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"Water supply and drain"

Manual

Lectures and Guide to laboratory work
for students of specialty
6.060101 "Civil Engineering"

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This manual provides lectures and guidance material for performing eight laboratory works, two homework tasks as well as test questions for defending laboratory works, test questions and tasks for module control on the discipline "Water supply and drain".

Intended for students of specialty 6.060101 "Civil Engineering".

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INTRODUCTION

«Water supply and drain» is one of the basic academic disciplines studied in the fifth semester. In the process of expert training, it forms a theoretical basis of a whole complex of knowledge and skills required when seeking qualified solution to the existing complex issues related to water intake from sources, water treatment in compliance with consumer requirements, trunk transportation to localities and industrial enterprises, distribution between individual consumers, waste water collection, treatment and discharge.

The main purpose of the course is to give students the basic concepts of the main elements of water supply and drain systems, the principles of their application and operation; introduce the latest developments and advanced experience of the leading home and foreign enterprises in reducing losses and costs of energy sources in these systems; study technologies that provide the optimum use of water supply and drain facilities.

Lectures and laboratory works have been prepared to deepen students' knowledge of water supply and drain, form their skills and teach students to use regulatory, reference and educational literature, apply standard solutions when designing and calculating water supply and drain systems, and implement the latest advances in sanitary equipment of buildings.

Students who attended lectures on relevant sections of the discipline "Water supply and drain" are allowed to perform laboratory works.

This guide includes eight modules that a student is supposed to study. These modules must contain the tables with experimental data and calculations.

Laboratory works are performed by students independently. Upon the completion of each task, a conclusion should be made. At the end of each work you can find questions that can help you defend your work.

This manual provides material and guidance for performing eight laboratory works, two homework tasks as well as test questions for defending laboratory works, test questions and tasks for module control on "Water supply and drain".

Each module is supplemented with test questions.

1. WATER SUPPLY

1.1. Water supply systems and schemes

A system of water supply is a complex of engineering structures, machines and apparatus, which are designed to extract water from natural sources, improve its quality, store and transport water and, finally, supply it to consumers. The system consists of water receiving barrage, water treatment, water pressure and controlling structures, trunk sluiceways and distribution network, automation tools. Depending on local conditions, some of these structures may not be used or may be combined.

Water supply systems are distinguished by such parameters: functional purpose (domestic consumption, industrial consumption, fire-prevention); service sector (combined and separated); type of property (urban, rural, industrial, etc.); territorial coverage of water consumers (local, centralised, grouped); operation duration (temporal and permanent); type of natural source (using underground or surface water); means of barrage (gravitational and mechanical water supply); the use of water (straight flow, reverse and with repeated use of water); reliability of water supply.

Water supply systems intended for domestic consumption supply drinking water for cooking and sanitary procedures. The quality of water supplied by this system must meet the standards of drinking water. Industrial plumbing systems supply water to be used for technological needs. The requirements to water quality are established by technologists. Fire-prevention systems of water supply are intended for extinguishing fire. Water in fire-prevention systems can be non-potable. Combined water supply systems meet the needs of all consumers, while separate systems supply water for different needs separately. Local systems supply water to individual water consumers (for example, cattle farm, industrial enterprise, or a group of buildings), centralised systems - to all consumers of a given locality. Grouped, or district water supply systems are designed to supply water to a number of localities, farms or enterprises, which are distant from each other (they are designed, as a rule, in place lacking fresh water, so they have lengthy sluiceways).

In compliance with СНиП 2.04.02-84, by reliability of water supply centralized systems are divided into three categories. Water supply systems intended for domestic consumption in localities with the population of up to 5 000 people refer to category III. For these localities, water supply volumes can be

reduced by not more than 30% for the period of 15 days and fewer, with water supply being discontinued during repair works for no longer than 24 hours. Category II covers localities with the number of people from 5 to 50 thousand. For this category, water supply can be discontinued during up to 6 hours; the period of reduced water supply must not exceed 10 days though. Localities with more than 50 thousand people refer to category I. For these localities, water supply can be discontinued during not more than 10 minutes, while the period of reduced water supply must not exceed 3 days. For individual elements of water supply system, the category is set depending on their functional purpose in the entire water supply system.

The layout of individual elements and structures within a particular water supply system is called water supply scheme. What structures are selected mainly depends on the following factors: type of natural source and the quality of water in it; category of water consumers and their requirements to free water pressures, quantity and quality of water consumed; reliability of water supply; lie of the ground.

The scheme of water supply from open water sources (Fig. 1.1) is, as a rule, most costly to build and is difficult enough to operate, as it requires the availability of water treatment plants and other facilities. By this scheme, water from the open reservoir gets to water intake structures, from which it is pumped to water treatment plants. The quality of water is improved at water treatment plants, after which water is supplied to the reservoir of clean water (RCW), from which through sluiceways it proceeds to the water supply network to be delivered to consumers. On the territory of a locality (usually in highest locations) a water tower is built, which, like RCW, is intended for water storage, pump regulation and keeping required pressure in a network. In the tower, water is accumulated when the volumes of water supplied by the pumps exceed the volumes of water consumed; water from the tank is used up, when water consumption exceeds water supply.

Underground water is supplied more often. When compared with surface water, underground water contains less admixtures, including radioactive admixtures, with water supply facilities being not so complicated. If the quality of underground water doesn't meet consumer requirements (for example, increased content of iron admixtures), the scheme including water treatment plant (Fig. 1.2) is used; if underground water by its physical, chemical and sanitary measures meets the requirements set to drinking water, the simplest scheme of water supply is used (Fig. 1.3).

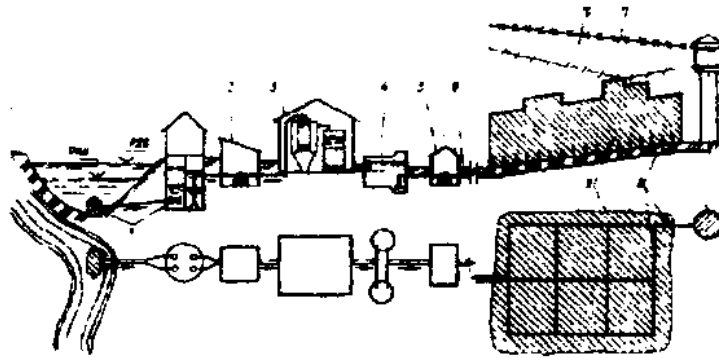


Fig. 1.1 Scheme of water supply from surface sources (river)

1-river water intake; 2- first lifting pumping station; 3-water treatment station; 4- reservoir of clean water; 5-second lifting pumping station; 6-sluceway; 7-water tower; 8-plumbing network; 9-water supply object; 10-piezometric line in the network in the point of maximal water consumption; 11-the same at the point of maximal transportation of water to the tower

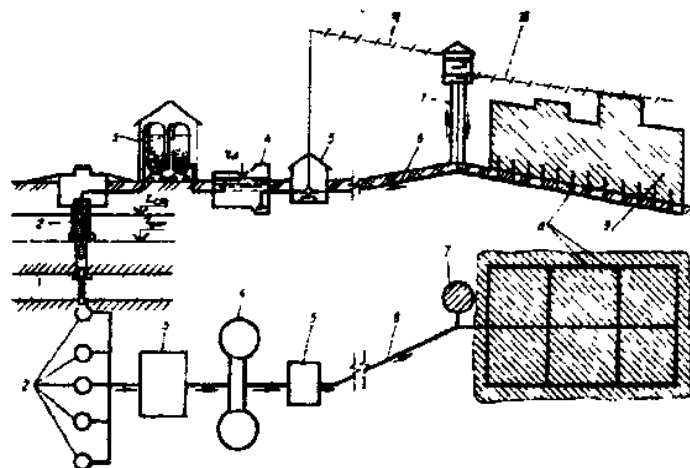


Fig. 1.2. Water supply scheme with underground water treatment:

1-aquiferous layer; 2-mining hole; 3-water treatment station; 4-reservoir of clean water; 5-second lifting pumping station; 6-sluceway; 7-water tower; 8-plumbing network; 9-water supply object; 10-piezometric line in the network in the point of maximal water consumption; 11-the same in sluceways

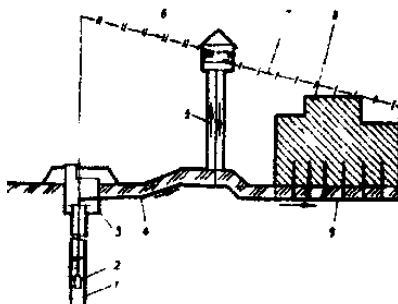


Fig.1.3. Water supply scheme from the mining hole:

1-water intake mining hole; 2-deep electric pump; 3-base above the mining hole; 4-sluceway; 5-water tower; 6-piezometric line in sluceways in the point of maximal water consumption; 7-the same in the network; 8-water supply object; 9-plumbing network

Localities at the foot of the mountains can have the water source located higher than they are. In this case gravity water supply system with or without water treatment station is provided.

Industrial enterprises differ in terms of a variety of technological processes, they consume water of varied quality and require different pressure levels within workshops. A peculiar feature of water supply technical systems is water turnover for different needs. That's why water supply systems of industrial enterprises are quite complicated. If an enterprise is on the territory of some locality and consumes negligible quantity of non-potable water, it's advisable that water should be supplied to the enterprise from urban networks. If a considerable quantity of non-potable water is consumed, then it's advisable that separate systems of service water supply be arranged: straight flowing (Fig.1.4a), in which water after one-time use is discharged into drains; with repeated use of water (Fig.1.4b), when water is used successively in several technological operations; reverse (Fig.1.4b), in which water after having been used for technical needs is purified and cooled, then it is used for the same object in the same technological operations. It's technical economic calculations that should be taken into consideration when selecting service water supply scheme.

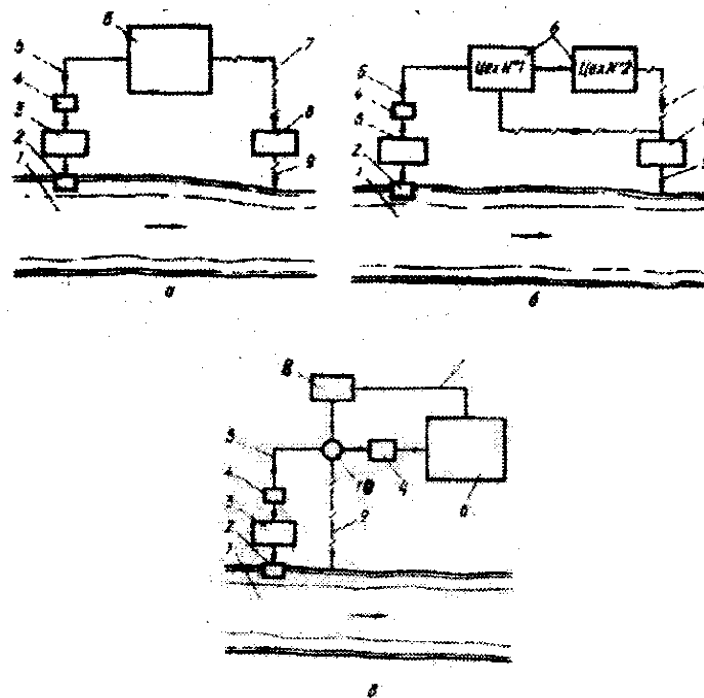


Fig.1.4 Service water supply schemes

- 1-river; 2-water intake structure; 3-water treatment plants; 4-pumping station; 5-service water; 6-enterprise; 7-sewage water; 8-water treatment station; 9-dumping water into the river; 10-distribution chamber

1.2. Specific water consumption

When designing water supply systems, one should be aware of the water volume to be supplied by plumbing system, types and the number of water consumers with the perspective development plan of the object being taken into account, estimated water consumption rates for each consumer type as well as daily water consumption mode.

Water consumption rate is a volume of water spent on particular needs per one unit of time or unit of product. For localities water consumption rates are established based on the study of the actual water consumption volume and mode under similar conditions or, in case it's impossible, according to CHiП 2.04.02-84. Average daily per capita rates of domestic drinking water consumption in localities (per year) when building houses equipped with indoor plumbing and sewage system, are the following: without baths – 125-160l per day; with baths and local water heaters – 160-230l per day; with centralized hot water supply – 230-350l per day. For localities where water intake geysers are used, specific expenditure constitutes 30-50l per day. Given the needs of local industries and unexpected expenditure, specific water consumption increases by 5-10%.

Specific water consumption for industrial needs depends on the product type, adopted technology and equipment installed. These data are stipulated in a technological passport of an enterprise. To estimate water consumption by enterprises, water consumption rates for a unit of product are used. Thus, for example, at milk factories processing 1 l of milk requires $7.5-12\text{m}^3$ of water; in mechanized bakeries - $1.8-4.8\text{m}^3$ of water per 1tn of bread; on meat processing plant - $10-40\text{m}^3$ of water per 1tn of meat products; at sugar factory - $18-25\text{m}^3$ of water per 1tn of sugar; at canning factory - $8-28\text{m}^3$ of water per 1thousand of cans; at brickworks - $1.3-1.8\text{m}^3$ of water per 1thousand bricks. Along with industrial expenditure, water consumption by households should be taken into account. The rate of drinking water consumption by households is determined as follows: 45l per person during a shift with heat release of more than 23.2Wt/m^3 ; 25l in other workshops. Consumption is calculated at the end of the shift and makes 500l/hour for one shower during 45 minutes.

Specific water consumption on watering depends on local weather conditions and makes: for mechanical cleaning of passages and squares with improved coverage – $1.2-1.5\text{ l/m}^2$ per one watering, mechanized watering of passages and squares – $0.3-0.4\text{ l/m}^2$ per one watering, hosing of the same passages – $0.4-0.5\text{ l/m}^2$, watering of lawns and flower beds – $4-6\text{ l/m}^2$ per one watering, watering of green spaces and smallholdings – $3-4\text{ l/m}^2$ per day.

When the data on the area of passages and green spaces watered are not available, specific consumption on watering is calculated 50-90 l/day per capita depending on weather conditions (more in southern regions), the amount of water in the source (less in meager sources), the number of building improvements and other local conditions.

In addition to regular meeting domestic and industrial needs, water supply system provides water for fire extinguishing, if necessary. Water is used for fire extinguishing only in case of fire, so it is taken into account only when making checking calculations of plumbing network as well as when determining the volumes of spare reservoirs (RCW, water tower, fire prevention reservoirs).

Water consumption for outdoor fire extinguishing in a locality and the estimated number of fires are given in Table 1.1

Table 1.1

Water expenditure for extinguishing outdoor fire in a locality

The number of people in a locality, thousand people	Estimated number of simultaneous fires	Water expenditure for extinguishing outdoor fire, l/sec, with buildings	
		up to 2 floors	3 floors and more
Up to 1	1	5	10
1-5	1	10	10
5-10	1	10	15
10-25	2	10	15
25-50	2	20	25
50-100	2	25	35
100-1000	3	-	40-100

Fires at industrial enterprises, which are located within the boundaries of a locality, are included in the estimated number of simultaneous fires. Moreover, water expenditure for extinguishing indoor fires in houses, public and industrial buildings equipped with internal fire faucets, should also be taken into account. A list of such buildings and water expenditure rates for indoor fire extinguishing are given in CHiII 2.04.01-85. It takes estimated 3 hours to extinguish a fire. The estimated water expenditure on fire extinguishing should be provided with larger hourly water expenditure for other needs. At this, water expenditure on watering, taking showers, washing floors and technological equipment is not taken into account.

1.3. Water consumption mode, determining estimated water expenditure and required water pressure

In a locality, domestic water consumption mode on a daily, monthly and yearly basis varies and depends on numerous factors (life style, season, local conditions, etc.). It is usually assumed that there are summer and winter fluctuations of water consumption. In calculations these fluctuations are expressed by the ratio of daily non-uniformity: the highest ratio being $K_{\text{day max}}=1.3$; the lowest- $K_{\text{day min}}=0.7$.

During the day hourly expenditure varies, which determines the ratio of hourly non-uniformity:

$$\text{the highest ratio} \quad K_{h \max} = \alpha_{\max} \cdot \beta_{\max} \quad (1.1)$$

$$\text{the lowest ratio} \quad K_{h \min} = \alpha_{\min} \cdot \beta_{\min} \quad (1.2)$$

where $\alpha_{\max}=1.2-1.4$; $\alpha_{\min}=0.4-0.6$; - ratios that take into account building improvements, operation of enterprises and other local conditions (CHiII 2.04.02-84), and β – a ratio that takes into account the number of residents in a locality (Table 1.2).

Depending on the value of $K_{h \max}$ a typical distribution chart of hourly water expenditure during the day is drawn up (Supplement 1). For industrial enterprises hourly water expenditure for technological needs is assumed to be uniform during the shift or at the request of technologists, but for domestic needs daily or variable water expenditure is distributed according to Supplement 6. Water expenditure on showers is distributed in proportion to daily expenditure after each shift on the enterprises.

Table 1.2

Values of ratio β [15]

Ratio	Number of inhabitants, thousand people										
	up to 0.1	0.2	0.5	1.0	4	10	20	50	100	300	1000 and more
β_{\max}	4.5	3.5	2.5	2	1.5	1.3	1.2	1.15	1.1	1.05	1
β_{\min}	0.01	0.02	0.05	0.1	0.2	0.4	0.5	0.6	0.7	0.85	1

Calculations assume uniform hourly water consumption. The hour that accounts for the largest value of hourly water expenditure for the entire locality is the hour of the largest water consumption, and individual water consumption during this hour is taken as estimated.

Estimated (average annual) daily water expenditure, m^3/day , on domestic needs is determined by the formula:

$$Q_{\text{дооб.м}}^H = \frac{g_{\text{ж}} \cdot N_{\text{ж}}}{1000}, \quad (1.3)$$

where $g_{\text{ж}}$ -specific water expenditure, l/day per capita, $N_{\text{ж}}$ -estimated number of people.

Estimated expenditure per day of the highest and the lowest domestic water consumption is equal to:

$$Q_{\text{доб.маx}}^H = K_{\text{доб.маx}} \cdot Q_{\text{дооб.м}}^H; \quad (1.4)$$

$$Q_{\text{доб.мин}}^H = K_{\text{доб.мин}} \cdot Q_{\text{дооб.м}}^H; \quad (1.5)$$

where $K_{\text{доб.маx}}=1.3$ and $K_{\text{доб.мин}}=0.7$ are ratios of daily non-uniformity.

Estimated (average annual) daily water expenditure, m^3/day , on watering makes:

$$Q_{\text{дооб.м}}^{\text{ног}} = 10g_{\text{ж.пол.}} \cdot F_1; \quad (1.6)$$

where $g_{\text{ж.пол.}}$ - specific water expenditure, l/m^2 per one watering, F_1 – watering area, ha.

Estimated (average annual) daily water expenditure, m^3/day , on industrial needs, m^3/day , is equal to:

$$Q_{\text{дооб.м}}^{\text{н}} = g_{\text{ж.п.}} \cdot N_2 \quad (1.7)$$

where $g_{\text{п.}}$ - specific water expenditure, m^3 per one unit of product, N_2 – quantity of products manufactured.

When estimating water supply systems, the hourly water expenditure for each category of water consumers is, as a rule, determined first, and then these values are summarized, i.e. the hourly water consumption of the whole locality is determined. Hourly water expenditure by a consumer, m^3/hour , is equal to:

$$q_r = \frac{a}{100} \cdot Q_{\text{дооб.маx}} \quad (1.8)$$

where a – daily expenditure distribution, $Q_{\text{дооб.маx}}$ – for a particular hour, %.

Maximal hourly water consumption by one type of a consumer, m^3/hour , can be determined as:

$$q_{\text{hr.маx}} = K_{r.\text{маx}} \cdot Q_{\text{дооб.маx}} / 24 \quad (1.9)$$

Maximal hourly water consumption in a locality is determined by the chart of water consumption.

The highest expenditure per second, l/sec, is:

$$q^{\text{tot}} = \frac{q_{\text{hr.маx}}}{3.6} \quad (1.10)$$

where $q_{\text{hr.маx}}$ – the highest hourly water expenditure, m^3/hour , for the entire locality or an individual water consumer.

In plumbing system there should be the pressure that will ensure rising and outpouring of water in the highest water intake point. So, free pressure (m) in the network is required

$$H_b = h_r + \Sigma h_w + h_p \quad (1.11)$$

where h_r – geometrical height of water rise from the ground surface to the highest point, m; Σh_w – pressure losses from the point of plumbing network connection to water intake armature, m; h_p – working pressure for outpouring from water intake armature, m, which is determined by CHiП 2.04.01-85.

According to CHiП 2.04.02-84, the required free pressure should be ensured in the external plumbing network

$$H_b^H = 10 + 4(n - 1), \quad (1.12)$$

where n – the number of floors in a building.

For high-rise buildings located among low-rise buildings or elevated buildings, local pumping structures can be provided in order to increase pressure. Free pressure at water intake geyser must to be not less than 10 m. Free pressure in the external network of industrial plumbing is determined by technical data depending on the equipment used.

Free pressure in domestic plumbing system which is close to consumer location must not be more than 60 m.

Free pressure in plumbing network during fire extinguishing depends on fire extinguishing system. There are systems of high and low pressure. In high pressure systems fire is extinguished directly from the network with the help of fire sleeves that are connected to fire-cocks (Fig. 1.5).

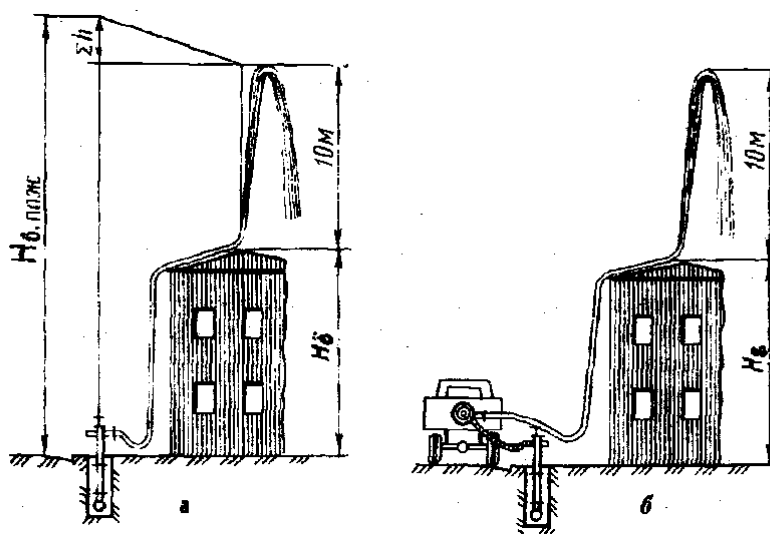


Fig.1.5. Schemes of fire extinguishing from water plumbing system with high (a) and low (b) pressure

Free pressure in high-pressure plumbing network should be high enough to supply water to the highest point of the building on fire through fire sleeves which are 120 m long, thus ensuring a compact jet of water from the barrel to a height of 10m. Tentatively this free pressure can be determined by the formula:

$$H_{\text{с.пож}} \gg H_{\text{б}} + 28\text{м}, \quad (1.13)$$

where $H_{\text{б}}$ – the height of building, m.

In low pressure fire extinguishing systems water is pumped by fire engines from fire cocks of plumbing network and through fire sleeves is supplied to the place of fire, the pressure being the same as for high pressure systems (Fig.1.5b). In case of fire, a relatively low pressure of 10 m is maintained in the plumbing network.

1.4. Sources of water supply

1.4.1. Requirements to water quality

Water quality is assessed by its composition and properties, which is followed by determining its suitability for a particular need. Particularly strict requirements are set to drinking water consumed in industrial, residential and public buildings. This water must meet “drinking water” standards stipulated in GOST 2874-82. Regulation of concentrations of particular substances is conditioned by the necessity of providing favorable organoleptic properties of drinking water, harmlessness of its chemical composition and safety of water with respect to sanitary standards. If one of these standards doesn't meet GOST 2874-82 requirements water is found to be undrinkable.

For all standardized substances a limiting indication of hazard – organoleptic or sanitary and toxicological - has been determined. For example, iron contained in water even in great concentrations (more than 0,3 mg/l) does not have any toxic effect on human organism, but makes water yellow-brown, worsens its taste, causes development of iron bacteria and forms sediment in pipelines. A limiting indication of harmfulness for iron combinations is organoleptic property. The same is true for manganese. Inversely, such chemical substances as compounds of strontium, nitrates are toxic for human organism but they do not change organoleptic properties of water. For example, strontium with concentrations of more than 7 mg/l suppresses the activity of most enzymes. At the same time, water gets a bitter taste only when strontium concentration is more than 12 mg/l. For such compounds sanitary and toxicological property is the limiting indication of harmfulness.

The sulfates content in water which exceeds 500 mg/l or chlorides content of 350 mg/l gives water salty taste and causes stomach disorders. Such water possesses increased corrosiveness, higher non-carbonate hardness, damages reinforced concrete structures.

Fluorine, iodine, bromine, boron etc. have a noticeable impact on people's health. Thus, deficiency or excess of fluorine in drinking water damage teeth and cause change in skeleton, deficiency or absence of iodine contribute to the development of endemic goiter etc. Salts of heavy metals and radioactive elements have toxic effect on human organism and warm-blooded animals.

Cations of calcium and magnesium determine the hardness of water. Though they do not make any particular harm to human organism, their high concentration in water is unacceptable, because such water is of little use for domestic needs. Hard water increases consumption of detergent and soap when washing clothes, boiling meat and vegetables takes more time. Hard water is unsuitable for the systems of inverse and hot water supply or boilers, it can't be used in many industries. Siliceous acid is not harmful for health, but its increased content in water makes such water unfit for boilers because of silicate scale formation.

For drinking water to be safe, the total amount of bacteria per 1 ml of water must not exceed 100, and the amount of bacteria of intestinal bacillus group per 1l must not be more than 3.

According to organoleptic measures, the turbidity of drinking water must not exceed 1,6 mg/l, color must not be more than 20 degrees by platinum-cobalt scale, smell and taste must not exceed 2 points. There must not be any membrane on the surface of drinking water or aquatic organisms, which can be seen with the naked eye. The permissible content of chemical substances, mg/l, which can have effect on organoleptic measures are as follows: dry residue – 1000, chlorides- 350, sulfates – 500, manganese – 0,1, copper – 1,0, zinc-5, polyphosphates – 3,5, iron – 0,3, aluminum – 0,5.

The total hardness of drinking water must not be more than 7 мгЧекВ/л, with hydrogen pH index being 6-9. For the pipelines which supply water without any special treatment, according to Sanitary and Epidemiological service, the total hardness of water of 10 мгЧекВ/л, dry residue of 1500 mg/l, iron content of up to 1 mg/l, manganese content of up to 0,5 mg/l are allowed.

Harmless chemical composition of water can be obtained provided the concentration of toxic chemical substances is not more than, mg/l: beryl – 0,0002, molybdenum – 0,25, arsenic – 0,05, nitrates – 45, polyacrylamide – 2, plumb – 0,03, selenium – 0,01, strontium – 7, fluoride – 1,5 (for 1st and 2nd climatic regions)

1,2 (3rd), 0,7 (4th), uranium – 1,7. The content of radium must not exceed $1,2 \cdot 10^{-10}$ Ки/л, the content of strontium must be up to $4 \cdot 10^{-10}$ Ки/л.

If there are a number of substances contained in water (except fluoride, nitrates and radioactive substances) their concentration must comply with the formula:

$$\frac{C_1}{ГДК_1} + \frac{C_2}{ГДК_2} + \dots + \frac{C_n}{ГДК_n} \leq 1 ,$$

where $C_1, C_2 \dots C_n$ – detected concentrations, mg/l, $ГДК_1, ГДК_2 \dots ГДК_n$ – established marginally acceptable norms.

Requirements to water quality at industrial enterprises depend on the nature of production and can vary. In the first place, attention is paid to interaction of water with pipelines, equipment, raw materials and industrial products. If requirements to the quality of service water have not been set by technologists, performance standards should be like those of similar businesses or, as an alternative, the reference book “Increased standards of water consumption and drain for different industries” can be used.

1.4.2. Sources of water supply

A source of water supply must provide the required amount of water taking into account perspective increase in water consumption, ensure that water supply is not disrupted, supply water which requires cost efficient treatment and supply to consumer. Besides, the source should be potent enough for the intake of water not to destroy the complex ecological system. There can be distinguished surface and underground sources of water supply.

Surface sources of water supply (rivers, lakes, channels, storage reservoirs) are characterized by noticeable changes in water quality depending on seasons. Water quality in rivers, lakes, reservoirs significantly depends on the intensity of atmospheric precipitations, melting of snow, agricultural and production activity of a man in the water intake area.

River water is rather turbid, especially in the period of spring floods and rains, it's rich in organic admixtures and contains a great amount of microorganisms. At the same time the content of salts and the hardness of water are, as a rule, negligible. Water in lakes and reservoirs is typically less turbid, but it can have some coloring as a result of algae and plankton development. As a rule, the quality of water taken from surface sources does not meet the requirements of the State Standards, that's why it should be purified and disinfected. When using surface water one should take into account the requirements of the Sanitary and

Epidemiological service, the Fishery Conservation service, the Water Transport and Water Conservation service.

By its occurrence, ground water can be divided into non-pressure ground water and pressure interlayer water (deep-well water). The natural rise of the ground water to the surface creates a so-called spring water. The ground water also includes infiltration water, which is surface water filtered through the river bottom and drained by a water intake structure.

The ground water (underground, deep-well, spring) normally does not contain any insoluble admixtures, does not have any color, possesses a high degree of transparency and can usually be used by households without any treatment provided. In comparison with the surface water, the ground water is more mineralized and, as a rule, contains more iron Fig (1.6).

When selecting the source of water supply from the point of view of its safety, preference should be given to (in the following order) artesian, ground, under river bed water as well as surface river water, lake water and water stored in reservoirs. In all cases technical and economical estimation and grounding should be given.

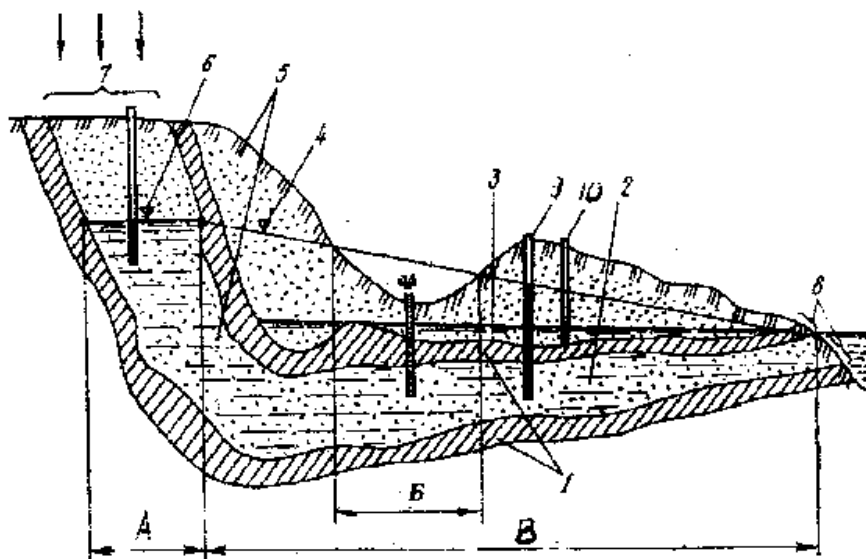


Fig 1.6. Scheme of the ground water occurrence:

A-non-pressure ground water area, Б-gushing water area, В- pressure water area:
 1 – waterproof layers; 2- interlayer artesian water; 3-ground water; 4- piezometric level of pressure water; 5 –filtering rocks; 6 – level of free surface of pressure water; 7 water feeding field; 8 – source area; 9,10 – wells of pressure and non-pressure water

In compliance with CHиП 2.04.02-84, sanitary protection zones are established in the area of all water supply sources and plumbing constructions are

designed for domestic needs, to provide safety of the systems of centralized and local water supply in localities.

A sanitary protection area has 3 zones. The first zone is a controlled area. It includes the source of water supply and the pipeline constructions for water intake, treatment and storage. For rivers, the boundaries of the first zone of sanitary protection area are as follows: upriver– not less than 200 m from the water intake area, downriver – not less than 100 m from the water intake area. For water reservoirs (lakes, reservoirs) the boundaries of the first zone shall be not less than 100 m in all directions.

The territory of the first zone of sanitary protection area and plots with plumbing structures are fenced, ordered, with trees planted. The planning of this territory should provide drainage of the surface layer beyond the zone. Any construction works (except plumbing works), housing, wastewater drainage, swimming, watering or pasturing cattle are forbidden on the territory of the first zone. It is also forbidden to use the territory for growing vegetables, washing, fishing or using pesticides, organic and mineral fertilizers for plant treatment. This territory must be restricted to unauthorized people.

