces on special stands with turning mechanisms which can ensure the orientation of each collector in the right direction and with a given of slope to the horizon.

Laboratory thermometers were used for determining the temperature of a heat carrier and the air.

5. MAIN PART

Experimental research was carried out at such conditions and simplifications:

- incoming of solar radiation on the collectors was received in parts concerning the maximum possible;
- all solar collectors are put in the best given surfaces;
- liner size of pipelines was not changed;
- one constant orientation of the collector and 4 changeable its orientations were taken;
- measurements were done 6 times per year Fig. 2 with further average quantity of efficiency K_{ef};
- obvious results of the experiment and approximation α = 0,95 are accepted;
- during mathematical evaluation of the results for discrete orientations continuous functional dependences were set.

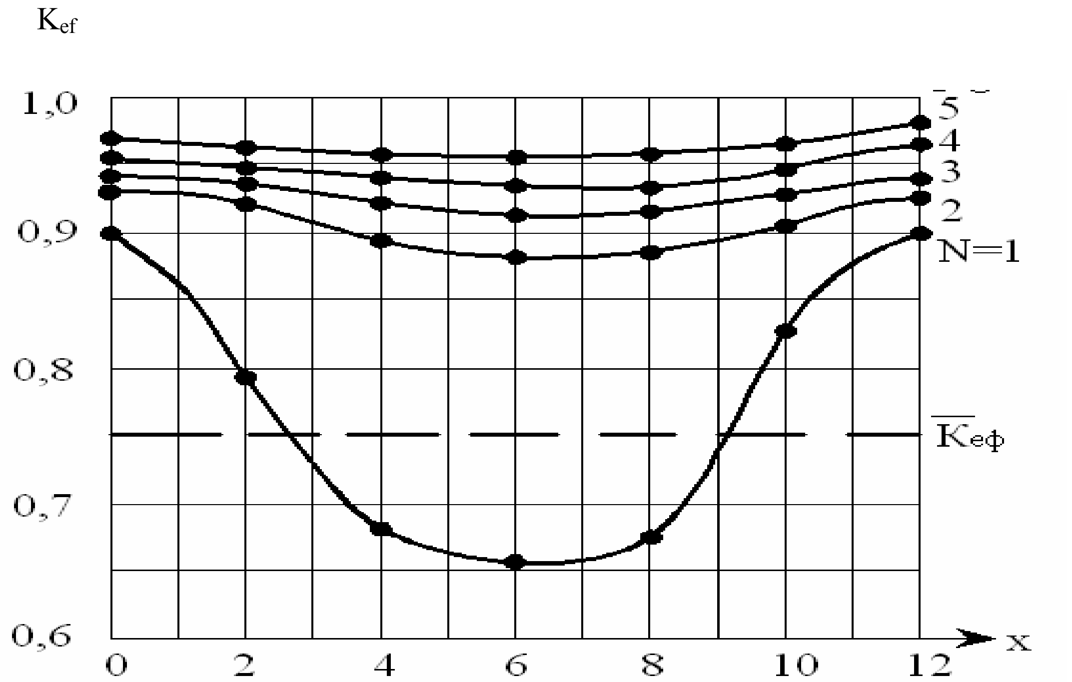

Fig.2. Yearly changing of coefficient effectiveness K_{ef} of discrete methods of orientations N

Daily incomings to solar radiation on collector surface will be maximum when not only every direction during discrete orientation will be the best, but the time of reorientation will also be optimum for two next positions. Such condition is possible at receiving equality of the amount of solar radiation, which comes for a unit of time on the surface of receiving during the former and the next orientations [8].

On the basic of the data of the diagram Fig. 2 one can state that constant orientation (N = 1) of solar collectors on the south is the most effective, besides the smallest K_{ef} (K_{ef} = 0,65…0,67) comes on summer months, when incoming of solar radiation is the highest.

On Fig. 2 we can see the curves of incoming solar radiation for all month of the year at different variants of orientations in regard to the maximum possible incoming of radiation on the collectors of follow orientation are shown.

This reference is the coefficient of efficiency $\bar{E}$ of discrete method of orientation.

Diagrams Fig. 2 are approximated by the following way:

1. For constant orientation of a solar collector:

$$N=1: K_{ef}= 0{,}66 + (x - 6)^2 * 0{,}010$$

2. For changable orientation of a solar collector:

- $N=2$: $K_{ef}= 0{,}88 + (x - 6)^2 * 0{,}002$;
- $N=3$: $K_{ef}= 0{,}93 + (x - 6)^2 * 0{,}001$;
- $N=4$: $K_{ef}= 0{,}95 + (x - 6)^2 * 0{,}001$;
- $N=5$: $K_{ef}= 0{,}96 + (x - 6)^2 * 0{,}001$,

where x – is the number of a month.

Then average figure of efficiency coefficient $K_{eф}$, was determined due to efficiency $\overline{Kef}$ was determined with the help of integration, during the year was determined its average year figure $\overline{Kef}$, according to different number of discrete orientations of the collector N.

The average figure $\overline{Kef}$ was determined by means of approximation of diagrams Fig. 2 and further integration in limits from 0 to 12 by months. So, ensuring equality of surfaces of a curvilinear trapezium ($S_1 = \int_0^{12} f_i(x)dx$) and corresponding rectangles ($S_2 = \overline{K}ef * 12$) the average figures were the following:

$$\overline{K}_{ef} = \frac{1}{12}\int_0^{12} f(x)dx. \quad (1)$$

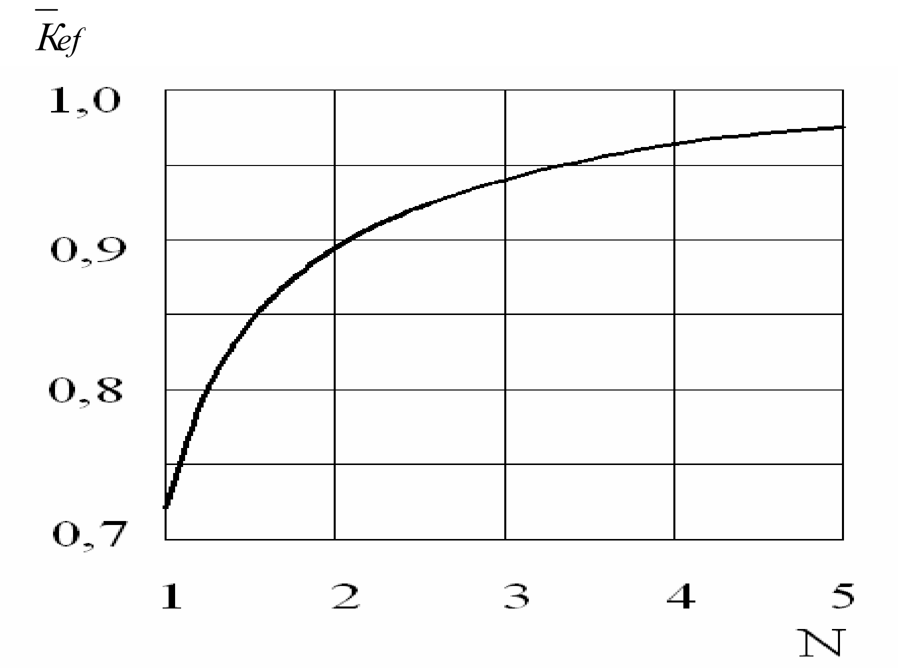

Fig. 3. Dependence of effectiveness coefficient $\overline{Kef}$ of quantity discrete orientations N

On the graph Fig. 3 one can see average figures of the effectiveness coefficient as for the constant position of a solar collector (N = 1), as well as for its changeable (N = 2…5) discrete orientation taking into account the yearly change of efficiency coefficient Fig. 2.

Average figure $\overline{Kef}$ (for example for N = 1) was received in such way:

$$\overline{Kef} = \frac{1}{12}\int_0^{12} (0{,}65 + (x-6)^2 * 0{,}01)dx = \frac{1}{12}(0{,}65x\Big|_0^{12} + 0{,}01\frac{1}{3}(x-6)^2\Big|_0^{12} =$$

$$\frac{1}{12}(7{,}92 + 0{,}72) = 0{,}72.$$

As the diagram, on which we can see the dependence of $\overline{Kef}$ against amount of discrete orientation N, shows that the curve asymptotically comes to the straight line $\overline{Kef}$ =1,which belongs to the follow system of orientation.

Ggraph Fig. 3 is approximated by dependence:

$$1 - \overline{K}_{ef} = \frac{a}{N+a}, \qquad (2)$$

where a is a constant coefficient.

While using mathematical methods of calculating results of the experiment, the constant a was defined: $a = 0{,}21$, and formula looks like this:

$$\overline{K}_{ef} = \frac{N}{N + 0{,}21}. \quad (3)$$

But at increasing the amount of discrete turnings, the cost of the device is increasing too, that is why it is necessary to give corresponding economic data Fig. 4.

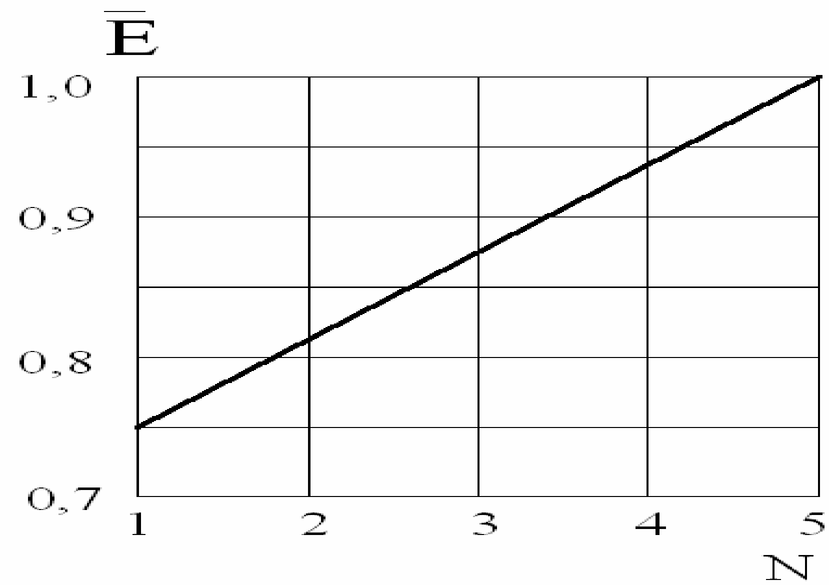

Fig. 4. Dependence relative cost Ē from quantity discrete orientations N

On graph Fig. 4 is shown dependence of relative value $\bar{E}$ (relation of amount of discrete orientations E_i to maximum value E_{max} at constant (N = 1) collector and 4 changable orientations (N = 2…5) $\bar{E} = E_i / E_{max}$) from the amount of discrete orientation of the solar collector N.

This graph is described by linear dependence:

$$\overline{E} = 0{,}69 + 0{,}06N \quad (4)$$

Graph Fig. 3 which characterizes efficienency K_{ef}, does not have points of extremum and is increasing monotonously but the graphic Fig. 4 which characterizes the cost, has the same principle. On account of this it is not possible to get the desired result in the points of maximum or minimum, since they do not exist.

So, it is necessary to establish the criteria of optimization – specific value E_o , as relation of the relative value $\overline{E}$ to the average coefficient of efficiency of getting solar energy $\overline{K}ef$:

$$E_o = \frac{\overline{E}}{\overline{K}_{ef}} \quad (5)$$

Taking into account dependences Eqn. 3 and Eqn. 4 we get:

$$E_o = 0{,}06N + 0{,}7 + \frac{0{,}145}{N} \tag{6}$$

Function $E_o = f(N)$ is not monotonous, it has point of minimum, so after differentiation it is not difficult to define $N = 1{,}55$.

At it was mentioned in conditions and simplifications one builds the graphic dependence, tabbing the Eqn. 6. This graph Fig. 5 gives a real character of the function $E_o = f(N)$ and confirms the existence of the point of minimum (point A), for which indeed $N = 1{,}55$.

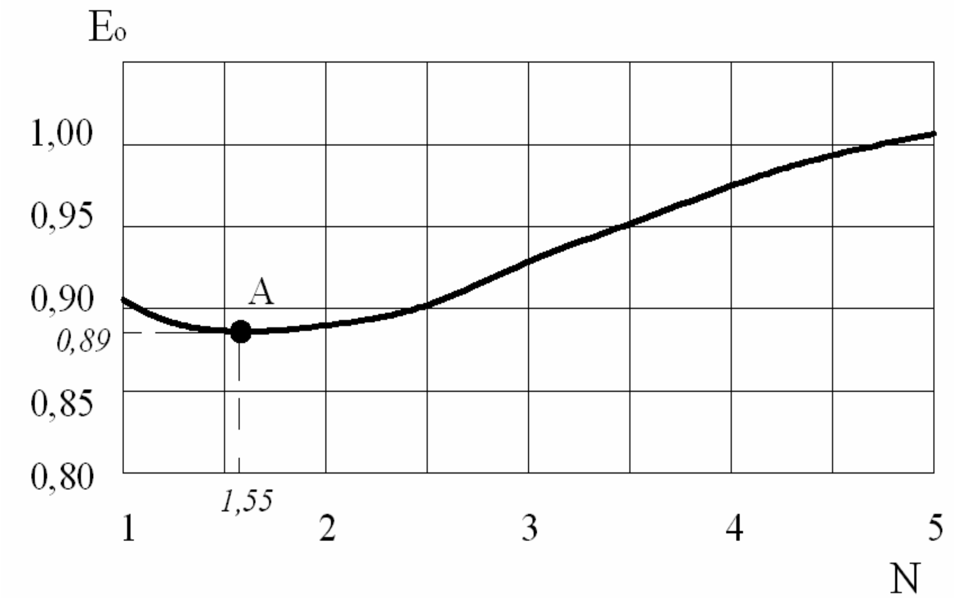

Fig. 5. Dependence of specific cost E_0 against quantity of discrete orientations N

As a result it is necessary to round to the number $N = 2$.

6. CONCLUSIONS

Using of discrete orientation is the most effective in summer when it is possible to use the incoming of energy on the collector during the light 24 hours (in comparison at constant orientation the light period is only 70…80 %). So, due to discrete orientation it is possible to increase the process of taking energy from solar collectors to the figures which are slightly different from maximum possible.

Since with such increasing of the amount of discrete turnings, cost of the device is increasing too, the device with the smallest amount of turnings is better, that is $N = 2$. So, double orientation of a solar collector is enough for ensuring practically maximum incoming of solar energy on collector with such minimum expenses on orientation.

Acknowledgements. In this article are used results from projects VEGA 1/3234/06 and Nato – ESP. NUKR. CLG 982978.

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RENEWABLE ENERGY SOURCE FOR TODAY SITUATION - GEOEXCHANGE SYSTEMS

ABSTRACT

An increased utilization of renewable energy sources in the heat and electricity generation is one of priority tasks of the Slovak Republic to boost the use of domestic energy potential and thus to decrease the Slovakia's dependence on imported fossil fuels. For this reason the experimental workplace "Economic Research Centre for Renewable Energy Sources and Distribution systems" was founded last year. In the article we deal with heat pumps offering the most energy-efficient way to provide heating (central and water heating) and cooling in many applications, as they can use renewable heat sources in our surroundings. It is argued that heat pumps are very energy efficient, and therefore environmentally benign. Within good conditions the energy from low-potentional heat, in other way unusable, is used for the price of supplied energy for heat pump performance. This article determines applicability of this system supports utilization of electric energy low tariff rate, which is also valid for the other electrical appliances on the real administrative building.

KEYWORDS: heat pump, operation, low-potentional heat, electric energy

1. INTRODUCTION

The principle of the heat pump (HP) or so-called GeoExchage system is known for more than 100 years. The usefulness of heat pump is clearly demonstrated by relatively low cost of the system and the competitive prices of other energy sources. Heat pumps can be thought of as a heat engine which is operating in reverse. For examples are food refrigerators and freezers and air conditioners and reversible-cycle heat pumps for providing thermal comfort. The sources of energy are in our surroundings (water, air, ground), which are huge natural resources at low temperature level. Their utilization is efficient when the energy at low

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temperature level is overdrawn by HP to higher temperature level. The useful heat consists of the energy extracted from the source (in this case the groundwater at 10 °C is cooled down) and the heat, which is equal to with delivered electrical energy. From these energies it is possible to define the coefficient of performance. The term coefficient of performance (COP) is used to describe the ratio of the output heat of the supplied work.

$$COP = \frac{E_1 + E_2}{E_2} \tag{1}$$

Where is
E_1 energy extracted from the source (water temperature from 10°C to 6°C), in kWh
E_2 delivered electrical energy for HP, in kWh.

The COP depends on work conditions. This number is spaceless and it is the main indicator of quality, or particularly appropriate of the source. On the input side there is the temperature of the cooled down water, HP quality and working order and on the output side temperature of heated medium (water for heating or heated water). When the temperature difference between heated and cooled medium is smaller, the COP is higher. On the contrary, with the higher temperature difference COP goes down. For example: with COP = 5 the output energy is 5kWh and electrical energy input is 1 kWh. Therefore we want to use the low temperature heating systems.

It is argued that heat pumps are very energy efficient, and therefore environmentally-friendly. With good conditions the energy from low-potential heat, in other way unusable, is used as a source of energy for heat pump performance. The applicability of this system supports utilization of electric energy at low tariff rate, which is also valid for operation of other electrical appliances. Analyses show the fact that the process of climatic changes is closely tied to the increase of greenhouse emissions in the atmosphere. Depletion of planet's sources is exceeding 30% of its natural ability of recovery [1]. These facts support the motivation to decrease energetic costs of energy primary sources in combination with reduction of greenhouse gases emissions. It is the primary ecological debt of the planet in combination with climatic changes that creates the danger of generation of future costs ranging from 5 to 20 % GDP [2]. The report developed by commission administered by Lord Stern also shows the fact that yearly investments of 1% GDP during next 20 years will enable volume stabilization volume of emissions in atmosphere, and therefore also the increase of temperature and climatic changes to acceptable level. The aim is to reduce the greenhouse gas emissions by 80% by year 2050. From the point of view of all consumed energy, which is the main producer of emissions, the buildings contribute by 40%. One way of achieving this goal is reduction of energetic costs of primary energetic sources of buildings for delivery of heating and cooling. Together with reduction we focus on the technique of production of energy and its consumption by intelligent systems of buildings.

Current situation is focused on sustaining emissions on limited figures by allocating quotas by the European Union Commission with exact assignment to the producer. Emissions which are within quota limits are funded by the state. The costs related to elimination of damage caused by emissions are not included in the price of energy. In this aspect, the renewable resources are economically handicapped in comparison to fossil fuels. The level of handicap is created by the value of emissions produced by particular type of energy source to energy unit.

2. THE DESCRIPTION AND OBJECTIVES OF EXPERIMENTAL WORKSTATION

In 2008 the experimental workplace: Economic Research Centre for Renewable Energy Sources and Distribution systems was founded with the purpose of investigating possibilities to reduce the energetic costs of buildings tied to economy. The Centre operates in the region of Slovakia, which is placed in Central Europe, in mild climatic area. Its founders are the most significant Slovak Universities. Two of them are of technical orientation and one of them is a university of economics orientation together with enterprising subject. The aim of this association is to create conditions for active solutions of economical and legal questions related to implementation of renewable resources and sources of energy with low level of emission production.

The aim of the Research Centre is:

- To define unified market of renewable energy sources (RSE) and energy produced by fossil fuel
- To handle the priority of RSE input into energy distribution system
- To define legal conditions for investments and investors‘ investments protection
- The review of individual types of RSE based on geographical and other characteristics and set their mutual priorities.
- To ascertain principles for review of influence of forced character of energy source in a particular distribution system.
- To solve elimination of RSE implementation legal barriers
- To consider the lack of European Union’s own energy resources
- To understand the coherence of solutions and implementation of projects in practice and legislation.

By founding experimental workstation we conduct applied research and development of RSE – heat pump and indoor technologies. The goal is:

- To cut down CO2 emissions to less than 90% of current level
- To ensure that the building is supplied by at most 20% of fossil fuel energies and that at least 80% energies have come from renewable sources
- To reduce operation costs
- To secure standard working environment with the aim of increasing the standard by use of summer cooling
- To ensure economic return on investments
- To provide economic justification for symbiosis use of sophisticated fossil fuel – natural gas with RSE energy carriers
- To propose legislative outputs
- To ensure the connection between the pedagogical practice with applied research and implementation of outputs

The realized project of the Centre creates real environment for effective implementation research of technologies in laboratory and operative conditions: technologies of co-generative elements, heat pumps, thermal capillaries, and technologies in field of measurement and regulation. The solution is the project with possibility to repeat it on other similar applications as well as the utilization of experience and determination of economical expedience of researched technologies implementation. The quality of buildings’ environment influences health, efficiency and comfort of building’s users. Current studies show that the costs of internal environment quality improvement are often higher (for company, employer and building’s owners) than costs of energy consumed in the building. Energetic declaration without declaration of relation to quality of inner environment therefore does not make sense and is not sufficient. Specification and consideration of design criteria for parameters of inner environment are needed for design of buildings, energetic calculations, operation and regulation of buildings. Next phase of the research will be evaluation of operative behavior of the building, interaction with building constructions and study of inner climate parameters.

Figure 1 – Building of the Centre and Experimental office room

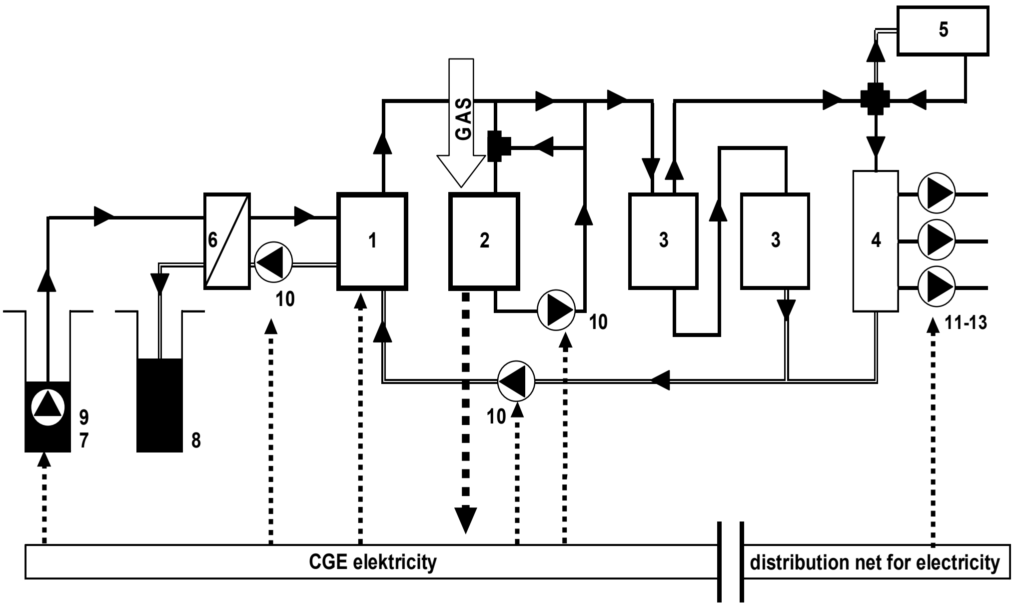

Figure 2: Diagram of energy supply
1 Heat pump (HP), 2 Co-generative element (CGE), 3 Accumulation tank, 4 Heated object, 5 Supporting and top source, 6 Heat exchanger, 7 absorbing well, 8 suction well, 9 well pump,10 circulatory pumps- engine room, 11-13 circulatory pumps – object

2. LAYOUT OF DESCRIPTION OF EARLY MEASURES

The experimental laboratory is an administrative building with space for laboratory and training (see Figure 1). It was built in 1975 according to then valid standards and principles. The characteristics of constructions and heating system were influenced by the need for energy and heat supply. This object did not contain air condition or cooling system. This building was modified by long-running premeditated process to reduce energy supplied for operation of the object. These can be divided into two phases:

1. Constructional and technical modifications of the object effecting the reduction of heating consumption
2. Change of energy and fuel source, to secure increase in efficiency of primary energy use and reduction of CO2 emissions.

Fallout of these modifications in both phases 1 and 2 in years 1996-2006 can be seen in Figure 3.

2.1. Original condition

The studied building was without changes to circuit constructions and the heating system since its construction until 1996. The supply of energy came from central distribution system. Heating plant - transmission station - object. The source was the city's heating plant burning up coal and natural gas in combination with electrical energy production. Heat consumption as measured at its entry to the object of heating was 3200 GJ (=100%). These initial data will be used to compare the effects of taken subsequent measures.

2.2. Building insulation and change of windows

In 1997 change of windows and insulation of circuit constructions of the object took place. The average consumption of heat in years 1997 – 2004 was 1678 GJ (=52% of original consumption.

2.3 Thermostatisation

In 2005, the average consumption was reduced to 1165GJ (about 36%) by hydraulic regulation and installation of thermostatic valves. Installation of thermostatic valves on heating bodies enabled local regulation of each heating body. There is also the possibility to consider heat gain in each room by reduction of necessary heating output.

3. DESCRIPTION OF ACQUIRED MEASURES

3.1. Heat pump (HP)

The main change in the system of heat supply happened after installation of RSE – Heat pump- in the object in 2007. The original source works as peak and backup source. Heat energy is taken from groundwater (see Figure 2). The energy gained by its cooling transforms heat pump to more efficient mode. It is driven by electric energy. By using heat pump, coefficient of performance (COP) 1:3 was reached. In numbers, this means that the amount of electric energy is 380 GJ (decrease to 12 %) If we compare years 2007 and 2006 (to find out the effect of renewable resource only), the result of the source change is the decrease to (380/1080=35%), which stands for 65% saving.

3.2. Capillary mats

Installation of capillary mats to the ceilings anticipates reduction of necessary primary energy needed to supply the heat pump to 260 GJ. The reason of heating system change from conventional heat conducting heating units (bodies) to emanating low temperature way is the increase of heat production effectiveness. COP of heat pump production is expected to be COP 1:4.3 instead of 1:3. However, if we compare original levels in year 1996, the consumption of primary energy is at the level of just (8%). The expected consumption of primary energy when compared with year 2006 means reduction to (260/1080 i.e. about 26%).

The change of system brings on new quality in form of the possibility to conduct summer cooling in this object. It is enabled by parameters of water in the well in summer (15 degrees) and the demand for cooling water of 18 degrees. The heat pump is completely excluded from the process of cooling and we only need pumping labor for circulation of cooling water. The proportion of pumping labor will be determined by COP of coolness production on level 1:2, which means 7 times increase in effectiveness.

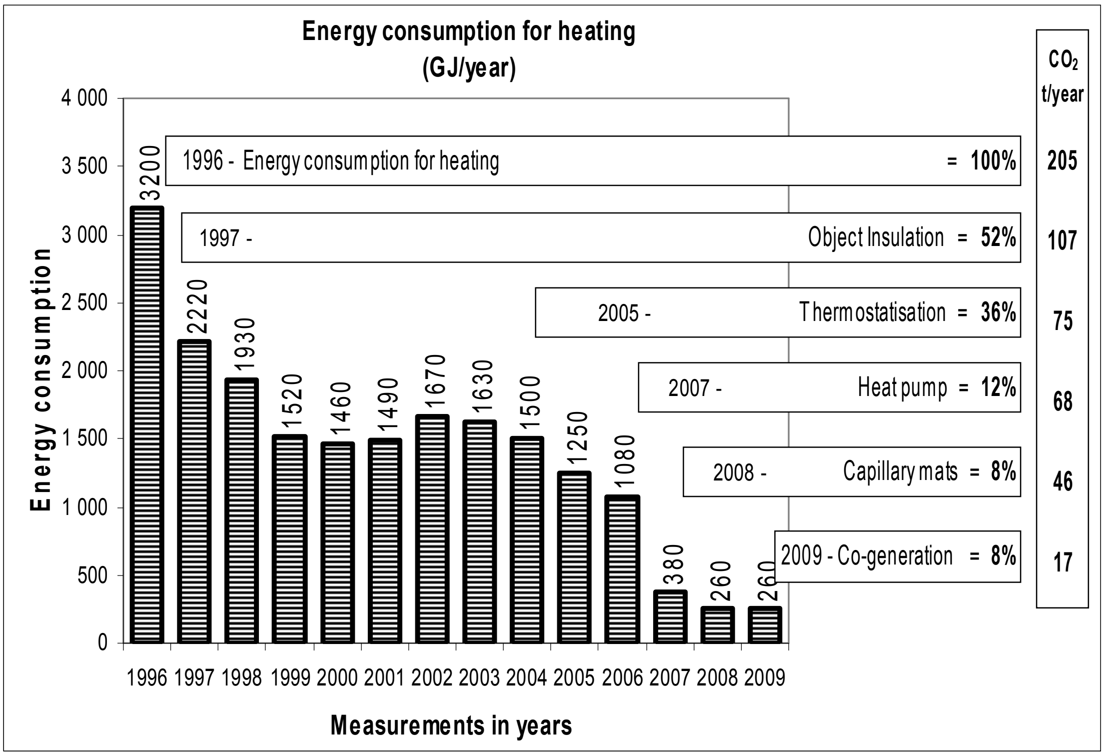

Figure 3: Energy consumption and emission level of the studied building

3.3. Co-generative element (CGE)

In the process of production we monitor the CO2 emissions parameter. The source of energy for the drive of heat pump is electrical energy. The CO2 emission coefficient for production of electrical energy in Slovakia is declared to be 0.640 Kg/kWh. The CGE will be installed to the heat pump system. It will produce the electrical energy to drive heat pump by burning up the gas and it will replace supply of electricity from distribution net. Simultaneously, heat produced by burning will be used to increase the temperature of heating body emerging from heat pump. The CO2 emission coefficient for combined production of heat-electricity in co-generative element is 0.23 kg/kWh. The benefit of CGE is cheaper electrical energy produced directly at the place of consumption and also significant decrease in produced CO2 emissions. It has no significant effect on the amount of supplied heat (about 8%). The produced CO2 emissions calculated in tones per year can be seen in Figure 3.

4. THE DESCRIPTION OF HEAT AND COOLNESS SOURCE AFTER IMPLEMENTED AND PROJECTED CHANGES

The system enables production and supply of heat for heating and cooling to ensure the desired climate in summer. It is made of wells (suction and absorbing types), heat pump, co-generative element and heating-cooling system with help of capillary mats. The energetic potential is contained in ground water. After pumping, this water is cooled by approx 4 degrees. Gained energy is transformed by heat pump to higher level (the demand of capillary mats is approx 35 degrees). Water is then heated by energy produced by burning the gas in the co-generative element and will be transferred via accumulation and regulation system into heating system. Heating system is made of ceiling capillary mats (so there is no heat wasted). Electrical energy produced in CGE will be used as fuel for heat pump and other supporting electrical devices. In the cycle of production and consumption, the interesting part is geothermal energy gained from primary energy in the form of gas, which makes substantial part of operating costs. The one day running course of the system is shown on the Figure 4.

4.1. Winter operation mode

Main source is the renewable low potential geothermal energy (groundwater of approx 12 degrees). Transformation of heat from low potential level into higher (approx 35 degrees for heating with capillary mats) is happening in heat pump, propulsion of which is done via electrical energy produced by burning up the gas in CGE. Production efficiency of electrical energy in CGE by burning up the gas is 30-35%. The rest of heating energy will be used for raising the temperature of heating water, which enables the efficiency of CGE of 85-90%. Produced electrical energy will be used for propulsion of heat pump and supporting electrical devices (circulatory pumps). Evaluation of electrical energy for production and delivery of heat is defined by heating factor COP, which has the value of 4.3 during heating season. This means 4.3 times higher amount of produced heat than that delivered in electrical energy. The overall energetic utilization of gas via production of heat, production of electricity and the labor of heat pump and delivery of geothermal energy at 200%.

4.2. Summer operation mode

The energy of water from the well is used for cooling during the summer. In case of cooling by capillary mats, the temperature of water in capillaries is 18 degrees. Groundwater sustains temperature of approx 15 degrees in summer. Its temperature is lower than the temperature demanded for cooling. It is not necessary to produce coolness; the necessary temperature of 18 degrees will be produced by mixing in the returned cooling water which is already heated. The demand for energy for production and distribution of coolness will consist of just pumping labor for circulation of cooling water via capillary mats. Heat pump doesn’t have to be in operation during cooling. Electrical energy produced by CGE will be used as propulsion of circulatory pumps and the heat produced by burning the gas will be used for heating up the water. The production and delivery of coolness via COP is 14. If we use the gas burned in CGE together with heat to heat up the water to produce electrical energy, the utilization of gas is 480%. Energetic utilization of gas for heating, cooling and heating up the water, during the whole year is 270%.

Yearly balance shows the proportion of production of heat and coolness 3/1. COP of heating is 4.3 and COP of cooling is 14, yearly balance of whole system is 6.7.

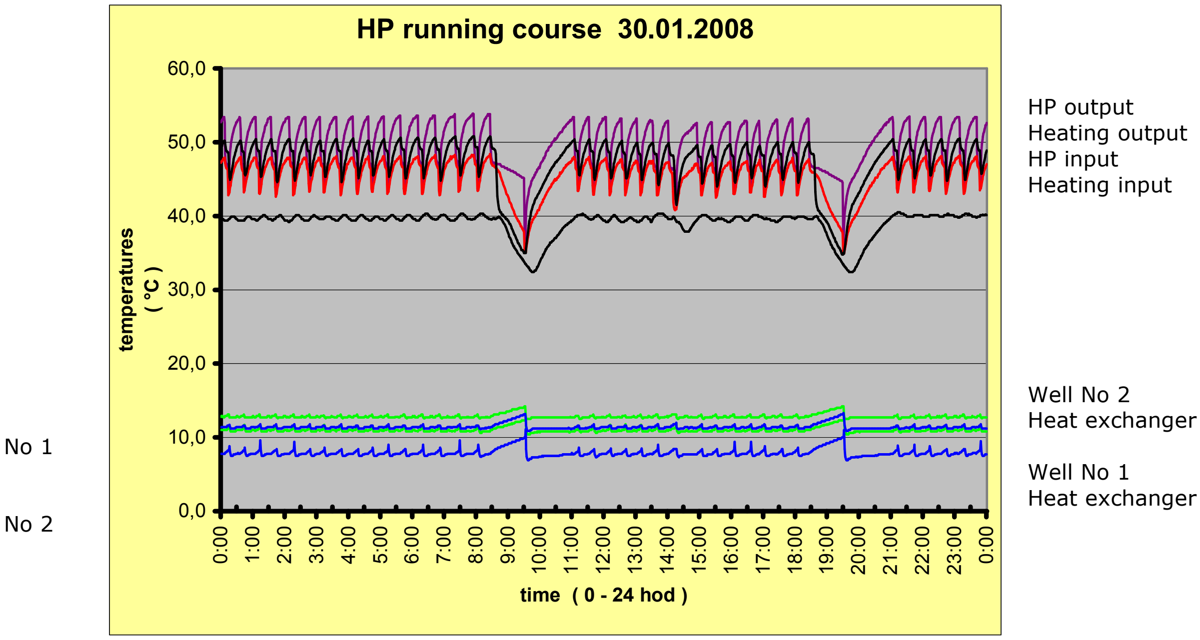

Figure 4: Daily running course of heat pump

5. CONCLUSION

The balance of measured and calculated figures of operation of the building confirms the correctness of assumptions and accuracy of projected balance. From the point of view of energetic balance, the consumption of primary energy (geothermal energy is not being considered) was decreased from original 3200GJ in year 1996 to 260GK. This means decrease by 92%. The structure of resource and fuel base was changed. The coverage of consumption has significantly lower amount of CO_2 emissions. The decrease from original 205 tones per year to 17 tones per year makes 92%.The structure of fuel for production of primary energies in year 1996 consists of 100% fossil fuel. After adjustments, it consists of geothermal energy and electrical energy produced by burning gas in year 2009. If eventual COP for yearly operation of heat pump is 6.7, then the proportion of energies is as follows: 85% of energy is from geothermal source and 15% of energy is from electrical energy. Overall efficiency of co-generative element is 90%.Calculating primary energy 15%/0.9 = primary energy = 16.7%. Proportion of geothermal energy will be decreased to 100% - 16.7 % = geothermal energy = 83.3%. The rest of produced heat from co-generative element will be used in distribution net for other consumers for heating and heating of hot water. The realized project creates real environment for effective implementation research of technologies in laboratory and operative conditions: technologies of co-generative elements, heat pumps, thermal capillaries, and technologies in field of measurement and regulation. The solution is the project with possibility to repeat it on other similar applications as well as the utilization of experience and determination of economical expedience of researched technologies implementation. The quality of buildings' environment influences health, efficiency and comfort of building's users. Current studies show that the costs of internal environment quality improvement are often higher (for company, employer and building's owners) than costs of energy consumed in the building. Energetic declaration without declaration of relation to quality of inner environment therefore does not make sense and is not sufficient. Specification and consideration of design criteria for parameters of inner environment are needed for design of buildings, energetic calculations, operation and regulation of buildings. Next phase of the research will be evaluation of operative behavior of the building, interaction with building constructions and study of inner climate parameters.