The second and the third zones of sanitary protection area are restricted zones. Waste must not be dumped here since this might decrease water volume or deteriorate water quality in water supply sources. The area of the second zone is determined so that it took not fewer than 5 days for the water flowing from the border to reach the water intake point. Downriver distance must be not less than 250 m. The third zone has the same parameters as the second one.

The ground sources of water supply should also have 3 zones of sanitary protection area. The boundaries of the first zone of sanitary protection area (controlled area) are determined depending on the degree of water bearing horizons protection from pollution caused by the ground surface and hydrogeological conditions at a certain distance from the water intake source: for safely protected horizons this distance is not less than 30 m; for insufficiently protected horizons – not less than 50m.

The boundaries of the second zone are determined given the fact that it takes from 100 to 400 days for the water contaminated with microbes to flow from the border to the water intake source. For the third zone, the chemical pollution of water supply source should be considered. Chemical pollutants should move as long as water intake source is used, but not less than 25 years.

When taking infiltrative or underflow water, the boundaries of sanitary protection area remain the same as for surface water supply sources.

Restrictions and prohibitions for sanitary protection areas of the ground water-supply sources are the same as for sanitary protection areas of surface water supply sources.

1.5. Water intake constructions for surface water sources

To conduct water intake from surface sources, riverbed or riverbank water intake structures are mainly used, which may differ as far as their location relative to river bank is concerned. For shallow rivers with aslope banks riverbed water intake structures are set, which consist of a water receiver, gravity or siphon pipelines and a bank well (Fig. 1.7)

Intake openings in receivers are at the height of 0,5-1,5 m from the river bottom. They are protected with grating against rubbish, floating objects, fish etc. To make them more reliable, gravity lines which connect the receiver and the bank are designed in the form of two independent pipes. The bank well is equipped with receiving nets, mesh size varying from 2x2 to 5x5 mm. When water is filtered through the grill or netting, it is subjected to rough pre-treatment which prevents damaging pumps and other equipment. The bank well is located on the bank that does not get flooded, at the same time, though, it shouldn't be located far from the receiver since this will reduce pressure in gravity lines. If possible, the bank well is connected with the pumping station of the first lifting, which decreases capital expenses and simplifies operation.

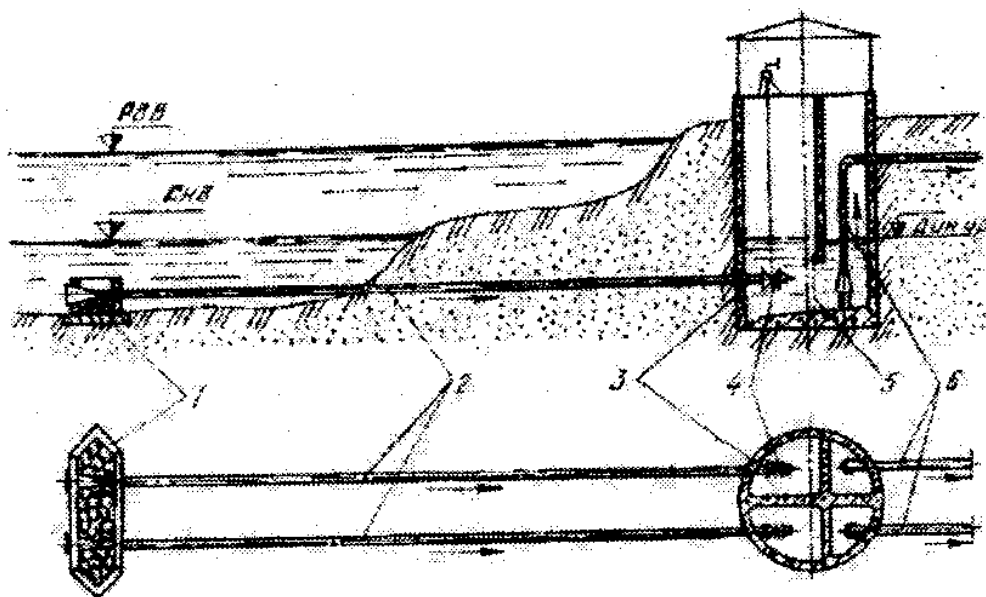


Fig 1.7. The scheme of the flow water intake with gravity lines:
1 – receiver; 2 – gravity pipes; 3 – bank well; 4-bolts; 5 - netting; 6 - absorbing pump pipes

Unlike riverbed water intake structure, riverbank water intake structure doesn't have gravity lines and is located on the bank (Fig. 1.8). Such water intake structures are installed for deep rivers with steep banks. Water gets into the water receiving well through the windows that are equipped with grating to prevent littering. Throughout the year water level in the river varies, therefore, two levels of water receiving windows for the intake of the purest water are, as a rule, provided. After going through grating, water is filtered through netting and is pumped by the structure of the first lifting.

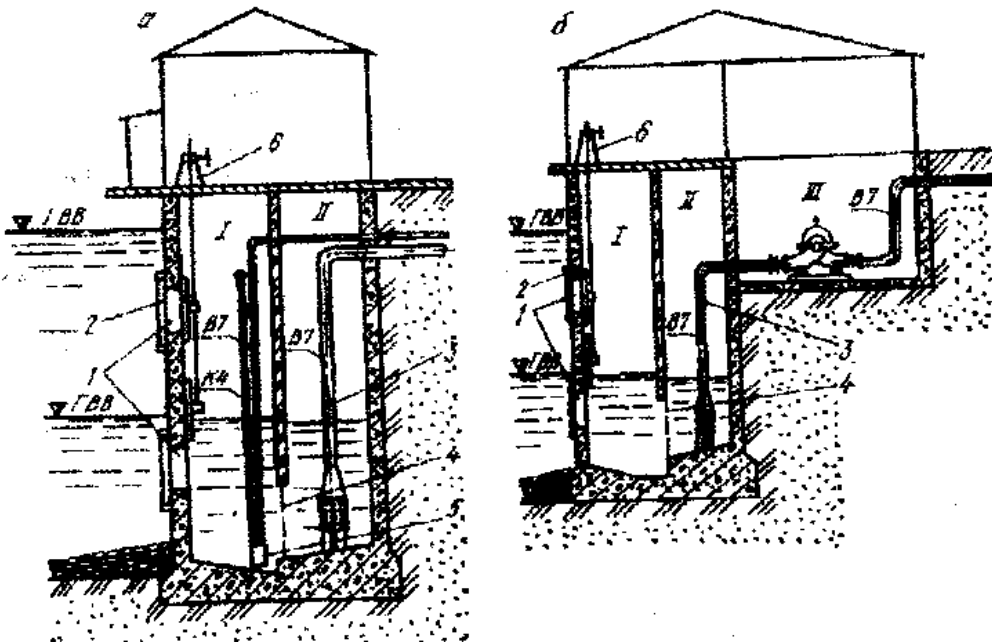


Fig 1.8. Schemes of riverbank water intake structures:

a – separated; b- joined; 1 – water receiving chamber; 2 – absorption pipes chamber; 3- first lifting pumping station; I – water receiving windows; II – grating; III- absorbing pump pipes; IV – netting; V – water stream pump; VI – control column

In some cases for rivers that are not wide enough with a lot of suspended substances or sludge in winter, riverbank water intake structures are placed in special constructions – backwater-dippers. Water receiving dippers have the form of pits dug on aslope banks, or are separated from the river by a dam and connected to the mainstream with a branch (Fig.1.9). The size of dipper is conditioned by the ice emerging from the depth or falling of suspended substances. If the branch is located at the bottom of the dipper (Fig. 1.9a) the dipper feeds on bottom flows and there's less sludge. If the branch is at the top of the dipper (Fig. 1.9 b), then only upper water flows get into water intake structures. The latter is

used when water intake is conducted from the rivers with a large amount of suspended substances (the closer to the bottom the more suspended substances). For sludgy and turbid rivers, combined dippers (Fig. 1.9 c) are installed, with water access being regulated by overlapping closures of respective hosepipes.

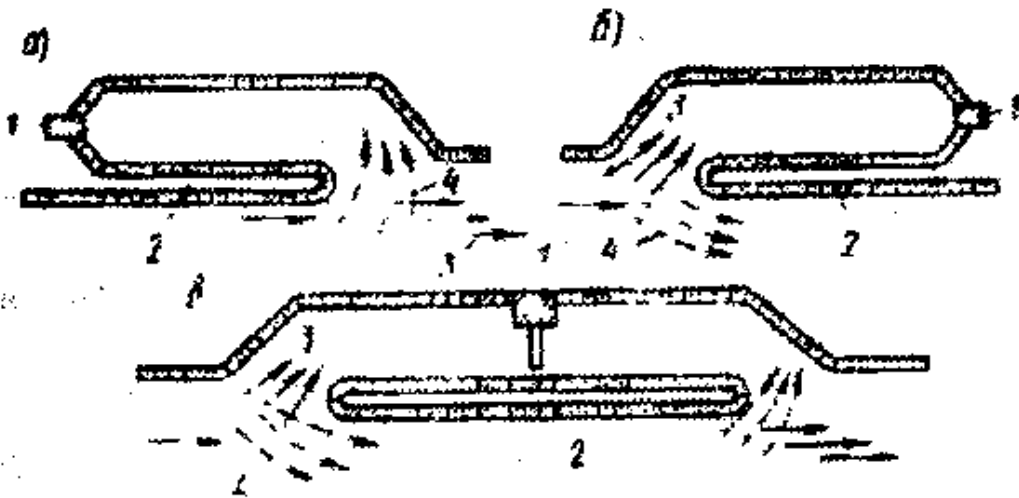


Fig 1.9. Scheme of receiving dippers:

1 – water intake construction; 2 – dam; 3 – surface streams; 4 – bottom streams

For temporary plumbing, mobile and floating water intake structures are installed. A mobile water intake structure is a light-weight pumping station which with change in water can move by sloping railway paved on the bank (Fig. 1.10a). In floating water intake structures pumping units are installed on the rivercraft: barges, pontoons, etc. (Fig. 1.10).

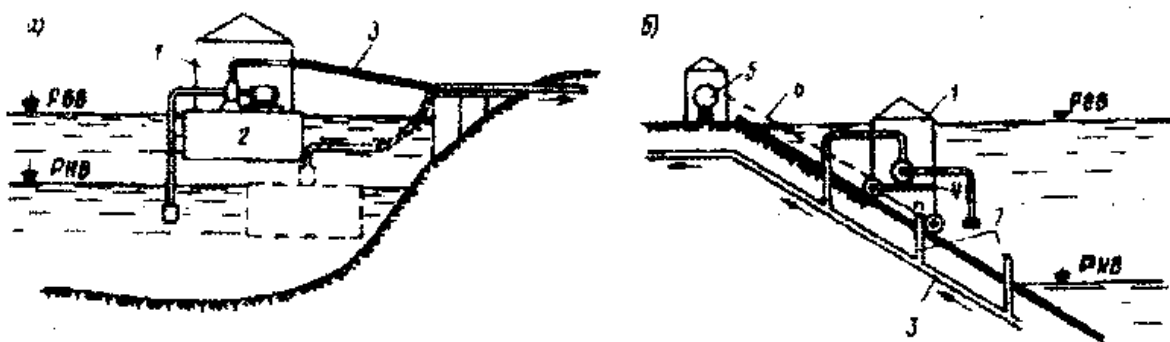


Fig 1.10. Schemes of floating (a) and mobile (b) water intake structures:

1 – pumping station; 2- pontoon; 3 – penstock; 4- platform; 5 – windlass; 6 – rope; 7 – connecting pipes

Mobile and floating water intake structures provide a constant height of pumping regardless of the water level in the river; they can be mounted quickly.

The disadvantages of such water intake structures include flexible insert pipes and difficult operation conditions in the winter period.

River water intake structures are installed downriver in places with the required water depth, higher than the locality is situated as close to the mainstream as possible, preferably close to the concave bank.

1.6. Water intake constructions for ground water sources

For the ground water intake there exist various constructions – holes, shaft wells, horizontal and ray water intake structures, catchment chambers.

Shaft wells are mainly used for extracting ground non-pressure or interlayer water of the upper horizons. Normally, shaft wells are not deeper than 10 m but in some cases they can be up to 30 m deep. Isolated wells are predominantly used for local systems of water supply, so they are more common in rural areas. For centralized water supply groups of shaft wells are used, pipelines connecting them to the collecting well. Water is pumped from the collecting well.

A shaft well is a vertical shaft of a rectangular or round cross-section with the diameter of 1-1,5 m (Fig.1.11). Water receiving part of the well shaft is deepened into the aquifer by not less than 2 m. The bottom of the shaft is covered with sand and gravel filter. The water receiver of the shaft is 0,8 m above the ground surface; it is covered by a lid or a hatch and equipped with ventilation system. The area around the well is paved and locked. The shaft is made of wood, stone, brick, concrete and reinforced concrete, the wells of reinforced concrete rings being preferable.

Water intake from the wells can be conducted with airlifts, piston and centrifugal pumps. When estimating shaft wells the following parameters are determined: their diameter and number at a given expenditure, their discharge and the acceptable level of water depth.

Water intake holes (tube wells) are used when ground water is more than 10 m deep, with the aquifer capacity being not more than 5m. A hole consists of 3 basic elements (Fig. 1.12): receiver, shaft and filtration part. The receiver is intended for fixing the mouth of the hole, protecting against polluted surface water. It also houses fittings and equipment. The receiver must be not less than 2,5 m high.

The shaft of the hole is fixed by tubes to protect its walls from the collapse of loose rocks. The filtering part of the hole is equipped with a filter to protect against the particles of water-bearing rocks. There can be used different types of filters: pipe filters with round and slotted openings; net filters in which filter net is

wound on the frame; gravel filters in which coarse sand or gravel is placed between aquifer ground and support frame.

When selecting place for the hole it should be kept in mind that in the process of pumping water there occurs a drop in the static level at some distance around the well. The drop in level reaches its maximum value right near the well. The farther from the well, the smaller the drop in the static level, with the static level being unchanged on some distance. The drop in the static level around the well in its cross-section is shown by a curve called a cure of depression (Fig. 1.13).

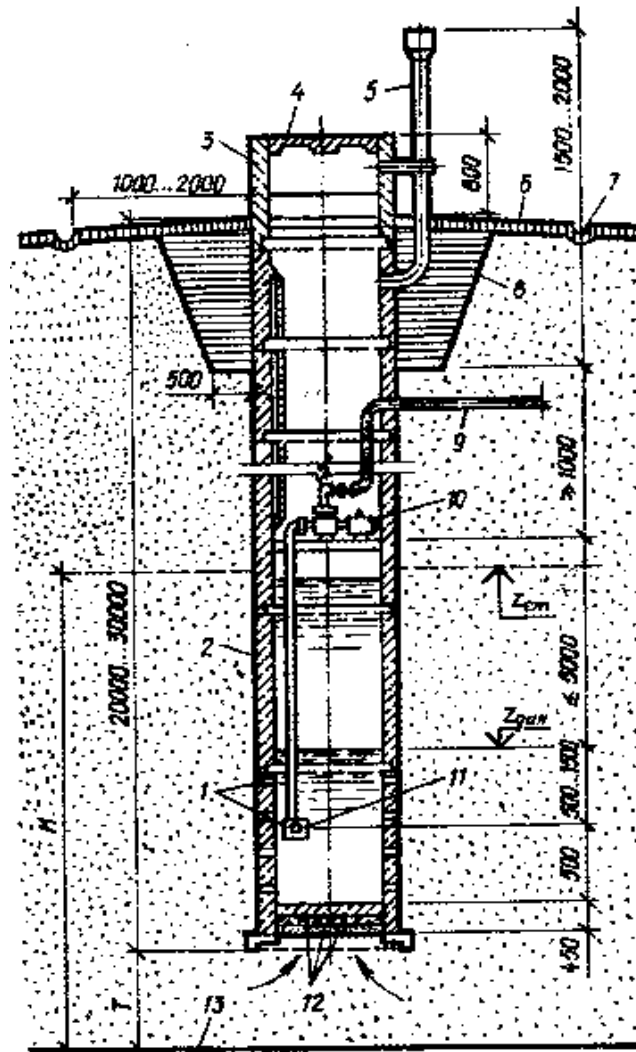


Fig 1.11. Scheme of a dug well:

1 – windows of porous concrete for water filtration; 2 – shaft; 3 – receiver; 4-lid; 5- ventilation tube; 6-paving; 7 – channel for water drainage; 8 – clay lock; 9 – penstock; 10 – pumping unit; 11 – receiving valve; 12 – inverse filter; 13 – aquifer sole

The line going from the well axis to the contact point of the curve of depression with the line of the static level is called a radius of depression. The area around the well limited by the curve of depression is called a cone of depression.

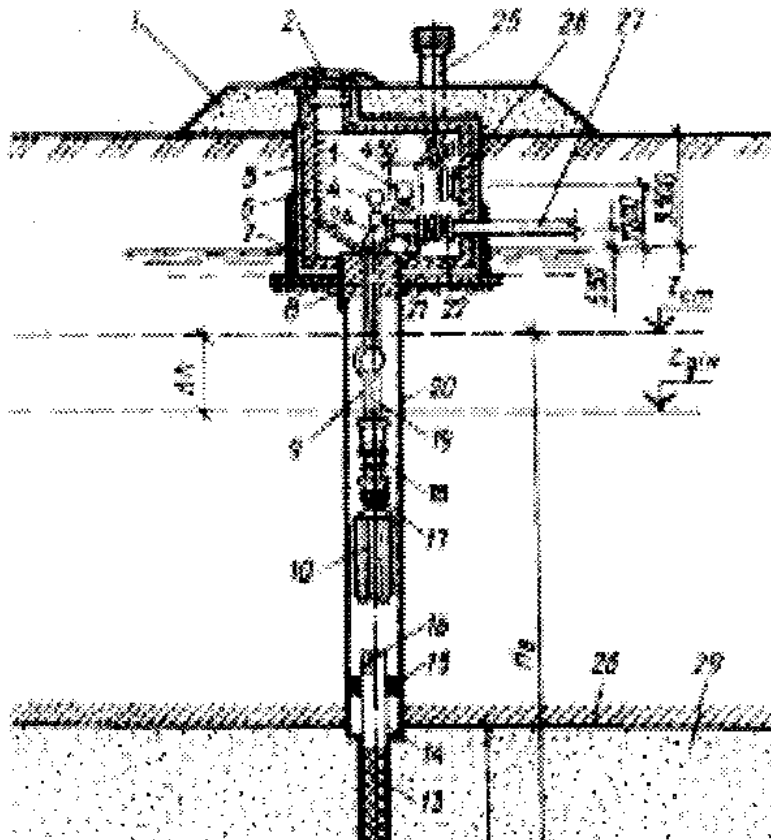


Fig 1.12. Scheme of the water intake hole:

1 – a layer of soil for receiver insulation; 2 – a hatch; 3 – a plunger with a flap; 4-a manometer; 5-bitumus isolation; 6 – stairs; 7 –the bottom of the receiver; 8 – the mouth of the neck; 9 – electric cable; 10 – electric engine; 11 – cork; 12 – a sump; 13 – filter area; 14 – an over-filter pipe; 15 – an oil seal; 16 - a lock for lowering the filter into the hole; 17 –a screen filter; 18 –a pump; 19 – a pump string; 20 – operation casing; 21 – preparation of the splinter; 22 – a flap; 23 –a check valve; 24 – a pipeline with a valve for dumping wash water; 25 – a vent; 26 – a differential pressure gauge; 27 – a penstock; 28 – the floor of the aquifer; 29 – an aquifer; 30 – the sole of the aquifer

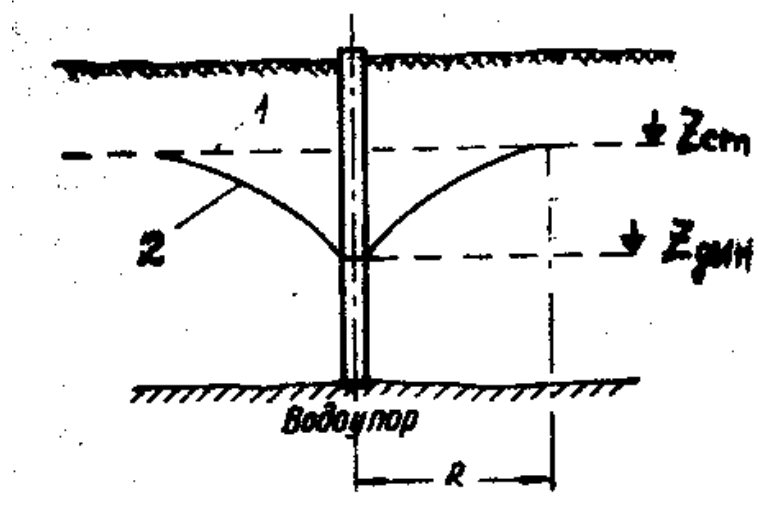


Fig 1.13. Curve of depression

1 – the static level of the ground water; 2 – the curve of depression

The radius of the curve of depression depends on the nature of water-bearing rock. Knowing the filtration coefficient of the rock we can determine the radius of well effect and, therefore, the boundaries of cone of depression. If one more well is set within the area of the cone of depression of another well, the two wells will interact, and the total water expenditure will be less. Thus, the wells should be located at some distance from each other, this distance being at least twice as large as the radius of the curve of depression.

The parameters of water intake constructions should be calculated by the formulas given in special literature.

Horizontal water intake structures (Fig. 1.14) are constructed when the flow rate of the ground water is low (up to 10 m/s) and the aquifer is up to 8 m deep, mainly close to surface drains and basins. Such water intake structures are set within the aquifer boundaries perpendicular to the direction of the underground stream, with localities, industrial enterprises and animal farms, etc. being situated lower than these structures. Control wells are intended for ventilating and inspecting the water intake structures.

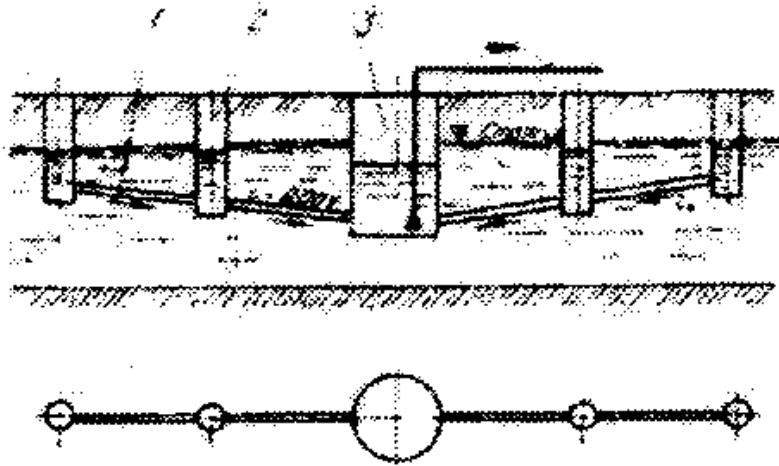


Fig 1.14. Scheme of the horizontal water intake structure:
 1 – drainpipe; 2 – control well; 3 – collecting well

Ray water intake structure (Fig.1.15) is a type of dug wells consisting of a water intake well and water-receiving rays (drains). They are often used for ground water extraction near the rivers. To extract water of the underflow stream water intake structures of infiltration type can also be used (Fig.1.16). By their design, these water intake structures are similar to dug wells. They are set along the river.

In places where the ground water comes to the surface, springs are formed. Such water is collected with the use of catchment chambers, which are water intake structures of different design. Reinforced concrete collecting chambers, that collect water through their bottom or walls, are most often used. (Fig.1.17). Catchment chambers are intended for opening and equipping the source outlet, protecting it from surface polluting and supplying water to the collecting chamber. It is advisable that they should be installed in the absence of other sources of water supply, which proved to be more reliable. They should be installed provided the discharge is sufficient and the sanitary protection against pollution is possible. Catchment chambers can also be installed for some special purposes (for instance, a source of medicinal mineral water).

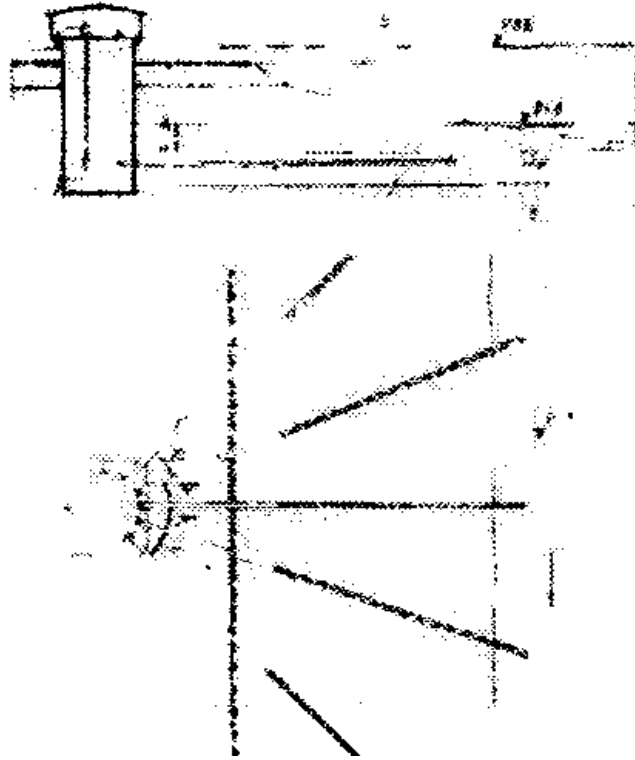


Fig 1.15. Ray water intake structure:
 1 – reinforced concrete dug well; 2 – drains; 3 – filtering part
 of drains; 4 – overhead pavilion; 5 – aquifer ground

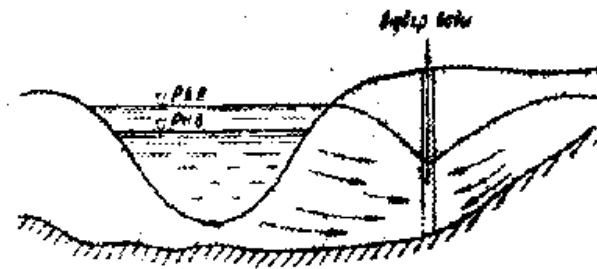


Fig 1.16. Water intake structure of infiltration type

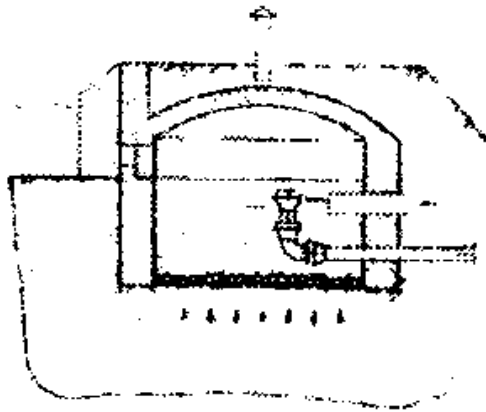


Fig 1.17. Catchment chamber for receiving water from the original source

1.7. Pumps and pumping stations

1.7.1. Types of pumps

Pumps are hydraulic machines which transfer the energy received from the outside to the liquid flowing inside them. Due to this the liquid rises to some height or gets affected by some pressure. Mechanical energy is supplied to the pumps (centrifugal, piston, etc.) or, in rare cases potential or kinetic energy of liquid or gaseous medium is used (ray, airlifts, etc.).

By their operation and design of working units, volumetric and dynamic pumps can be distinguished. In dynamic pumps, the force makes the liquid move inside the chamber which is permanently connected with the pump inlet and outlet. In volumetric pumps, a periodic change in the chamber volume makes the liquid move, the chamber being alternately connected with inlet and outlet. For each cycle, the liquid is supplied in certain portions – volumes.

Dynamic pumps include: vane pumps (centrifugal, axial, diagonal), in which the fluid bypasses the vane impeller (Fig.1.18a,b); vortex pumps in which the fluid flows in the periphery of the impeller (Fig. 1.18 c); screw pumps in which the fluid flows along the screw axis (Fig.1.18d); airlifts (air water lifts) whose operation is based on the principle of the difference between the density of the fluid and air-water mixture in the system of connected pipelines (Fig.1.19); jet pumps which use the energy of the fluid supplied from the outside (Fig.1.20); water rams in which the fluid is lifted by the energy produced by a hydraulic shock, etc.

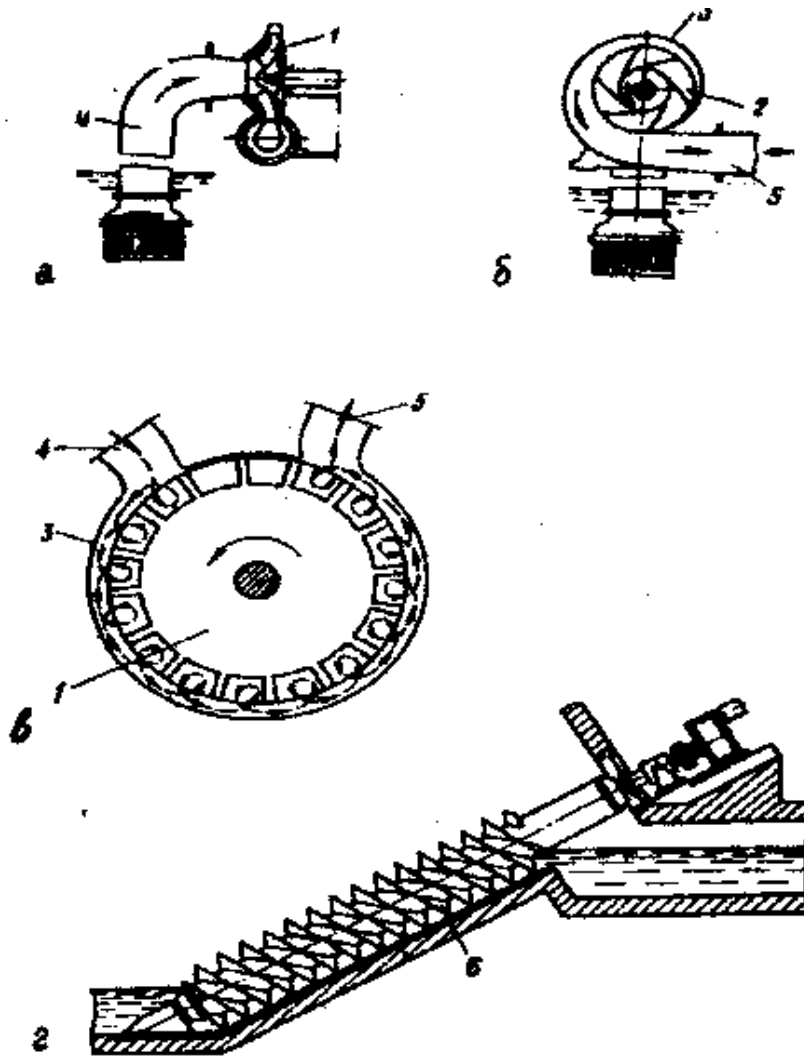


Fig 1.18. Schemes of centrifugal (a,b), vortex(c) and screw (d) pumps: 1 – impeller; 2- curvilinear vanes; 3- frame; 4,5 - suction and penstock lines ; 6 - screw

Volumetric or piston pumps work on the principle of the forced mechanical displacement of the closed volume of fluid (Fig.1.21).