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POTABLE HOT WATER AND ITS MICROBIOLOGICAL QUALITY

ABSTRACT

The presence of the bacteria Legionella in water systems especially in the hot water distribution system represents in terms of health protection of inhabitants is the crucial problem which is not possible to overlook. Expenses on the elimination of Legionella from the water distribution systems are very high and the results are not often sufficient. It should be the common goal of designers and operators to reduce the risk of Legionella bacteria in the installation inside buildings. To prevent the tragic events it is obviously needed to monitor the issue in the word and pay attention to precautionary regulations. There are a lot of common shortages in hot water distribution systems of the large buildings. The age of system, material base, missing regulation and lack of maintenance play the most important role. In the article we would like to describe technical possibilities for prevention of Legionella growth from contaminated hot water and which could be transferred into operation of water distribution system from the point of view of solving by current European legislation.

KEYWORDS: Legionella, hot water system, European legislation, operators

1. INTRODUCTION

Drinking water supply is an essential public function but is at the same time exposed to risks. Since a totally risk-free society is not attainable, risks need to be managed efficiently to achieve an acceptable level of risk. A reliable supply of safe drinking water is vital and the World Health Organization emphasises an integrated risk management approach, including the entire drinking water system from source to tap [1]. A number of colonies forming units of Legionella bacteria in portable water distribution systems depends on numerous factors and can undergo changes over time and place.

Microorganisms occurring in water distribution systems affect their growth and multiplication, and therefore it is important to reduce and monitor them. Risk analysis is one of the methodological procedures to identify possible contamination threats by Legionella pneumophila in water distribution systems. It is an analysis of problems based on the latest scientific- technical knowledge to make basis and inferences for effective decisions. The goal

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is to estimate necessary precautionary measures since specific risk assessment is essential for their successful implementation.

2. LEGISLATION

In the last years particular parts of the ‘STN EN 806 Specifications for installations inside buildings conveying water for human consumption’ have been accepted by the Slovak Republic. Installations inside buildings conveying water for human consumption must involve EN 1487, EN 1488, EN 1489, EN 1490 a EN 1491. STN EN 806 provides 30 seconds after fully opening a draw off fitting the cold water temperature should not be kept below or equal to 25 °C and hot water temperature should not be less than 60 °C. Hot water systems should have the facilities to enable the temperature at the extremities of the system to be raced to 70°C for disinfection proposes. The most important factor for the possible development of Legionella bacteria in hot water systems with circulation pipes could be the temperature difference between heater output and circulation pipe input to heater maximum 5 K. These criteria are consistently reflected in guidelines and regulations developed in many individual countries for the design, operation and maintenance for tap water systems to avoid the growth of Legionella (the Slovak Republic does not have any guidelines or regulations related to Legionella bacteria).

Technical commission TC 164, which creates European standards (as the EN 806), currently working on the final version of Technical report: Recommendations for prevention of Legionella growth for installations inside buildings conveying water for human consumption, which will complete the standard EN 806 [2].

The following conditions encourage the Legionella growth:

- water temperature between 25 °C and 50 °C;
- stagnation of the water;
- biofilm and sediment in the installation and water heater.

2.1. Standards of Care in United States

There are two main Standards of Care in the United States and an internationally recognized one in the United Kingdom. They are broadly consistent in their guidance for risk analysis followed by a systems of control, or maintenance procedure for “at risk” systems. ASHRAE - 12-2000 Environmental and operational guidance for minimizing Legionella contamination in building water systems. ASHRAE is currently in the process of converting the "guideline" into an official Standard, designated "SPC 188." The standard will result in an affirmative duty upon building owners to establish Legionella auditing and prevention programs. The new standard will include language on Legionella hazard analysis, whereas the current 12-2000 guideline does not [3].

Hazard (or risk) analysis and control implementation shall include seven elements:

1. Identification of critical control points;
2. Establishment of critical limits at critical control points;
3. Establishment of a monitoring plan for critical limits at critical control points;
4. Establishment of corrective actions for each critical limit;
5. Establishment of procedures to document all activities and results;
6. Establishment of procedures to confirm that:

a) the hazard had been eliminated or controlled under operating conditions (validation),
b) the plan is being implemented properly (verifications) and
c) the plan is periodically reassessed [3].

2.2. United Kingdom ACoP L8

The British Health & Safety at Work Act 1974 (HSWA) and Control of Substances Hazardous to Health Regulations 1988 (COSHH) include for the risks from hazardous micro-organisms, including legionella. Under the Regulations risk assessments and the adoption of appropriate precautions are required to be made. Furthermore, the Approved Code of Practice and Guidance L8 (Legionnaires' disease. The control of legionella bacteria in water systems), (the ACoP), sets out statutory requirements for dealing with such risk. The ACoP applies to the risk from legionella bacteria in any circumstances where the HSWA applies. In order to comply with their legal duties, as detailed in the ACoP, employers and those with responsibility for the control of premises should:

- Identify and assess sources of risk, (the ACoP dictates that persons responsible for undertaking the risk assessment need to have access to competent help and advice)
- Prepare a scheme for preventing or controlling the risk;
- Implement, manage and monitor precautions;
- Keep records of the precautions; and
- Appoint a person to be managerially responsible [3].

3. RISK ANALYSIS

Risk analysis evaluates specific conditions on the basis of information about current contamination that comprises the assessment of possible ways of proliferation, exposure risk, and the target group risk in each situation. Risk analysis involves risk assessment and risk management Fig.1.

3.1. Identification and assessment of the risk

Building owners, landlords and managers are responsible for assessing sources of risk in water distribution systems. The employer, where the risk from their undertaking is to their employees or to others:

- a self-employed person, where there is a risk from their undertaking to themselves or to others;
- the person who is in control of premises or systems in connection with work where the risk is present from systems in the building (e.g. where a building is let to tenants but the landlord retains responsibility for its maintenance);
- the person who is in control of premises used for overnight accommodation, such as hotels, holiday apartments, campsites and cruise ships where the risk is present from water systems in the building.

The person performing the assessment must be competent to assess the risks of exposure to Legionella bacteria in the water systems present in the premises and the necessary control measures.

Risk analysis includes four following steps:

1. system assessment - identification of risk sources and groups
2. risk assessment
3. risk management
4. conclusions of risk analysis.

As a part of the risk assessment, it is significant to determine level of risk from the exposure to Legionella bacteria. It is a tool for choosing the proper preventive measures in order to reduce the risk to acceptable level. Risk management is an activity directed towards implementation of control and precautionary measures based not only on the estimated risk but also in a technically competent [4].

Fig.1. Process Initiation - Scheme

3.2. System assessment

It is essential to identify factors and critical points which contribute to contamination of water distribution systems. Particular components of a potable water distribution system that should be assessed include:

- the quality of water entering the system;
- the design and construction of equipment (including operational information about temperature regime and water circulation);
- treatments (e.g. anticorrosion, antiscaling and disinfection) and timing of treatments;
- systems, system components and equipment that have the potential to generate aerosols;
- the temperature of storage tanks and the environment in which the system is located (both in buildings and outside), including the location of the system network (e.g. pipes in conduits, ceilings, walls and floors);
- the periods of water use; for example, on a daily or weekly basis (e.g. sports facilities may use water on a weekly basis);
- the turnover of water in areas such as storage tanks;
- the population using the system, including any particularly susceptible people;
- the management structure;
- the competence of personnel responsible for the system [5].

Risk of Legionella infection is not equally detrimental to inhabitants. We consider the most commonly affected group; people with weakened immunity, after organ transplantations, suffering from chronic Bronchitis, Diabetes, and lung tumors. Fatality rate significantly increases by age. The latest researches also prove various death rates by sex. About 20% of infected men in contrast to15 % of infected women die from contracting the Legionnaires disease. People at greater risk are mainly smokers with weakened immunity. Due to the fact that Legionnaires` disease is difficult to diagnose the death rate is constantly increased.

3.3. Risk assessment

To get a complex approach it is essential to identify the level of risk Tab.1. The key question remains: what amount of Legionella penetrate with aerosols into the lungs. This amount does not directly depend on the number of bacteria occurring in the water. Current estimates show that a number below 10^2 pathogen microorganisms is sufficient for outbreak of Legionella infection. If we use the shower space with the volume 10m3, flow amount of water from a shower head is 10 l/min with concentration of Legionella about 10^6 per liter. We can assume that 1% of shower water forms water aerosols about 10^4 in $1m^3$ air. While inhaling the volume cca. 20 liters of air per min., the selected situation would represent the inhalation risk of 200 bacteria per minute in case of usage cost-cut showers with aerosols [6].

Table 1: Description of the risk

	Level of risk	Measures
0	No risk	No measures
1	Low risk with rare changes in operation	Preventive sampling
2	Medium risk without changes in operation	Preventive sampling, periodical increment of temperature in the water systems
3	Serious risk	Technical measures, thermal disinfection
4	Acute risk	System’s shutdown and implementation of a package of measures

3.4. Risk management

The next step is risk management- a package of remedial regulations, appointment of a person to be managerially responsible, and preparation of a scheme for preventing or controlling a risk to eliminate sources of pollution.

It is inevitable to set the data for repeated hygiene monitoring. In addition it is required to analyze individual variants of remedial measures. Also control points for regular monitoring of cold and hot water, and concentration of biocide - if it is dosed are necessary to determine. Keeping system records so called logbooks is an inseparable part of management policy. As a result of risk management is a document that ensures safe and correct operation of hot water at the end of distribution systems for users. All the above items stem from constant diagnoses, proved findings and implemented requirements [4].

3.5. Conclusion of the Risk analysis

Conclusions of risk analysis involve summary of risk assessment together with risk management as well as a scheme of precautionary measures to reduce risk.

4. LEGIONELLA CONTAMINATION IN KOSICE

Total of 46 water samples were collected from private homes, hospitals and boiler houses of Kosice. The selection was made on the basis of the water distribution systems inside the town and buildings and heater types in each area.

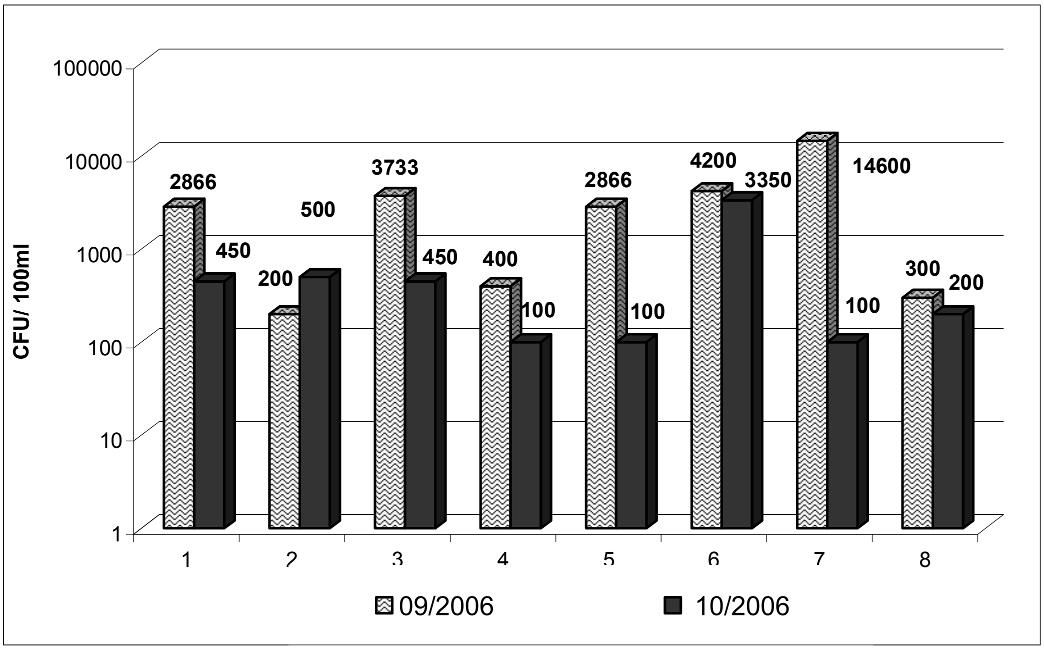

Fig.2. Legionella positive samples

After we identified each building, we asked a random family, or a work collective to participate in the study, i.e. to complete our questionnaire and give informed consensus for water collection. Laboratory examinations and Legionella analysis were made by the Regional Health Office – referential centre for potable water in Kosice. Legionellas presence was detected in 8 samples out of analysed drinking water samples. In water for human consumption (PWH) volume of legionellas were detected, from sporadic colonies of 200 CFU/100ml up to massive colonizations in the quantity 14600 CFU/100ml per a sample. We repeated sampling after thermal disinfection in contaminated places. After 12 days the level of Legionella colonies was almost the same as before this measure Fig.2 [7].

4.1. Operational reliability

The evaluation of the risk time analysis has proved that the most risky periods of the day for the humans in terms of infection by bacteria Legionella pneumophila are hours in the morning and in the evening.

Table 2. Hot and cold water services [5]

Service	Task	Frequency
Hot water services	Arrange for samples to be taken from hot water heaters, in order to note condition of drain water	Annually
	Check temperatures in flow and return at calorifiers	Monthly
	Check water temperature up to 1 minute to see if it has reached 50°C in the sentinel taps	Monthly
	Visual check on internal surfaces of water heaters for scale and sludge. Check representative taps for temperature as above on a rotational basis	Annually
Cold water services	Check tank water temperature remote from ball valve and mains temperature at ball valve. Note maximum temperatures recorded by fixed max/min thermometers where fitted	6 monthly
	Check that temperature is below 20°C after running the water for up to 2 minutes in the sentinel taps	Monthly
	Visually inspect cold water storage tanks and carry out remedial work where necessary. Check representative taps for temperature as above on a rotational basis	Annually
Shower heads	Dismantle, clean and descale shower heads and hoses	Quarterly or as necessary
Little used outlets	Flush through and purge to drain	Weekly

Control measures have proved that the thermal disinfection is not a suitable system treatment. New strategies are tend to permanent disinfection due to the fact that spasmodic disinfection is not enough reliable to ensure required standard. It is on the designer to safeguard the maximum reliability not only for a startup operation but for the whole longevity of the design system. It should involve controlled maintenance and its requirements such as: preventive maintenance and frequencies, necessity of spare parts, inspection of gaugers. Operation reliability involves expenses in case of unexpected problems or technical breakdown of the prepared system and distribution.

The quality of water must be guaranteed not only for the heating and distribution but also for monitoring parameters which were suggested by a designer to support the functioning of the system as a whole as well as the solitary functioning of its critical items. The exact specification enhances maintenance and operation of the system to be very reliable. It is apparently seen e.g. in hospitals where technical and medical staff must cooperate and perform regular outlet of hot water – PWH in foreseeable parts of the distribution system - to explain why it is necessary, competence and how to follow precautionary measures. Keeping records of current operation state, especially problematic situations ,figures is the best education and management for improving the system for all involved parts such as: an user, a designer and an installing firm.

Therefore the designer together with the engineering firm should inspect the quality of water for a longer period. It would be appropriate to give names of the responsible employees, the designer and the installing firm.

Water quality of heating and distribution system ensures as following:

- to guarantee monitoring of parameters which were suggested by a designer to support the functioning of the system as a whole as well as the solitary functioning of its critical items.
- necessity of the exact specifications - enhances maintenance and operation of the system to high reliability.
- cooperation of the staff is very important (e.g. in hospitals where technical and medical staff must cooperate and perform regular outlet of hot water – PWH in foreseeable parts of the distribution system - to provide explanation why it is necessary, competence and how to follow precautionary measures Tab.2.

4.2. Risk analysis in contaminated places

From the point of view of coordination it is necessary to collect all information about each site. After setting up a monitor schedule we plan microbiological examination.

- **capacity examination** – if the production of the hot water is capable to meet the needs of users in quarter of the rush hour (it is carried out on top floor with the simultaneously turned on taps of the building- for 15 min.). The record is taken by the water meter in the starting point 0 and consequently every minute by data logger reading of temperature on the discharged and reversible piping of the hot water installation.
- **microbiological examination** - there is carried out sampling together with temperature measurement at certain monitor points in hot water system - after 60 seconds of flow.

To get a complex approach we have to identify the level of risk: it was **Level 3** – Serious risk, technical measures, especially thermal disinfection were recommended. Our measures have proved that the thermal disinfection is not a suitable system treatment therefore it is inevitable to search for a new complex solution.

Along with any disinfection methods of treatment used, the following are recommendations and sound practices to help manage and reduce the incidence of Legionella contamination within (hot and cold) water systems. We prepared a package of precautionary recommendations and technical measures to reduce the risk of Legionella as the result of the Risk analysis - for example Tab.3.

- Reduce dead legs (stagnant lines and stubs) in the system,
- Clean and inspect hot water tanks regularly – annually as a minimum,
- Continually run hot water circulation pumps – avoid recycling to mixing valves only,
- Store hot water at a minimum temperature of 60 °C and deliver to the taps at a minimum temperature of 50 °C,
- Store and distribute the cold domestic water below 20 °C – if not possible, then consider monitoring for Legionella and using a disinfection system if Legionella are not under control,
- Flush the entire water system on a regular basis,
- Consider routine potable water treatments – including the use of approved biocides.

Table 3. Part of documentation for monitoring and corrective action in the evaluated system

Process step	**Indicator**	**Monitoring**		**Operational Lim.**	**Corrective actions**	
Heating of water	Temperature	What	Temperature	Outlet Not less than 65°C	What	Improve circulation and increase water temperature
		How	Thermometer or thermocouple data logger		How	Add extra pump on the return to water heater Turn-up thermostat on calorifier
		When	Daily or online	Return Not less than 63°C	When	Immiadately
		Where	Return to water heater and at outlet of the heater		Who	Plumber for pumps B.engineer for calorifiers
		Who	Building Engineer			

5. CONCLUSION

The increased public awareness of environmental health issues and the acceptance of the legislation now approved have ensured that risk assessment and appropriate preventative maintenance steps, should now be considered as the norm for every building. Our control preventive measures have been in progress in order to search for an effective way to suppress the spread of the Legionella bacteria in water systems. Risk analysis helps the managers reduce the Legionella infection and gives a well arranged summary of risk assessment together with risk management as well as a scheme of precautionary measures to reduce risk.

ACKNOWLEDGEMENTS

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RAIN WATER MANAGEMENT FOR THE PURPOSES OF SUSTAINABLE DEVELOPMENT

ABSTRACT

Sewage systems of residential units were constructed as a single system in the past. Tribal sewers of most cities are now congested. A new built-up area is situated to a greater distance from the historic centre. Reconstruction investments of tribal sewers are expensive. Consequently, there are strong pressures to limit the runoff of rain water from the newly constructed buildings at the edges of cities. Therefore the sophisticated use of alternative supplies of water, such as the purified waste water from households and capture rain water is essential, to help reduce water consumption. Reasonable rain water management leads to maintain or recover a sound and sustainable water cycle. This involves retentions, infiltrations, vegetation strips, paving and design techniques, and so on. Changes in the amount of hard (impervious) surfaces in urban areas have significantly altered the way rain water moves over, and infiltrates into, the land.

KEYWORDS rain water management, infiltration systems, sewage systems, sustainable development

1. INTRODUCTION

"We are living beyond our means when it comes to water. The short-term solution to water scarcity has been to extract ever greater amounts of water from our surface and groundwater assets. Overexploitation is not sustainable. It has a heavy impact on the quality and quantity of the remaining water as well as the ecosystems which depend on it," said Professor Jacqueline McGlade, Executive Director of EEA (European Environmental Agency) [1]. In many parts of Europe water use is unsustainable and therefore is desirable to

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provide recommendations for a new approach to managing water resources in practice. According [2] enlargements of settled areas, in consequence of urbanization and industrial activities, instead of greenery prevent from rain water infiltration and temperature around the countryside is increasing. A problem of settled areas is to sustain comfortable microclimate especially in the summer. Dense urbanization change nature water regime of the natural ecosystem. Settled areas prevent rain water infiltration and resupply of groundwater. We need to think about what can be done to reduce the construction of water runoff from the territory to avoid compromising the building's own water.

The concept of drainage in cities, which aims to mitigate the impact of urbanization on the hydrological regime of the country and on aquatic ecosystems, come from our experiences and knowledge of current method of sewerage. New concept of capture and use water from surface run-off provides a platform for a new technical and non-technical measures, both in drained on each property, as well as the public part of urban drainage area. The common denominator is the search for high energy and raw materials efficiency. There are examples to be fully implemented in practice. Such a concept of urban drainage is documented in the case studies from Switzerland, Japan and Germany [3]. Although in recent years occurred in Europe and overseas to the implementation of several different types of objects infiltration leads to errors caused by neglected scientific claims in their planning and operation. In an area where, however, appear poorly permeable rocks, must be in the subsurface water infiltration to proceed very cautiously. In its meeting the requirements for collecting rain water for the land property must proceed with the professional care that it can not damage the objects [2]. Compliance captures and use water from surface runoff with the principles of sustainable development worldwide, received little attention.

Infiltration is the downward movement of water from the land surface into the soil profile. Infiltration can occur naturally following precipitation, or can be induced artificially through structural modifications in the ground surface. Some water that infiltrates will remain in the soil layer, where it will gradually move vertically and horizontally through the soil and subsurface material. Eventually, it might enter a stream by seepage into the stream bank. Some of the water may continue to move deeper (percolate), recharging the local groundwater aquifer. A dry soil has a defined capacity for infiltrating water. The capacity can be expressed as a depth of water that can be infiltrated per unit time, such as inches per hour. If rainfall supplies water at a rate that is greater than the infiltration capacity, water will infiltrate at the capacity rate, with the excess either being ponded, moved as surface runoff, or evaporated. If rainfall supplies water at a rate less than the infiltration capacity, all of the incoming water volume will infiltrate. In both cases, as water infiltrates into the soil, the capacity to infiltrate more water decreases and approaches a minimum capacity. When the supply rate is equal to or greater than the capacity to infiltrate, the minimum capacity will be approached more quickly than when the supply rate is much less than the infiltration capacity [4].

The emerging goal of urban rain water management is to achieve effective control of pollutants in rain water runoff and reduce the volume and rate of runoff to control downstream impacts from flooding and stream-channel erosion [4]. In principle, decentralized projects based on ecological sanitation can be applied to all areas, from informal settlements to luxury multi-storey apartments or office blocks. If decentralized sanitation and reuse infrastructures and techniques should be applied at household level, its concepts should be involved in the earliest stages of urban planning and the urban planners have therefore responsibilities to support the design by allocating extra space within the requirements for the architect of building. At present, experiences are still extremely rare in large settlement and in dense-populated urban areas. From the point stand of urban planner, there remains an urgent need of setting up showcases in other projects at municipal or large neighborhood level, which should cover different household types, settlement structure, population density, income levels, cultural and geographical conditions within one urban area [5].

This paper investigated the state-of-art technological options for rain water management. It demonstrated the implementation of rain water harvesting, as well as investigated the water- and cost-saving potentials. Important results are that applying integrated decentralized water management is significant benefit for holistic and sustainable development.

2. PRINCIPLES OF SUSTAINABLE RAIN WATER MANAGEMENT

Measures of the conceptual solution for urban drainage in the future are marked as sustainable rain water management after fulfilling of the following principles [2]:

- For the same or more activities use less energy and material.
- Do not transfer problems in space or time nor to other persons.
- No reduction or degradation of water and soil resources in the long run.
- Integration of the human being into the natural cycles of water and food.

The current technique and technology in urban drainage does not meet these criteria and fulfill these criteria is not expected in short time. So far, lacks sufficient, scientifically based information regarding the identification of existing problems, the accurate determination of target concepts. The relevant data, which in this context is lacking, are called environmental indicators, of which assistance could be that the above criteria better assessed.

The following Table 1. gives a general comparison of the measures and results by using traditional rain water drainage and decentralized rain water management [5].

Table 1. Comparison of traditional rain water drainage and new management

Traditional rain water drainage	**Rain water new management**
Acceleration of surface flow (from settlement)	Slow down of surface flow (from settlement)
Centralized combination of surface water and other wastewater in sewage systems	Decentralized retention and storage, infiltration, and evaporation of surface water
Flow-peak always becomes larger	Flow-peak always becomes smaller
Shrinking of evaporation and infiltration ratio	Stabilization and expansion of evaporation and infiltration ratio
Maximal of surface flow	Minimum of surface flow

A new concept of urban drainage system defines the urban drainage of much wider angle than previous approach. By planning and management of urban drainage are included in addition to the technical elements of the water streams and ground water. Instead, the rapid drainage of all waste water is supported by exactly the opposite way drainage: connecting the least amount of rain water and the slowest transport to the waste water treatment plants where the recipient. This can be achieved by mitigating the negative effects of urbanization on the local hydrological regime and aquatic ecosystem.

Decentralized alternative approach seeks to redesign the urban landscapes, in order to minimize the volume of runoff that flows into the sewer system. Using storm water harvesting technologies and infiltration with modern implementation strategies, this approach shifts the focus from remediation to prevention by slowing, percolating, retaining and treating water where it falls, all before entering the piped wastewater system. However, there are neither universal formulae nor measures for the realization of decentralized rain water management. The desired and attainable effects as well as the applicable technologies for decentralized rain water management are dependent on the specific local basic conditions and sustainability criteria of each development area, e.g., infrastructure and natural basic conditions, culture and economy.

3. POSSIBILITIES OF RAIN WATER TREATMENT

Concerning the proportion of evaporation, infiltration and runoff, rain water infiltration can contribute essential benefits to the harmonization of natural water balance, and also positive influence for soil, weather, fauna and vegetation. Hence, they can not only significantly reduce the peak runoff in sewers, but also reduce the size of the sewage pipes required to handle the waste stream, which is important when aging systems have to be rebuilt. In addition, the construction of retention and infiltration systems is usually more economic than the construction of technical rain water utilization system and the related construction work generally does not limit the use of space above ground, since the systems can be also installed underground.

The initial focus of rain water management programs is on pollution prevention and source control. The subsequent treatment of collected rain water is expected to be a rather costly alternative. There may be opportunities, however, for installation or retrofitting of structural control. The objectives of this element are to study the various treatment alternatives available, to test the feasibility of conducting the activities, and to determine the effectiveness of the treatment through pilot-scale projects. The main available treatment system alternatives are the following [6, 7, 8, 9, 10, 11]:

1. *Infiltration systems*, which capture a volume of runoff and infiltrate it into the ground. Infiltration facilities may include infiltration basins, infiltration trenches, or porous pavement systems – Fig. 1.

Fig. 1. Infiltration trenches
1-paved area, 2-trench, 3-green infiltration belt

2. *Detention systems*, which capture a volume of runoff and temporarily retain that volume for subsequent release. Detention systems do not retain a significant permanent pool of water between runoff events; a common type is shown in Fig. 2..

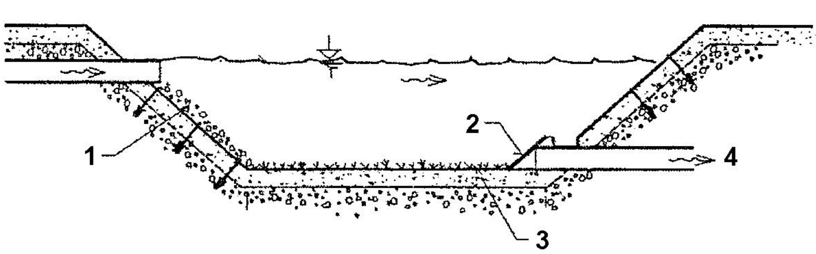

Fig. 2. Detention system
1-embankment, 2-bar, 3-green belt, 4-outlet

3. *Retention systems*, which capture a volume of runoff and retain that volume until it is displaced in part or in total by the next runoff. Retention systems, therefore, maintain a significant permanent pool volume of water between runoff events. The details of a retention pond are shown in Fig. 3..

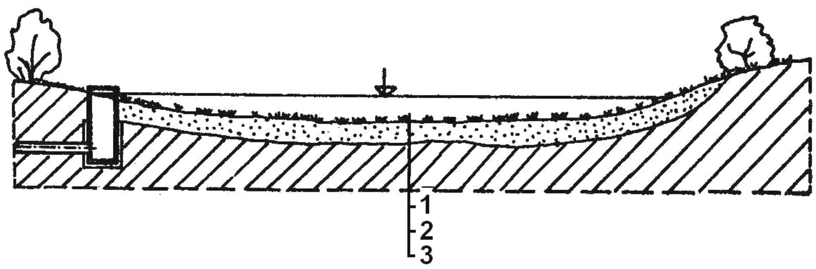

Fig. 3. Retention system
1-infiltration basin, 2-permeable ground, 3-sand

4. *Constructed wetland systems* are similar to retention and detention systems, except that a major portion of the water surface area (in pond systems) or bottom (in meadow-type systems) contains wetland vegetation (Fig. 4.). This group also includes wetland channels.

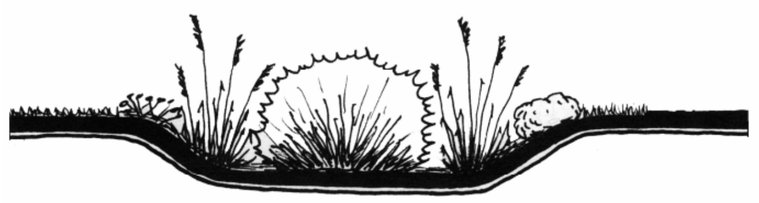

Fig. 4. Wetland

5. *Filtration systems* use some combination of granular filtration media, such as sand, soil, organic material, carbon or a membrane, to remove constituents found in runoff. A typical filtration system is shown in Fig. 5..

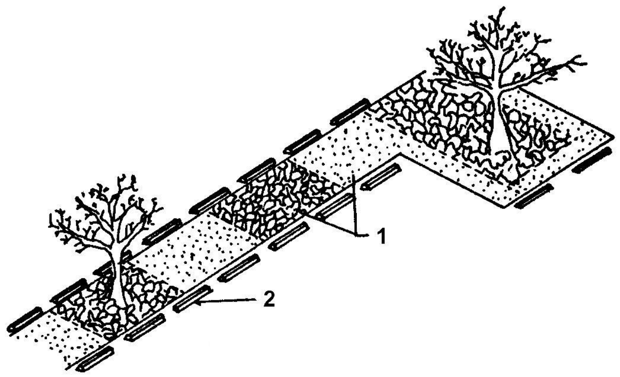

Fig. 5. Filtration system
1-rock and soil stretch, 2-discontinuous curb

6. *Vegetated systems (biofilters or bioretention systems)*, such as swales and filter strips, are designed to convey and treat either shallow flow (swales) or sheet flow (filter strips) runoff. A diagram of a typical bioretention area is shown in Fig. 6..

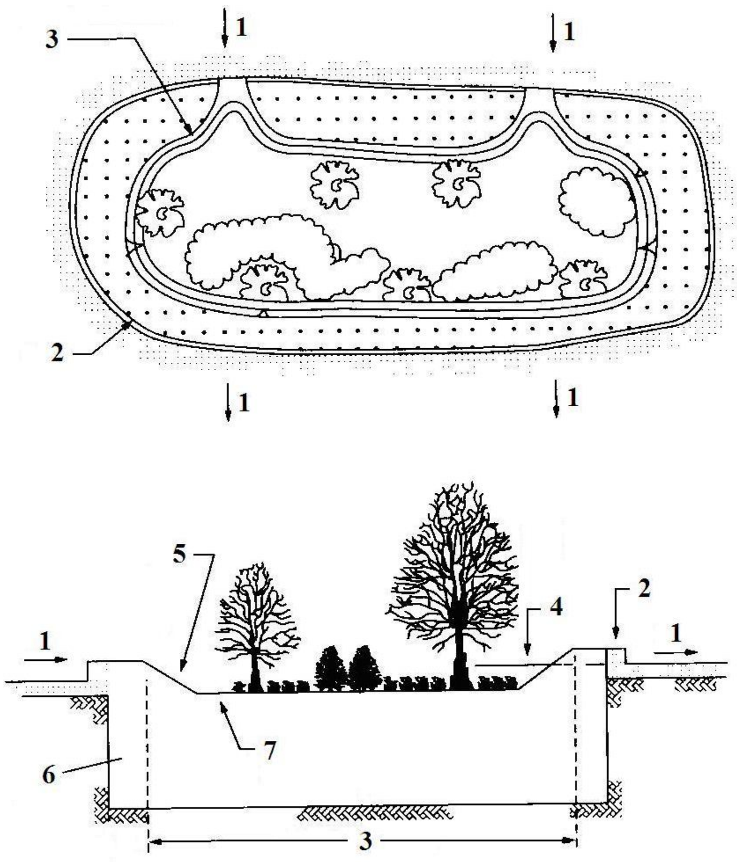

Fig. 6. Bioretention system
1-flow, 2-curb, 3-bioretention area, 4-maximum ponded water depth, 5-ground cover or mulch layer, 6-planting soil, 7-proposed grade

Infiltration trench and infiltration basin systems rely directly on the site soil conditions to infiltrate the design capture volume of rain water. Infiltration trenches and basins can be used on single/multifamily residential sites of up to 10 acres and up to 5 acres for commercial sites. Bioretention best management practices use an additional prepared soil and vegetation layer on top of the infiltrating soil surface to provide an additional filtration process prior to infiltrating all or part of the filtered rain water. Rain gardens are a smaller design variant of the class of Best management practices called bioretention areas. Rain gardens are typically constructed on residential sites and use a depression in the native soil profile supplemented with permeable upper soil, mixed with vegetation, to capture and treat the runoff. A rain garden is typically constructed without an aggregate subbase or subdrain system, and the captured runoff volume will be limited to that which can infiltrate into the local subsoil within 12-24 hours. The last two practices, soil quality restoration and native landscaping, are intended as complementary integrated practices that can be implemented to improve the infiltration capacity of compacted urban soils, and provide a vegetation system to maintain a healthy soil profile for infiltration [4].