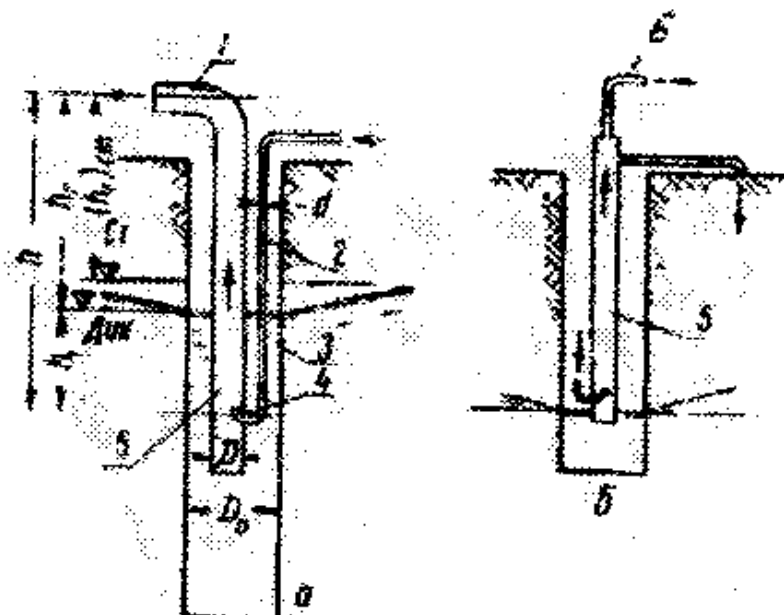


Fig 1.19. Scheme of airlift operation:
 a –forcing airlift; b- suction airlift; 1 – pump string; 2 – air pipe from the compressor; 3 – casing pipe; 4 –sprayer; 5-emulsion;
 6 – pipe to the vacuum pump

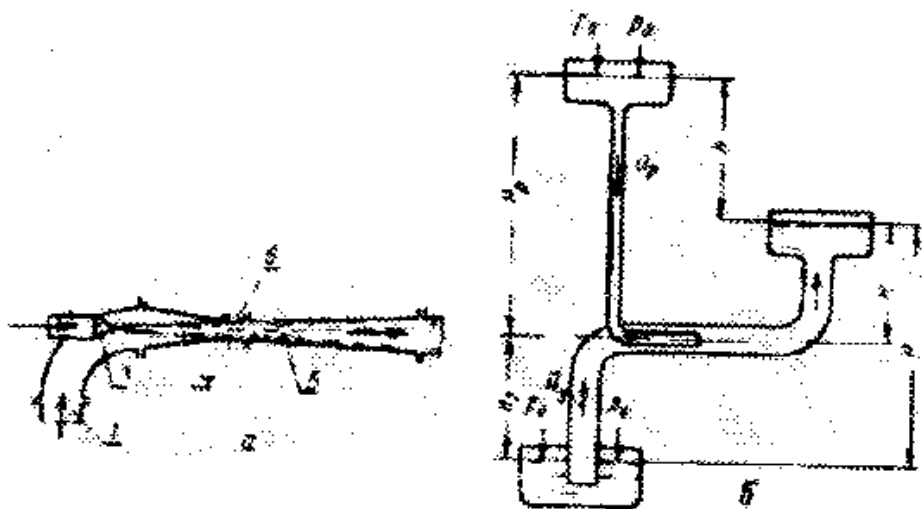


Fig 1.20. Waterjet pump:
 a –the scheme of the pump; b – the scheme of the pump installation;
 1- suction pipe; 2-penstock; 3-nozzle; 4-mixing chamber; 5-diffuser;
 2- 6 – manhole

Plumbing pumping stations are, as a rule, equipped with centrifugal pumps, which have a number of advantages compared with other types of pumps: being of a simple design they are reliable in use, providing a uniform supply of the fluid. They can be directly connected to electric engine. Centrifugal pumps are

subdivided by the following characteristics: pressure – low pressure of up to 0,2 MPa, medium pressure of 0,2-0,6 MPa and high pressure of more than 0,6 MPa; the number of impellers – one-impeller and multi-impeller; shaft location – horizontal or vertical; their use – water, sewage, acid, slurry, etc.; water absorption – one-side and two-side input; installation conditions – ground, floating, subsurface, artesian, etc. The efficiency of these pumps is high enough – 0,6 - 0,8.

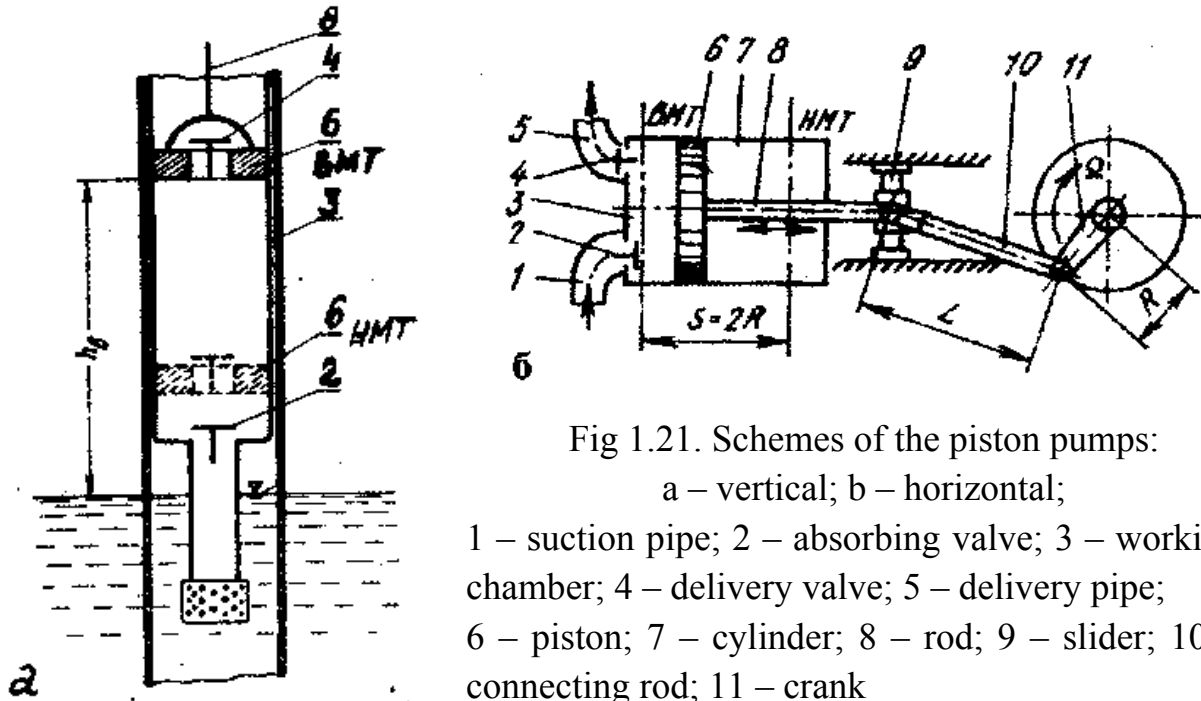


Fig 1.21. Schemes of the piston pumps:

a – vertical; b – horizontal;

1 – suction pipe; 2 – absorbing valve; 3 – working chamber; 4 – delivery valve; 5 – delivery pipe; 6 – piston; 7 – cylinder; 8 – rod; 9 – slider; 10 – connecting rod; 11 – crank

Piston and vortex pumps are rarely used for lifting water, they are mostly used in cases when high pressure is required, costs being low. Piston pumps are low-speed, are of a large size and weight but they can be started without water poured; their efficiency ranges between 0,7 and 0,9.

1.7.2. Main characteristics of pump operation

Each pump's operation within the installation (Fig.1.22) can be described by the following parameters: pump delivery Q , pump head H , the power of the pump N , pump efficiency η and the vacuum metric height of absorption H_{vac} .

To lift and supply water, air water lifts (airlifts) use compressed (rarefied) air, which requires building compressor stations. Airlifts are simple, have a reliable design and operation characteristics, but their efficiency is quite low - 0,25-0,35.

Jet pumps are widely used for pumping sediment from water intake and slop structures, suctioning air from suction pipes when big centrifugal pumps are started, heat supply to mix and circulate water.

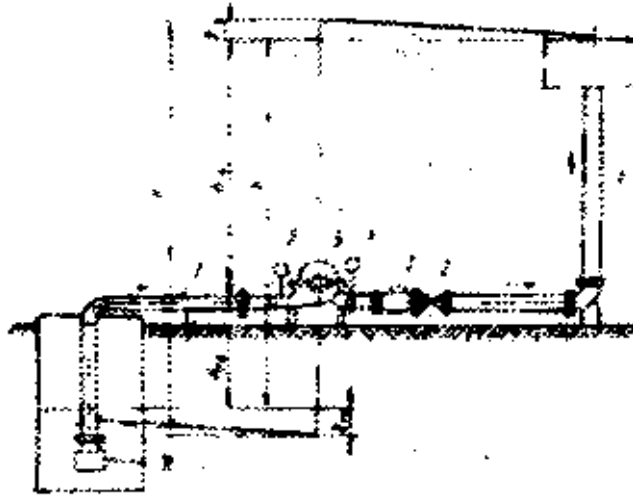


Fig 1.22. Scheme of centrifugal pump installation:

- 1 – penstock; 2 – flap; 3 – inverse valve; 4 – manometer;
- 5 – pump; 6 – vacuum meter; 7 – suction pipeline;
- 8 – receiving valve; H_{gr} – geometric height of suction;
- H_g – geometric height of water lifting; H – pump total head;
- h_{rs} – loss in pressure in suction pipeline; h_{gn} – loss in pressure in penstock

The pump delivery Q (l/sec, m^3 /hour) – is the volume of the fluid supplied by the pump per time unit.

A pump head H (m) is an increase in the power of the fluid flowing through the pump. There can be distinguished manometer and required pump heads. Monometer pump head is determined by manometer and vacuum meter readings.

$$H = \frac{H_M + H_B}{\rho g} + \frac{V_k^2 - V_n^2}{2g},$$

where H_M and H_B are manometer and vacuum meter readings to the axis of the pump, Pa; V_k and V_n – are the velocities of the fluid motion in the discharges and suction nozzles, m/sec; g – acceleration of gravity, m/sec^2 ; ρ -fluid density, kg/m^3 .

If the pump operates with overpressure the pump head is:

$$H = \frac{H_i + H_B}{\rho g} + \frac{V_k^2 - V_n^2}{2g},$$

where H_i are manometer readings on the suction line, m.

The required pump head is the geometric height of water lifting and pressure losses in the process of suction and forcing. For the installation shown in Fig.1.22 the required pressure is:

$$H = H_g + h_{TR} + h_{FR}$$

The power of the pump N (Vt) consumed for particular Q and H is:

$$N = \frac{\rho \cdot g \cdot Q \cdot H}{\eta} ,$$

where η is pump efficiency established by the pump manufacturer, with all power losses connected with fluid supply being taken into account (hydraulic, volumetric, mechanical).

The power of the drive N_{DV} (Vt) is set to be higher than that of the pump in the case unforeseen overload occurs:

$$N_{DV} = N \cdot k ,$$

where $k = 1,1-1,25$ – power margin coefficient which is set depending on the engine power.

When the pump is connected with the engine through intermediate gearing, the power of the drive is:

$$N_{DV} = \frac{N \cdot k}{\eta_{nep}} ,$$

where η_{nep} is the efficiency of the gearing.

There can be distinguished vacuum metric and geometric heights of suction.

Vacuum metric height of suction is the difference between atmospheric and vacuum metric pressures expressed in meters of liquid column:

$$H_{Bak} = \frac{P_{atm} - P_1}{\rho \cdot g} ,$$

P_{atm} – atmospheric pressure , Pa; P_1 – absolute pressure in the suction pump cavity, Pa.

The geometric height of suction H_g is a vertical distance from the free water level in some source to the horizontal axis going through the point of suction of the pump cavity with minimal pressure.

The allowable geometrical height of suction is:

$$H_{Bak}^{доп} = \frac{P_{atm} - P_n}{\rho \cdot g} - \Delta h - h_{FR}$$

where P_n is the pressure of the saturated steam at the temperature of the fluid being pumped, Pa; Δh is allowable cavitation reserve (increased pressure in the suction

pump under the action of saturated steam at a given temperature), m ; h_g are pressure losses in the suction pipeline.

The characteristic of the pump is the dependence of pressure, power, efficiency and allowable height of suction on the pump delivery for a particular frequency of rotation n and the impeller diameter D . There are analytical and graphic characteristics of pump. Working curve characteristics of pumps are wavy lines on the curve $Q-H$ indicating the recommended segment of pump use which corresponds to the most stable and economical operation mode as well as maximal efficiency.

The curve characteristics of the pump Д 1600-90 with impeller rotation frequency of $n=1400 \text{ min}^{-1}$ is shown in Fig. 1.23. The characteristics of the pump are given for the constant maximal impeller rotation frequency.

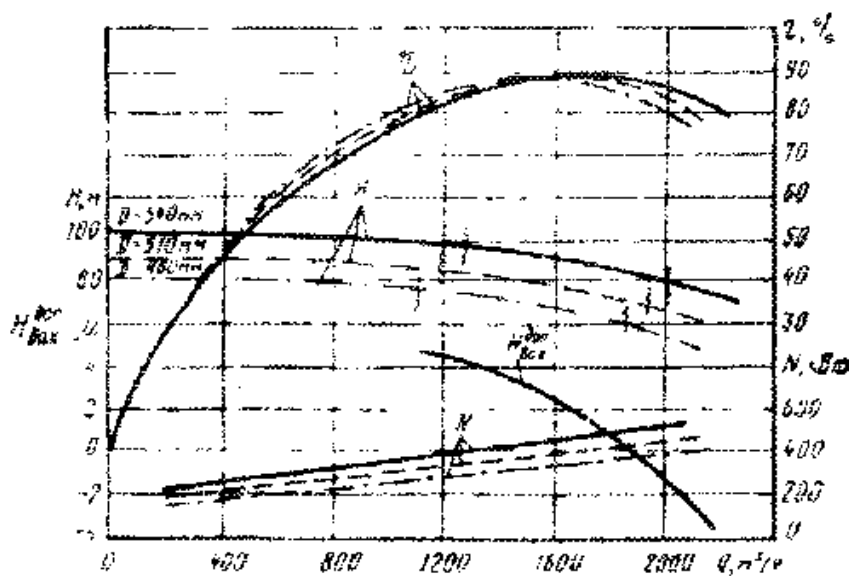


Fig 1.23. Characteristics of centrifugal pump Д 1600-90 at $n=1450 \text{ min}^{-1}$

For the pumps having some different rotation frequency n , pressure, gearing, power and allowable vacuum metric height of suction for one and the same pump are calculated by the formulas:

$$Q = Q \cdot \frac{n_1}{n}; H_1 = H \cdot \left(\frac{n_1}{n}\right)^2; N_1 = N \cdot \left(\frac{n_1}{n}\right)^3; H_{\text{max}1} = H_{\text{max}} \cdot \left(\frac{n_1}{n}\right)$$

The area of pump application can be widened at the expense of making the impeller diameter smaller (10-20 % of its maximal diameter). Efficiency η with a considerable change in rotation frequency (up to 50%) and making the impeller diameter 20% smaller, undergoes small changes which can be neglected when

making calculations. When preselecting pumps, their features summary can be used (Fig.1.24).

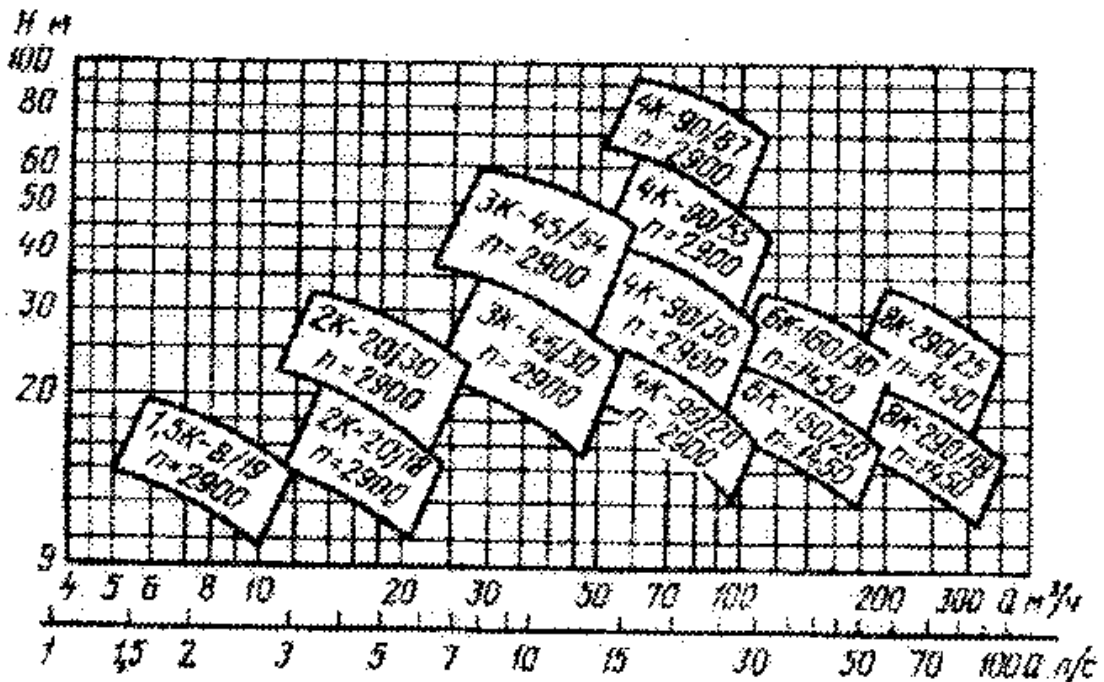


Fig 1.24. Features of the pumps of K and KM types

By their characteristics pumps are selected to supply fluid at a given expenditure and required pressure. It is necessary to know the pipeline (or pipeline system) characteristic, which is found as a sum of the geometric height of water lifting and pressure losses:

$$H = H_r + \Sigma h_{\text{пот}}$$

Graphically, the characteristic of the pipeline is presented by a parabola with its top being on the y-axis at the distance H_g of the x-axis. To determine the optimal pump operation mode for a given pipeline the common characteristics of the pump and the pipeline are built.

Fig. 1.25 shows the characteristics of the pump Q-H. Having drawn the straight line CD parallel to the axis Q at the distance H_g , and having added $\Sigma h_{\text{пот}}$, which corresponds to some particular values or expenses Q, to H_g we will get the characteristics of the pipeline CE. Point 1 at which the pump and the pipeline characteristics intersect is called “working point”. It characterizes delivery Q_1 , efficiency η and pump power N_1 for a given pipeline. The pump should be selected so that the working point was within the highest values of efficiency.

Fig. 1.25 shows one pump’s performance for one pipeline. Design solutions may vary, namely two or more pumps’ performance with one or more drainages. Fig. 1.26 shows the parallel performance of two identical pumps for one drainage.

In this case the pump's characteristics are doubled for the same pressures, i.e. $Q=Q_1+Q_2$ $H=H_1=H_2$. The efficiency of two identical pumps that perform in parallel is equal to the efficiency of one pump and corresponds to point 3. The power of each working pump is marked by point 6.

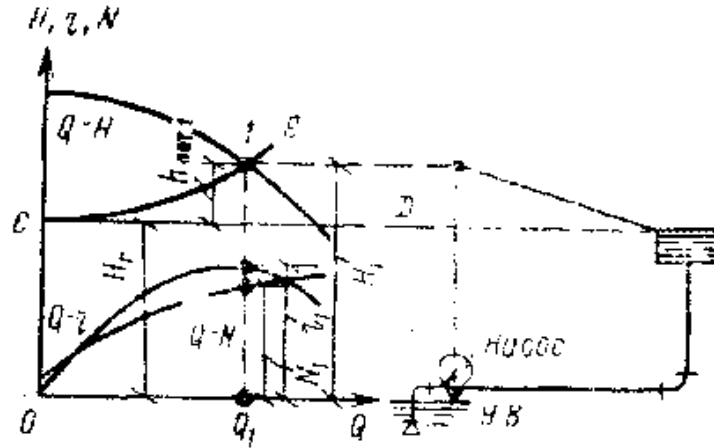


Fig 1.25. Common operation of a pump and plumbing

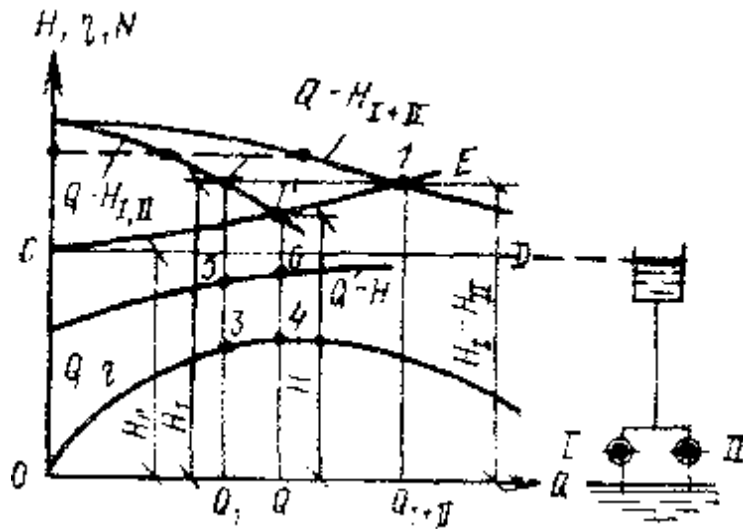


Fig 1.26. Characteristics of two identical pumps working in parallel

A bolt and a vacuum meter are, as a rule, installed on the suction line of each centrifugal pump, while a return valve to protect the pump against a hydraulic shock and prevent reverse water flow, a bolt to regulate expenses and to start the pump, and a manometer to determine the pump pressure are installed on the pressure line.

1.7.3. Water pumping stations

Pumping stations include primary and back up working units, pumps for special purposes (fire prevention, draining) as well as support equipment that ensures normal work of other equipment (electric equipment, lifting equipment, checking and signaling devices, etc.). In project plans the buildings of the pumping stations are, as a rule, of a round or rectangular shape.

According to their place in the general water supply scheme and their assignment, pumping stations are subdivided into stations of the first and second lifting, upward and circulating stations.

Stations of the first lifting are intended for pumping water from the source of water supply to wastewater treatment plants or reservoirs of clean water if water treatment is not required. To ensure stable operation of water intake and wastewater treatment plants, the stations of the first lifting are designed to provide uniform water supply during the day. The station of the first lifting operating round the clock, the pump delivery should be, normally, taken as equal to average hourly water expenditure during the day of the largest water consumption, with water expenditure on the restoration of fire-fighting water supplies, the wastewater treatment plants and water supply system as a whole.

Stations of the second lifting pump water from the reservoirs of clean water to consumers. Since water consumption by households is non-uniform during the day the pump stations provide water supply with this non-uniformity being taken into consideration. The delivery of the pumps of the second lifting should be determined in compliance with the water consumption schedule and the adopted scheme of water supply. Also, it should be taken into consideration that in the absence of water tower the aggregate supply of the pumps shall not be less than maximal hourly expenditure. Water supplied to consumers should meet not only quantity and quality requirements but it shall be supplied under some certain pressure provided by the station of the second lifting and the water tower.

To ensure the estimated water supply for fighting fire, with the required free pressure unchanged, fire units in the pump stations of the second lifting or special fire pump stations should be provided.

Circulation pump stations are installed in the systems of service water supply in cases when it is necessary to provide water circulation, for example, in closed cooling systems.

Upward pump systems increase water pressure in the plumbing network. In this case, pumps are connected immediately to the plumbing network.

When designing pump stations, the category of reliability of the pump station, the number of primary and back up working units and other indexes should

comply with CHiII 2.04.02-84. The optimal mode of pump operation is determined according to the results of hydraulic calculation of the network and technical and economical calculations of the cistern volume of water towers and reservoirs of clean water. According to the results of calculations the standard projects of pump stations are selected. Fig.1.27 shows the construction of the pump station of 1st lifting.

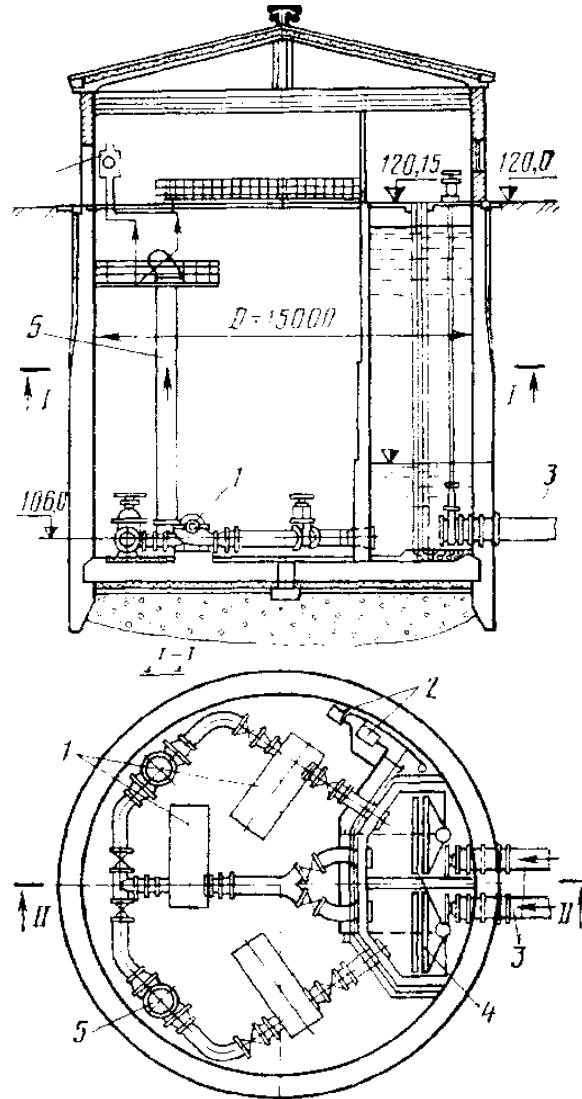


Fig 1.27. Round sunk pump station of the first lifting combined with the chamber of river water intake net: 1 – pumps; 2 – silt pumps; 3- self floating lines; 4-nets; 5 – pressure pipeline

1.8. Control and replacement facilities

Control and replacement facilities in the water supply system are pressure or non-pressure tanks with a certain volume of water needed to regulate the operation of the system and make an emergency store in case of fire or accidents. Control implies agreement in different modes of water supply and consumption with accumulating tanks being used. When the water supply exceeds consumption

needs, it is accumulated in the tanks, while in case of water deficiency it is taken from these tanks. Control provides a relatively constant work of water intake structures, wastewater treatment plants and pump stations.

It is recommended that control and replacement tanks be housed in one facility. Apart from being economically profitable it helps avoid deterioration of water quality in case of prolonged storage.

Pressure control facilities include water towers, highly located overhead pressure reservoirs and also air-water (hydro pneumatic) tanks. They are placed at the highest points of the terrain close to or directly on the locality network. In addition to controlling function, water intake towers and reservoirs, level pressure in the network, with change in the pump supply do not affect the network.

Non-pressure control and replacement facilities (ground and underground reservoirs) are, as a rule, located near the pump stations. They are employed to control water intake structures operation, wastewater treatment plants operation, and store emergency, fire prevention and other supplies of water.

It is recommended that the control volume of the water tower tank be determined by step or integral graphs of water inflow or outflow (Fig.1.28). Fig. 1.286 shows the daily step graph of water consumption. Provided the pumps work continuously and uniformly throughout the day their hourly supply will be $100/24 = 4.17\%$ of daily expenditure.

Graph 1.28 shows that within the period of 0 to 6 and 20 to 24 o'clock water consumption is less than water supply while from 6 to 20 o'clock it exceeds water supply. Thus, with the tank available, water can be collected in it from 0 to 6 o'clock and from 20 to 24 o'clock, and it can be delivered to consumers in the period from 6 to 20 o'clock (apart from pumps supply). In the absence of a control reservoir the pumps with an hour supply of 6.2% of the daily expenditure would be advisable, which would lead to an increase in the power of the station and the reduction of its efficiency, since most of the day the pumps would work under loaded.

According to the integral graph, the control volume is:

$$W_{per} = \frac{\alpha - \alpha_2}{100} \cdot Q_{r.d.} \quad (1.25)$$

where α_1 and α_2 - the largest ordinate values between the integral lines of water consumption and the water supply by the pumps with relation to the surplus and deficiency, % of $Q_{r.d.}$; $Q_{r.d.}$ - estimated daily water expenditure (maximal water consumption per day), m^3/day .

In the absence of water consumption and water supply graphs, the control volume of water is calculated according to СНиП 2.04.01-85 depending on the operation mode and the efficiency of the pumps.

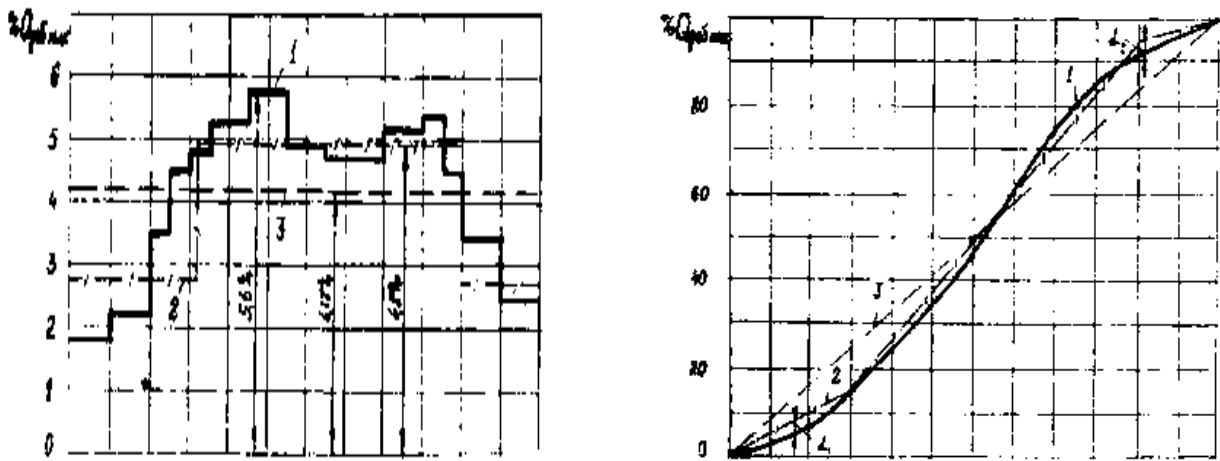


Fig. 1.28. Daily graph of water inflow and outflow:
a-step graph, b-integral graph; 1– water outflow; 2– water supply by the pump station of the II lifting; C – water supply by the pump station of the I lifting

Fire-prevention reserve (supply) of water is determined by estimating the duration of fire extinguishing of the estimated number of fires. For water towers and pressure reservoirs this duration makes 10 minutes while for reservoirs of clean water- 3 hours.

Thus, the volume of the water pressure tower (or reservoir of pure water):

When making specific estimates the control volume is determined with the correction coefficients which take into account an increase in the reliability of the facility operation or its location (for example, a network with a counter reservoir or a communicating tower). The values of these coefficients range within 0,6 - 1,3 and is defined by [4,11,12].

By their design, water towers present a water pressure tank, which is installed on the support of the estimated height (Fig. 1.29). The height of the water tower:

where H_p is free estimated pressure in the dictating point of the network within the zone of the water tower influence, m ; $\sum h$ is pressure losses in the pipeline from the tower to the dictating point, m ; Z_0 and Z_d are the geodetic marks of the ground near the tower and the dictating point respectively, m .

According to formula 1.27, water towers in highest locations will be lower.

Depending on relief and network configuration water towers can be located at the beginning of the network (communicating tower), at the end of the network (counter reservoir) or in its intermediate points.

Depending on the material of the barrel towers can be brick, reinforced concrete, steel, etc. Inside the barrel the necessary equipment- pipes, fittings, devices are housed (Fig. 1.29). Tanks in the towers can be made of metal or reinforced concrete. Depending on weather conditions, water temperature, tank dimensions and tower operation mode (the duration of the water exchange process in the tank), water towers can have marquee-like cover in order to prevent overheating or freezing of water, or they can be without any cover. Compared with the covered water towers the non-covered water towers are 15-20% cheaper. There

have been designed standard solutions of water towers with the tank volume of $15 - 800 \text{ m}^3$ and the height of the barrel of $6 - 42 \text{ m}$.

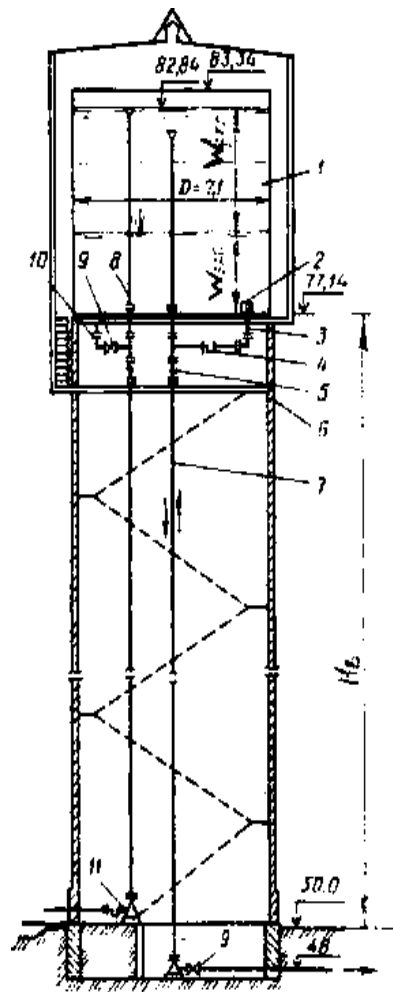


Fig. 1.29. Water tower:

1- tank; 2 - receiving grid; 3 - drainage pipeline; 4 – reverse valve; 5 - temperature compensator; 6-barrel of tower; 7-pipeline for water supply or drainage; 8-overflow pipeline; 9 – snaps; 10 - pipeline for emptying the tank; 11- hydro gate

In some cases, hydro pneumatic tanks are installed instead of water towers. In such facilities the required pressure is created by compressed air (Fig. 1.30). Higher pressures of pump stations, which leads to additional power consumption, and the presence of compressors are the disadvantages of such systems. The advantage of hydro pneumatic facilities is that they can be placed anywhere in the water pressure network as well as in special underground premises. (Fig.1.31).

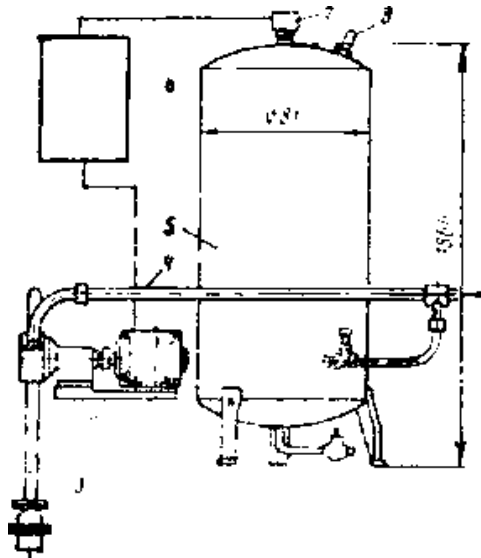


Fig.1.30. Hydro pneumatic pressure regulating unit:
 1 – electric motor; 2-pump; 3 - suction pipe;4 - pressure pipe;
 5 - air-water tank; 6- control block; 7 – pressure switch; 8 –
 safety valve (dimensions, *mm*)

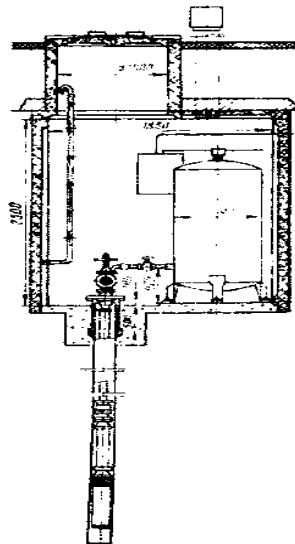


Fig.1.31. Hydro pneumatic pressure-regulating unit with a subsurface pump
 mounted in an underground chamber (dimensions, *mm*)

It is advisable that hydro pneumatic installations should be used at little water expenditure (local or internal systems).

As it has been previously mentioned, the reservoirs located on the high marks, can be employed as pressure reservoirs substituting water towers which are more expensive. But in the external water supply systems non-pressure reservoirs of wastewater treatment plants (reservoirs of clean water) are more often used. Prefabricated reservoirs made of reinforced concrete with flat ceiling have been most commonly used. (Fig. 1.32). The reservoir is deepened into the ground and engulfed with a 0.8–1.2 *m* layer of soil in order to insulate its upper part.

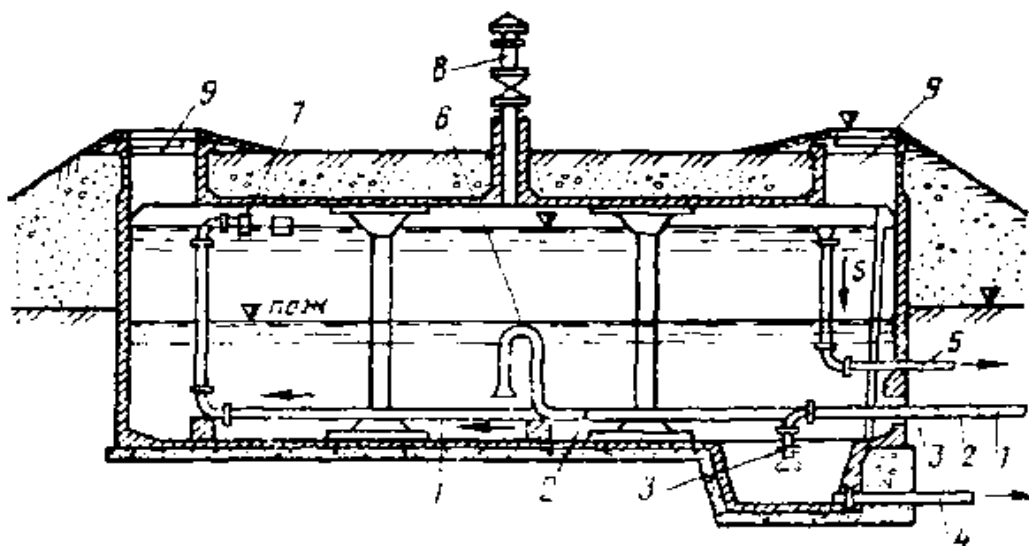


Fig. 1.32. Reinforced concrete reservoir:

1 - water supply pipe; 2 - suction pipe of economic pumps; 3-suction pipe of fire pumps; 4 - pipe for sludge disposal; 5- overflow tube; 6 - curved pipe with an aperture for vacuum unsealing after economic water supply has depleted; 7- float valve; 8 - ventilation shaft, 9-manhole

To ensure safe continuous operation of the water supply system at least two reservoirs are required. The special switching chambers are placed between them. In the reservoir of clean water all water should be exchanged within the period which does not exceeded 48 hours or 3-4 days provided there's some valid grounding. For this purpose water circulation with partitions or circulating pumps being installed is provided.

In reservoirs it is necessary that inviolability of fire prevention water supply be ensured, which is achieved by taking water for economic and fire prevention purposes from different marks or installing a siphon. The latter option is preferable because water is stored at the bottom of the reservoir all the time, and there are no stagnant water zones. With a decrease in water level lower than fire prevention supply mark, air is adsorbed through the apertures in the siphon bend, vacuum unsealed and water intake stopped.

When finding the volume of the reservoirs of clean water not only control and fire prevention water supply are considered but also water supply for the station maintenance needs (washing of filters, etc.) and emergency situations:

$$W = W_{reg.} + W_{res.} + W_{pr.} + W_{acc.} \quad (1.28)$$

where $W_{reg.}$ - control volume, m^3 ; $W_{res.}$ - fire prevention volume, m^3 ; $W_{pr.}$ - volume for the station maintenance needs, m^3 ; $W_{acc.}$ - emergency water volume, m^3 .

On the whole, the advisability of having control and replacement containers, selecting their location and type should be determined based on estimating the operation of a network, water pipelines and pump stations, with local conditions and technological requirements being taken into consideration.

1.9. External water supply networks

1.9.1. Schemes of water network tracing

Water networks are designed to transport water from water supply sources to consumers. These networks include sluiceways, arterial networks and distributing pipelines. Through sluiceways, water is supplied from pump stations to a locality with a network of arterial and distributing pipelines.

Sluiceways are laid in at least two lines that are connected by bridges, which ensure continuous water supply. The distance between individual lines must be at least 5 m with diameter of pipes of up to 300 mm and 10 m for pipes of a larger diameter.

Arterial pipelines are intended for transporting the main water mass transit. Distributing pipelines supply water from arterials to consumers.

All water supply networks are designed based on locality development plan. At the same time locality configuration, interposition of the source of water supply and consumers; the layout of streets, quarters and concentrated water consumers (plants, factories, etc.) and the lie of the ground are taken into account. Networks are laid along thoroughfares or roadsides parallel to the construction line. At a particular constant depth, in longitudinal profile pipelines have the relief similar to that of the terrain. The slope of the pipes, which is not less than $0,001$, is directed towards discharge, which provides the emptying of the network and air discharge.

For that reason, in higher points of the network vents are installed while in lower points - outlets. The degree of deepening of water pipes depends on the depth of soil freezing, the temperature of water going through the pipes and the mode of water supply. The pipelines must be $0,5\text{ m}$ lower than the estimated depth of soil freezing, but not less than $0,7\text{ m}$ lower than the upper part of the pipe.

By interposition of pump stations, water supply networks and pressure control constructions there can be distinguished the following power supply schemes for a water pipeline network: the scheme with one-way power supply or a communicating tower (Fig. 1.33 a); the scheme with two-way power supply or a counter reservoir (Fig. 1.33 b); combined scheme (Fig. 1.33 c).

By their layout in the plane of arterial lines there can be distinguished blind (extensive) networks, annular (ring) and combined networks (Fig.1.34).

Extensive water pipeline is cheaper, but it is used only when water supply can be discontinued during the time required for accident elimination. Ring water pipelines proved to be more reliable ensuring continuous water supply to consumers. In localities, combined schemes are most often used. The ring network covers the areas with the largest water consumption, with blind networks being laid from the ring to the consumers. In prospect, as the territory of the locality expands these blind networks can be ringed. It should be mentioned that fire prevention networks are made according to the ring scheme. Blind schemes are suitable only for short lines, while at the length of 200 m and more fire prevention basins must be provided at the end of water pipelines.

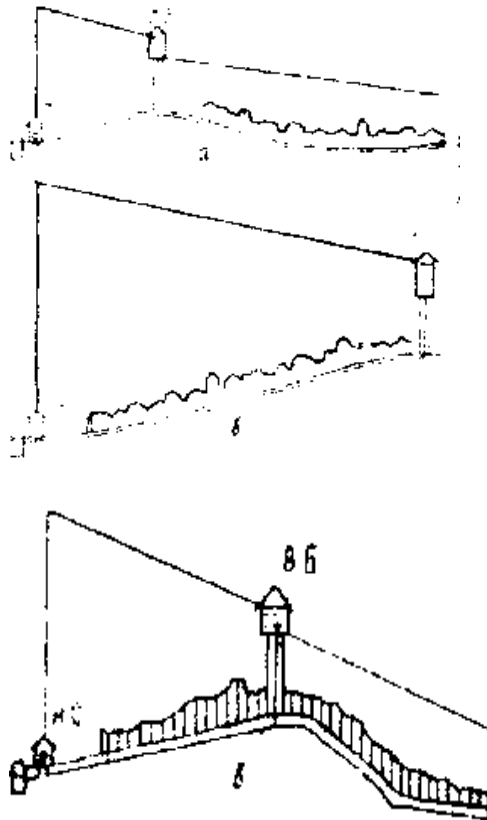


Fig. 1.33. Plumbing systems: a- with a passage tank; b- with a counter tank; c – combined; P.S. – pumping station; W.T. – water tower

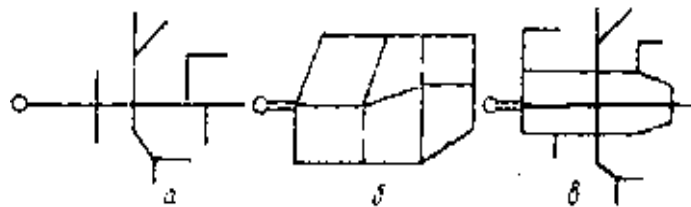


Fig. 1.34. Scheme of water supply networks: a-blind; b-ring; c- combined

Domestic water supply pipeline must not be laid through rubbish dump area, cemeteries or burial places of the livestock.

1.9.2. Basics of water supply network calculation

To determine pipe diameters and pressure losses across the network, hydraulic calculations of water lines and water supply network are made. Data on pressure losses are required to determine the height of the water tower and the pressure of the pumps. Hydraulic calculation is made only for trunk lines and sluiceways. Depending on the power supply scheme, network is calculated for such typical cases: maximum water consumption, maximum water consumption and extra water expenditure on fire prevention needs; transit to the pressure tank.

The first two situations require calculation made for all network schemes, and the third – for the schemes with a counter reservoir.

The preparation of a network for calculation implies drawing a notional calculation scheme. When making hydraulic network calculation all real points of water withdrawals by consumers can't be taken into account, that is why the real scheme is substituted by the notional scheme, with the junctions of water withdrawal normally found at the intersections of the trunk lines. These junctions divide the network into estimated areas. The procedure of water expenditure determination in the areas is as follows:

1. According to water consumption schedule for a particular mode the estimated expenditure is determined (q_{max} , l/sec).

2. Specific expenditure q_{sp} , in l/sec per 1 m of the network, without concentrated water consumers being taken into account, is calculated:

$$q_{sp} = \frac{q_{max} - \sum q_{conc.}}{\sum L} \quad (1.29)$$

where $q_{conc.}$ is total expenditure by concentrated water consumers, l/sec; $\sum L$ is total length of the network sites which give water, m (network sites intended only for water transportation are not included).

For different types of buildings (high-rise, low-rise, individual) specific expenditure is determined for each particular region depending on the population density.

3. Given that water withdrawal from the networks is uniform, travel expenditure for each site can be determined:

$$q_{tr.} = q_{sp} \cdot \tau \quad (1.30)$$

4. In order to simplify calculations travel expenditure is substituted by expenditure conditionally concentrated in junctions, determining it as half the sum of travel expenditure of the sites adjoining to a given junction:

$$q_{n.} = 0,5 \sum q_{tr.} \quad (1.31)$$

If expenditure is concentrated in the junction, then:

$$q_{n.} = 0,5 \sum q_{tr.} + q_{conc.} \quad (1.32)$$

The total incoming expenditure found at the junction must be equal to the total outgoing expenditure at the junction.

5. Given that in addition to the travel expenditure the transit expenditure q_b goes through the estimated area in order to supply power to the network sites that follow, the estimated expenditure at each site can be determined:

$$q_i = q_{tr.} + 0,5q_{conc.} \quad (1.33)$$

where 0,5 is a coefficient showing that at the beginning of the site $q_i = q_{tr.} + 0,5q_w$ (1.33), while at the end of the site $-q_i = q_{tr.}$

With the estimated expenditure at network sites known and the material from which the pipes are made adopted, the diameters of arterial pipelines can be determined:

$$d = \sqrt{\frac{4Q}{\pi \cdot V}} \quad (1.34)$$

where Q is estimated expenditure at the site, m^3/sec ; V is water velocity in the pipe, m/sec .

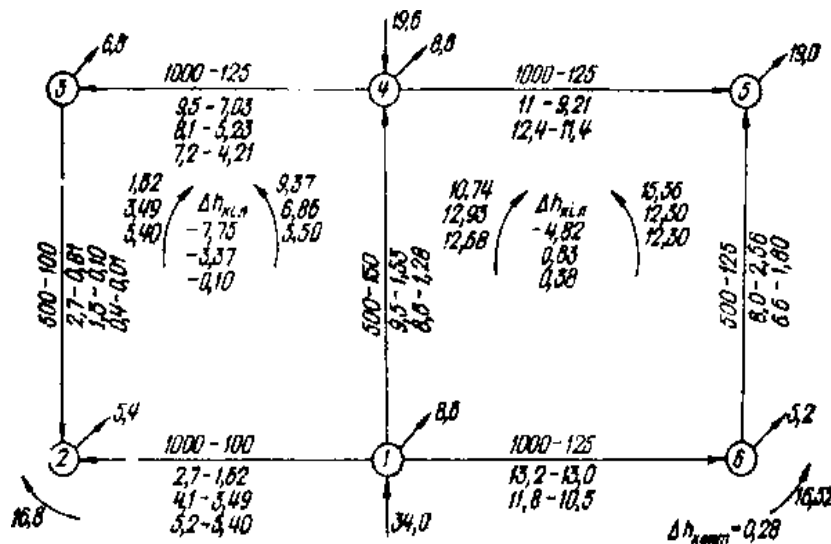
When determining water velocity value it should be taken into account that small water velocity values lead to an increase in diameter, while large water velocity values – to a decrease in diameter. The former makes construction costs increase, while the latter leads to increasingly large loss of pressure in the pipes, which, in its turn, causes extra power expenditure, i.e. increased operating costs. The most economical velocity is: for small-diameter pipes - $0,6-0,9 m/sec$; for big- diameter pipes - $0,9-1,5 m/sec$.

Using the formulas of hydraulics, with diameters and expenditure at network sites known, the pressure expenditure is determined. To simplify calculations by these formulas the tables have been made [18]. Using these tables the total pressure loss is found:

$$h_i = i \cdot \tau \quad (1.35)$$

When estimating arterial lines, pressure loss being comparatively negligible is not taken into account.

A simple scheme of a pipeline with the estimated network is given in Fig. 1.35. When estimating more complicated ring networks there can be many different solutions as for water distribution sites. In these cases, the network is "tied up" so that the total pressure loss of ring sites with clockwise water flow equaled the total pressure loss at sites with counterclockwise water flow ($\sum h = 0$).



Marks on the scheme:

Pipe: length, m - diameter, mm .

Water losses, l/sec - pressure losses, m .

Fig. 1.35. Scheme of hydraulic estimation of network

The losses at the network sites being approximated and the diameters selected, for reasons of economy the total of pressure loss is not equal to zero but is of a particular positive or negative value $\sum h$, which is called "a hitch". To tie up the network, a part of the initially taken estimated expenditure should be moved from a more loaded semi ring to a less loaded one. After pressure losses have been corrected, pressure losses are determined again. Estimation is carried out until an acceptable value of "the hitch" is reached ($\sum h = 0,3 - 0,5m$).

The pipeline network must constantly supply a locality with the required amount of water with the pressure providing normal water consumption. Network operation is most intensive at the time of maximum water consumption, when maximum volumes of water go through the pipes and pressure losses reach their maximum values. In these hours the line of piezo metric pressures takes the lowest position, i.e. pressure in the network will be minimum (Fig. 1.36).

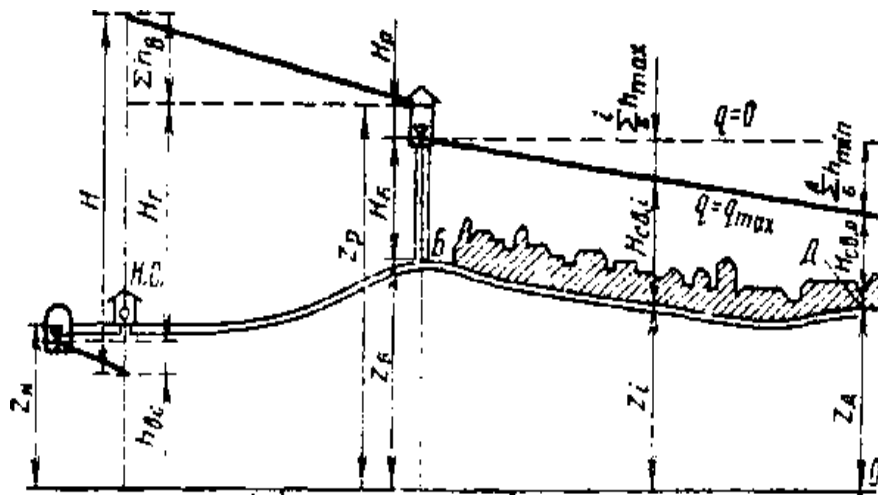


Fig.1.36. Scheme of water supply pipeline operation for economic water consumption

Pressure in the pipes in different points of the network depends not only on the position of the piezo metric line, but also on the height of the point location on the terrain. Piezo metric pressure in the pipes, which is calculated from the surface of the ground is called free pressure. It should be sufficient enough to ensure normal water pumping from sanitary units, including those on the top floors of buildings.

Minimum free pressure is determined according to the standards depending on the number of floors in buildings: for one-story building it makes 10 m; for multistory - extra 4 m for each floor. Free pressures for industrial zones are determined with technological requirements being taken into account.

Large pressures are unacceptable in the network, since non-industrial water loss increases, the risk of accidents also increases, and water pumping becomes inconvenient. Therefore, it is recommended that the greatest pressure in the water pumping network should not exceed 60 m (acceptable pressure). To supply water

to top floors of high-rise buildings standing separately, local pumping stations are used.

The network point in which free pressure during the maximum water consumption will have the minimum value is called a dictating point. If the required free pressure is achieved in the dictating point, then in the other points of the network it will be larger. Given this fact the height of the water tower is determined. Typically, this is the highest point which is most distant from the tower.

Having defined the height of the water tower by formula 1.27, the pressure of the pumps can be found:

$$H = (Z_t + H_t + H_p) + \sum h_w - Z_p. \quad (1.36)$$

where $\sum h_w$ is the total of pressure losses in sluiceways and pumping stations. Other signs are given in Fig. 1.36.

1.9.3. Pipes for water networks

To install external water supply networks steel, cast iron, asbestos cement, reinforced concrete and plastic pipes are used. The material of the pipes is selected in compliance with technical and economic estimates, which consider operating internal pressure, aggressiveness of soil and water, working conditions of the pipeline, sanitary requirements, etc. For external pressure networks it is recommended that mainly non-metallic pipes should be used, while metal pipes can be used only on certain areas where the network's performance is expected to be more reliable.

Steel pipes are welded having no seams (with a straight or a spiral seam). Seamless pipes have high strength and that's why these pipes are used to make underground passes under the rails and highways, in siphons, in seismic areas and sank soils. Steel pipes are widely used for indoor water pipelines. According to the current GOCT standards steel pipes with the diameter of 6–1400 mm and with the length of 4–12 m are produced.

Steel pipes laid in the ground must be protected from corrosion, otherwise these pipes will quickly get out of order. In order to prevent corrosion active or passive protection of steel pipes is used. In case of passive protection pipes are coated with some insulation material. Most often bitumen mastic and insulation roll materials are used for this purpose. Before being coated, pipes are thoroughly cleaned and covered with bitumen undercoat (bitumen solution in benzine), after that hot bitumen mastic is applied and pipes are wrapped with kraft paper. Depending on soil corrosiveness the most appropriate type of insulation is selected – standard, reinforced or super reinforced. The type of insulation is determined by the number of layers of mastic applied as well as the number of strengthening covers (bryzol, hidroizol or fabric). Besides, polymer and enamel covers are used for coating internal surface of pipes.

The interaction between metal of the pipeline and aggressive ground waters results in electric and chemical corrosion. In such cases it is recommended that

cathodic or tread protection of the pipes should be used (active methods). With cathodic protection, old pipes or rails, connecting with the positive pole of the direct electric current source are buried in the ground near the pipeline. The pipeline is connected to the negative pole of the same source. Electric current flowing from the old pipes (anode) in the form of positive ions of a metal, destroys them thus protecting the pipeline.

When electric current flows from electric transport there appear the so-called stray currents which damage the pipes. In such cases, tread protection proved to be rather effective since it doesn't require a direct current source, with a metal rod with higher electric and chemical potential than that of metal of the pipe (zinc, aluminum or their alloys) being buried in the ground near the pipeline. The pipeline is connected to the electric conductor (metal rod), which results in appearance of electric steam in which the current flows from the rod to the pipes protecting the latter from corrosion.

Often, active methods of protection against corrosion are applied in combination with passive methods, which makes the use of metal pipelines much cheaper.

Steel pipes are, as a rule, welded. When mounting steel pipelines bent, stamped and bead steel shaped parts are used that are welded to the pipes. Thread connections are mainly used for indoor networks.

Cast iron pipes in comparison with steel pipes are more durable due to thicker walls. The disadvantage of cast iron pipes is their heavy weight, fragility at dynamic loads and limited working pressure.

Cast iron faucet pipes and their shaped parts have the diameter of 50–1200 mm and the length of 2–7 m. Depending on the wall thickness the cast iron faucet pressure pipes used for water pipes are divided into three classes: JIA, A and B. Cast-iron pipes being used, the maximum working pressure should not exceed 1,0–1,5 MPa .

When connecting pipes, the corpulent end of one pipe is embedded into the socket of another pipe so that the ring air gap was of the same perimeter. The joint is pressurized by hempen strand or some plastic material- lead, aluminum, rubber (Fig. 1.37).

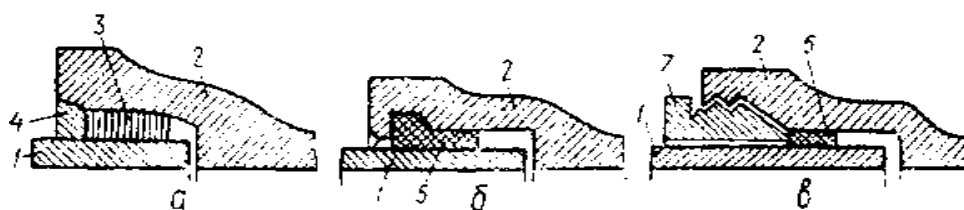


Fig.1.37. Joints of cast iron pipes:

a-with asbestos cement caulk; b-with a rubber ring: 1-corpulent end of the pipe; 2-socket; 3-tarred sleeve; 4- asbestos cement sealant; 5-self thickening rubber ring; 6-rubber thickening ring; 7-refused ring with fine thread

Reinforced concrete pipes are mainly used for water pipes. These pipes are durable, their production does not require a lot of metal, but they are rather heavy though. Reinforced concrete pipes are made by fibro forging and centrifuging, with the previous voltage of the armature with the diameter of 500–1500 mm for working pressure of 0,6–2,0 MPa and with the length of up to 5,2 m. The connection of the reinforced concrete pipes is of a socket type. Joints are pressurized with rubber rings.

Asbestos cement pipes are corrosion resistant and light, have smooth walls with low hydraulic resistance, low thermal conductivity, require easy tooling, but these pipes are fragile, requiring special caution during transportation and dynamic loads. Asbestos cement pipes are made from the mixture of 75–85% Portland cement and 25–15% asbestos fiber, their diameter being 50–500 mm and length - 3–4 m. For water supply the asbestos cement pipes of brands BT-6, BT- 9 and BT-12 are used, working pressure being 0,6;0,9 and 1,2 MPa respectively. Asbestos-cement pipes are connected by asbestos-cement and cast iron couplings. Joints are pressurized with rubber rings.

Plastic pipes are made of polymer materials: polyethylene of high and low density, polybutylene, polypropylene, polyvinyl chloride and others. Pipes are made for the pressure of 0,25–1,00 MPa, their diameter being up to 630 mm and their length - 6–12 m. Small-diameter pipes (up to 63 mm) are made long and are wound up. Plastic pipes are much lighter than metal pipes, they are corrosion resistant, have low hydraulic resistance and low thermal conductivity, they are easily tooled and compressed being flexible and plastic, but they have a high coefficient of linear spread and as the temperature fluctuates they can change their properties.

Electric insulation of polymers eliminates galvanic and electrochemical corrosion, which is very important when laying pipelines in the ground. Due to specific structure of materials, the pipes do not transmit vibrations, noises being suppressed. Plastic pipes do not accumulate any sediments: lime, stone, or any another chemical compounds.

Metal plastic (multilayer) pipes are a variety of plastic pipes (Fig. 1.38), which combine the advantages of metal and plastic pipes.

Metal plastic pipes are made in the following way: first, an aluminum strip 0,2–0,25 mm thick is given the shape of a tube and then it is welded with the use of ultrasound or laser. Then the aluminum pipe, both inside and outside, is coated with a layer of glue and high-density polyethylene. The inside layer, that is made from structured food polyethylene, is thicker than the outside layer.

Having all the advantages of plastic pipes, metal plastic pipes can withstand significantly greater pressure (up to 4 MPa), are more resistant to change of water temperature (the working temperature from 0°C up to 95°C), are hard to flex and have a low coefficient of linear expansion (only twice as high as for steel pipes).

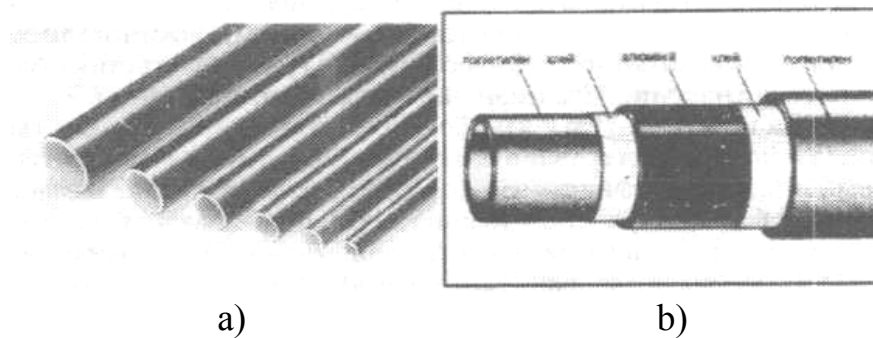


Fig. 1.38. Metal plastic pipes:
 a) exterior; b) construction of the pipe

Plastic pipes can be welded, glued, or connected by sockets on flanges. When mounting indoor water pipelines connecting threads can be used, with plastic or metal shaped parts being used (couplings, angles, tees, crosses, junctions, etc.)

1.9.4. Reinforcement of outdoor water supply networks

For the purpose of adequate operation, locking and controlling armature (bolts), safety armature (safety and reverse valves, air valves) and water fittings (standpipes, fire hydrants) are provided on outdoor water supply networks.

Bolts are intended for handling the water flow in the network and shutting off separate areas for inspection and repair. Bolts are installed at the intersections of arterial and branch pipelines so that not more than five fire hydrants were shut off during repair work. The passage in the bolts is blocked by locking disks moved by a screw spindle. According to locking disk design, bolts (Fig. 1.39) are divided into parallel and wedge bolts, and according to spindle design - bolts with retractable and non-retractable spindle.

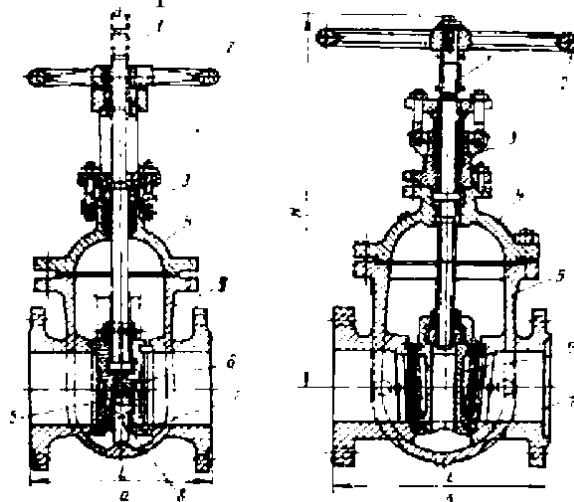


Fig. 1.39. Bolts:
 a - parallel; b - wedge (with non-retractable spindle): 1 – spindle; 2 - flywheel;
 3– oil seal; 4 – cap; 5 –body; 6 – disk; 7 - brass sealing rings; 8 - supporting
 wedge

Reverse valves are designed to pass water only in one direction (Fig.1.40a). These valves are installed on pressure lines of pump stations. Safety valves are intended to protect pipelines from destroying when the pressure level becomes higher than acceptable.

Fig. 1.40 b shows a spring loaded safety valve, in which the pressure of opening the valve is regulated by the compression of the valve spring.

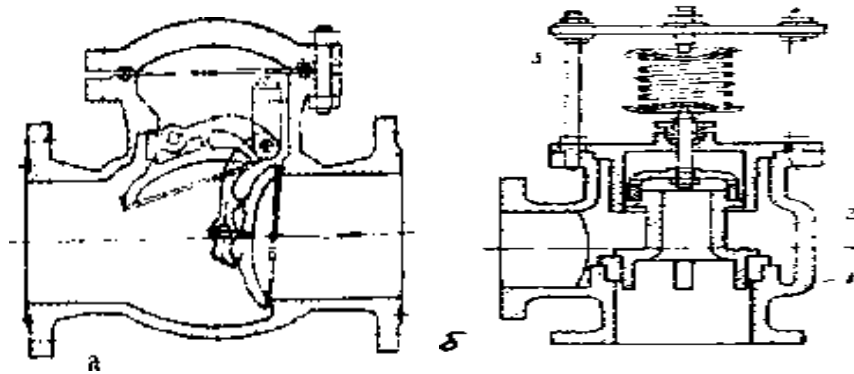


Fig. 1.40. Valves:
a – reverse; b – safety; 1 – body; 2 - valve; 3 - spring

Air valves (Fig. 1.41) are installed in the highest points of the pipeline for automatic venting in the pipeline.

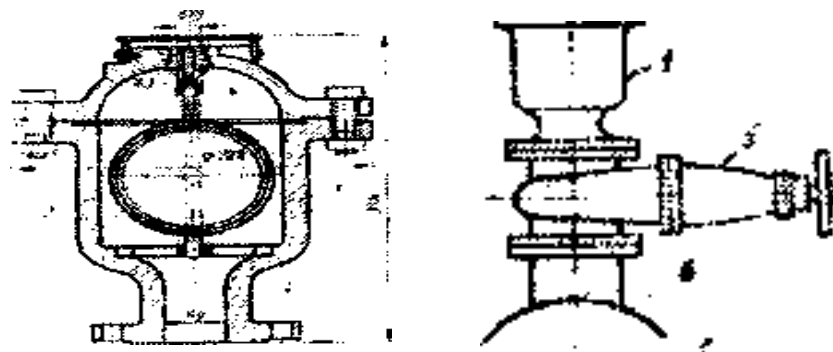


Fig. 1.41. Air valves:
a - general view; b-installation on the sluceway: 1- body; 2- manhole;
3 – ball float; 4 – venting valve; 5 – bolt; 6 – sluceway

Accumulation of air in the water pipe is unacceptable because it reduces the pipeline capacity, causes hydraulic shocks and accidents. As air accumulates, the water level in the air valve decreases, the float goes down, the valve opens and under the pressure of water air is released into atmosphere. When vacuum is created, the valve opens under atmospheric pressure.