The method of minimizing directly connected impervious surfaces describes a variety of practices that can be used to reduce the amount of surface area directly connected to the storm drainage system by minimizing or eliminating the traditional curb and gutter. This is considered to a nonstructural practice, but it has been included here because of the need to design and construct alternative conveyance and treatment options. There are also miscellaneous systems that do not fit under any of the above categories. These may include catch basin inserts, hydrodynamic devices, and filtration devices.

4. METHODOLOGY FOR RAIN WATER TREATMENT SYSTEMS DESIGN

The methodology for rain water treatment systems design include following.

4.1. Monitoring of rainfall intensities and precipitations and derived realistic calculation of values for the conditions of the region

Solution methodology is based on analysis and evaluation of the current state of discharges of sewage, as well as specific knowledge of measuring the qualitative and quantitative indicators of rain runoff. The proposal for a rain water drainage system is necessary to determine the volume of rainfall, depending on the duration of rainfall and its intensity. For practical use of available statistical data produced from the intensity of the rain period of about thirty years ago. There are large discrepancies between the intensity of rainfall for the drainage design of buildings and intensity of rainfall values for the dimensions of the public sewer system.

4.2. Establish rules for the design of rain water infiltration. Create a national rule those certain procedures for the experimental verification of in-situ taken over from German AVT, or from other European national legislation.

The issue of water from surface runoff is not explicitly addressed in the legislation. The European standards are described waste water, but lack of water from surface runoff. In SR rainfall is fully protected under the Water Act No. 364/2004 Z.z. and in the run-off law for Water Supply and Sewerage No. 442/2002 Z.z.. Tampering with the drawback of water is governed by different regulations. In the case of rainfall infiltration is not a unique interpretation of the law - it is the manipulation of groundwater - the artificial enrichment of underground water resources, surface water, which is necessary for the authorization of the competent authority. With the development of construction in large cities and their surroundings are increasingly addressing the problem of overloading sewage systems. Now operators can provide to investors and hinder the construction of sewage water connections, only a need to address the management of rain water separately, especially their infiltration. Is that it proposes various designers completely different ways, indicating different amounts of water. An important prerequisite for infiltration is hydro-geological survey, which is often restricted to a minimum or only to the finding of data from maps and hydrological data. To tackle rainfall infiltration from surface runoff into the soil, there should be a new standard / technical advice, which would take care of setting the conditions of rain water infiltration. Infiltration of rain water is not in any standard or regulation addressed.

4.3. Accelerate the implementation of large scale urban projects

Although there are now quite a number of relatively large-scale rain water treatment systems either being planned or in implementation in urban areas around the world, most of them are implemented in relatively homogenous contexts, and complex systems covering a range of household types, income levels, cultural and geographical conditions within one urban area are still extremely rare. These complex systems are needed to develop a variety of technological, organizational and economically viable solutions for densely populated urban areas and to obtain results concerning the costs and performances of different systems in both industrialized and developing nations. Up to now only a few private investors have shown a readiness to invest in closed loop sanitation systems for urban area - which would be an important pre-condition for these systems being widely applied and accepted as standard. In order to have rain water treatment systems introduced on a large scale, their functioning and acceptance would still have to be proven. To achieve the latter, it is of utmost important to successfully hold the dialogue with decision makers. And rain water treatment systems are going to be introduced in developing countries on large scales probably only when they have been introduced and operated in the industrialized countries in a much wider scale, showing clearly the advantages to the existing conventional systems, especially in urban and semi-urban areas [5].

4.4. Modeling and validation of the results obtained on selected objects in practice

Addressing issues of design and assessment of infiltration systems and reducing rain runoff and pollution of urban river basin is the most important part of achieving the objectives of the best rain water management practices. The results of a study of several methods of surface runoff will be coordinated and used the opportunities to reduce runoff and pollution through unpolluted rain water infiltration directly to the basin. This part of the solution include detailed description of infiltration systems, their advantages and disadvantages, criteria for the framework design, as well as guidance on the detailed design of concentric diffuse of infiltration systems. It is necessary to focus on forecasting and concept development of advanced methods of drainage and disposal of rain water from urban catchments. This study will serve as a conceptual focus for the development of the legislative, regulatory and technological in the field of sewage management. Implementation of selected proposals will enable in situ monitoring of the proposed theoretical solutions in real terms.

Monitoring is an essential component of any control. The objectives are to obtain quantitative information to measure program progress and effectiveness, and to document the reduction of pollutant loads (if any). The monitoring activities include primarily the baseline monitoring of storm drain discharges and receiving waters and to evaluate the effectiveness of specific control measures [6]. Establish technical standards, cost analysis and risk comparisons is inevitable issue [5]. In order to enable a successful implementation of the concept of rain water treatment systems, the future efforts will be focused on generating the necessary data, technology and policies required to affect a major change in the way human settlements relate to the environment, with an emphasis on testing, research and development and social marketing, as well as cultural, financial, legal and institutional issues. Some decision makers and planners remain an information deficit, which limits the range of choices available to them. Even when information is available, it is not often insufficient, leading to wrong assumption. The lessons learnt from existing systems must be therefore better documented and disseminated. More practical knowledge on system construction, operation and maintenance and on the safe use of the products, as well as cost evaluation needs to be developed and given to more attention.

5. CONCLUSION

Decentralized wastewater system based on ecological sanitation is a relatively new concept in many parts of the world, although in the last few years this promising approach has assumed an increasingly prominent position in the international discourse on sanitary provision and is recognized as an innovative approach which could play an important role in achieving sustainable development. Much process has been made, but much more is still needed before this approach will be recognized as the standard approach.

In order to find legal and technological ways of implementation, it is necessary to be involved in an early stage of urban planning. When the settlements and dwellings come to be equipped with rain water treatment systems, these systems should be considered from early on in the planning stage and integrated into the processes of urban planning, facilitating considerably the consideration of all relevant aspects of town planning, land use, urban agriculture, and management. Even with reliable and proven systems, rain water treatment systems require integrated planning for implementation. Help will probably come from the changes in energy supply to more decentralized structures where synergies can be found for semi-central installations in urban areas. It is very obvious that cooperation with city planners is a key issue. Therefore, besides the urgent need for expanding education of engineers and capacity building in the region city planners must get basic knowledge about alternatives. Based on urban location and the favorable planning conditions, the treatable resources (rain water) should be integrated into urban sanitation systems [5].

Best management practices that mirror the natural process of infiltration found in undeveloped watersheds can effectively increase the volume of water returned to the soil and reduce the volume of direct runoff to streams and sewers. Increased infiltration will maintain pre-development base flow in local streams, and also help reduce the frequency of bank-full flow in urban stream channels. Infiltration practices are the one group of best management practices that can effectively reduce the volume of net annual direct runoff to streams. When site conditions permit, a portion of urban storm water runoff can be managed through infiltration. The water volume from infiltration is transferred to the soil-water system and released slowly over time through the local water table and into local and regional stream base flow. Additional water is transferred back into the atmosphere through evapotranspiration [4].

The new challenge of rain water management requires a fundamental change in the way we think about storm water. Instead of thinking of rain water as something to be collected and treated, then disposed of outside the city, rain water should be regarded as a resource, and the amount of rain water introduced into combined system should be reduced. Therefore, decentralized rain water management can be regarded as an alternative, the sustainable strategy and redevelopment of rural and urban human settlement, practically considering ecological, economical and social criteria.

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APPLICATION OF APARTMENTS LARGE VOLUME RADIATION HEATING SYSTEMS

ABSTRACT

In this article are submitted results engineering choice of installation height infra-red heaters and definition of the heating area of industrial and agro-industrial rooms.

KEYWORDS: infrared heating, air temperature, convection heating, irradiation.

1. RAISING OF PROBLEM

After the estimations of specialists, the thermal networks wear approaches critical values on this time in Ukraine, more than half requires them replacements. In force of it, and also ramshackle flow sheets the heated systems presently are one of those spheres in which introduction of new energy keepings technologies can bring a most return. The effulgent heating is included in the number of such decisions.

The effulgent (infra-red) heating is the system of heating on the basis of cal radiance. Such radiation, as well as ordinary light, is not taken in air that is why all energy from the heated device without losses arrives at surfaces, that is heated and living organisms in the area of his action. The effulgent heating differs this from the widespread convection systems which are expected, above all things, on heating of air in an apartment. At the infra-red heating a temperature of air can be below at the same level of comfort for people and agricultural zones.

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2. ANALYSIS OF THE LAST RESEARCES AND PUBLICATIONS

Possibility of application of infra-red heaters and efficiency of the radial heating was probed many authors [1-3].

Is an infrared an electromagnetic radiation which is in the range of spectral region from λ = 0,74 mkm (visible light) to λ = 2 mm (short-wave radio emission). As a rule, the spectrum of infrared radiation divided on an area – short (λ = 0,74…2,5 mkm), middle (λ =2,5…50 mkm) and long (λ = 50…2000 mkm). In the heated systems can be used different family emitters, it depends on a producer, technological process, as apartments, but the purpose of such systems consists in an energy saving method maintenance of the thermal mode of workings areas of large volumes apartments. Infra-red heaters work in an infra-red spectrum and located mainly under ceiling of apartment. The heated element radiates harmless electromagnetic waves which are taken in hard objects, promoting their internal energy, which become the sources of heat directly on workplaces.

Today there are plenty of various infra-red heaters. Mainly they are divided into two categories: high intensity, in which incineration of gas takes place on-the-spot ceramic attachments which are heated to the temperature 950 °C; low intensity, in which a process of combustion into the heated pipe and its surface is heated to the temperature 350 ... 450 °C.

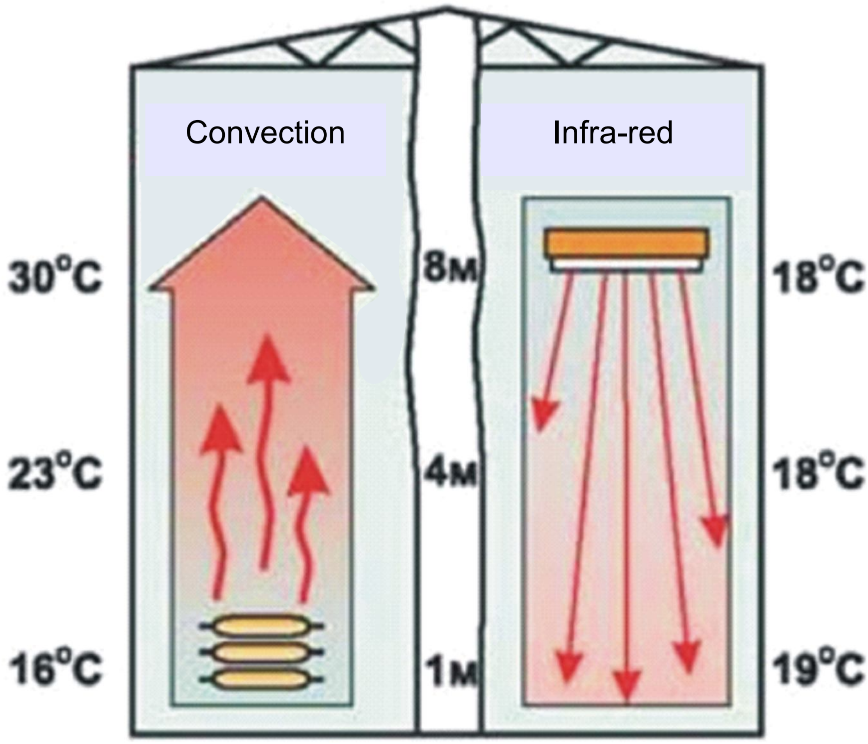

Fig.1. Temperature gradient at the convection and infra-red methods of heating

On fig.1 comparative description of distributing of air temperatures is represented in the whole volume of apartment. Such picture is characteristic for objects enough large height.[4].

At the convection heating air is at first heated, whereupon warmly passed to the man. At the convection heating air is at first heated, whereupon warmly passed to the man. Warm air, naturally, goes up, creating powerful convection streams, and cold air accumulates down. As a result greater part of thermal energy is outlaid on heating of air higher working area. As thermal energy from infra-red heaters is not taken in air that is why all warmly from a device almost without losses arrives at objects and people in the area of his action and heats exactly them. Thus it is not observed expressly expressed temperature a gradient on the height of apartment which does these devices irreplaceable at the decision of tasks of the economic heating of apartments with the high ceilings. As a rule, application of the infra-red heating is provided by to 40% energy-savings.

It should be noted that the infra-red heating is the unique method that allows carrying out the local heating of workplace or area in an apartment. There is an opportunity to support different temperature conditions in different parts of apartment and fully to disconnect devices in separate areas by the infra-red heating. For example, if workplaces are on considerable distance one from the second, an apartment on the whole can and not to have an identical temperature. Even from point of comfort different workings situations are assumed whiz different temperatures. The local heating is arrived at by the location of devices above separate workers placed without heating of all apartments.

Purpose of this work – carry out the estimation of work efficiency of infra-red heaters as TL (Solaronics) and get dependences which can simplify the engineering's calculations of the infra-red systems of heating.

3. EXPOSITION OF BASIC MATERIAL

Analytical researches and analysis of factors which influence on intensity and efficiency of work of infra-red heaters in shop floors with the purpose of their heating were conducted. One of basic such factors there is a correct location of the heated devices.

At the location of the heated devices take into account those surfaces of apartment, which convection is on, that, in the first turn external defenses, window armholes. It is necessary by emitters to get the cal radiance of identical intensity in a working area from every quarter. The wrong location of the heated devices can result in considerable discomfort. For example, if to dispose a device on ceiling, and from the side of lateral walls there are considerable transmission heat of loss and temperature of lateral walls low, and the difference of temperatures is greater, a different heat transfer from two sides creates noticeable discomfort. Such location of the heated devices is possible only then, when stays of man in this apartment of short duration, for example, storage facilities. De after part, if intensity of radiation is too strong, in such case a man has feeling of discomfort also.

The recommended minimum height of arranging of heaters can be defined from dependence:

$$H = a + b \times Q, \quad (1)$$

H – minimum height of pendant, m;
a – factor of height;
b – factor of power;
Q – power of emitter, kW.

In a table 1 the resulted values of factors of height and power are presented.

Table 1. Size of factors of height of establishment and power of heaters

Form of heater	U-similar		Linear	
Pendant	horizontal	30°	horizontal	30°
«a»	2,9	2,5	2,75	2,3
"b"	0,05	0,046	0,048	0,044

Putting the value of factors and size of power of heaters in dependence (Eqn. 1) it is possible to get the minimum height of pendant (Tab. 2)

Table 2. Minimum height of establishment of infra-red heaters.

Variant	Editing	Power of heater (kW)										
		10	**15**	**20**	**25**	**30**	**35**	**40**	**45**	**50**	**55**	**60**
U - similar	horizontal	3,4	3,7	3,9	4,2	4,4	4,7	4,9	5,2	5,4	5,7	5.9
	30°	3	3,2	3,4	3,7	3,9	4.1	4,3	*4,6*	4,8	5	5,3
Linear	horizontal	3,2	3,5	3.7	4	4,2	4,4	4,7	4,9	5,2	5,4	5,6
	30°	2,7	3	3,2	3,4	3,6	3,8	4,1	4.3	4,5	4,7	4,9

Taking into account the minimum height of pendant of heaters it is possible graphically to define the area of irradiation of surface (ris.2) [4].

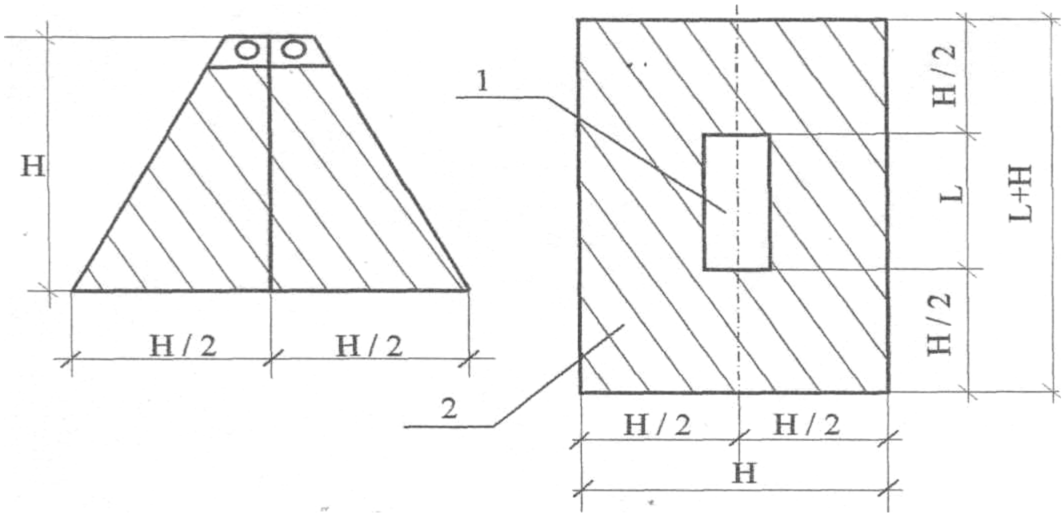

Fig. 2. Illustration of method of determination of area of irradiation
1 - infra-red heater long L, m is set on height of N, m; 2 - area of irradiation.

In-process for comfort calculations graphic dependence of area of irradiation from the height of establishment of heater was set.

For an example the emitters of Solaronics undertook as TL.

Fig. 3. An infra-red heater of Solaronics is as TL.

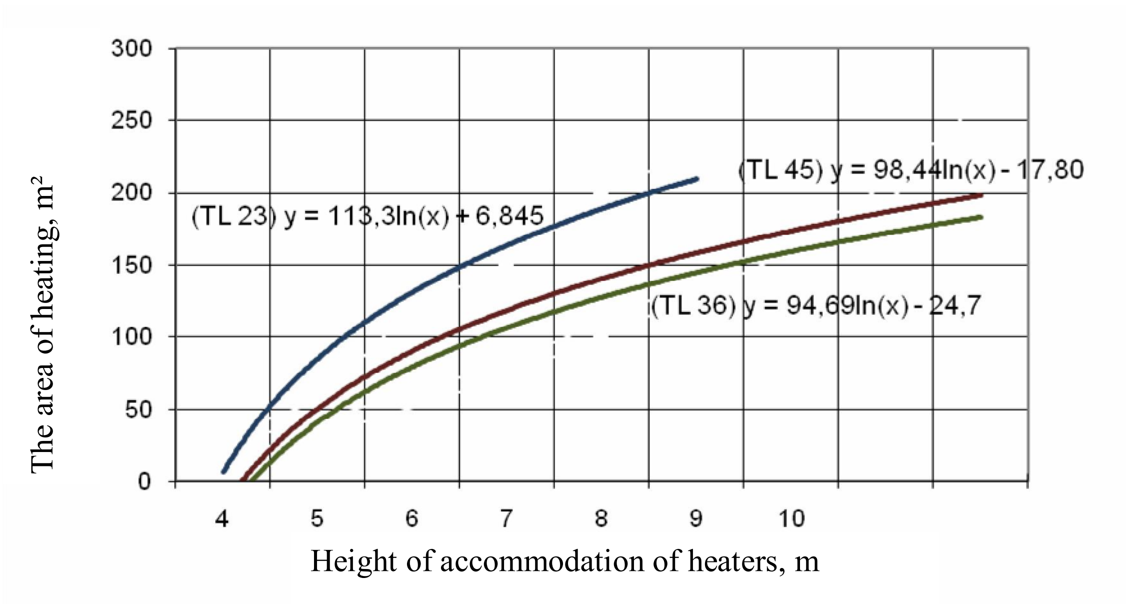

Fig.4. Dependence of area of irradiation from the height of hanging of emitter

4. CONCLUSIONS

As a result has got graphic and analytical dependences which enable to define the area of irradiation depending on the height of infra-red heater's establishment as TL (Solaronics) during planning of the infra-red heating systems.

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TIME OF CONCENTRATION FOR LINEAR CATCHMENTS WITH VARIABLE SLOPE FOR THE RAINS OF CONSTANT INTENSITY

ABSTRACT

New theoretical method of the stormwater hydraulic calculation for linear catchments with variable longitudinal slope is substantiated. It is obtained the dependence of the time of concentration from the catchment's length, middle slope, coefficient of the slope variation and rain intensity.

KEYWORDS: stormwater, hydrograph, time of concentration, longitudinal slope.

1. INTRODUCTION

In design of stormwater systems and drainage structures, stormwater runoff is usually considered in terms of peak discharge and hydrographs as dependence of discharge versus time. The principal parameter of the runoff hydrograph is the time of concentration.

In the known methods [1–4] the catchments are assumed as flat surfaces, with constant longitudinal slope. On the other hand, usually catchments have a variable longitudinal slope.

2. MATHEMATICAL MODEL

In the paper are presented the results of theoretical investigation of the catchment's slope scheme influence on the time of concentration for the rains of constant intensity.

The catchments with longitudinal slope, given by the linear function, were studied:

$$i = i_o + k(x - L/2), \tag{1}$$

where i_o, i – longitudinal slopes at the middle cross-section and in the x-section respectively; k – coefficient of the slope variation; L – the full length of linear catchment (Fig. 1).

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Maximum absolute values of the coefficient of the slope variation are limited with condition i>0 in any point of catchment, so

$$|k|_{\max} = 2i_o / L\,. \qquad (2)$$

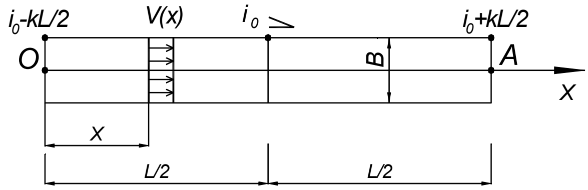

Fig. 1. Scheme of overland flow at the linear catchment with variable longitudinal slope

Stormwater discharge in any cross section was defined by Shezi's equation with a consumption of the turbulent flow zone and rough wall field along the catchment:

$$Q(x) = \frac{B\sqrt{i}}{n} h^{1+z}\,, \qquad (3)$$

where: B – catchment's width; h – flow depth; n – roughness coefficient; z – degree coefficient defined by the Pavlovsky's equation or equal to 2/3 according to Manning.

From the other hand

$$Q(x) = \psi_{mid} q_0 Bx\,, \qquad (4)$$

where: ψ_{mid} – middle value of runoff coefficient; q_o – rainfall intensity, m^3/(m^2·s).

It was derived an analytical equation for the time of concentration of the runoff from the linear catchments with variable longitudinal slope:

$$t_{con} = \left[\frac{n}{(\psi_{mid} q_o)^z}\right]^{\frac{1}{1+z}} \cdot I_{i_o,L,k}\,, \qquad (5)$$

where $I_{i_o,L,k} = I(i_o, L, k)$ – analytical function, defined as

$$I_{i_0,k,L} = \int_0^L \frac{dx}{x^{\frac{z}{z+1}} \cdot [i_o + k(x - L/2)]^{\frac{1}{2(z+1)}}}\,. \qquad (6)$$

3. COMPUTATION PROCEDURE

Eqn. (6) was derived with computer program at different values of length L of linear catchment, middle longitudinal slope i_o and coefficient of the slope variation k. In this study degree coefficient z was assumed to be constant and equal to 2/3 according to Manning.

Catchment was divided to 1000 intervals in the longitudinal direction and integration process was realised numerically. The control of accuracy was executed, comparing the results obtained at k = 0 (case of the flat catchment with constant slope) with results of the calculation with theoretical formula [5]:

$$t_{con} = \frac{5}{3}\left(\frac{1}{\Psi_{mid} q_o}\right)^{2/5} \cdot \left(\frac{nL}{\sqrt{i_o}}\right)^{3/5}. \tag{7}$$

Comparing Eqn. (5) and Eqn. (7), we can conclude, that integral (6) when $k = 0$:

$$I_{i_0,k=0,L} = \frac{5}{3}\left(\frac{L}{\sqrt{i_o}}\right)^{3/5}. \tag{8}$$

Relative error of the computation procedure was less then 0.4% in all cases.

3. RESULTS OF INVESTIGATION

Dependences of the integral $I = I(k)$ at $i_o = 0.01$ and different L are shown in Fig. 2.

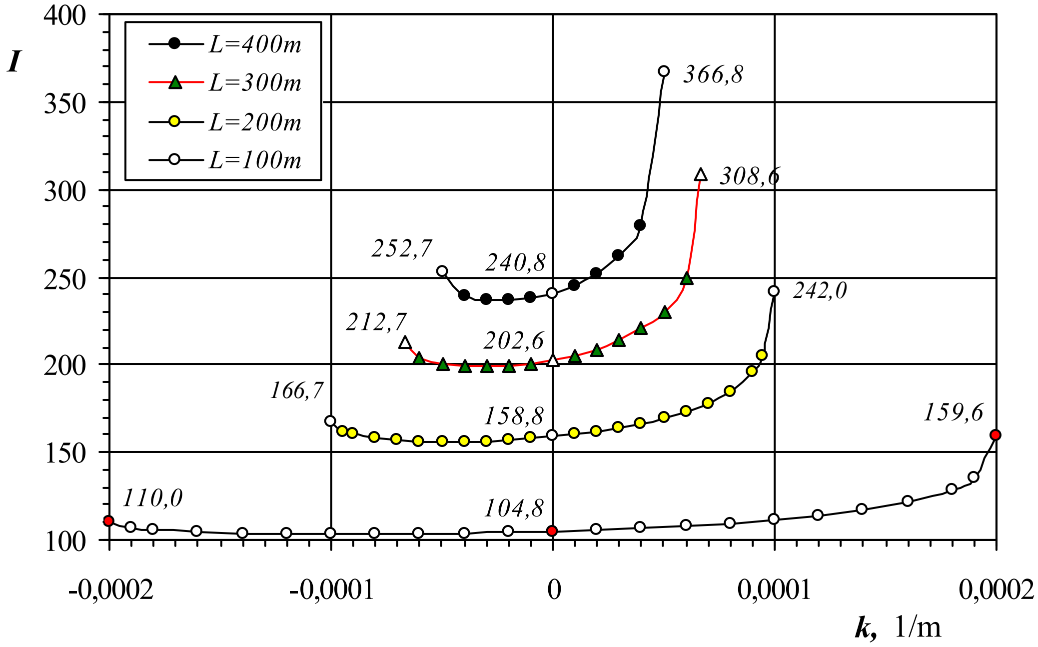

Fig. 2. Dependences $I = I(k)$ at $i_o = 0.01$ and different L

Some special values of the integral I, corresponding to minimal, middle and maximum values of the slope changing coefficient, are depicted in Fig. 2. The longer is linear catchment, the more is the difference between the time of concentration at $k = 0$ and at k_{max} or at k_{min}. From the other hand, in all cases their relation is constant. For example, values of the integral I, corresponding to k_{max} ($I_{k_{max}}$), are 1.523 times more than at $k = 0$, and $I_{k_{min}} = 1.05 \cdot I_{k=0}$. Minimal values of the integral I and thus of the time of concentration are at the slope variation coefficient $k = -k_{max}/2 = -i_o/L$ and equal to $0.982 \cdot I_{k=0}$.

Dependences of the integral $I = I(L)$ at $i_o = 0.01$ and different k are shown in Fig. 3. Time of concentration for the catchments with slope variation coefficient less then $k = 3 \cdot 10^{-4}$ m^{-1} do not differs from the base case ($k = 0$) more than 10%. But if $k > 3 \cdot 10^{-4}$ m^{-1} time of concentration increases more strongly.

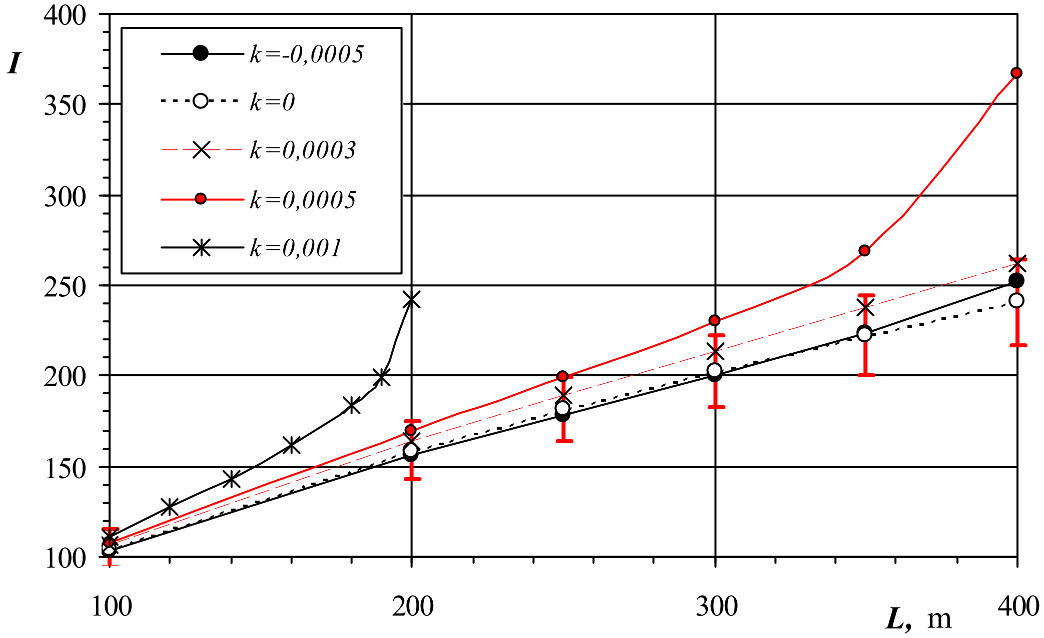

Fig. 3. Dependences $I = I(L)$ at $i_o = 0.01$ and different k

4. CONCLUSIONS

The mathematical model, presented in this paper, simulates the runoff process and computes the time of stormwater concentration from the linear catchments with changing longitudinal slope. It is obtained, that the time of concentration depends significantly on the longitudinal slope scheme of the catchment and must be taken into account in design procedures. Time of concentration for catchments with increasing slope is greater, compared to the catchments with constant or diminishing slope. Minimal time of concentration corresponds the slope variation coefficient $k = -k_{max}/2 = -i_o/L$, maximal time of concentration corresponds $k = k_{max} = 2i_o/L$.

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STORAGE VOLUME OF TWO-SECTIONAL STORMWATER STORAGE TANKS FOR THE LINEAR CATCHMENTS FOR THE RAINS WITH CONSTANT INTENSITY

ABSTRACT

Storage volume coefficient of two-sectional stormwater storage tanks is obtained as function of initial coefficient of regulation α_o, coefficient of head changing *b*; dimensionless rainfall duration X_d; dimensionless chamber's area relationship coefficient *k*, defined as overflow chamber's area divided by the full tank's area.

KEYWORDS: stormwater, storage tank, storage volume.

1. INTRODUCTION

Storage volume of stormwater storage tanks (SWST) is a basic technical feature of these structures. Two-sectional storage tanks include overflow and accumulation chambers. Overflow chamber is small, so outflow from these storage devices increases quickly to its maximum value, causing the reduction of necessary storage volume [1].

Storage volume of SWST is a function of runoff hydrograph and outflow discharge characteristic [1−3]. Dependences of the storage volume of one-sectional SWST versus the storage tank dimensions and outlet device characteristics were investigated in the previous works [4−5].

Storage volume of two-sectional storage tanks depends from the relationship between overflow and accumulation chamber's area. In the paper are presented the results of theoretical investigation of the storage volume coefficient K_{st} as function of initial coefficient of regulation α_o, coefficient of head changing *b*; dimensionless rainfall duration X_d; dimensionless coefficient *k*, defined as relation of the overflow chamber area to full SWST area. The objective of this paper is to develop an improved method of hydraulic calculation of storage volume of two-sectional stormwater storage tanks.

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2. STORAGE VOLUME OF TWO-SECTIONAL SWST

An important hydraulic task is determination of optimal height of overflow wall, that provides full capacity of SWST during the design storm. Thus, effective height of overflow and accumulation chambers should be equal to the height of overflow wall: $h_1 = h_2 = h_w$.

Storage volume of SWST is defined as integral of the difference between runoff inflow and outflow [1, 2]:

$$W_{st} = \int_{t_o}^{t_f} \left(Q_o - Q_c\right) dt \ , \tag{1}$$

where Q_o, Q_c – runoff discharge and outflow rate respectively; t_o, t_f – time of beginning and ending of the filling of the SWST.

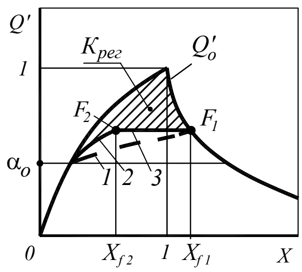

Fig. 1. Dimensionless storage-discharge relationship for one-sectional and two-sectional storage tank: 1 – dimensionless outflow curve for the one-sectional SWST; 2, 3 − dimensionless outflow curves for the first and second stage for two-sectional SWST

Storage volume of any SWST:

$$W_{st} = K_{st}\, Q_r\, t_r \ , \tag{2}$$

where K_{st} – storage volume coefficient; Q_r – peak runoff discharge corresponding to the time of concentration t_r.

3. RESULTS AND DISCUSSION

Fig. 2 shows that the smaller the area of overflow chamber, then the less necessary storage volume of SWST. For example, when k=0.1 and b=3 coefficient K_{st}=1.03, while when k=0.5 and b=3 – K_{st}=1.11, that requires 7% greater storage volume. For the simple one-sectional storage tank, i.e., when k=1, and b=3 coefficient K_{st}=1.24, thus required storage volume is 16.7% greater than when k=0.1.

It was obtained also, that when the coefficient of head changing b increases, then the storage volume decreases. If coefficient b=0.1 the difference between the coefficient of the storage volume K_{st} for one-sectional tank and two-sectional tank with the k=0.1 is only 1.6%; instead if b=3 the difference is equal to 16.7% and if b=10 – then 20. 9%.