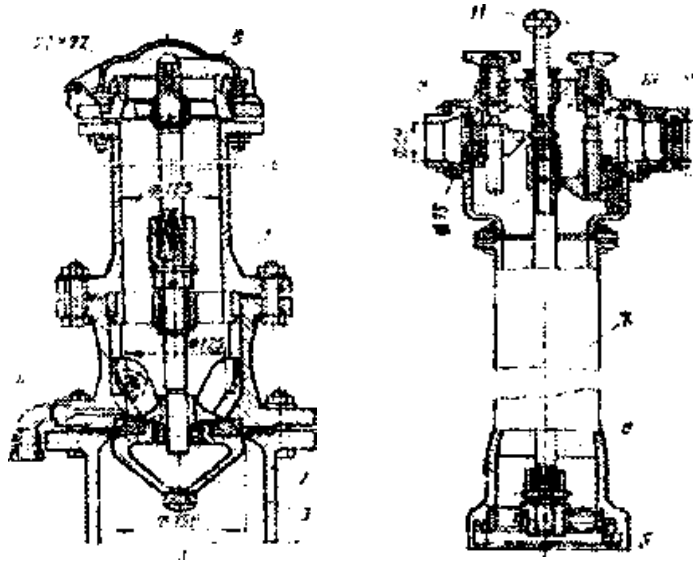


Fig. 1.42. Design of a fire hydrant and a stander:

- a - fire hydrant; b - stander: 1 – riser; 2 - fire stand; 3 - valve, 4 - square-headed rod; 5 - drain device; 6 – cap; 7 – the body of the stander; 8 – square-headed bar of stander; 9 - coupler for connecting a fire arm; 10 – locking device of a coupler; 11 - handle (mm)

Fire hydrants (Fig. 1.42a) are intended for water intake from the outdoor networks for extinguishing fire. Fire hydrants are installed in wells on a special stand. When using a hydrant a portable stander is screwed on it. (Fig. 1.42b) Firehoses are connected to a stander. Also, surface hydrants that are connected to standpipes can be used. Hydrants are installed on a pipeline network at a distance not more than 150 m from one another. The wells, where fire hydrants are located must not be closer than 5 m to the walls of buildings and must be approachable. In residential areas with no sewage system, water is taken directly from the outdoor network through a system of standpipes installed on it (Fig. 1.43).

Standpipes are, as a rule, arranged along the streets and at crossroads on the condition that the reach of each standpipe doesn't exceed 100 m. Network pressure being more than 0,1 MPa, standpipes show standard operation.

To ensure the required operation of the network, pipeline armature should be installed so that water supply could be easily regulated, and separate areas could be shut off for the period of repair work. The layout of armature, shaped parts, water wells and other details on the network is shown by symbols on special drawing called detailing of a network (Fig. 1.44).

The detailing is made on the scheme without scale so that its configuration corresponded to the network outline. Using detailing data, the specification of fittings, armature and water plumbing wells is drawn up.

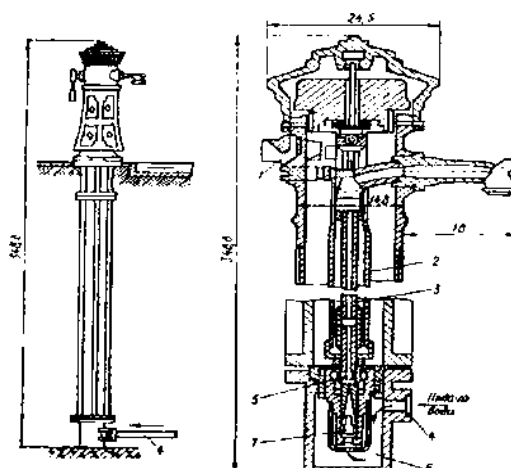


Fig. 1.43. Standpipe:

a - general view; b-a detail of the upper part; 1 – lifting lever with a handle;
 2 - tubular rod; 3 - feeding pipe; 4 – branch pipe; 5 – ejector; 6 - receiving tank;
 7-valve

1.9.5. Constructions on water supply networks and water pipelines

Water supply wells are designed to house plumbing armature, devices for armature control, repair and maintenance. A well has a working chamber with a manhole above it (Fig. 1.45). The manhole is covered by a cast iron or steel hatch, which can be of two types: T and L. Heavy hatches of a T type are installed on driveways, while hatches of an L type -on sidewalks and driveways for the transport with lifting capacity of up to 5 tn.

Hatches are placed so that not to hinder traffic and to prevent surface water from getting into the wells. In the absence of a hard road surface, the hatches must be 5 cm above the ground, with the paving around them which is 1 m wide.

By their shape given in the plan, water supply wells can be round and rectangular. The shape and dimensions are selected depending on the diameter of pipes and the dimensions of armature and fittings. Wells are made from reinforced concrete, brick, and, in rare cases, from foam concrete. To prevent ground waters (for wet soils) from getting into the well, the bottom and walls of the well are insulated, insulation being 0,5 m above the ground water level.

A series of model projects of water supply wells with different schemes of fittings and armature for dry, wet and sifted soils have been developed.

To prevent damaging the pipeline by internal water pressure, concrete pawls are installed in turning points and dead ends. Dimensions of the pawls are calculated so that when affected by soil deformation, they moved less than 0,3 cm .

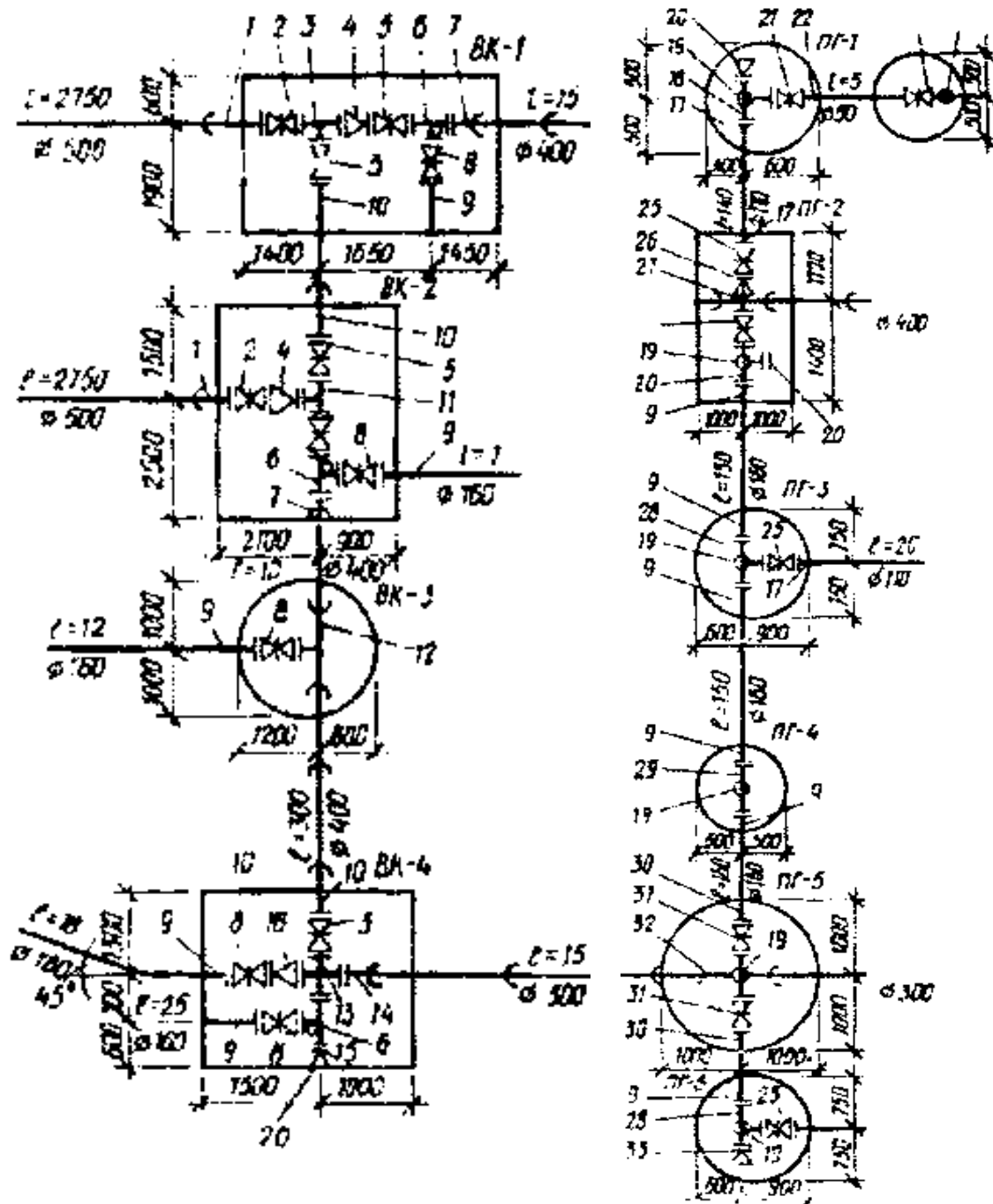


Fig. 1.44. Detailing a network area:

1,10-branch pipe "flange-smooth end"; 2,5,8,25,31-bolts; 3,11 – flanged tee; 4,16,26- flange transition; 6- flange outlet; 9,17,30-branch pipe "smooth end with a sleeve flange"; 7,14-branch pipe "flange-socket", 12-tee "socket-flange";13- flanged cross; 15,33 – cap;18,28- flanged tee with a fire stand; 19 - fire hydrant; 20, 33 – pawl; 21, 23 – vent; 24 – standpipe; 27 - "socket-flange" cross; 29 – flanged fire stand (non-standard); 32- "socket-flange with a fire stand" cross.

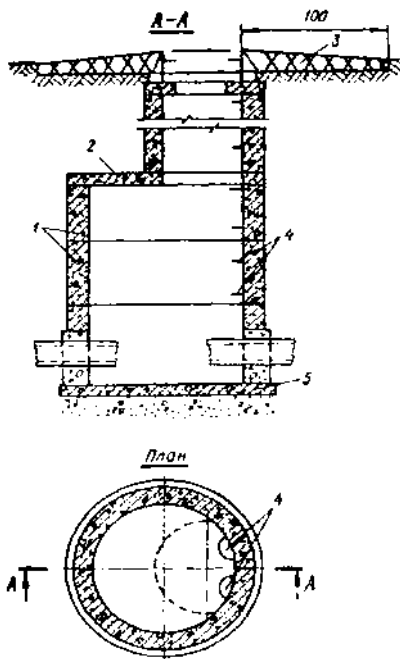


Fig.1.45. Prefabricated reinforced concrete manhole:
1 – rings; 2 - floor slab; 3 – paving; 4-way cramps; 5-
bottom slab

When passing through railway or motorways, the pipeline is placed in a safety case made of steel tubes (Fig. 1.46 a).

The cases (coats) protect the railway or motorway against destruction, should some pipeline accident occur. The pipeline is also protected against external forces arising from traffic. The cases can be laid with the use of an open (trench) or close (puncturing, thrusting, horizontal drilling) technique. The cases have anticorrosive insulation and protection from electric and chemical corrosion (cathodic polarization with tread units).

The internal diameter of the case must be 200 *mm* larger than the external diameter of the working pipeline. When calculating the case diameter, with the closed technique used, the length and diameter of the pipeline are taken into consideration as well as the requirements stipulated in “Safety rules in construction”. Space between the case and the pipeline is filled with insulating materials or cement and sand mortar.

When making transitions, passable or impassable tunnels can be used instead of cases. The pipe of the case or tunnel can be laid at the depth of not less than 1,0 *m* in case open technique is used and not less than 1,5 *m* with close technique used.

In the event of an accident, at the ends of the case the wells with the bolts for shutting off the pipeline are installed.

The distance between wells (end of the case) to the axis of the extreme track is supposed to be not less than 8 *m*, to the edge of excavation or drainage channels - at least 3 *m*, to the foot of the fill - 5 *m*.

Across the river, ravine or channel the pipeline can be laid with the use of a pipeline siphon (Fig. 1 .46 b) or in insulated coats under the bridge, or on an overpass (Fig. 1.46 c, d). When crossing the river, a two-line steel pipeline siphon coated with reinforced anticorrosion insulation is laid on the bottom of the river. The minimum distance between the top of the tube and the bottom of the river is 0,5 *m*, and for shipping within the limits of the fairway- 1,0 *m*. The distance between the pipes, shown in the plane, is 0,7...1,5 *m*. When installing siphon

through ravine or channel is all the above-mentioned requirements should be met. Due attention should also be paid to the slopes of the ravine. For transitions through extensive, though not deep ravines overpasses can be used as pedestrian bridges. In this case, the pipeline is laid in the insulated box (Fig. 1.46d).

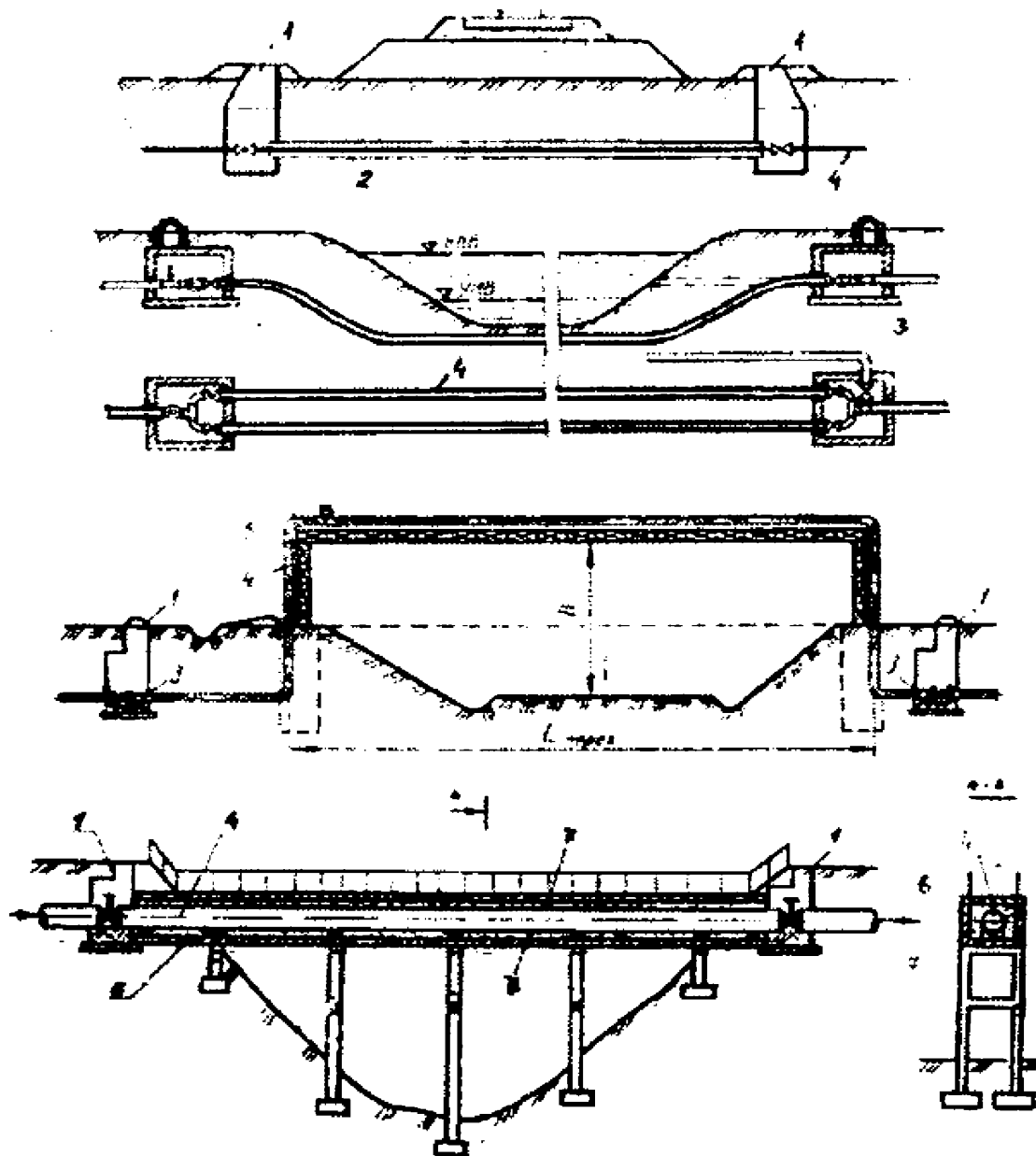


Fig.1.46. Transition schemes:

a - under the rail; b-with the use of a siphon under the river; c- on the overpass over the motorway; d-on the overpass across the ravine: 1 – well; 2 –case; 3 - drain pipe; 4 - working pipe; 5 - air valve; 6-box; 7-insulation

1.9.6. Pipeline testing and commissioning

Upon the completion of construction and installation works, water pipeline elements compliance with design solutions is checked. In the first instance, the

quality of welding and assembly work, work of fittings, straightness and deepening of the pipe lay are checked. After visual inspection water pipeline is tested twice: before and after filling the trench. The plot that is not more than 1 km long is subject to testing; its ends are tightly flanged, and the pipeline is filled with water.

The value of the pressure for testing the pipeline is specified in the project or СНиП 3.05.04-85. Typically, for metal and plastic pipes pressure is 1,5 times higher compared with working pressure, while for reinforced concrete and asbestos cement pipes it's 1,3 times higher, but it shouldn't exceed the values received by factory testing.

Pressure pipeline is considered to have passed the tests if its plastic compounds were not damaged by pressure. During the final testing after the pipeline has been filled, water outflow must not exceed the limits established by СНиП 3.05.04-85.

Before commissioning the pipelines, water supply facilities are washed (cleaned) and disinfected. The order of washing and disinfecting must comply with the requirements of СНиП 3.05.04-85. According to test results a report is drawn up. Test certification is signed by representatives of the construction, assembling, and operating organizations as well as representatives of the customer. The act of disinfecting is signed by representatives of Sanitary and Epidemiological service.

1.10. Improvement of water quality

1.10.1. Main technological processes and schemes of water quality improvement

The main technological processes of water quality improvement lie in removing admixtures the amount of which exceeds the acceptable norms. As a rule, water is discolored, disinfected and made more transparent.

To make water more transparent, all suspended are removed from water, i.e. its turbidity decreases. It can be done through settling and filtration. However, traditional settling is time-consuming and requires large areas and spacious facilities, with costs being considerable. To speed up the process of settling, the chemical substances – coagulants - are added to water, which along with suspended and colloid particles form flakes which very quickly get separated from the water (for flakes, precipitation speed is about 100 times higher than for micronized clay particles).

Water disinfection is the extermination of microorganisms, bacteria, viruses (mainly pathogenic), that can cause gastro enteric diseases: cholera, dysentery, paratyphoid, etc. A considerable part of bacteria and viruses are eliminated in the process of water settling and filtering, and those that remain are destroyed through water treatment by chlorine, ozone, silver or when water is irradiated by bactericidal ultraviolet light.

Water discoloring - is the removal of substances which determine water coloring. As a rule, the discoloration of water occurs when the water is purified

and disinfected. Substances that determine water coloring are removed due to coagulation and oxidization.

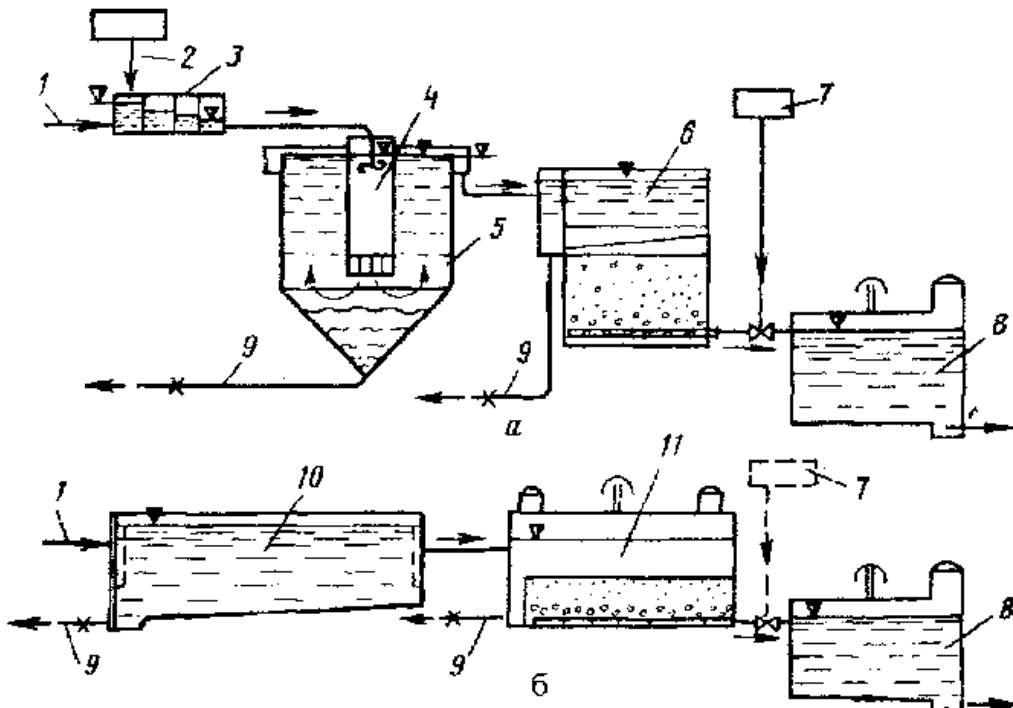


Fig. 1.47. The scheme of water treatment station:

a – treatment with the use of reagents: b – treatment without reagents: 1–raw water supply; 2-reagent structures; 3-mixer; 4-flake formation chamber; 5-settler with suspended sediment; 6-quick filter; 7-water disinfection; 8-reservoir of clean water; 9-pipelines for sediment and wash water disposal; 10-horizontal settler; 11-slow filter

Water is purified with chemical agents (coagulants, chlorine, ozone, etc.) being used or without them. In the latter case water is purified through natural settling and slow filtration through fine filters. So, there can be distinguished water purification methods with the use of reagents and methods with no reagents used.

The scheme of water treatment station with reagents used for water purification is shown in Fig.1.47a. Raw water is supplied to the mixer, with a number of coagulant solutions being added. Then, the water gets into the chamber, where the reaction of flake formation takes place after which it proceeds to the settler. In order to be ultimately purified the supernatant water is supplied to the filters, after which it is disinfected and supplied to the reservoirs of clean water.

The technology of water purification with no reagents used becomes simpler (fig.1.47b) because it doesn't require any reagent structures i.e. facilities and devices for storing, preparing, transporting and dosing reagents; mixers and chambers of flake formation. The main structures in such systems are settlers, fine slow filters and water disinfection devices.

Technological schemes intended for the ground water treatment for economic needs are much simpler compared with those intended for surface water, as they contain only water disinfection structures. Since the ground water contains iron, fluorine, manganese and other elements, the schemes of their treatment include structures designed to remove iron and relevant admixtures.

1.10.2. The use of coagulation process for water purifying and discoloring

Coagulation of admixtures in water is a process of enlargement (agglomeration) of colloidal and suspended particles due to the forces of molecular interaction with further formation of flakes. The coagulation of the particles which become separate from water finishes this process. In addition to the suspended and colloidal particles, the flakes absorb a considerable amount of bacteria and substances which give color to the water. The dose of coagulants ($\text{Al}_2(\text{SO}_4)_3 \cdot 18\text{H}_2\text{O}$, FeSO_4 , FeCl_3) depends on the composition of the polluted water, pH value, water acidity, settling time and, as a rule, is within the range of 25-125 mg/l. The optimal dose of coagulants can be determined more precisely in the course of laboratory experiments. For this purpose the researched water is poured into a cylinder adding to it coagulants in different doses. The dose that causes the formation of the largest flakes in the water within the period of 10-15 minutes and the highest settling rate within 30-60 minutes, is considered to be optimal. If this can't be done, the dose of coagulants is predetermined according to СНиП 2.04.02-84.

In the process of water coagulation the compliance of the natural acidity of water with the adopted dose of coagulant is checked. The acidity of water being insufficient, the alkaline reagents are added: lime or soda. Alkaline reagents are added to mixers in the form of a solution or lime milk together with coagulants.

To intensify the process of coagulation, water is sometimes treated by flocculants – substances that accelerate coagulation (polyamide or silica acid). As a result of such treatment still larger flakes are created, the process of settling taking less time.

The coagulation of admixtures in water can be achieved with electrical and chemical method used: water, which is being purified is passed through electrolyzer with aluminum (or iron) plates (electrodes), to which direct electric current is supplied. From anode plates the aluminum (or iron) gets into the solution in the form of ions, which get hydrolyzed and form flakes.

At water treatment stations, solutions are prepared in the departments (reagent structure), where special tanks with solutions and dispensing devices are located.

Solutions of coagulants are mixed with water, which is being purified, in special devices – mixers.

Intensive mixing in mixers is achieved due to vortex flows of water formed by fixed directing surfaces or due to mechanical mixing by mixers.

Mixers can be of tray type – with holes and partitions and vortex type (Fig.1.48). The water is supplied to the vertical vortex mixer with the speed of 1-1.2 m/sec; as a result of a sharp drop in speed the vortex streams are created in the conical part to which the coagulant is added.

The process of mixing takes 2-3 minutes before the flakes are formed. From mixers water gets to the chamber where flakes are formed at a speed that prevents the flakes from settling.

The water remains in the chamber for 20-30 minutes. Within this time period the process of coagulation is completed, with pretty big flakes being formed. Among the most widespread are chambers with partitions (Fig.1.48b), vortex chambers (by the type of vortex mixer – Fig. 1.48a) and swirl chambers (Fig. 1.48B).

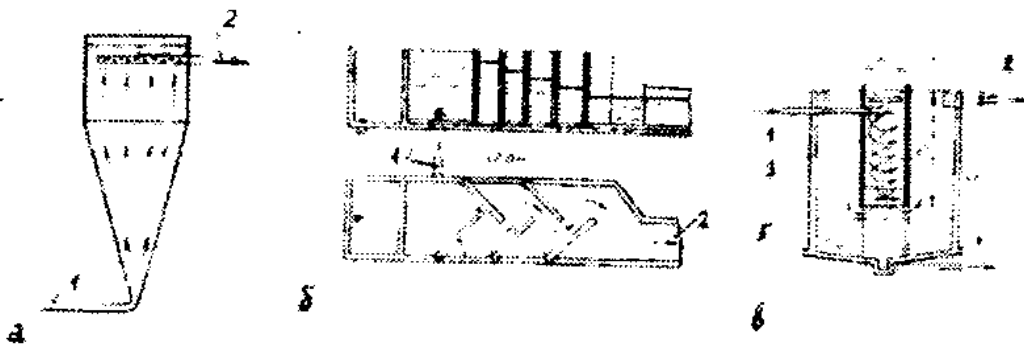


Fig. 1.48. Mixers

a-vortex; б-with partitions; в-with swirl chamber; 1-water supply; 2-water drainage; swirl chamber where flakes are formed; 4- pipe with nozzles on a tangent; 5-vertical settler

From the chambers where flakes are formed water gets into the settlers, where flakes precipitate. By their design and water flow direction settlers can be horizontal, vertical and radial (Fig. 1.49). Settlers can be combined with the chamber where flakes are formed in one structure.

Horizontal settlers (Fig. 1.49a) – are rectangular, stretched in the plan according to water movement, reinforced concrete reservoirs in which water moves in horizontal direction from one end of the building to another.

Vertical settlers (Fig.1.49б) are reinforced concrete reservoirs which are of round or square form in the plan, with vertical movement of water from top to bottom.

Radial settler (Fig.1.49B) is a round reinforced concrete reservoir whose height is small compared to the diameter. Water moves horizontally from the center to the periphery in the radial direction.

The water velocity in settlers varies from 0.5-0.75 mm/sec for vertical settlers, to 3-8 mm/sec for horizontal settlers.

In order to intensify and cheapen the process of settling, shallow settlers – thin- layer - are used. As a rule, for this purpose blocks of plates are mounted on

conventional settlers (Fig.1.50). It usually take 10-15 minutes for water to get transparent in such settlers.

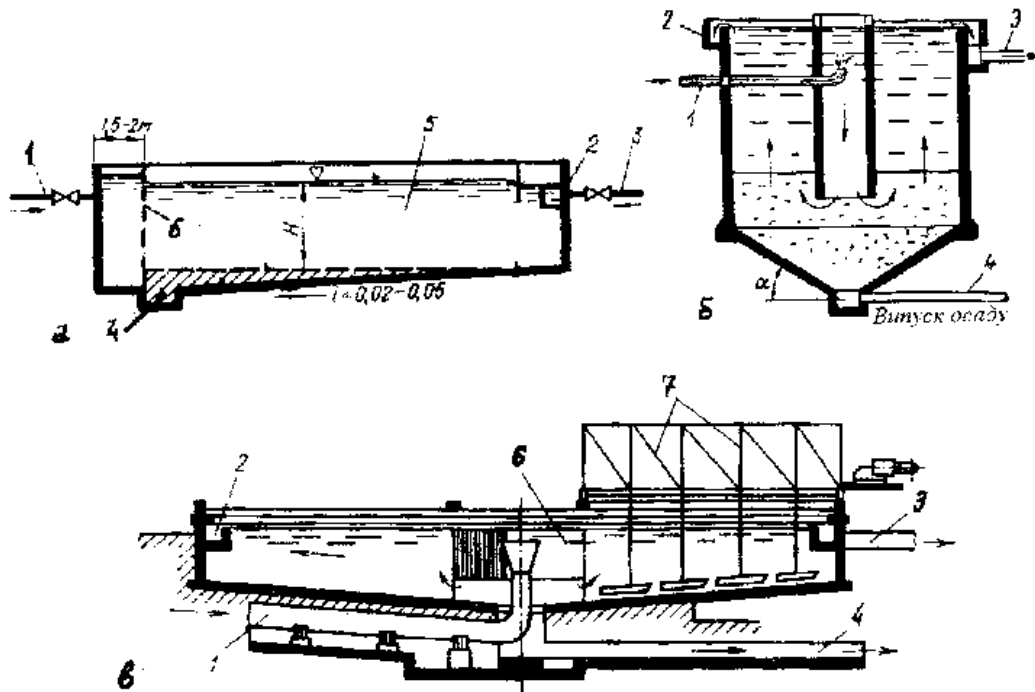


Fig. 1.49. The schemes of settlers:

а-horizontal; б-vertival; в-radial: 1,3-pipelines for water supply and drain; 2- collecting tray; 4-pipeline for sediment disposal; 5- settling area; 6-device of even distribution of water; 7-farm for raking sediment

Besides settlers in order to make water transparent hydro cyclones are used, in which due to centrifugal force solid phase is separated from liquid phase (Fig.1.51). Water that is being purified is supplied tangentially to the cylindrical part of the cyclone. Solid phase (the flakes) is thrown to the walls and slips down under the action of centrifugal force. The purified water flows out through the branch pipe located in the upper part of hydro cyclone.

The processes, taking place in hydro cyclones and thin-layer settlers, are combined in the settlers with the spiral shelves (Fig. 1.52), which have a cylindrical base with conic bottom. The central pipe with rigidly mounted spiral shelves is installed in the hull. The polluted water is supplied tangentially to the upper part of the settler, which allows it to rotate at the entrance to the viral shelves, than the water moves by descending spiral to the hole at the lower part of the central pipe and is drained out of the settler. In such settlers water gets transparent within 6-15 minutes.

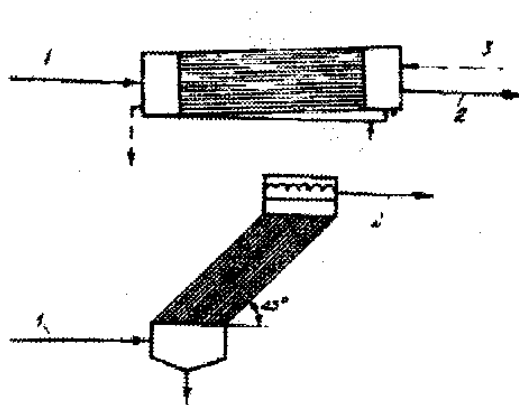


Fig. 1.50. The schemes of thin-layer settlers:

a-with sloped plates; b-steeply sloped plates: 1-water supply; 2-treated water; 3-wash water

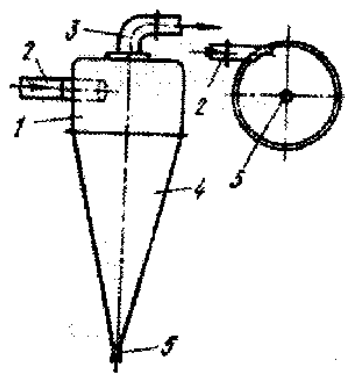


Fig. 1.51. Hydro cyclone:

1-cylindrical body; 2-intake pipe; 3-discharge branch pipe; 4-cone; 5-outlet

When purifying water, the method when water is passed through the sediment layer, is used (Fig. 1.53). After going through the mixer, water gets into the lower part of the water purification device, where sediment is suspended. This sediment intensifies the process of flake formation.

From the water purification chamber excessive sediment through the windows gets into the silt-compacting chamber, from which it is removed. The velocity of the ascending flow equals 0.5-1.2 mm/sec, which ensures effective purification of water which is collected in the trays and then supplied to filters. After the process of settling the residual of particles suspended in water is allowed to be 8-12 mg/l.