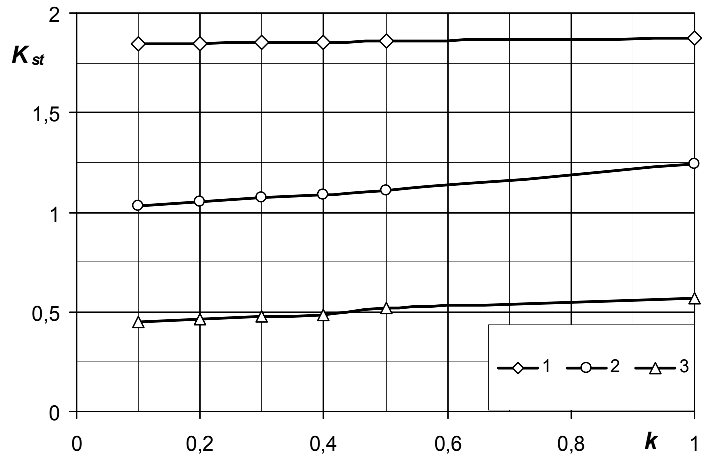

Fig. 2. Storage volume coefficient as function of area relationship coefficient k for: 1 – b=0,1; 2– b=3; 3 – b=6; 4 – b=10 (α_o=0.3; X_d=3; n=0.71)

Fig. 3. shows that the greater is head changing coefficient b, then the less necessary storage volume of SWST.

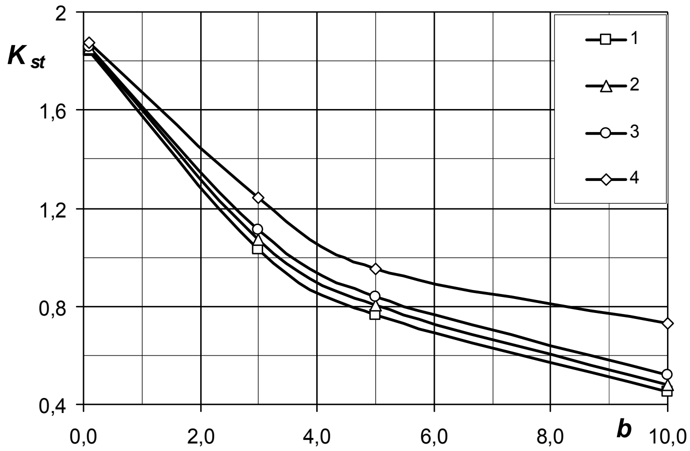

Fig. 3. Storage volume coefficient as function of head changing coefficient b for: 1 – k=0.1; 2– k=0.3; 3 – k=0.5; 4 – k=1 (α_o=0.3; X_d=3)

4. CONCLUSIONS

Storage volume coefficient of two-sectional stormwater storage tanks is obtained as function of head changing coefficient b and dimensionless chamber's area coefficient k for initial coefficient of regulation α_o=0.3 and dimensionless rainfall duration X_d=3.

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NATURAL PRESSURE INFLUENCE ON AIR FLOW THROUGH HOLES AND NON SOLIDITY OF ROOM ENCLOSURE

ABSTRACT

It is considered that thermal pressure influences are caused by densities of external ρ_e and internal ρ_i air. They directly proportionally depend on height of ventilation pipe.

Analysis shows, that there are not taken into account at least such values: pressure influences of convective flows, which are resulted from heat sources; temperature division of internal air; variability of boundary layer external air density against running height of building. It must be noted, that only gravital pressure influences are taken into account, but wind pressure influences are ignored. However, wind pressure influences are based at natural ventilation of rooms in different seasons.

KEYWORDS: gravital pressure, natural ventilation, convective flows.

1. RESEARCH TASK

Task of research is to analyse influence of thermal and wind pressure influences on air flow rate, that flows through holes and non solidity room enclosure, namely at forced ventilation systems.

2. ANALYSIS OF EXTERNAL AND INTERNAL NATURAL PRESSURE INFLUENCES ON AIR FLOW RATE THAT FLOWS THROUGH HOLES AND NON SOLIDITY ROOM ENCLOSURE

Flow of air through non solidity of windows and doors or holes of external enclosures occures under influences of pressure difference **ΔP** (external and internal air):

$$\Delta P = (\Delta P_t - \Delta P_W) + \Delta P_V \qquad (1)$$

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where $\mathbf{\Delta P_t}$ - difference of thermal pressure, caused by convection air flows due to heat sources; $\mathbf{\Delta P_w}$ - pressure difference that in caused by pressure influences of wind in boundary layer of separate building enclosures; $\mathbf{\Delta P_v}$ - pressure difference that is caused by fan action. At absence of forced ventilation systems, of course, $\mathbf{\Delta P_v = 0}$, so:

$$\Delta P = \Delta P_t + \Delta P_w \tag{2}$$

Due to pressure difference air flows will flow both through non solidity of external room enclosure and through pipes of forced ventilation systems.

Let us analyse thermal pressure influences indoor and out of the room. It is known, that air flow and heat flow appear near surfaces of heat sources (convective jets). For estimation of air temperature, velocity and flow rate in convective jets, that appear near heat sources and near vertically heated surfaces (for example external surfaces of windows or wall in cold season) there is often used empiric, analytic and calculating method of liquid and gasses mechanics. All convective jets from heat sources of the room are often turbulent and ordered to laws of physics.

The most of analytical equations for determination of convective flows parameters (velocity, excessive temperature and air flow rate) refers to point and line heat sources or vertical heated surfaces.

Complicated nature of the convective jet from a round heated plate has been investigated by experimental research. Cold air, that flows from everywhere to the plate heat source, moves as separate horizontally directed jets to the centre of heat source. These jets move in the top part of the boundary layer, vertically directed jets of heated air, that rises from surface of heat source. Cool air falls down to surface of heat source in this place, from which heated air mass has rosen up and some vacuum has appeared. In boundary layer we can see air flow up and down. Thickness of boundary layer equals nearly 0,2 of a round plate heat source diameter or 0,2 of rectangular heat source less size.

From boundary layer heat jet leaks not unbroken flow, but as separate jets. These jets of cool air, flowing from border of heat source to its centre, form lattice, through which vertically directed jets of hot air rise up.Velocity of separate hot jets is more, than average by flow rate velocity of total heat jet.

As a result ejectional action of separate hot jets over surface of heat source (in boundary layer) vacuum appear, that causes flowing of surrounding cool air from the all directions to heat source. The most intensity of flowing is seen in boundary layer and intensity decreases over it. At situation of heated plate on vertical support cool air flows to heat source from bottom along border surface of support [12]. By this air flows to support from far away at low velocities. Vacuum promotes both over top and bottom surface of heat source, that spread also on neighbour surfaces of support in floor direction. It must be noted, that over top surface held horizontal heat source appeared less vacuum, that over surface of heat source, which was mounted at the same level with horizontal wall or floor [12]. As a result, at the same convective heat educing over surface held over floor heat source higher velocities appeared and flow rate of convective jet, but less excessive temperature comparatively jet, that appeared over heat source being mounted on floor level.

Due to these investigations we can do conclusion, that near surface of three-dimensional heat source, which is situated on a room floor or held over it, but in the borders of serviced area, there appear vacuum of internal air in bottom of the room. Due to dynamic action of convective jets in top of the room there appeared static positive excessive pressure.

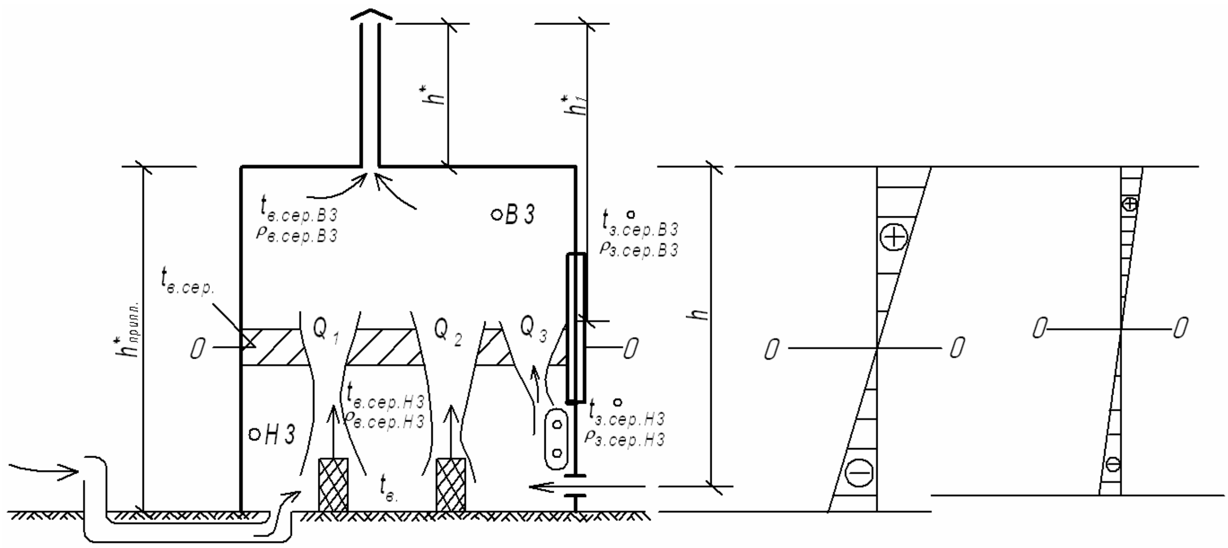

Fig.1. Scheme of system of pipeless and particular pipe thermal pressed ventilation of room with heat educing sources on a floor and epures of excessive pressure of thermal layered internal air

It is obvious, that determination of internal air excessive pressure, that appear as a result of convective jets is difficult, because theoretical base and real effects of this phenomenon are not enough studied.

Many phenomena in ventilated rooms, for example vertical temperature gradient, velocities in layered internal air, thickness of layerization and efficiency of room common ventilation can be analysed by Arkhimed criteria. This criteria shows relationship between force of rising and force of innertion. This value is calculated by equation:

$$A_V = \frac{\Delta\rho \cdot L \cdot g}{\rho \cdot V^2} \tag{3}$$

where **Δρ** - is difference of densities of surrounding cool internal air and convective flow, that is caused by heat source, kg/m^3; **L** - specific size, m; **V** - average velocity of convective flow, m/s; **g** - accelleration of gravity, m/s^2 (g = 9,81 m/s^2).

Arkhimed criteria can be determined by different manner, for example by difference of air densities (as in formula (3)) or by difference of temperatures. But base mark of this criteria remains constant: higher value $\mathbf{A_r}$ shows advantage of rising forces, but lower value $\mathbf{A_r}$ - advantage forces of innertion.

Using Arkhimed criteria and Mendeleyev-Klapeyron law we can analyse pressure influence of heat source on thermal layered internal air. Then potential of excessive pressure of internal air we can present as:

$$\Delta P_{t.i} = +P_{t.i} - (-P_{t.i}) \tag{4}$$

where $\mathbf{+P_{t.i}}$ - positive excessive pressure of internal air; $\mathbf{-P_{t.i}}$ - negative excessive pressure of internal air; $\mathbf{\Delta P_{t.i}}$ - potential of excessive pressure of internal air.

Namely convective flows act together with room enclosures and its holes as thermal pump.

For thermal pressed ventilation of the room it must be unite with atmosphere, at least by two holes, that are situated in the different levels of external enclosures (see fig.1.).

By this, as a result of potential of internal excessive pressures of air, air movement will appear: through the bottom hole cool external air without excessive pressure will flow in vacuumed space of bottom air zone, but hot internal air with positive excessive pressure will leak from the top area in cool atmospheric air without excessive pressure. Therefore, if temperature of external air in the places of air taking and exhaust devices is the same, then windless external air causes neutral excessive pressure influences. In this case :

$$\Delta P_{t.i} = h \cdot (\rho_{i.BZ} - \rho_{i.TZ}) \cdot g$$
$$\Delta P_{t.i.max} = h_r \cdot (\rho_{i.BZ} - \rho_{i.TZ}) \cdot g \quad (5)$$

where $\boldsymbol{\rho_{i.BZ}}$ - average density of internal air of the room bottom zone; kg/m^3; $\boldsymbol{\rho_{i.TZ}}$ - average density of internal air of the room top zone, kg/m^3; h- vertical distance between the holes centres for incoming of external air in the room and exhaust of internal air from the room, m; $\mathbf{h_r}$ - height of the room, m.

In case, when temperature of external air in place of air taking on bottom zone level is lower, than temperature of external air in place of exhaust device, that is situated on top zone level we have (see fig.1.):

- difference of gravity pressure, that causes flowing of external air in the room :

$$\Delta P_{g.BZ} = \frac{h}{2} \cdot (\rho_{e.BZ} - \rho_{i.BZ}) \cdot g \quad (6)$$

- difference of gravity pressure, that causes flowing of internal air leakage out of a room:

$$\Delta P_{g.TZ} = \frac{h}{2} \cdot (\rho_{e.TZ} - \rho_{i.TZ}) \cdot g \quad (7),$$

where $\boldsymbol{\rho_{e.BZ}}$ and $\boldsymbol{\rho_{e.TZ}}$ - average densities of external air, as a result, at levels of bottom zone and top zone, kg/m^3 (see fig.1.).

Difference of gravity pressure, that causes ventilation of the room:

$$\Delta P_g = h \cdot (\rho_{e.av} - \rho_{i.av}) \cdot g \quad (8)$$

where $\rho_{e.av} = (\rho_{e.BZ} + \rho_{e.TZ})/2$

$\rho_{i.av} = (\rho_{i.BZ} + \rho_{i.TZ})/2$

It is obviously, that

$$\Delta P_{g.max} \le h_r \cdot (\rho_{e.av} - \rho_{i.av}) \cdot g \quad (9)$$

Convective flows near vertical heated surfaces, for example near surfaces of windows and external walls, are interesting for ventilation and heat exchange processes. In many floor buildings with the same heat educing per floor, near surface of their external enclosures appear vertically directed convective flow with rising against height temperature and velocity.

Taking into account, that air temperature in convective flow (boundary thermal dynamic layer) increases against height, we can do conclusion, that $\mathbf{\Delta P_g}$ (9) decreases against height.

Thus efficiency of gravity ventilation system at the same constructive solutions will be the highest in a room of the first floor (value $\rho_{e.av}$ is maximum) and the will be lowest in the room of the highest floor (value $\rho_{e.av}$ is minimum).

This effect is not connected with pipe (duct) height of incoming - exhaust ventilation system.Besides this, vertically directed convective flow of the boundary external air causes ejective effect, which promotes of internal air leakage through holes and non solidity of vertical external enclosures and the most expressively is shown on level of the highest thermal ventilated namely at wind absence house floor (the leakage of air out of a building).

From fig.1 and analysis of formula (8) we can do such conclusions: height **h** do not exceed height of the room $\mathbf{h_r}$; room height is constructive, namely conditionally constant parameter, but values $\rho_{i.av}$ and $\rho_{e.av}$ are variable in time and in space; pipes (ducts) height of exhaust gravitical system do not influence on value $\Delta\rho$, thus these pipes causes only additional resistance air flowing, decrease room air exchange; at pipe taking of external air on distance from a house value $\Delta\rho_g$ can some increase as a result increasing of value $\Delta\rho_{e.av}$ (air taking beyond the border of wall convective flow), but air exchange of the room will not increase proportionally, because pressure lost at flowing external air through ventilation pipe will increase.

Therefore, the most effective nature gravity ventilation of the room in pipeless ventilation “aeration” due to holes of regulated square for incoming of boundary external air and exhaust of boundary internal air, there are both in top and bottom levels of external wall or due to holes in near floor area of external wall and holes in ceiling.

Value $\pm\mathbf{P_w}$ (see equations (2) and (3)), that are base force for nature ventilation of rooms at wind action, we can determine due to aerodynamic coefficients $\mathbf{C_i}$, which are needed for estimation of wind pressure influence on external house enclosures [4;19]. Wind pressure influence on real objects (at increasing wind speed) and on model at their blowing by air flow, that is formed in working area of wind tunnel. Epures of exceeded wind pressures on only house with horizontal roof are schematically shown on fig.2.

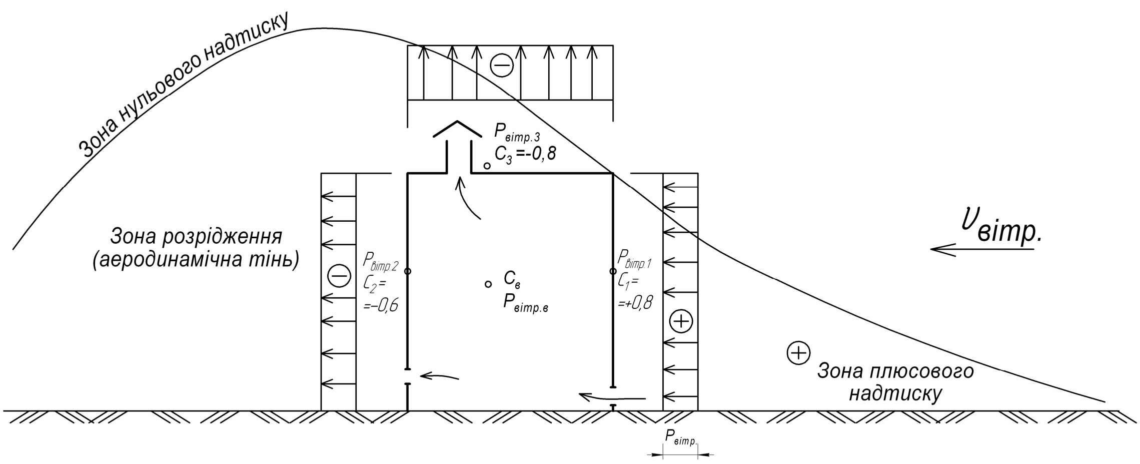

Fig.2.Epures of exceeded wind pressure on only house:

$C_1 \ldots C_3$ – average values of aerodynamic coefficients [19].

It is obviously, that at the first $\Delta P_W = \pm P_{wj} \pm P_{wi}$ ($\mathbf{P_{wj}}$- exceeded wind pressure on j- external enclosure of house(room); $\mathbf{P_{wi}}$ - exceeded pressure of room internal air, which appears at ventilation, that is caused by wind pressure $\mathbf{P_{wj}}$).

Difference of gravity exceeded pressure $\Delta P = \Delta P_g \pm \Delta P_w$ caused flowing of boundary external air through the adequate hole in the room under influence of some part of its value, which let us mark $\mathbf{\Delta P_{exh}}$ (namely $\Delta P = \Delta P_{inc} \pm \Delta P_{exh}$).

In the first approximation it can be assumed $\Delta P_{inc} \approx \Delta P_{exh} \approx 0{,}5 \cdot \Delta P$.
At action only gravity pressure, when $\mathbf{P_{wj} = 0}$, it is recommended to assume $\Delta P_{inc} = (0{,}2 - 0{,}3) \cdot \Delta P_g$ [4].

Knowing value $\mathbf{\Delta P_{inc}}$ or $\mathbf{\Delta P_{exh}}$ average by flow rate velocity of air flow, which flowing through the hole of external room enclosure, can be calculated by equation:

$$V = \sqrt{2 \cdot \Delta P_{inc(exh)} / \rho_{inc(exh)}} \tag{10}$$

Its mass flow rate – by equation :

$$Q_6 = \mu \cdot V \cdot A \cdot \rho \tag{11}$$

where: μ - coefficient of hole flow rate;
ρ - density of air flow, kg/m^3;
A - square of hole, m^2.

CONCLUSIONS:

1. Known from references equation for determination of difference of thermal exceeded pressure (gravity pressure) does not taking into account determining factors of influence temperature layering of internal air; convective jets, that are formed by heat sources; variability of boundary layer external air density against running height of house, especially in heating season.
2. In recommendation of gravity room ventilation system calculation at first thermal pressure influence are taking into account and there was not paid needed attention to wind pressure influence, which are based at ventilation of different aim rooms in different seasons, namely due to used or not used system of forced ventilation.
3. Convective jets from heat sources, for example stationary heaters (radiators, convectors and other) and other heat sources of rooms causes the most vacuum of internal air in their floor area and the most positive exceeded pressure in ceiling area.
4. Value of exceeded pressure of thermal layered internal air depends direct proportionally from room height and average density difference of internal air of top and bottom levels of room. Convective jets from room heat sources are base reasons of thermal ventilation of room. They form vacuum in bottom room level and positive exceeded pressure in top room level.
5. Value of gravity pressure difference, that cause room ventilation, directly proportionally depend on vertical distance between the hole centre for flowing of boundary external air in the room and exhausting of boundary internal air and average densities difference of boundary external and internal air in this level, but it does not depend from height of ventilation pipes.
6. Pipes of thermal (gravity) exhausting and incoming ventilation systems cause resistance to air flowing through rooms, thus decrease its air exchange.
7. Pressure wind influence are base reasons of nature ventilation of different air rooms in different seasons, namely at heat sources absence and forced ventilation systems.

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EXPERIMENTAL AND ANALYTICAL RESEARCH OF PRESSURE EFFECTS INSIDE THE SECTIONAL SOURCE AIR DISTRIBUTOR

ABSTRACT

Results of experimental and analytical research into the distribution of static pressures inside a sectional source air distributor with interior and exterior perforated walls and horizontal shelf pressure equalizers inside the first pressure chamber are presented in this article. A four-factor experiment matrix has been compiled, a regression equation generated and analyzed. Optimal relative dimensions of pressure equalizers has been established.

KEYWORDS : displacement ventilation, sectional source air , horizontal shelf pressure equalizers.

1. NTRODUCTION

The issue of using source filter air distributors for displacement ventilation systems is poorly researched in Ukraine. The purpose of such air distributors is the generation of air flows with uniform initial velocities and temperatures. Such flows feed the convective streams of heat sources and are capable of displacing pollutants out of working areas and counteract their movement inside working areas [1; 2; 3; 4;5].

2. PREVIONUS RESEARCH ANALYSIS

Research into using cylindrical filter air distributors in displacement ventilation systems which function in working areas with heat and gas pollution has been conducted at the Department of Heat and Gas Supply and Ventilation of Lviv Polytechnic National University [6; 7; 8].

Cylindrical source air distributor constructions and corresponding area ventilation were protected by former USSR certificates of recognition [9; 10; 11] and Ukrainian patents of invention [12; 13].

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Cylindrical panel air distributors 2m high and different in diameter were used for the ventilation of frame welding department at Ternopil' combine-building plant.

A mockup of one of the introduced air distributors 1,85m in height and 0.85m in diameter has been carried oft in Aerodynamics and Ventilation Laboratory of the Department of Heat and Gas Supply and Ventilation, Lviv Polytechnic National University. Mockup overview is available in Figure 1.

The majority of air distributors used in displacement ventilation systems have the drawback of consisting of only one chamber and thus being unable to equalize pressure vertically, i.e. ensure uniform initial velocity of air inflow.

Fig. 1. Overview of cylindrical filter air distributor

3. PROBLEM-SOLVING SUGGESTIONS

In order to reduce constructional drawbacks of source air distributors to the minimum, we have suggested a new construction of panel two-chamber perforated air distributors whose first pressure chamber is equipped with horizontal shelf pressure equalizers [14]. Such an air distributor may be considered among those of the last generation. Horizontal shelf pressure equalizers **III** in the first pressure chamber **I** of the air distributor (Fig. 4) are designed for static pressure equalization.

4. RESEARCH AIM

Research aim is to define relative lengths of horizontal shelf pressure equalizers which can provide equal static pressures in the first pressure chamber and inside the whole air distributor. This aim can be achieved through experimental research into an air distributor mockup or scaled model, with the application of known mathematical methods of design of experiments [15].

5. METHODS OF EXPERIMENTAL RESEARCH. MEASUREMENT INSTRUMENTATION AND RESEARCH CONDITIONS

Figure 2 shows an overview and Figure 3 – the structure of the model which was subjected to experimental research. Air distributor scaled model (M1:4) was studied in the Scientific and Research Laboratory of Lviv Polytechnic National University (see Fig. 4).

Research was carried out in the following order:

- A geometrically similar model of air distributor with horizontal shelf pressure equalizers of certain lengths $l_1 \ldots l_4$ was assembled (Fig. 4) as well as a unit for its research (Fig. 2);
- unit was switched on, its stationary mode of operation at a certain air flow discharge was established;

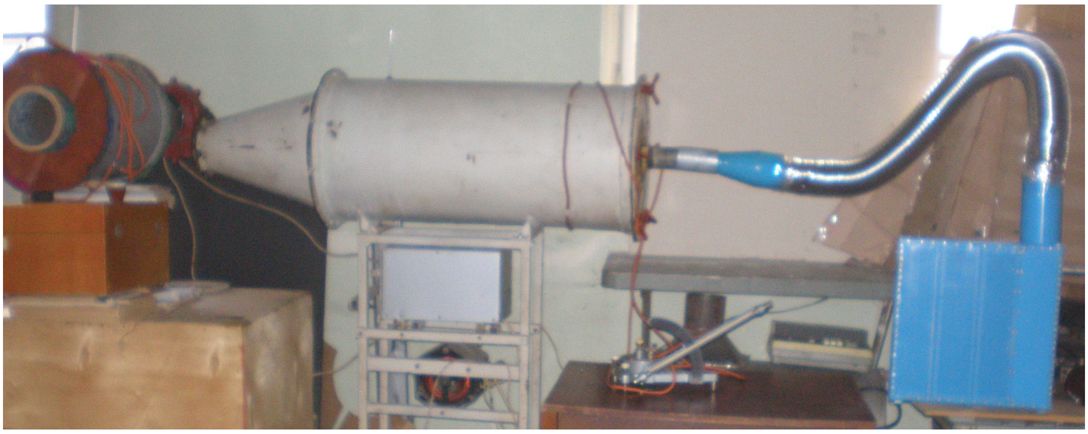

Fig. 2. Overview of experimental unit for researching
a model source 2-chamber horizontal shelf air distributor

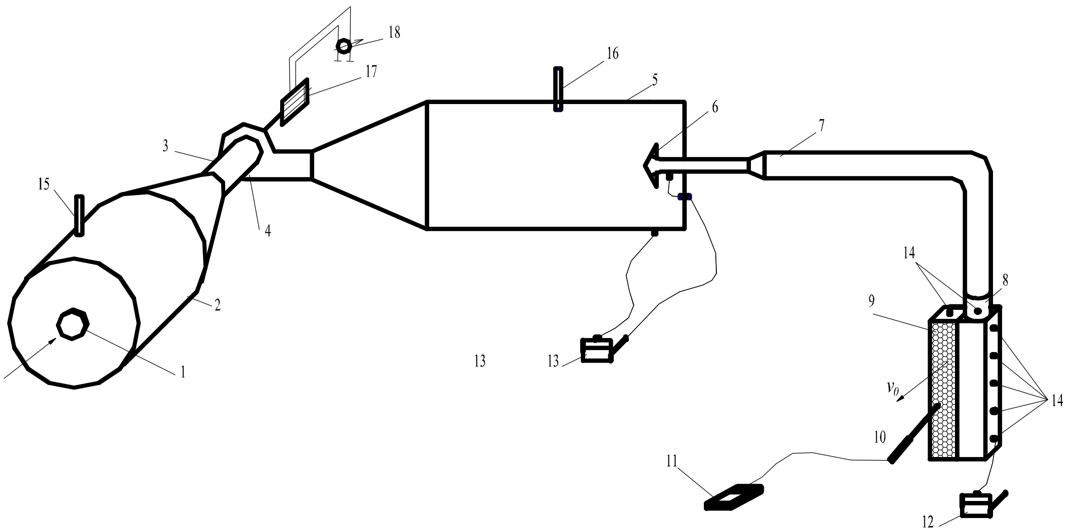

Fig. 3. Structure of experimental unit for researching a model source 2-chamber horizontal shelf air distributor:1 – intake pipe; 2 – negative superpressure chamber; 3 – air pipe; 4 – radial ventilator; 5 – positive superpressure chamber; 6 – discharge-measuring collector; 7 – flexible air pipe; 8 – inlet tube air distributor; 9 – model air distributor; 10 – teat loss anemometer probe, 11 – thermoanemometer «LIOT»; 12,13 – differential micromanometers MMN-240; 14 – checkpoints (nozzles) of static pressure measuring; 15-16 – alcohol thermometers; 17 – electric stimulus of direct current; 18 – rheostat

- Static pressures $p_1 ... p_5$ were measured with a differential micromanometer in 5 checkpoints of the first pressure chamber 1…5 (Fig. 4) according to the formula:

$$p_{stat} = (l_{stat.end} - l_{stat.ini}) \cdot k \cdot 9.806\ Pa \quad (1),$$

where $l_{stat.end}$ – end index of micromanometer 12, mm (Fig. 2); $l_{stat.ini}$ – initial index of micromanometer 12, mm; k – factor depending on the inclination of micromanometer 12 reading tube, kgf/m^2 (Fig. 3);

- Air temperature and barometric pressure in the laboratory were measured;
- Average static pressures in the first and the second pressure chambers $p_{I\ aver.stat}$ and $p_{II\ aver.stat}$ were calculated according to the formula:

$$p_{I\,aver.stat} = \frac{\sum_{i=1}^{5} p_i}{5} \tag{2}$$

where Σp_i – the sum of static pressure values in checkpoints 1…5 (Fig. 4);

- Factors of static pressure distribution nonuniformity in the first pressure chamber were defined according to the formula:

$$\varphi = \frac{p_{aver.stat}}{p_{max}} \tag{3}$$

  where $p_{aver.stat}$ – the value of average static pressure in the first pressure chamber; p_{max} – the value of maximum static pressure in a first pressure chamber checkpoint;
- The discharge of air flow was changed by changing the number of turns of electric stimulus 17 of fan 4 (Fig. 3). Pressures were measured again. Air flow discharge was changed three time;
- The relative length of horizontal shelf pressure equalizers installed in the first pressure chamber was changed; static pressures were measured at three values of air flow discharge.

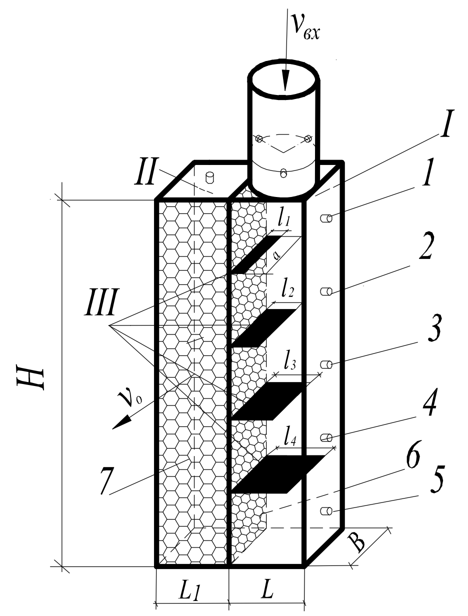

Fig. 4. Air distributor model structure.
I – first pressure chamber; II – second pressure chamber; III – horizontal shelf pressure equalizers; 1…5 – nozzles of point static pressure measurement in the first pressure chamber of air distributor; 6 – interior perforated wall; 7 – exterior perforated wall

In the course of the research metrologically certified measurement instrumentation was used. The instrumentation is shown in Table 1.

The previous experimental research into aerodynamic characteristics of panel source 2-chamber air distributor showed that dimensions of horizontal shelf pressure equalizers (Fig. 4) affect vertical distribution of static pressures in the first and second pressure chambers of the air distributor[20].

Table 1.Measurement instrumentation

No	Instrumentation item	Characteristics
1	Aneroid barometer BAMM-1, No9132	8000…106000Pa; ± 200Pa accuracy
2	Thermometer, No20922	<0.1°C accuracy
3	Micromanometer MMN-240(5) – 1.0 TU 25-01-816-74 No1314 and TU 25-01-816-79 No2018	± 1Pa accuracy

Experimental research was carried out in the following conditions:

- Isothermal flow;
- Linear dimensions of the first pressure chamber of air distributor model (Fig. 4), length $L = 0.1m$, breadth $B = 0.1m$, height $H = 0.4m$ were not changed;
- The distance between horizontal shelf pressure equalizers was not changed and constituted 0.08m;
- Relative dimensions of horizontal shelf pressure equalizers $\bar{l}_1 ... \bar{l}_4$ ($\bar{l}_1 = l_1 / L$; $\bar{l}_2 = l_2 / L$; $\bar{l}_3 = l_3 / L$; $\bar{l}_4 = l_4 / L$) were changed with $\bar{l}_1 = 0,2...0,3$; $\bar{l}_2 = 0,3...0,4$; $\bar{l}_3 = 0,4...0,5$; $\bar{l}_4 = 0,5...0,6$.

The number of experiments was calculated according to the formula:

$$N = P^K \tag{4}$$

where P – the number of levels of factors (P = 2); K – the number of factors (K = 4), therefore:

$$N = 2^4 = 16 \text{ experiments.}$$

The following magnitudes were accepted as input factors:

- $x_1 = \bar{l}_1$ – relative length of the first horizontal shelf pressure equalizer;
- $x_2 = \bar{l}_2$ – relative length of the second horizontal shelf pressure equalizer;
- $x_3 = \bar{l}_3$ – relative length of the third horizontal shelf pressure equalizer;
- $x_4 = \bar{l}_4$ – relative length of the fourth horizontal shelf pressure equalizer.

The nonuniformity ratio $\varphi = \frac{p_{aver}}{p_{\max}}$, where p_{aver} and p_{max} – average and maximal pressure in the first pressure chamber of air distributor respectively, becomes the response function (optimization parameter).

It is necessary to establish functional dependence $\varphi = f\,(x_1; x_2; x_3; x_4)$.

Four-factor experiment design matrix, nonmetering factor interaction effect, is given in Table 2.

The following regression equation is obtained:

$$y = 0,84 - 0,0025x_1 - 0,01x_2 + 0,0006x_3 + 0,01x_4 \tag{5}$$

On the basis regression coefficients analysis we state the following:

factors x_2 (relative length of the second horizontal shelf pressure equalizer) and x_4 (relative length of the fourth horizontal shelf pressure equalizer) produce considerable effect on response function behavior.

Table 2. Measurement instrumentation four-factor experiment design matrix

№	x_1	x_2	x_3	x_4	y	№
1	1	-1	-1	-1	0,77	1
2	-1	1	-1	-1	0,83	2
3	-1	-1	-1	1	0,86	3
4	-1	-1	1	1	0,85	4
5	-1	1	1	-1	0,84	5
6	-1	1	-1	1	0,86	6
7	1	1	1	-1	0,81	7
8	1	1	1	1	0,79	8
9	1	1	-1	1	0,84	9
10	1	-1	-1	1	0,87	10
11	-1	-1	-1	-1	0,83	11
12	-1	-1	1	-1	0,80	12
13	-1	1	1	1	0,82	13
14	1	-1	1	-1	0,9	14
15	1	-1	1	1	0,91	15
16	1	1	-1	-1	0,87	16

Remarks: Figures +1 and-1 denote code values of levels of factors of the experiment (the smallest value of the parameter is -1, the biggest +1);
y – experimentally defined ratios of nonuniformity of static pressure distribution in the first pressure chamber of air distributor

Therefore in order to achieve an increased ratio of static pressures distribution nonuniformity φ of the first pressure chamber of air distributor it is necessary to reduce relative dimensions of the second horizontal shelf pressure equalizer and increase those of the fourth one.

6. CONCLUSIONS

1. Optimal relative lengths of horizontal shelf pressure equalizers that ensure the most uniform distribution of static pressures inside the air distributor have been found.
2. The nonuniformity ratio of static pressure vertical distribution in the first pressure chamber has been defined and optimized for various values of relative lengths of horizontal shelf pressure equalizers.

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