1.10.3. Water filtration

The ultimate purification of water is achieved by filtration, i.e. by passing water through the fine layer of filtering material (quartz sand, haydite, ground anthracite, foamed polisterol, etc.).

By their speed of filtration, filters can be quick ($V=5-10\text{m/hour}$), super quick ($V=25-100\text{ m/hour}$), and slow ($V=0.1-0.1\text{ m/hour}$). Quick filters are used when purifying coagulated water, slow – when purifying water without coagulants, super quick filters can be used in both cases.

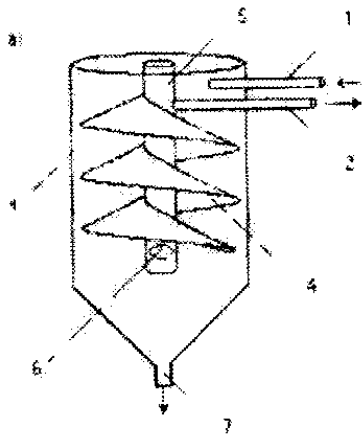


Fig. 1.52. Settlers with spiral shelves:
1-body; 2-intake pipe; 3-discharge pipe;
4-hole of cleared water intake; 5-central
pipe; 6-spiral shelf

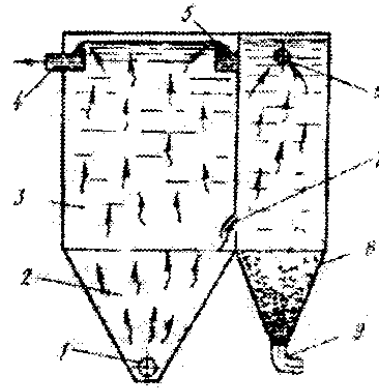


Fig. 1.53. Water purification device
with suspended sediment:
1-intake pipe; 2-layer of suspended
sediment; 3-water purification
chamber; 4-discharge pipe; 5-ring tray;
6-extra discharge pipe; 7-windows; 8-
silt-compactor; 9-sediment disposal

By their construction, filters can be opened (pressure filter) and closed (free-flow filter). Quick filters are normally made opened in the form of a reinforced concrete chamber filled with filtering material (Fig. 1.54). Filters can have homogeneous filtering material or heterogeneous materials: two-layer or multi-layer filters. The thickness of the filtering layer ranges within 0.7-2 m, with the diameter of grains being 0.5-2 mm. For the filtering material not to be washed away, the space between the grid and the filtering mass is loaded with a supporting layer of gravel.

In the process of operation quick filters get clogged, so they need regular washing by the inverse water flow as often as 1-2 times a day.

As a rule, filters are loaded with quartz sand, anthracite, haydite, foamed polisterol. In case of foamed polisterol, the loading is lighter than water, so such filters are referred to as filters with floating loading (FFL). Most often these filters work with the ascending water flow, and washing is conducted by water flow going from top down.

With water being purified with reagents used, the parameters of the filtering loading of quick filters and their operation mode should comply with СНиП 2.04.02-84. The properties of the filtering materials, the composition and the height of the loading layers are specified in the course of operation.

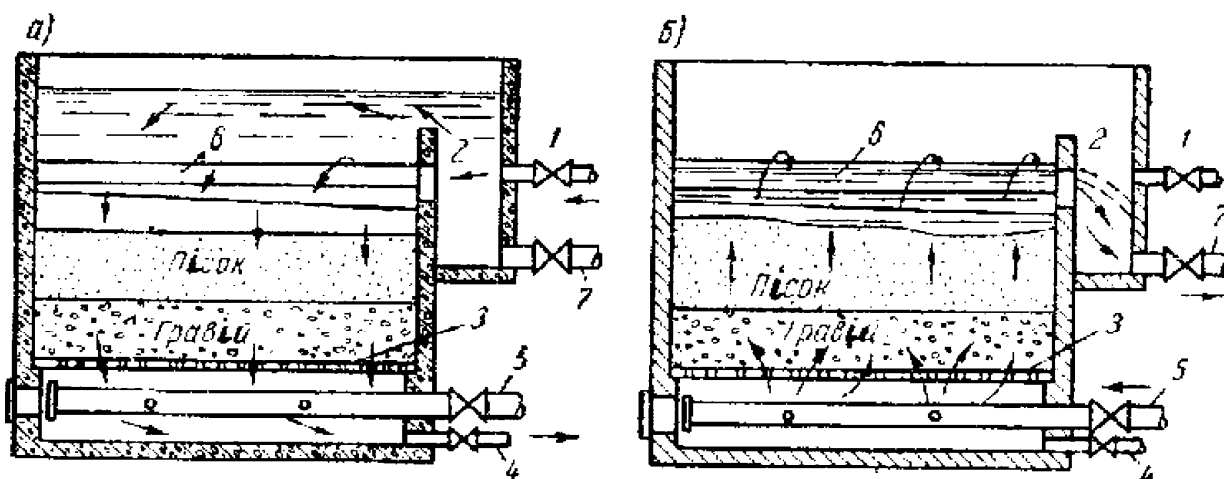


Fig. 1.54. The scheme of a quick filter:

a-filtering; b- washing; 1-water supply; 2-side pocket; 3-drainage; 4-clean water discharge; 5- wash water supply pipeline; 6-trays; 7-wash water discharge

Unlike quick filters, in slow filters suspended substances settle on the surface of the loading, with filtering membrane being formed in its upper layer which ensures a high degree of water purification without coagulation, and contributes to the sorption of most of bacterial contamination. The absence of reagent structure noticeably simplifies the use of slow filters, but low filtration speeds require considerable capital costs, that's why these filters are used only at small stations (up to 1000m³/day). As slow filters get clogged their upper layer of loading is cleaned, which is much more difficult than washing quick filters. By the regeneration of their loading, slow filters can be of two types: with contaminated upper layer removal; with washing contaminated layer which has been loosened or through hydraulic contamination removal.

For the working mode of slow filters, the water layer must be 1.5 m above the loading level, with loading layer being 1.3 m (0.85m – sand with the size of 0.3-2mm and 0.45m – gravel with the grain size of 2-40mm).

Super quick filters are used mostly for partial water purification. By their design they can be closed of vertical or horizontal type. In such filters filtering is done under pressure, with pressure losses reaching up to 10m.

Besides filters for water purification, the contact purification devices are also used, in which the processes of flake formation and filtration are combined. The principle of operation of purification devices is that when water is being filtered through the layer of grained loading, the colloidal and suspended particles are adsorbed on the surface of the filtering material. In contact water purification devices the water flows from the top down. The speed of filtration is 4-5.5m/hour. Loading of water purification devices of sand with the grain size of 0.7-5mm and gravel with the grain size of 5-40mm. The height of the filtration loading is 2.3-2.7m, the height of gravel - 0.4-0.6m.

In order to increase the reliability of the contact water purification devices as well as ensure the cleanness of loading, a continuous chlorination of water is

recommended. By their design, contact water purification devices do not differ from quick filters.

1.10.4. Water disinfection

Disinfection is used for ultimate elimination of living organisms, including pathogenic, in the filtered water. Water is disinfected with the use of chemical and physical methods. The former method implies the use of strong oxidants: chlorine, hypochlorite of sodium, chloride of lime, ozone, iodine, manganese, peroxide, etc. In case of the latter method water is processed with the use of bactericidal, electrolysis, thermal devices, etc.

Chlorination is the most widely-used method of water disinfection, with the solution of chlorine or chloride of lime being used, which produce prechloric and muriatic acids: $\text{Cl}_2 + \text{H}_2\text{O} \leftrightarrow \text{HOCl} + \text{HCl}$. Prechloric acid is unstable, it disintegrates releasing atomic oxygen and hypochlorite ion OCl^- , which show strong oxidative effect.

In order to disinfect water the amount of chloride added to it varies from 0.7-1mg/l (for ground water) to 3-5mg/l for raw water. The dose of active chlorine is established experimentally, with active chlorine being taken in excess ensuring its concentration of 0.3-0.5mg/l (a so-called residual chlorine) at the points of water pumping, which shows that the given dose is sufficient for the complete disinfection of water.

Chloric water is prepared from gaseous chlorine in chloric chambers. Chlorine is delivered to the stations in a liquid state in cylinders. Vacuum or pressure chlorinators are used for mixing and dosing water and chlorine. From the viewpoint of safety, vacuum chlorinators are more reliable, because the chlorine contained in them is under vacuum, with poisonous gas leak being unlikely (Fig. 1.55).

At small water treatment plants the chloride of lime (calcium hydrochlorite) or hypochlorite are used, which are prepared as 0.5-1% solutions with the use of devices similar to those used for the preparation of coagulant solutions. However, these reagents is in the deficit, and their use requires rather big structures. In these cases, hypochlorite of natruim, obtained by electrolysis of kitchen salt, is safer and more economical to use. To make 1 kg of active chlorine, 8-15 kg of kitchen salt is used. The duration of the contact between chlorine and hypochlorite should be not less than 60 minutes.

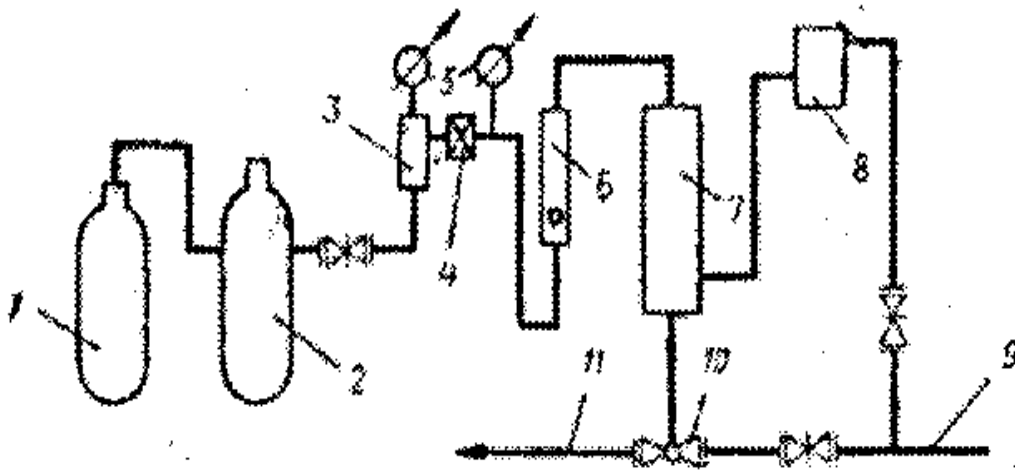


Fig. 1.55. The principal scheme of chlorinator JОНП – 100:
 1-evaporative cylinder ; 2-in-between cylinder; 3-filter; 4-regulation valve of pressure decrease; 5-manometer; 6-rotametr; 7-mixer; 8-tank with water; 9-water from water-plumbing; 10-ejector; 11-chloric water

In all cases, it's advisable that chloric structure be placed in detached buildings. When placed in a block of buildings, the choric structure must be separated by a blank wall. Chloric chambers should have two exits (one - through the portal, another – into the street). Artificial ventilation with a 12-fold air exchange is installed in the chambers. A wardrobe for overalls, gas-masks, devices for switching lighting and ventilation are found in the portal.

Disinfection by ultraviolet radiation with the use of bactericidal lamps is carried out mainly for ground water whose coli index is not more than 1000, iron content is not more than 0.3 mg/l, water color is up to 20⁰ and water transparency is not less than 30 cm. For ultraviolet radiation the electric lamps are used - quartz-mercury of high pressure or argon-mercury of low pressure. A device consists of radiation chambers, in which a thin layer of water is irradiated by ultraviolet rays. The effectiveness of disinfection depends on the duration and intensity of radiation.

Unlike chloration, the water after its being treated with the use of bactericidal devices does not taste or smell bad, and the whole process of disinfection and operation is quite simple and doesn't require reagents, but the use of this method is limited, with no residual effect of disinfecting.

Water ozonation implies the use of ozone, which can disintegrate easily with atomic oxygen being released, which destroys bacteria, spores, viruses and destroys organic admixtures. This allows to use ozone not only to disinfect water but also to discolor and deodorize it. Excessive ozone (unlike chlorine) does not deteriorate water quality 0.75-1mg/l of ozone is needed to disinfect ground water, and 1-3mg/l of ozone – for surface water. Ozone is generated by electric ozonizes at plumbing stations when electric discharge is passed through dried and cleaned air. The ozone-air blend generated by ozonizes, is mixed in special ejectors or

bubbled in cylinders or reservoirs. It takes from 5 to 7 minutes for water to contact with ozone.

1.10.5. Special methods of water quality improvement

Depending on the properties of water supply source or consumer requirements to the quality of water some special treatment of water might be required: softening, iron removal, stabilization, deodorization, demineralization, removal or adding some components, cooling, etc.

Water is softened to decrease its rigidity through removing or decreasing calcium and magnesia salts, mainly when water is prepared for boilers and technological needs of individual enterprises. For example, for individual workshops of textile or chemical industry the water supplied to medium and high pressure boilers should have rigidity of not more than 0.3 мгЧекВ/л. There can be distinguished reagent and cation methods of water softening. When softening ground water cation methods are normally used, while for surface water reagent methods, which are applied along with water purification.

Of all the methods of reagent softening the lime-sodium method is most commonly used. By this method lime is added to the water to remove the temporal (carbonate) rigidity and soda ash to remove permanent (non carbonate) rigidity. When the above mentioned reagents are added to the water, insoluble compounds are formed that precipitate, or compounds that are stored in water, but do not possess the properties of the salts of rigidity. Devices of reagent water softening include reagent structure, mixers, water purification devices with the suspended sediment, filters.

When lime-sodium method of softening water is used the alkalinity of water makes 0.8-1.2 мгЧекВ/л, and residual rigidity - 0.5-1 мгЧекВ/л. By heating water, the softness of 0.2-0.4 мгЧекВ/л can be achieved.

Method of cation water softening implies that some materials (cations) can exchange cations of sodium or hydrogen for cations of rigidity salts found in water. Sulphur coal (ground coal treated by concentrated sulfuric acid) or synthetic resins are most often used as cations.

To make it softer, water is filtered through cation exchanger that is loaded mainly in pressure filters. Water being filtered through cation exchanger, its hardness decreases to 0.03-0.05 мгЧекВ/л. In process of filtering hard water cation exchanger layer gradually loses its ability to soften water. For filters to regenerate, a solution of sulfuric or hydrochloric acid (H-cation exchanger filters) or solution of kitchen salt is passed through the layer of the cation exchanger.

Removal of iron from the water. With a considerable content of iron in it, water when having contact with oxygen becomes brown and has metallic taste. Flakes of iron oxide hydrate precipitate and can make the walls of the pipes thicker. Water with large amounts of iron is unusable for some enterprises, because it can damage the products through changing their color (production of fabrics, artificial fiber, paper, film, photographic paper, etc.). Iron content in drinking water

must not exceed 0/3 mg/l, and in service water iron content must comply with technological requirements.

Non-reagent methods are most often used to remove iron from the ground water, while reagent methods are used for surface water, which at the same time purifies water. With non-reagent methods used water is aerated in the first place, then it's filtered on contact and sand filters. For iron removal sulfate of aluminum, lime or oxidizing reagents are used as reagents.

Method of iron removal, calculated parameters and reagent dozes are best determined based on the results of technological tests carried out near water supply sources.

Water stabilization consists in giving water the properties, which prevent it from corroding or forming salts. Water stabilization is carried out mainly in industrial systems.

To remove its corrosive properties, water is alkalized or phosphated. When alkalizing water, lime or soda ash are added to the water. To prevent the thickening of the pipe walls water is acidified with sulfuric (hydrochloric) acid or decarbonized with combustion gases.

To fight biological thickening of pipe walls and equipment, chlorine and copperas are periodically added to water.

Desalting consists in removing soluble salts from water. The complete removal of salts is required for some technological processes such as preparation of water to be used in high pressure boilers. Partial removal of soluble salts is called desalination.

The water with the salt content of up to 2-3g/l is desalinated by ion exchange method, with the salt concentration of 3-15g/l – by hyper filtration or electrolyze methods, and for water with the salt content exceeding 10 g/l – by freezing, distillation or hyper filtration.

Water deodorization. To reduce the intensity of taste or smell water is oxidized followed by the sorption of substances. For this water is filtered through granular activated carbon which is periodically regenerated or replaced. Powdered carbon can also be used before settlers or filters. With the intensity of taste or smell being insignificant, water can be oxidized along with discoloring and purifying. Chlorine, ozone, permanganate of potassium can be used as oxidizers. The type of the oxidizer as well as its dose is determined based on the results of technological tests.

To remove chloric and phenic smells water ammonization – adding ammonia or its salt solution (for example, ammonium sulfate) to water – is effectively used. Ammonia is added to water with the use of ammonizers, which by their design are similar to chlorinators.

Aeration of water prior to adding chlorine or other oxidizers to water contributes to the lowering of the intensity of water smell or taste.

Degassing of water consists in removing insoluble gases contained in it. Natural waters normally contain the following soluble gases: oxygen, carbonic acid, nitrogen and rarely - sulphureted hydrogen and methane.

Chemical and physical methods are used for water degassing. Chemical methods are based on the use of reagents, which tie gases dissolved in water. Thus, metal shavings, sodium sulfate, hydrazine, sulfuric gas are used to remove oxygen from water. When removing hydrogen sulfite from water it is treated with chlorine, which results in the precipitation of the crystallized sulfur. To tie up free carbonic acid lime or caustic sodium are added to water, replacing it with carbonate-ions.

Physical methods of water degassing are based on creating conditions in which the solubility of gases approaches zero (heating or creating vacuum).

Fluoridation and fluorine removal from water. For human organism, both the complete absence of fluorine in drinking water and its increased concentration are harmful. The optimal fluorine content must be within range of 0.8-1.2mg/l. With the reduced fluorine concentration the reagents containing fluorine (silicic fluorine sodium or ammonium) are added to water; concentration being 1.5mg/l and more, fluorine is removed from water. Precipitates of magnesium hydroxide, aluminum or calcium phosphate can be used to sorb fluorine from water, aluminum or phosphate of calcium. Water can also be filtered through a sorbent which blocks fluorine.

Cooling of water. Ponds, pools, water cooling towers are used in the systems of industrial water supply for water cooling. In cooling ponds, the heated water is supplied at one end of the pond and at the other end of the pond the cooled water is collected. In cooling pools, the heated water is sprinkled on the water surface with nozzles being used, and cooled water is collected at some depth.

Water-cooling towers are most widely spread. In these towers the heated water is supplied to the top of the tower and then sprinkled on the entire surface. When being sprinkled, water flows down. Cool air is supplied to the bottom part of water cooling towers and when moving up it cools the water. The height of water cooling towers is 20-80m. Water cooling towers with forced ventilation are also used. Water-cooling towers are made of wood or reinforced concrete.

2. Sewerage

2.1. Systems and schemes of sewerage

2.1.1. Types of waste water

Water that has been used for different household or industrial needs and has been polluted with some admixtures (contamination), that caused changes in its chemical composition or physical properties, is called waste water. Atmospheric water which is drained from the territory of localities and industrial enterprises is also included in waste water.

Waste water pollution can be of mineral and organic origin. Mineral contamination is caused by sand, clay, slag, mineral salt solutions, acids and alkalis. Organic contamination can be of plant and animal origin. Contamination of plant origin contains remains of plants, fruits, cereals, vegetables and paper. From the chemical point of view such contamination basically contains carbon in the form of cellulose. Organic contamination of animal origin contains physiological waste of people and animals, fatty substances, organic acids, etc. The basic chemical element of this contamination is nitrogen in the form of protein substances. Besides carbon and nitrogen waste water contains phosphorus, potassium, sulfur, sodium and other chemical compounds.

There can be distinguished the so-called bacterial and biological contamination, which in waste water are represented by various bacteria, yeast fungi and molds, small algae.

By their physical state, contaminants contained in water can be in the form of solution, colloid, suspension and insoluble admixtures. Depending on the particle sizes, their specific weight and waste water velocity, insoluble might float on the water surface, be suspended in water or gravitate to the bottom. The degree of waste water contamination is determined by admixture concentration, i.e. the weight of the admixtures per unit of volume, mg/l or g/m³.

By their origin and the nature of contamination, all waste waters are divided into domestic (economic and fecal), production and atmospheric. Domestic waste water comprises water used in kitchens, toilets, showers, baths, laundries, canteens, hospitals, as well as domestic water used for washing floors. Waste water comes from residential and public buildings, from the premises of industrial enterprises. By the nature of contamination waste water can be fecal coming from toilets, which are mainly contaminated with physiological human waste, and economic, which are contaminated with various types of domestic waste.

The composition of domestic waste water is relatively constant and is characterized mainly by organic contaminants (nearly 60%) in insoluble, colloidal and soluble states, and also by different bacteria and microorganisms including pathogenic ones.

Industrial waste water results from the use of technological processes in industry.

The composition and concentration of industrial waste water contamination differ and depend on the type and technology of the production process, output raw materials and different components present in the technological process. Industrial waste water can contain organic, mineral, radioactive admixtures as well as poisonous and harmful substances. There can be distinguished contaminated and conditionally clean industrial waste water. For example, water used for cooling in heat exchangers is conditionally clean waste water.

Atmospheric waste water results from the rainfall or melting of snow. It mainly contains mineral contaminants and to a smaller degree – organic contaminants. Atmospheric waste water forming on the territory of industrial enterprises contain wastes and garbage of relevant enterprises.

Sewerage also deals with drainage and disinfection of atmospheric waste. It should be noted that such water is unevenly supplied. In dry weather it is absent, while during heavy rains its amount can be considerable.

The composition of waste water is researched in order to give most rational determination of the following conditions and circumstances: selection of waste water purification method; the possibility of recycling valuable substances contained in waste water and sediment (fats, fertilizers and others); the possibility of using cleaned waste water as a source of service water supply; determining the materials of pipes and canals which will drain waste water; preventive measures against waste water effect on them.

2.1.2. Basic elements of the sewerage of a locality. The systems and schemes of sewerage

Proper sanitary condition of localities and industrial enterprises can be achieved provided waste water is collected and removed in a timely manner with followed by its further purification and disinfection.

The sewerage of a locality is a complex of engineering structures and equipment intended for receiving and transporting waste water to waste water treatment plants. The plan of the object that is equipped with sewerage, with sewerage elements shown in it, is called the scheme of sewerage. The scheme of sewerage of a locality includes such basic elements: indoor sewerage equipment of buildings and facilities, outdoor and street sewerage network, collectors, sewerage pump stations and pressure pipelines, waste water treatment plants and outlets for treated waste water into reservoirs.

Indoor sewerage equipment is intended for receiving water water and removing it outside the building. In residential and public buildings sanitary units function as the receivers of waste water. At the industrial enterprises waste water is received with the use of special receivers in the form of carters, ramps, trays, which are installed immediately next to apparatus and technological equipment.

Street sewerage network is a system of underground pipelines which receive waste water from outdoor (block) networks and are intended for transporting waste water within the borders of a locality. Sewerage networks are mainly designed to

be flowing i. e. they are laid according to the lie of the ground. The territory is divided into drainage basins. A drainage basin is a part of the drained territory that is limited by watersheds.

Sewerage networks intended for removing atmospheric water are called rain networks, or drains; networks intended for removing domestic water are called domestic networks and networks intended for removing industrial waste water are called industrial networks. There are also networks for collective removal of different types of waste water (domestic-industrial, industrial-rain, etc.).

Street sewerage networks within the limits of each pool are united by one or several collectors. Collector is a sewerage pipeline which collects waste water from two or several street networks.

Since the flowing sewerage pipelines can be laid deep underground, the pump stations for lifting and pumping waste water are arranged. Sewerage pump stations are divided into local, regional and main. Local pump stations serve for pumping waste water from one or several buildings, regional pump stations – for pumping waste water of regions and basins. Main pump stations pump all waste water to waste water treatment plants.

Waste water treatment plant are structures intended for purifying and disinfecting waste water and recycling its sediment. The composition of waste water treatment plants differs and depends on the method of purification and the type of waste water. Waste water treatment plants are located downstream relative to the locality or industrial enterprise equipped with sewerage.

After being purified and disinfected waste water is dumped into a reservoir through special devices called outlets.

Depending on how some types of waste water are drained – together or separately – the sewerage systems are classified into general flow, separate (completely or partially) and semi-separate. The type of a town's sewerage system is selected based on comparing technical, economic and sanitary indicators.

In general flow system (Fig. 2.1a) all types of waste water are drained to waste water treatment plants through one sewerage network.

Separate sewerage system is a system in which different types of waste water containing different contaminants are drained through independent sewerage networks (Fig. 2.16). Separate sewerage systems in their turn are divided into completely separate and partially separate systems. Completely separate sewerage system provides not fewer than two networks: one – for receiving and draining domestic and industrial (similar to domestic waste water by its composition) waste water to waste water treatment plants; the other – for receiving and dumping atmospheric and conditionally clean industrial waste water into a reservoir.

Partially separate system provides draining of domestic waste water by a closed network to waste water treatment plants and unorganized draining of atmospheric water into a reservoir. Such design solution reduces simultaneous capital costs and in the future, with the networks being completed, allows switching to a completely separate sewerage system which from the sanitary point of view is reliable enough.

Semi-separate system (Fig. 2.1B) is a sewerage system in which at the intersection junctions of independent sewerage networks intended for draining different types of waste water the sluice-way chambers are installed, which allows delivering most contaminated rain water to domestic network, with costs being low, and draining it through the general collector to waste water treatment plants. In case of heavy rains a comparatively clean rain water is dumped immediately into a reservoir.

A partially separate sewerage system is mainly used in Ukraine. In general, a sewerage system is selected with local conditions, technical and economic indicators as well as sanitary requirements being taken into account. In terms of sanitary indicators the general flow sewerage system is considered to be most advisable, in which all waste waters are subject to purification. However, this system requires considerable capital and operation costs, since water treatment facilities substantially grow in size, with the power of equipment increasing. Moreover, these structures employ their full capacity only during heavy rains when all meteoric water mass gets to waste water treatment plants. To cut the cost of a general flow network, drain discharges are installed on the collectors along the reservoirs. During heavy rains these discharges help dump the bulk of meteoric water into a reservoir without any treatment. Such design solution decreases the sanitary reliability of general flow sewerage system and make it possible for diluted raw waste water to get into the reservoir. In terms of sanitary requirements the semi-separate sewerage system is a little more reliable. In this case raw waste water doesn't get into the reservoir, but the cost of this system isn't lower than that of general-flow system, which has limited the use of semi-separate sewerage system.

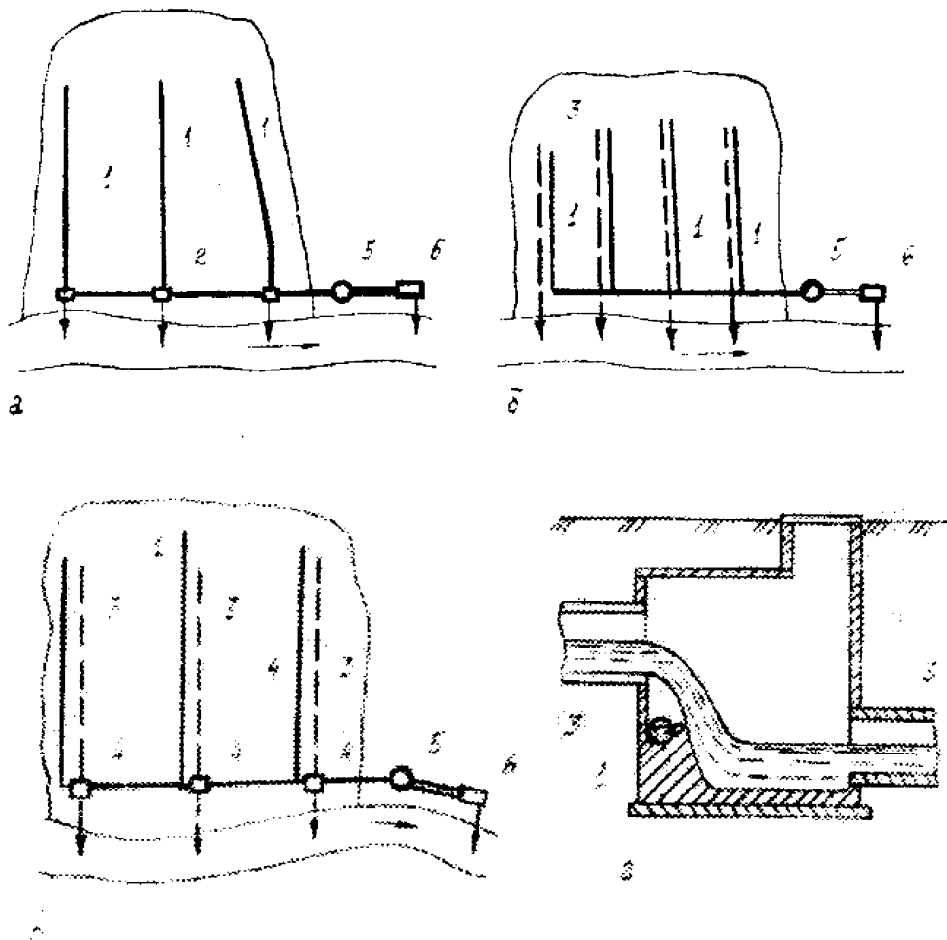


Fig. 2.1. The systems of sewerage:

a) general flow; b) completely separate; c) semi-separate; d) water dumping chamber: 1-collectors of domestic and industrial network; 2-drain discharges; 3-rain network; 4-water dumping chambers; 5-pump station; 6-waste water treatment plant

In all cases the choice of sewerage system for a locality must be grounded by technical and economic estimations, with sanitary requirements and a locality's development prospects being taken into account.

When selecting sewerage systems for industrial enterprises the following indicators are taken into account: the amount and composition of industrial waste water, the possibility to use industrial waste water in circulating and consistent water supply, the possibility of utilizing valuable substances and the practicability of integration with a locality's sewerage system, requirements to the industrial waste water dumping into the reservoir. As a rule, the sewerage at industrial enterprises is of completely separate system type.

Industrial waste water can be drained to the city sewerage, but in this case it shall not:

- disrupt the operation of sewerage networks and structures;
- contain substances that can contaminate the pipes of the sewerage network or accumulate on the walls of the pipes;

- deteriorate the material the pipes are made of or the elements of sewerage structures;
- contain combustible admixtures and soluble substances, which can form explosive and toxic gases in sewerage networks and structures;
- contain harmful substances in concentrations that disrupt the operation of waste water treatment plants or prevent the use of water in service water supply systems or dumping into water reservoirs (with the efficiency of purification being taken into account).

Requirements to waste water dumped into the city sewerage network, are standardized and stipulated in “Technical conditions of waste water quality and mode of waste water dumping by industrial enterprises into the municipal sewerage system”, approved by Minschytlokomungosp of Ukraine (order № since 21.05.90).

Marginally valid values of some pollutants are as follows, mg/l:

- petroleum and petroleum products – 25;
- surfactants – 20-50;
- copper, nickel – 0.5;
- chromium (trivalent) – 2.5;
- zinc – 1.0;
- mercury – 0.005;
- lead – 0.1;
- synthetic dyes – 25;
- suspended substances – 500;
- БПК – 750;
- adipose – 50-100;
- pH of waste water – 6.5-9.5.

Industrial waste water that does not meet these requirements must undergo preliminary treatment.

The schemes of sewerage networks of localities are drawn up in compliance with the master plan, with the relief of the locality, soil conditions, location of reservoirs as well as phased development of sewerage being taken into account. Since local conditions differ, it is difficult to offer some standard schemes of sewerage. However, the most common schemes are as follows:

Perpendicular scheme (Fig.2.2a), in which sewerage pool collectors are traced perpendicular to the direction of the river flow. Such scheme is basically used to discharge meteoric water which doesn't need purifying.

Interceptive scheme (Fig. 2.2b), in which sewerage pool collectors are intercepted by the main collector laid parallel to the river. This scheme is used for the locality relief descending to the reservoir and in cases when waste water needs purifying.

Parallel scheme (Fig. 2.2c) – sewerage pool collectors are traced parallel or at small angles to the direction of water flow and are intercepted by the main collector, that is located perpendicular to the direction of the river flow. This scheme is used for steep descends of a terrain to the river as the main collector is

not deep underground and waste water does not develop increased velocity in pipes.

Radial scheme (Fig.2.2d) – waste water is purified by two or more waste water treatment plants. According to this scheme waste water is discharged from the territory in a decentralized way. Such scheme is used for complicated relief of locality and sewerages in big cities.

Zonal scheme (Fig.2.2 e) – territory that is equipped with sewerage is divided into two zones: from the upper zone waste water is drained to waste water treatment plant under the force of gravity, from the lower zone it is pumped by a pump station. The use of such sewerage scheme allows to cut operation costs.

Sewerage network scheme is selected following the same rules as the systems of sewerage.

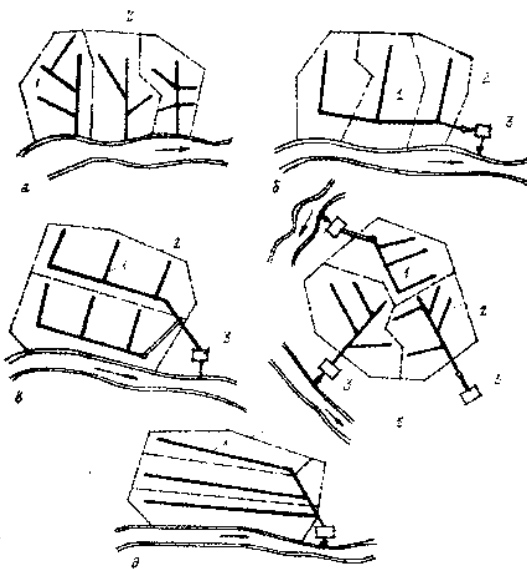


Fig.2.2. Schemes of sewerage networks:
a) perpendicular; b) intercept;
c) parallel; d) radial; e) zonal:
1-sewerage pools collectors;
2-borders of sewerage pools;
3-waste water treatment plant

2.2. Outdoor plumbing networks

2.2.1. Tracing of plumbing network

Tracing of plumbing network can be understood as determining the placement of street collector in the scheme of a locality. When tracing the main task consists in making self-flow discharges through pipes and channels as far from the locality as possible.

Right before tracing, the territory equipped with sewerage is divided into basins, selecting locations for waste water treatment plants and water discharge outlets. The borders of sewerage basins are determined by the relief of the locality and the project of vertical planning. The borders of basins, as a rule, coincide with watershed lines. The location of the waste water treatment plant is selected to be

lower than the locality's by the flow of the water providing sanitary protection zone to the border of residential development.

Tracing of the network depends on a large number of factors. Thus, when tracing the sewerage network the following factors should be taken into consideration:

- a) relief of the locality not to lay pipes too deep underground and to drain self-flow waste water; b) location of waste water treatment plant; c) preselected place for waste water discharge into a reservoir; d) accepted sewerage network; e) type of block development; f) sequence of construction.

Sewerage networks located in the centre of the basin are traced from watersheds to thalwegs. As a rule, street collectors are designed perpendicular to horizontals of the locality in the direction of the lower places of the basin. The main collectors are often directed along the river banks. Waste water is drained through the main collector beyond locality borders. The street sewerage networks can be traced by three basic schemes (Fig.2.3).

The scheme from the lower side of the block is applied for an expressed relief with ground levels falling down to one or two faces of the block (the slope of the land is more than 0,008-0,01). In this case street networks are laid only through the passages near lower sides of the block.

Covering scheme is applied for flat terrain (the slope of up to 0,005-0,007), large blocks, with no building development inside the blocks. Street networks are laid through passages, which cover the block from all sides.

Through-the-block scheme implies that street networks are laid within the blocks – proceeding from the blocks with higher location to the blocks with lower location, which shortens the sewerage network and reduces construction costs. However, the use of this scheme requires accurate coordination in building development and complicates network operation.

Sewerage lines should be laid linearly. In the places where networks turn, in the places where the slope of the line or the diameter of the pipe change, and also in the places where several lines join, wells should be installed. When projecting sewerage network tracing, the number of intersections with the railway, underground constructions or water barriers should be avoided or minimized, since these intersections are complicated, which causes operational complexity.

2.2.2. Basic data for network design

The master plan of a locality or an enterprise, in which locality's development prospects are considered, provides basic data for the locality's sewerage system design. Sewerage is projected for the entire estimated period during which the networks should have some definite capacity and conform to

their designation without being reconstructed or expanded. For cities this period is 20-25 years, and for industrial enterprises it is equal to the term during which they will operate at full capacity.

In addition to the master plan of locality (enterprise) development, the following data are needed for projecting the sewerage system:

- data on the location of the population and population prospects;
- the boundaries of the territory that is drained;
- data on the locality's public welfare and the sanitary condition of the locality;
- hydrological and geological characteristics of the territory;
- hydrological characteristics of the adjacent water reservoirs;
- meteorological characteristics;
- characteristics of natural and engineering and construction conditions, building and raw material bases.

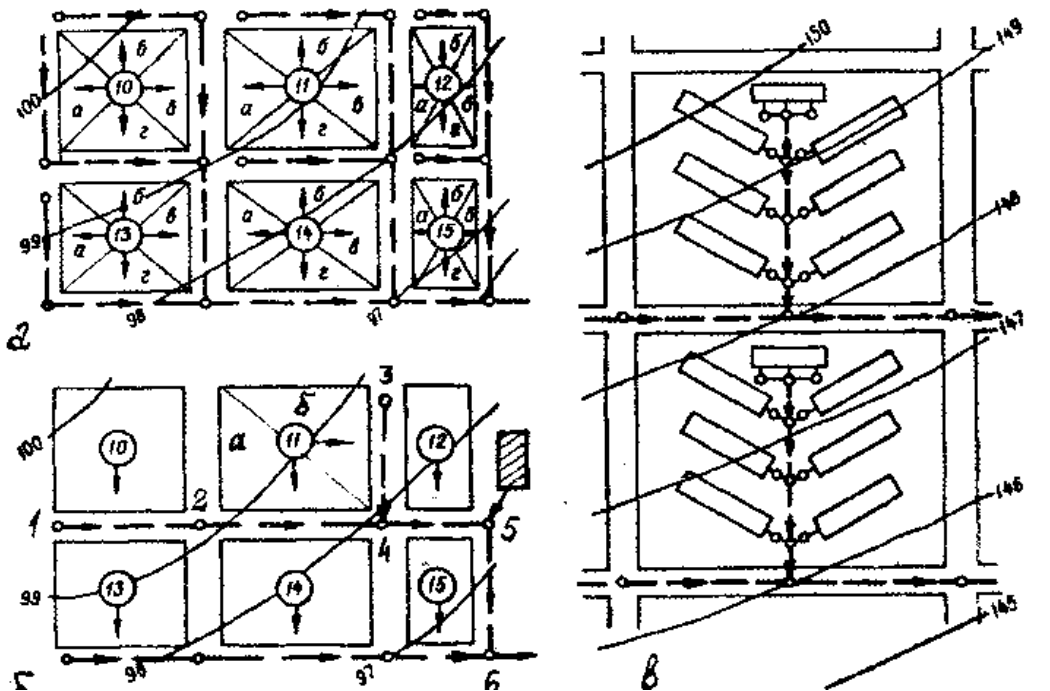


Fig 2.3. The schemes of sewerage network tracing:

- a) covering scheme; b) from the lower parts of blocks; c) through-the-block scheme;
 a, b, c, d – block sectors, 10-15 blocks numbers; 1-6 junction wells

The sewerage system is designed in accordance with the current normative documents, which stipulate the rules of selecting a sewage system, normative materials for estimating waste water expenditure and determining the dimensions of sewerage facilities, hydraulic estimation of networks and equipment, technological estimation of waste water treatment plants, etc.

2.2.3. The norms and the mode of water drainage. Estimated expenditure of waste water.

To estimate waste water expenditure at the end of accounting, data on the number of population and data on enterprises are to be provided.

The estimated number of inhabitants N is determined depending on the density of population of a given neighborhood (block):

$$N=pF \quad (2.1)$$

where F is the area of the neighborhood (block) that is drained, ha; p- the number of inhabitants occupying 1 ha of the relevant area – population density, men/ha.

The density of city and town dwellers varies depending on the number of stories in a building between 50 and 700 people per 1 ha.

Domestic waste water expenditure depends on the norms of water drainage and the number of dwellers using sewerage; industrial waste water expenditure depends on the norm of industrial waste water drainage and the output volume. The norm of water drainage is a per capita water expenditure, expressed in l/day, or the amount of waste water, m³, per a product unit produced by an enterprise. The norm of water drainage for localities is equal to the norm of water consumption and can be accepted within limits of 125-250 l/day (Table 2.1). Domestic waste water drainage from industrial enterprises should be considered separately (Table 2.2). When setting the norms of industrial waste water drainage, the data provided by technologists are used, while when setting the norms of waste water drainage for individual buildings and constructions for special purposes leading-away of industrial drainages are used technologists data, and while determination of norms of water drainage from separate buildings and constructions serving some special purpose the norms of indoor plumbing and sewerage are used.

Table 2.1

Norms of waste water drainage in residential developments

The degree of the neighborhood improvement	The norm of per capita water drainage, average daily (per year), q, l/day
Development with buildings having indoor plumbing and sewage, without baths	125-160
Development with houses having indoor plumbing, sewage and baths with local water heaters	160-230
Development with houses having indoor plumbing, sewage, and central hot water running system	230-350

Notes:

The norms of waste water drainage shall comply with the norms of water supply adopted for the given object.

The norm of waste water drainage for non-drained neighborhoods should make 25 l/day per person.

The amount of waste water drained from the enterprises of the local industry as well as unaccounted expenditure are assumed to constitute 5-10 % of the total amount of waste water for the given locality.

Table 2.2.

Norms of domestic waste water drainage of industrial enterprises

Type of manufacture	Norms of water drainage for one worker per shift, l	Coefficient of hourly non-uniformity of water drainage
In manufactures with considerable heat release (more than 23,2 Vt/m ³ *hour)	45	3
In other manufactures (cold)	25	2,5

Waste water gets to a sewerage network in a non-uniform manner on a daily basis as well as an hourly basis. The non-uniformity is characterized by the graph which is similar to the relevant graph of water consumption (Fig.1.28).

Estimated water expenditure per hour and per second expenses is determined by the general ratio of the non-uniformity of waste water inflow, K, which depends on average expenditure of domestic waste water:

Q	5	10	20	50	100	300	500	1000	5000
K	2,5	2,1	1,9	1,7	1,6	1,55	1,5	1,47	1,44

Domestic waste water expenditure is determined by formulas:

Average daily (2.2)

$$Q_w = \frac{N \cdot q_w}{1000}$$

Maximum daily (2.3)

$$Q_w = \frac{N \cdot q_w \cdot K_{\text{доб}}}{1000}$$

Maximum hourly (2.4)

$$Q_w = \frac{N \cdot q_w \cdot K_{\text{dep.max}}}{24 \cdot 1000},$$

Maximum per second (2.5)

$$Q_w = \frac{N \cdot q_w \cdot K_{\text{dep.max}}}{24 \cdot 3600},$$

where N is the estimated number of inhabitants; q is the average daily norm of water drainage, l/day;

K = 1,1-1,3 is the ratio of daily non-uniformity of waste water inflow.

Average daily, m³/day, and maximum per second, l/sec, expenditure of industrial waste water is calculated by formulas:

$$Q_w^* = \frac{\Pi \cdot q_w}{1000},$$

$$q = \frac{\Pi_i \cdot q_w^* \cdot K_u}{3600 \cdot T},$$

where P is the daily production output; P1 is the daily production output at maximum operation efficiency; q is the norm of industrial waste water drainage per product unit; K is the ratio of the non-uniformity of industrial waste water inflow.

In fact, sewerage networks are calculated by the maximum waste water expenditure per second. Estimated expenditure can be comfortably determined by drainage modulus, q. Drainage modulus is water expenditure, expressed in l/sec, per 1 ha of building development area:

$$q_D = \frac{q_w \cdot P}{86400},$$

where p is population density per 1 ha; q is the norm of water drainage, l/day.

Drainage modulus is determined for each block, which differs from others by its population density and the norm of water drainage.

Before making hydraulic estimation of the sewerage network, it is divided into estimation areas. An estimation area of a network is a part of sewerage line between two points (wells), on which estimated waste water expenditure is assumed to be constant.

The estimated expenditure for the area is found as the total of expenditures:

- en route expenditure which come to the estimated area from the residential building located along the area;
- transit expenditure coming from the above located blocks;

- side expenditure coming from the side lines which connect to the area;
- concentrated expenditure coming to the estimated area of the network from individual consumers of large quantities of water (for example, industrial enterprises).

En route expenditure is variable for the network area. It grows from zero at the beginning of the area up to its maximum value at the end of the area as courtyard and block networks connect to the area. To simplify estimations, it is assumed that all en route expenditures of residential blocks reach only the starting point of the area. For the estimated areas of the street sewerage network, the value of the en route wastewater expenditure is found by bisecting the block.

According to the covering scheme, waste water comes to the estimated area from the entire area of the adjacent block. When drawing the network from the lowered part of the block or when using through-the-block scheme, waste water comes to the area from the entire area of the block located above the estimated network area.

Water expenditure calculations are, as a rule, made in the form of a table (Table 2.3).

(Table 2.3).

Results of waste water expenditure calculations for the network given in Fig. 2.3b

Estimated Areas	The numbers of the blocks supplying water		Drainage area, ha	Drainage modulus, l/sec	Average drainage expenditure of blocks, l/sec			Ratio of non-uniformity of water inflow	Estimated expenditure of waste water, l/sec			
	En route	tributary			En route	transit	total		Domestic water	local	transit	total
1-2	10	-	6	0,6	3,6	-	3,6	2,50	9,0	-	-	9,0
2-3	11a	10	4+6	0,6	2,4	3,6	6	2,42	14,5	-	-	14,5
3-4	11b	-	4	0,6	2,4	-	2,4	2,50	6,0	-	-	6,0
4-5	12	10,11	3+14	0,6	1,8	8,4	10,2	2,10	21,4	-	-	21,4
5-6	-	10,11,12	17	0,6	-	10,2	10,2	2,10	21,4	16	-	37,4

2.2.4. Hydraulic calculation of sewerage networks

For the known water consumption, hydraulic calculation of sewerage network consists in selecting the diameter of the pipe and the slopes that would ensure such velocity of flow that would be sufficient to carry pollutants moving with the flow. Waste water can flow through the sewerage network under pressure or without it.

Domestic sewerage gravity network assume incomplete filling of sewerage pipes with waste water. It allows to create the most favourable hydraulic conditions for transporting suspended substances, ensure network ventilation, remove harmful and explosive gases from the network and create some reserve of the pipe cross-section to handle extra waste water expenditure, not foreseen by calculations.

Filling is the ratio of the height of the water layer in the pipe (h) to the diameter of the pipe (d). It is recommended that the following estimated fillings of the pipes depending on their diameter be accepted:

D, mm	150-250	300-400	450-900	More than 1000
h/d, no more	0,6	0,7	0,75	0,8

For the pipelines of the rain and general sewerage the complete filling of the pipes at maximum expenditure should be accepted.

With the estimated filling of the pipes of domestic sewerage, the velocity of waste water flow shall not be less than:

D, mm	150-200	300-400	450-500	600-800	900-1200	1500
V min, m/s	0,7	0,8	0,9	1,0	1,15	1,3

The highest estimated speed of wastewater flow should be: 8 m / s - for metal pipes and 4 m / s - for non-metal pipes. For rain sewerage the velocities of 10 and 7 m / sec are accepted.

For hydraulic network estimation the formulas of the uniform flow are used (2.9; 2.10)

$$q = \omega \cdot v,$$

$$i = \frac{\lambda}{4R} \cdot \frac{v^2}{2g},$$

where q - waste water expenditure, m^3 / s ; ω - cross section area, m^2 ; v - average water flow velocity m / s ; $i = h / j$ - hydraulic slope that is for uniform flow equals the slope of feeder pipes; λ - the coefficient of hydraulic friction; $R = \omega / x$ - hydraulic radius, m ; x - hydraulic perimeter, m ; g - acceleration of gravity, m/s^2 .

It is recommended that the coefficient of hydraulic friction be defined as (2.11):

$$\frac{1}{\sqrt{\lambda}} = -2\ell g \left(\frac{\Delta e}{13,68R} + \frac{a_2}{R_c} \right)$$

where Δe – equivalent hardness, cm ; a_2 – coefficient, depending on the pipe stiffness.

In practice, when making hydraulic estimations of sewerage pipes formulas are rarely used, with graphs, nomograms, tables made by these formulas being used more often.

Minimal pipe diameters of gravity sewerage make: for the street network - 200 mm, for the outdoor and block network – 150 mm, for the rain and the general flow street network – 250 mm, for the rain block network – 200 mm.

2.2.5. Deepening of sewerage pipelines

The cost and the terms of sewerage construction depend, to a high degree, on how deep the pipes are laid. It is advisable that the pipes are laid at the minimum depth, with the following requirements being taken into account:

- prevent waste water freezing in the pipes;
- protect the pipes from mechanical damage;
- provide connection of the outdoor and inside-the-block networks to the street network.

With the data on sewerage operation for the construction site or similar conditions being unavailable, the minimum deepening of the pipes with the diameter of up to 500 mm is 0.3 m less than the largest depth of soil freezing of soil in a given area, and with larger pipe diameters it is 0, 5 m less, but not less than 0.7 m to the top of the pipe. Laying pipes in the layer of soil freezing is allowed because the temperature of waste water does not fall below 7 ° C even in the coldest seasons.

To prevent damaging sewage networks by surface transport, the minimal deepening of the pipes of the outdoor and block networks is, as a rule, 0,7 m, and street urban networks – 1,5 m to the top of the pipe.

The initial deepening of the street network is determined taking into account the connection of the outdoor or block network by the formula (Fig. 2.4):

$$H = h + i(L + \ell) - (Z_2 - Z_1) + \Delta d,$$

where h is the least deepening of the pipes in the most remote and poorly located wells of the outdoor network; i is the pipe slope of the outdoor or block network, $(L + \ell)$ is the length of the outdoor or block network from the farthest well to the place of connection to the street network; Z_2, Z_1 are the benchmarks of the ground surface near the street well and the most distant yard well respectively, and Δd is the difference in pipeline diameters of the street and the block network at the point of their junction.

With open construction, the pipes are laid the deepest - 5 - 8 m depending on the type of soil, the level of the ground water and other factors. With closed operation the depth of pipelaying is virtually unlimited. However, it should be kept in mind that the closed methods of the pipelaying are costly enough, therefore, the depth of pipelaying should be limited.

On the plan, the distance between the pipelines and the underground parts of the building foundation and other underground structures for the pressure pipelines is not less than 5 m, while for the gravity pipelines it is 3 m. When laying pipelines with the open method applied, this distance shall not be less than determined by the following formula (2.13):

$$L = h / \operatorname{tg} \alpha + b / 2 + 0,5,$$

where h is a vertical distance between the foundation sole and the pipe tray, $\operatorname{tg} \alpha$ is a ground slope angle (in trenches without bracing); b - the width of the trench, m.

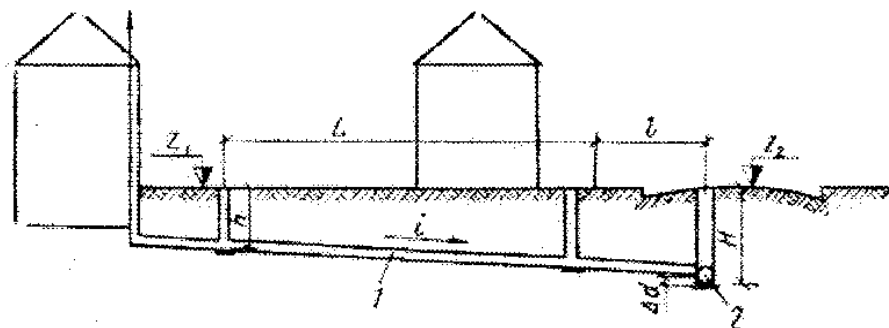


Fig. 2.4. The scheme of determining the initial depth of the street network:
1 – intradistrict network; 2-street network

When designing and constructing sewerage networks and laying pipelines the distance to other underground utilities should be considered:

- to heating lines -1.0 - 1.5 m;
- to power lines of under 35 kV - 5 m;
- to power transmission lines of over 35 kV - 1.0 m;
- to the valuable species of trees - 2.0 m;
- to the poles of lighting, communication, contact network -1.5 m.
- to the board stone of motorways -1.5 m;
- to the edge of the ditch - 1.0 m;
- to the tram and factory tracks -1.5 m;
- to the railways of the total network-4m (to the axis lines);
- to the foot of embankment - not less than the depth of the trench.

The minimum distance between the drainage network and the gas pipeline in case of parallel pipelaying depends on the gas pressure in the gas pipeline:

- at a low pressure of up to 5 kPa - 1.0 m;
- at an average pressure of up to 0.3 mPa - 1.5 m;
- at a high pressure of up to 0.6 mPa - 2.0 m;
- at a high pressure of up to 1.2 mPa-5m.

The minimum distance between the drainage network and the pipeline shall be:

- for the parallel pipelaying at the same level and with the water pipeline diameter of up to 200 mm the distance shall be not less than 1.5 m, for larger diameters - not less than 3 m;

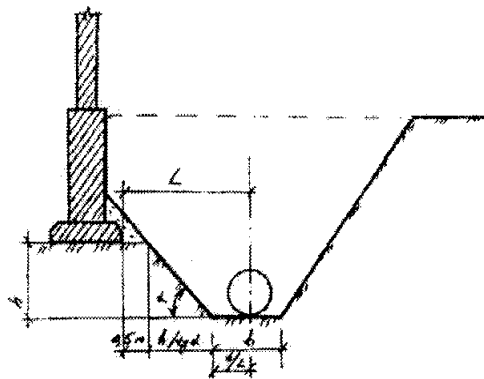


Fig. 2.5. The scheme of determining the distance between the building foundation and the drainage pipeline

- when laying the drainage network 0.5 m higher than plumbing, the distance between them shall be not less than 5 m.

In the points of intersection with plumbing, water drainage network is laid at least 0.4 m lower than plumbing, and in cases when the plumbing network is laid above the water pipeline, the plumbing should be protected with casing.

The length of the protected area on both sides of the intersection is: for waterproof grounds (clay) - not less than 3 m, for filtering grounds - 10m.

2.2.6. Requirements to the design and construction of the longitudinal profile of sewerage network

Normal hydraulic conditions for sewerage network operation are provided not only by accurate hydraulic estimation but also by the appropriate design of its individual elements. When designing sewerage networks the following requirements must be met:

- 1) sewerage lines between the wells should be laid in straight lines. On the plan (at the points where the pipes turn) or on the profile (with change in the slope) at the points where the pipes change their direction as well as at the points where one or more pipes are connected, wells should be installed;
- 2) in the wells, the pipes and reservoirs are connected in the form of open trays;
- 3) the pipes and channels in the wells must be connected at the top of the pipes or at the water level (Fig. 2.6a, b). For the pipes of different diameters, top connection is recommended, while for the pipes of the same diameter – connection at the water level.

In cases when the diameter of the preceding pipe is larger than that of the successive, “tray” connection is advisable (Fig. 2.6v).

When connecting inter-block and courtyard networks to outdoor street networks the connection scheme "pipe tray-water level" is used (Fig. 2.6h);

- 4) the calculated flow velocity must grow as water moves along the collector. Reduction in the estimated downstream flow velocity, but not less than the critical velocity, is acceptable provided the flow velocity in the preceding well also decreases;
- 5) counter currents or current blows are not acceptable at the points where currents join. The angle between the inlet pipe and the drainage pipe should be not less than 90 °. If a riser is installed in a well the flows can join at any angle;
- 6) the adjoining flows must be at the water level or higher than the main flow, with the flow velocity being smaller than that in the main pipe. Small pipes, block and courtyard pipes in particular, are joined to large collectors so that the tray of the small pipe is at water level of the large pipe.

Hydraulic estimation of the sewerage network is accompanied by altitudinal bunching of the pipes, with the longitudinal profile of the network being build with

regard to the above mentioned conditions. Pipe diameters and slopes, the length of the estimated areas, the marks of the ground surface and pipe trays as well as the well depths are indicated on the profile.

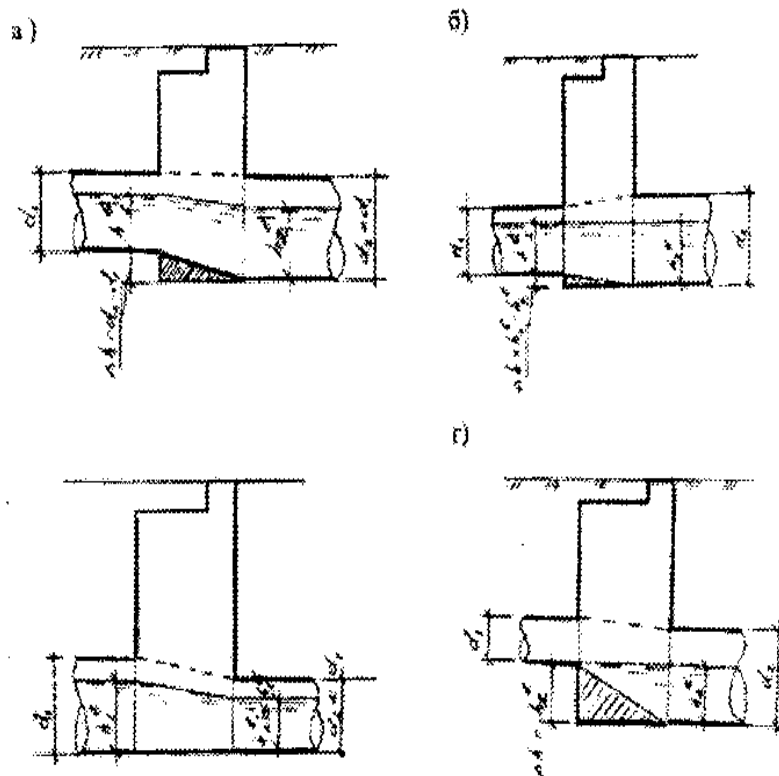


Fig 2.6. The schemes of pipe connection:
 a – top of the pipe connection; b – water level connection;
 c – tray connection; d – tray – water level connection

Also, all intersections with water barriers (rivers, channels), surface facilities (railways, motorways) and underground utilities are shown. Data on the grounds and the groundwater are given in the form of well and hole sections at the corresponding points of the profile design line.

The pipe trays are marked with the accuracy of up to 1 mm (with 3 decimal points), the ground surface and depth of wells – with the accuracy of up to 1 cm (with two decimal points). In the points where the pipe's size changes or in the drop points the pipe trays have two design marks. The horizontal scale of the profile is, as a rule, taken to be equal to the scale of the plan, while vertical scale is 1:100.

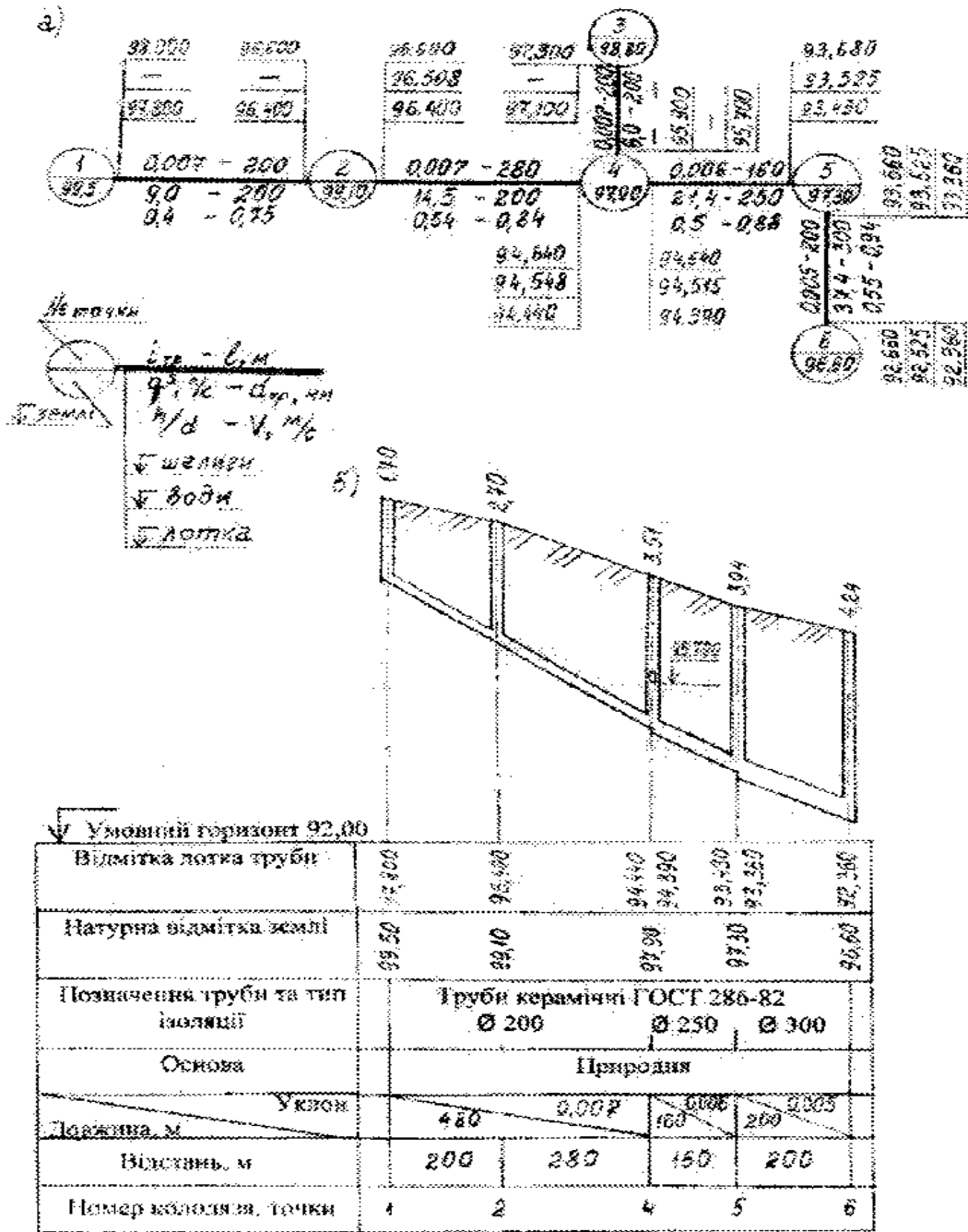


Fig 2.7. Estimation scheme of the altitudinal bunching of sewage network (a) and the longitudinal profile of collector (b)

Fig. 2.7 shows the scheme of altitudinal bunching and longitudinal profile of a network site given in Fig. 2.36 with the estimated costs given in Table. 2.3. Based on the longitudinal profile of the sewerage network more detailed profiles of working drawings are developed, with both estimated and line wells being shown. Working drawings are used to build sewerage pipelines.

2.2.7. Pipes, sewers and wells in a sewer network

The material the pipes, sewers and their connections are made of should meet a number of requirements: strength, no deformation under the weight of the soil or transport, corrosion and mechanical wear resistant, smooth inner surface, water resistance, no waste water leak (exfiltration) or ground water leak (infiltration). Ceramic, concrete, reinforced concrete, asbest-cement, metal and plastic pipes meet these requirements (Fig. 2.8).

Ceramic pipes are used for non-pressure sewer networks; these are pipes with circular cross-section having sockets, with inner diameter of 150 - 600 mm and the length of 800 - 1000 mm. When connecting ceramic pipes the spigot of one pipe is put into the socket of the other pipe. The gap between them is filled with a compactor by $1/3 - 1/2$ of the socket depth, with the remaining the gap being filled with the material which forms a lock keeping the compactor within the socket. Rubber rings, tarred hemp rope or strand are recommended to be used as compactors, and asphalt mastic, asbestos or cement can be used as the lock (Fig. 2.9a).

Ceramic pipes with conical plastizole rings, which are fixed on the pipe by a manufacturer, have been used recently. To assemble a joint, the pipes are gently joined. Both rings get wedged forming a tight flexible joint (Fig. 2.9b).

There can be manufactured concrete and reinforced concrete pipes of pressure type and non-pressure type, having sockets or smooth edges. Concrete pipes have a diameter of 200 - 600 mm, and concrete (non-pressure) - 400 - 3500 mm. The length of the pipes depends on their diameter and manufacturing method.

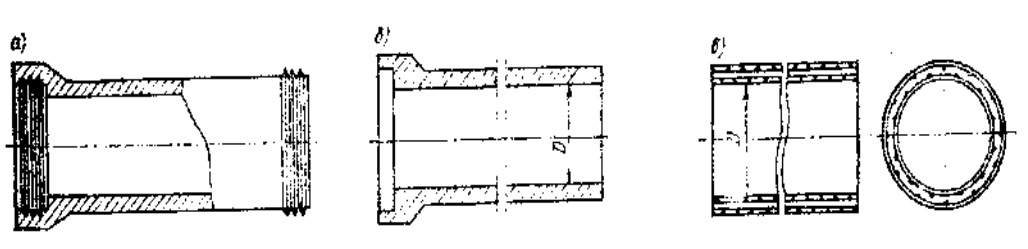


Fig 2.8. Sewage pipes:

- a) ceramic; b) concrete non-pressure with sockets; c) reinforced concrete with spigots

Socketed concrete and reinforced concrete pipes are connected in the same way as socketed ceramic pipes, while the spigot pipes are connected with the help of clutches or cement belts (Fig. 2.9v, d). Synthetic materials such as polyurethane can be used to pressurize the joints.

Asbestos cement pipes (pressure and non-pressure) have spigots with the diameter of 100-600 mm. They are connected with the help of cylindrical clutches. To make joints more compact, rubber rings are used or gaps are pressurized in the same way as gaps in socket joints for ceramic pipes.

Cast iron and steel pipes are mainly used for pressure sewage pipelines. For the outdoor non-pressure sewage network steel pipes are used only where a high degree of pipe impermeability is expected, for example, at the points of the pipeline intersection with railways, highways or water barriers. Metal pipes connection can be of a weld, flange or socket type.

When laying gravity sewer systems pipes made of synthetic materials (vinyl plastic, polyethylene, etc.) can also be used.

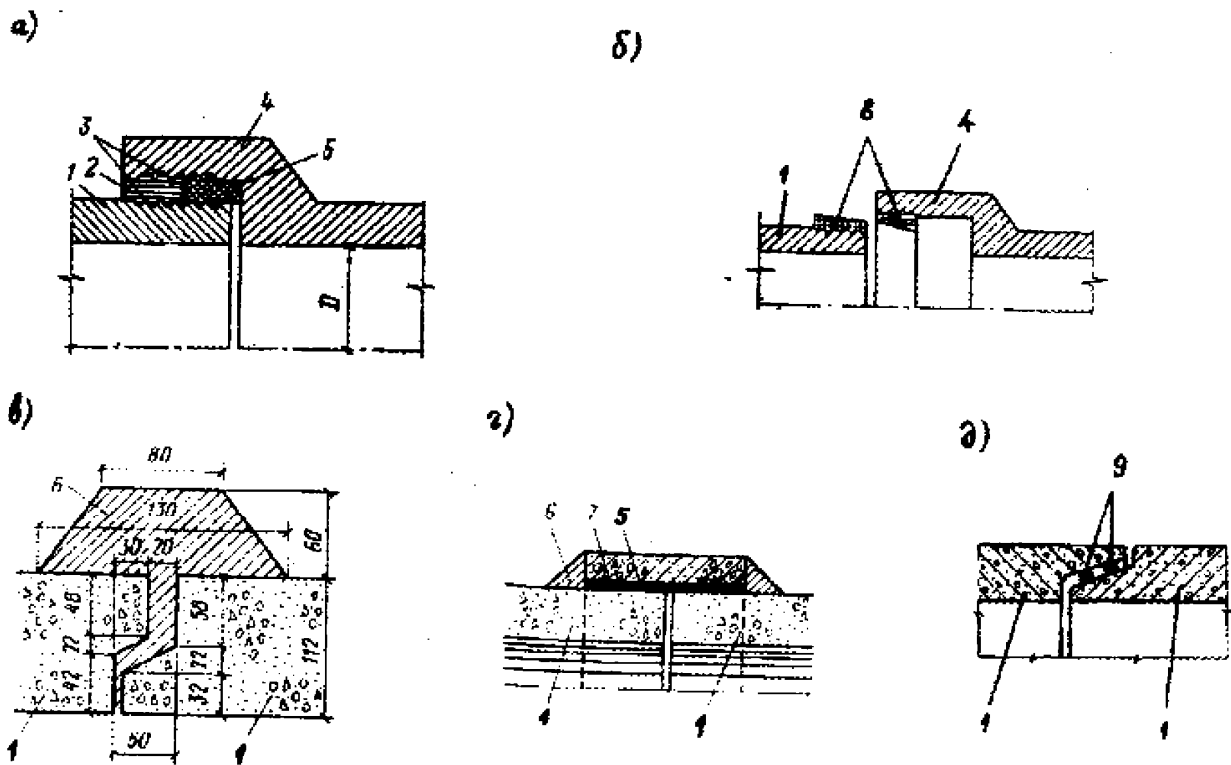


Fig. 2.9. Joints of ceramic (a, b) and reinforced concrete non-pressure pipes(c, d, e): 1 – pipe spigot, 2 - asphalt mastic or asbestos cement (cement) filling, 3 - uncoated furrows, 4-socket, 5-tarred hemp rope or strand, 6 - cement mortar, 7 - reinforced concrete clutch, 8 –plastisol rings, 9 - rubber rings

Depending on the type of soil, the material and diameter of pipes, the pipes are laid placed them directly on the ground or some artificial foundation. The use of artificial foundation to lay pipes on is necessary when the bearing capacity of the soil is poor or the bearing capacity of the soil decreases due to wetting or for some other reasons. For loamy, clayey and dry clayey soils the pipes are laid on a sand bag, for saturated soils – on the layer of gravel, road-metal or coarse sand, and in some cases - on a concrete foundation (Fig. 2.10,2.11).

In peat bogs, quicksand and weak bulk soils the foundation is made on piles for pipes of all diameters, with joints being sealed with elastic materials. Domestic, industrial, combined and rainwater sewers are manufactured mainly from large prefabricated concrete elements. Large size sewers can have circular, rectangular or other cross-section.

Sewage pipes and channels must satisfy hydraulic, static, economic and operational requirements.

In order to inspect and clean sewerage network manholes are built. They are arranged where the line changes its direction, diameter or slope. Depending on their designation manholes are divided into linear, turning, connecting, controlling, washing and drop manholes.

Linear manholes are set on the straight sections of sewer systems every 35-300 meters depending on the pipe diameter.

Turning manholes are installed in places where network changes its direction in plane or in height. Connecting manholes are installed at the junctions of sewer lines.

Washing manholes are set in those sectors of the sewer where some precipitation in the pipes can be expected.

Drop manholes are set in places where pipes are connected at various depths, which occurs when lateral inflows join the main sewerage network, or when drops are made due to sharp change in terrain, or when the speed of waste water flow should be reduced.

Manholes are installed before the red line of building development in places where yard, block or industrial networks connect to outdoor sewerage.

For pressure pipelines, manholes are installed when latches, outlets, air eliminators and other fittings are to be placed in them.

Manholes are made from bricks or concrete. On the plan they can be of a round or rectangular shape (Fig. 2.12).

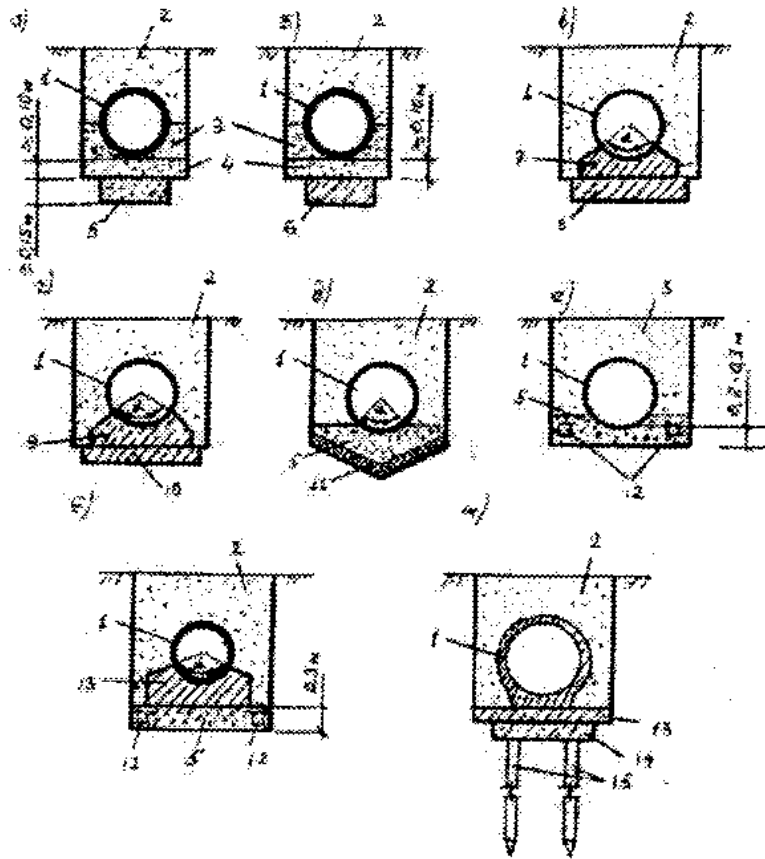


Fig. 2.10. Artificial foundations for gravity pipelines:

a-gravel and road-metal; b-flat reinforced concrete foundation ; c- concrete profiled; d-reinforced concrete profiled; d - road-metal with waterproof tray; e-gravel and road-metal; f - concrete with drainage; g-reinforced concrete on piles; h - pipeline: 2 - trench filling, 3 – dense trench filling, 5 – gravel and road-metal preparation; 6 – flat reinforced concrete foundation, 7 - concrete foundation (1st layer) 8 - concrete foundation (2nd layer), 9 - profiled reinforced concrete foundation, 10 - concrete preparation, 11 - waterproof layer (soil and asphalt), 12 - drainage, 13 - cement mortar; 14 – reinforced concrete belt, 15 – reinforced concrete piles

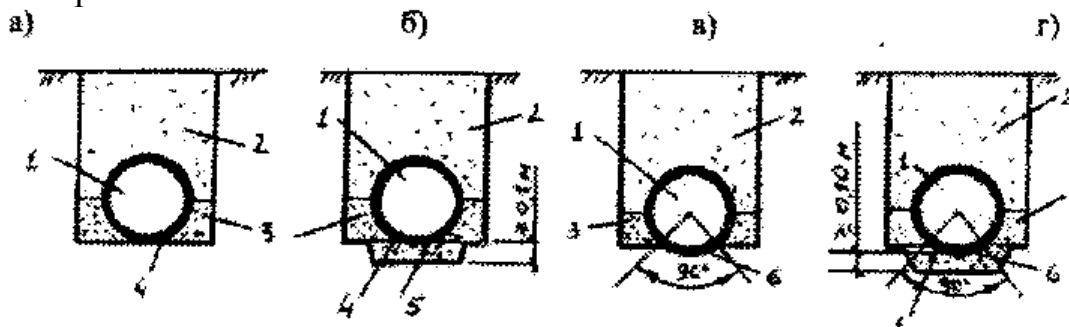


Fig. 2.11. Natural foundations for gravity pipelines:

a- flat ground foundation; b - flat foundation with sandy soil preparation, c- ground profiled foundation; d-ground profiled foundation; 1 – pipeline; 2 – trench filling; 3 - dense filling, 4 - flat foundation, 5 - sand bag, 6-profiled foundation

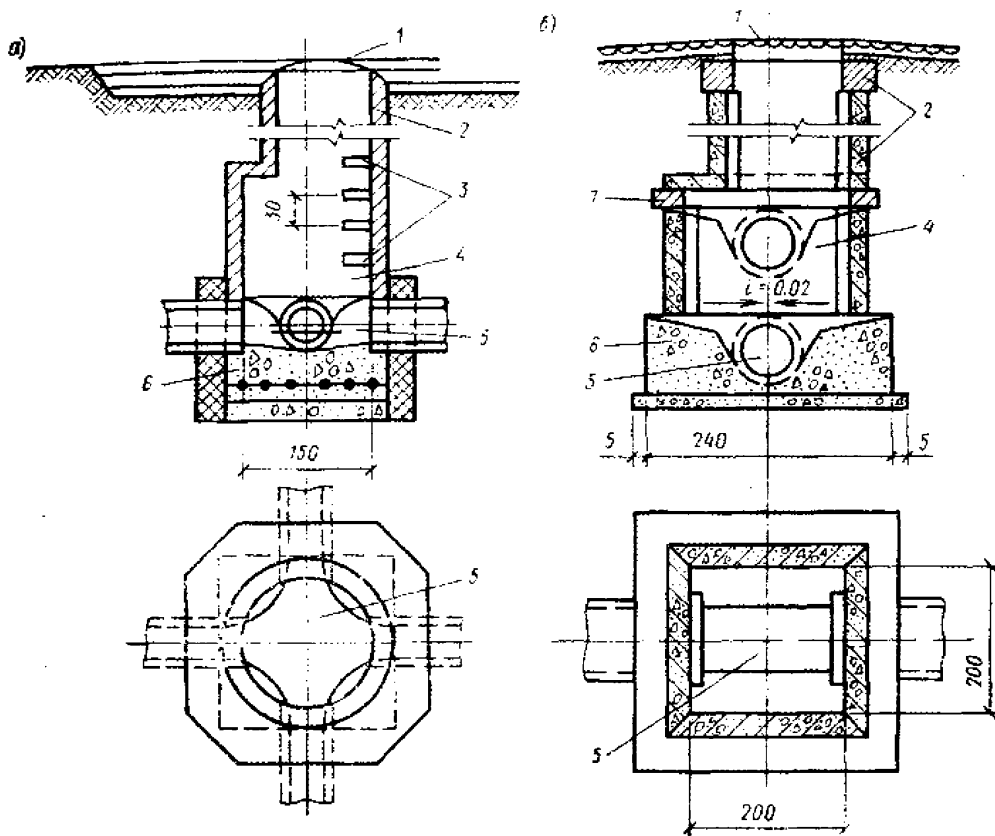


Fig. 2.12. Manholes:

- a) round b) rectangular: 1 – cast iron manhole with lid, 2 – manhole; 3 – clamps; 4 - working chamber, 5 – tray; 6 - concrete floor, 7 - floor slab

The basic elements of the wells are: foundation (preparation, slab and ramming tray), working chamber ceiling or transitional part, manhole with lid. As a rule, the height of working chamber is 1800 mm. The dimensions of the chamber make it possible to inspect, clean and maintain the network.

The diameters of round cells of linear wells in domestic network depend on the diameter of the largest pipe.

The dimensions of rectangular chambers are:

- for the pipes with a diameter of 700 mm -1000 mm;
- for the pipes with a diameter of more than 700 mm – the length L and width B are found by the formulas:

$$L = d + 400 \text{ mm}; B = d + 500 \text{ mm}, \quad (2.14)$$

The transitional part between the working chamber and the manhole is a flat ceiling or sided cone.

Workers get into the chamber through the manhole. Its height depends on the depth of pipelay. The diameter of the manholes in sewerage systems is 700 mm. Working chambers and manholes are provided with clamps and ladders for the workers to descend into the well.

Hatches are set at the same level with the top of the hard surface roads, and 50 ~ 70 mm above the ground in the green area. Cast iron hatches of "L" type and heavy hatches of "T" and "TM" type made according to GOST 3934-79 are most widely spread.

2.2.8. The intersection of gravity sewer pipelines with barriers

When laying sewer pipelines some barriers can get in the way: rivers, ravines, channels, underground pipelines and facilities, railways and motorways. The lay of sewage pipelines and the type of barriers, as well as local conditions determine how intersection is arranged.

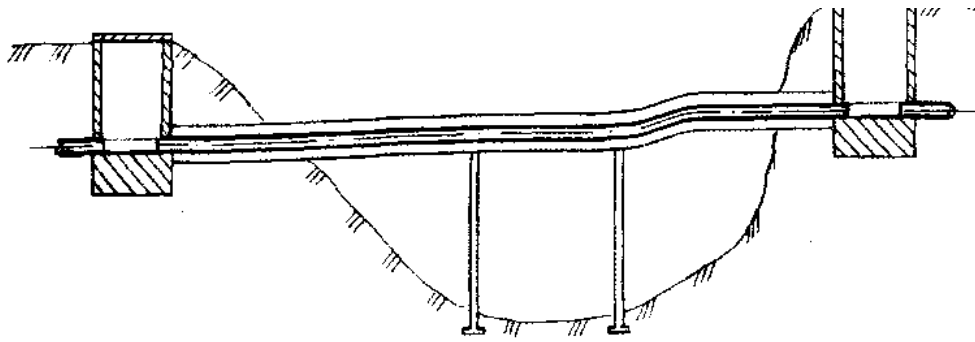
If sewage pipes are laid much higher than the barrier is, the intersection takes the form of a gravity pipeline which is laid along the overpass. An overpass is a supporting construction in the form of a bridge (Fig.2.13). The pipeline is laid in an insulated casing without any change in the slope of the sewer. Overpasses are made from the precast reinforced concrete mounted on the reinforced concrete or metal supports.

If sewage pipelines are laid much lower than the barrier is, intersections take the form of a gravity pipeline laid in a casing or in penetrable or impenetrable tunnels (Fig. 2.14).

If sewage pipelines and the barrier are at the same level or the level difference is negligible, the intersection takes the form of a siphon – a penstock connecting two gravity pipelines (Fig. 2.15). All penstocks have top and bottom chambers with two working ropes.

2.2.9. Construction and operation of sewer networks

Sewage networks are built in compliance with the agreed-upon and approved design and estimation documentation in accordance with the network segmentation. Technical control over construction is carried out by the customer (the department of capital construction or technical supervision service) and project organization.



Мал. 2.13. Естакада

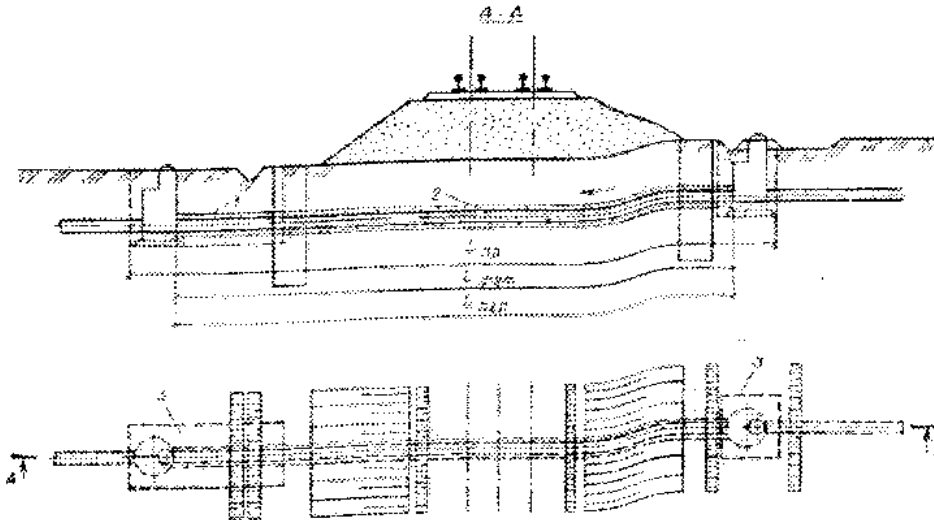


Fig. 2.14. Gravity pipeline crossing the railway:
1 - casing, 2-pipeline

Sewer networks are mainly built using the trench method. Trenches are made with the sloping or vertical walls. In the latter case trench walls are braced. The type of bracing depends on the depth of the trench, soil properties, the availability of the groundwater. The depth of an open trench shall not exceed 5 - 6 m in saturated soils and 7 - 8 m in dry soils.

The pipelaying begins from the bottom of the well, with the sockets against the flow of water. Simultaneously, the joints are sealed.

Before filling the trench it is recommended to carry out the light check of the pipelay. To do this, at one end of the section some light source (a torch) is set and in the other end a mirror is set at an angle to the axis of the pipe. The light disc of the correct shape (the pipe section) is supposed to be reflected in the mirror. The shift of the light disc upwards or downwards indicates that the pipe axis is bent in the profile; the shift to the right or the left indicates that the pipe axis is bent in the plane.

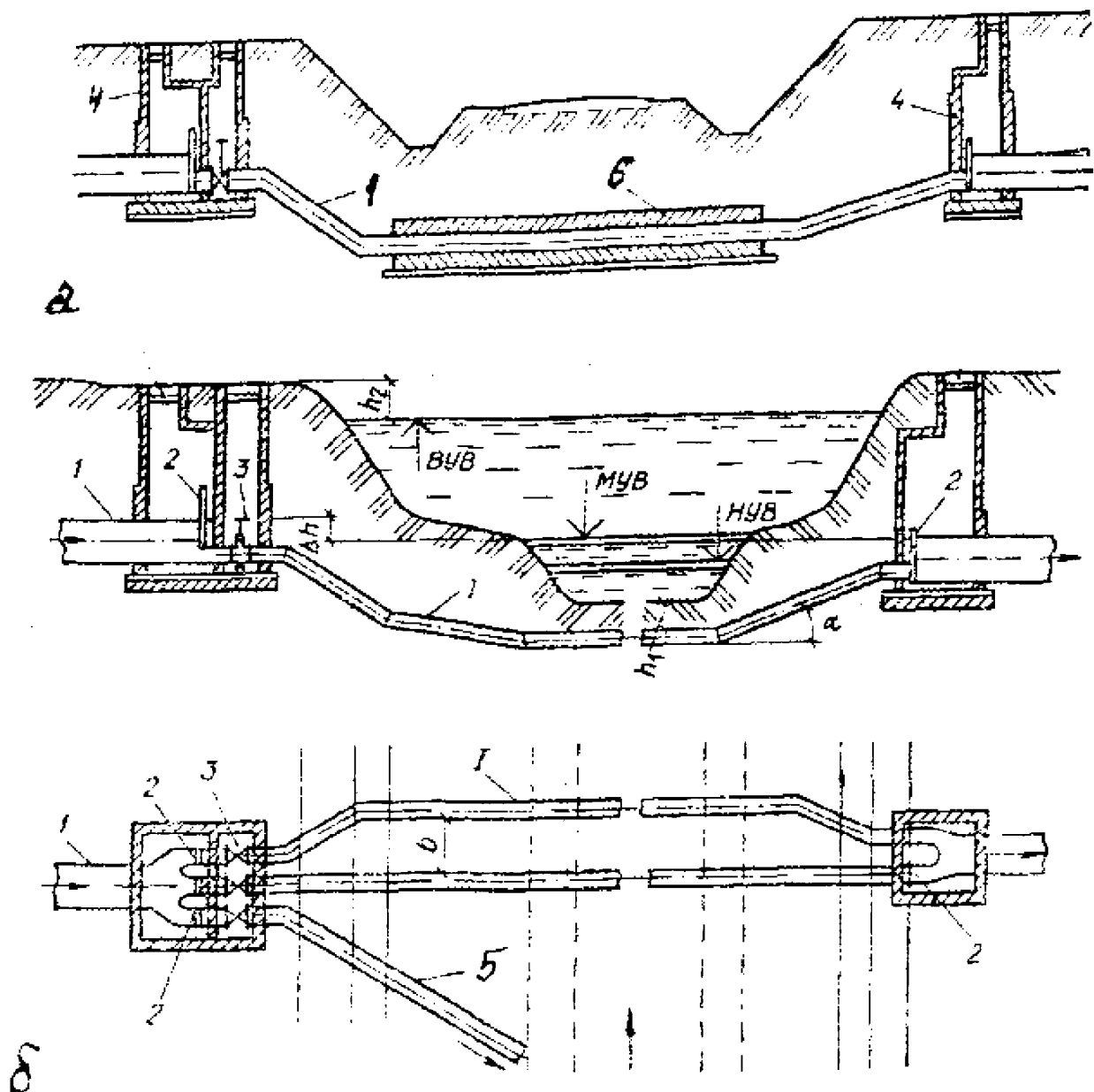


Fig 2.15. Siphons:
 under traffic arteries; b – under water barrier; 1 – pipeline; 2 – gate; 3 – latch;
 4 – well; 5 – emergency extension; 6 – casing

After the pipes have been laid, the trays of the manholes are filled and the walls of the manholes are mounted.

The closed method of laying sewer pipelines is used for building networks under the driveways with heavy traffic as well as the deep pipelaying. When making transitions under highways and railways with the closed method used, horizontal drilling and puncture are used. When sewers are built at great depths, underground shield passage is used similar to that one used in building subways. A shield passage is a mobile metal construction of a cylinder design under the protection of which the rock is developed, with a fortifying tunnel being mounted in the rear part

of it. Sewer networks that have been built must be taken into operation. For this a customer submits the following documents to the commission:

- run-built drawings of the network;
- acts of dismantling facilities;
- acts of hidden and special work (making the pipe foundation, sealing joints, waterproofing, welding and other);
- agreement to all changes in the project (with the customer and the authors of the project);
- acts of hydraulic test (exfiltration and infiltration);
- passports for pipes, building materials and details;
- certificate given by operating organization on the terms of defect elimination, if there were any.

When taking sewer networks into operation, special attention should be paid to:

- a) the quality of foundation under the pipes and the sealing of joints (recorded in the acts of hidden work);
- b) the straightness of the pipes laid between two joint wells using the light test. When examining the pipeline a deviation from the image of the correct circle is allowed to be not more than $1 / 4$ of the diameter horizontally, but not more than 50 mm in each direction. Vertical deviations from the right shape are not allowed;
- c) hydraulic testing of pipelines. Pipelines are tested for water leak by the amount of water added to the tank (Fig. 2.16). Visually, pipelines are tested for infiltration (groundwater getting into the pipes and wells at a high levels of groundwater) by the presence of water flow in the pipe. The results of hydraulic tests are compared with the data given in Table. 2.4.

For normal operation of the sewerage network as well as for safety reasons, the technical state of the network should be monitored. External inspection carried out by one or two workers detects defects of hatches and manholes, subsidence along the highway and near the wells. Such inspections are carried out every two months.

Technical inspection of sewer networks is carried out 2 times a year by a team of three fitters. The purpose of inspection is to detect any damage of the network (the condition of hatches, trays, braces), the presence of infiltration and ventilation, the fullness of pipes, the necessity of cleaning and repairing the network.

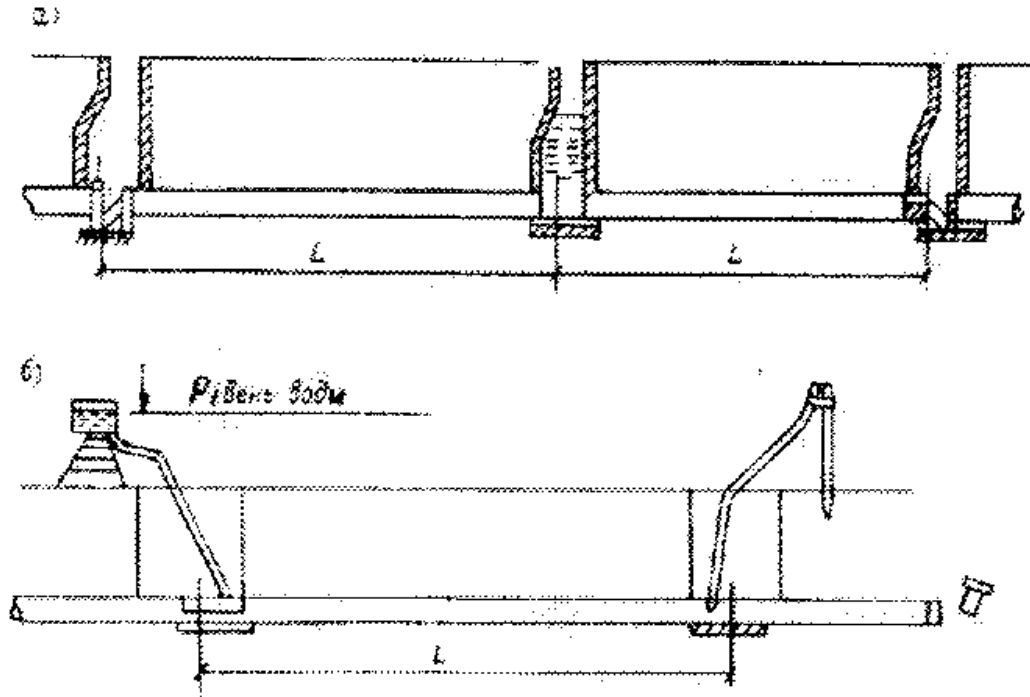


Fig. 2.16. Scheme of hydraulic testing of sewage pipelines:
 a - after installation of wells, and b – before installation of wells

Table 2.4

Allowable values of water inflow or water expenditure through the joints and walls of the pipelines.

Conditional diameter of pipeline, d, mm	Allowable volume of water added into the pipeline (water inflow) per 10 m of the pipeline being tested during 30 minutes for pipes		
	Concrete	ceramic	Asbestos-cement
100	1,0	1,0	0,3
200	4,2	2,4	1,4
300	5,4	3,6	1,8
400	6,7	4,2	2,2
500	7,5	4,6	-
600	8,3	5,0	-

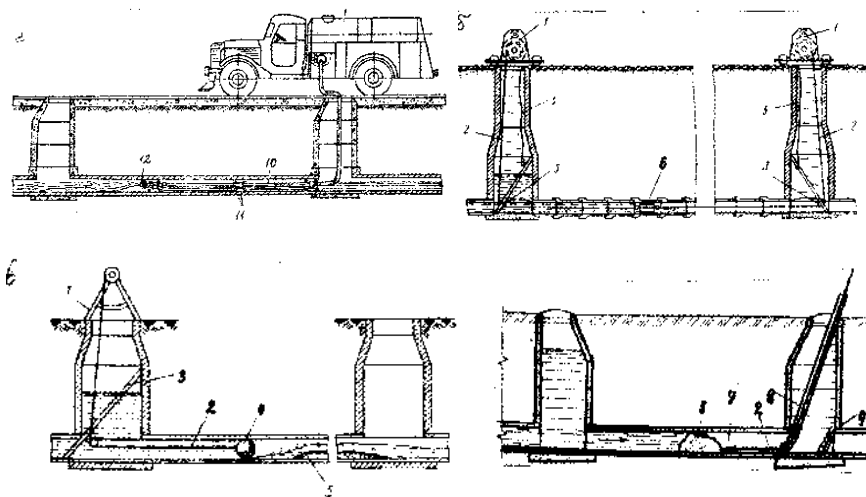


Fig 2.17. Schemes of network cleaning:

a – hydraulic; b, c, d – mechanical; 1 – winch; 2- rope; 3 – support rail; 4 – ball; 5 – jam; 6 – cylinder; 7 – tip; 8 – pipe; 9 – net; 10 – hose; 11 – clutch; 12 – nozzle

Cleaning the network during its operation can be of two types: preventive and emergency. Hydraulic and mechanical methods of cleaning can be used (Fig.2.17)

Hydraulic cleaning consists in watering and removing sediments with water jet supplied at high pressure directly to the pipe through a hose of a special machine. Such cleaning is completely mechanized and is quite progressive from the sanitary point of view. Hydraulic method is used to clean domestic, rainwater, industrial and combined networks with a pipe diameter ranging from 150 to 600 mm.

Hydraulic cleaning is based on washing and transporting properties of waste water flow. The flow of water at a high speed washes and transports sediment downstream. For hydraulic cleaning floating equipment in the form of cylinders or balls is used.

In the process of mechanical cleaning special rods, ropes or wires are used, as well as winches for special devices (ruffs, shovels, etc.).

Repair works carried out during sewer network operation are divided into two types - permanent repair and overhaul.

Permanent repair includes all kinds of work which might disrupt normal operation of the network and facilities. This includes replacement of hatch lids, elimination of cracks in wells, adjustment of hatch lids to the level of the driveway, repair of tray filling in wells, repair of latches and gates, replacement and fastening of braces, etc.

Overhaul implies time-consuming work which requires a lot of effort and materials, namely installation of new wells and pipes and replacement of old wells

and pipes which became unusable. Often, during overhaul the network section is deactivated.

Well-organized sewer operation allows to extend its service life, reduce material and labor costs.

2.2.10. Rainwater sewer network

Rainwater sewerage is used to divert rainwater and melt water. As a rule, it is traced by the shortest route to the place of discharge.

Outdoor rainwater drainage consists of open rainwater ditches and trays, rainwater inlets (rainwater inlet wells), a closed network of pipes and discharges. Through the rainwater inlets water gets into a closed rainwater network. Rainwater inlets are round or rectangular wells covered with metal grates that let water in and stop everything that can cause sewer network clogging (Fig. 2.18,2.19). Rainwater inlets are installed in the lowered part of passages near sidewalks and street intersections at a distance of 50 - 80m from each other.

Rainwater is discharged into reservoirs within the limits of the city or industrial enterprises. For sanitary and aesthetic reasons rainwater should be discharged lower than the river water level.

The sizes of pipes and sewers in the areas of rainwater network are determined by the estimated expenditure of rainwater. This expenditure can be determined by the formula (2.15):

$$q_{\text{p03p}} = q \cdot \psi \cdot F \quad (2.15)$$

where q_{p03p} is an estimated rainwater expenditure, l / s, q – rain intensity, l / ha; ψ – drainage coefficient, F – drainage area, ha.

The intensity of rain, q (l / SGA), is recommended to be determined by the formula (2.16):

$$q = \frac{20^n \cdot q_{20} \cdot (1 - C \lg P)}{t^n}, \quad (2.16)$$

where n and C - coefficients that take into account climatic peculiarities of a given area, q_{20} - intensity of rain, l / s, per hectare during 20 minutes as often as once a year (a constant for a particular area), P - period of time expressed in years during which the network is overflowed with water, and t - estimated duration of rain, min.

When estimating rainwater sewerage with the method of marginal intensities used, rain duration given in formula 2.16 is supposed to correspond to the time of rain duration from the farthest point to the estimated section. So each rainwater sewerage is estimated for the rain of respective intensity.

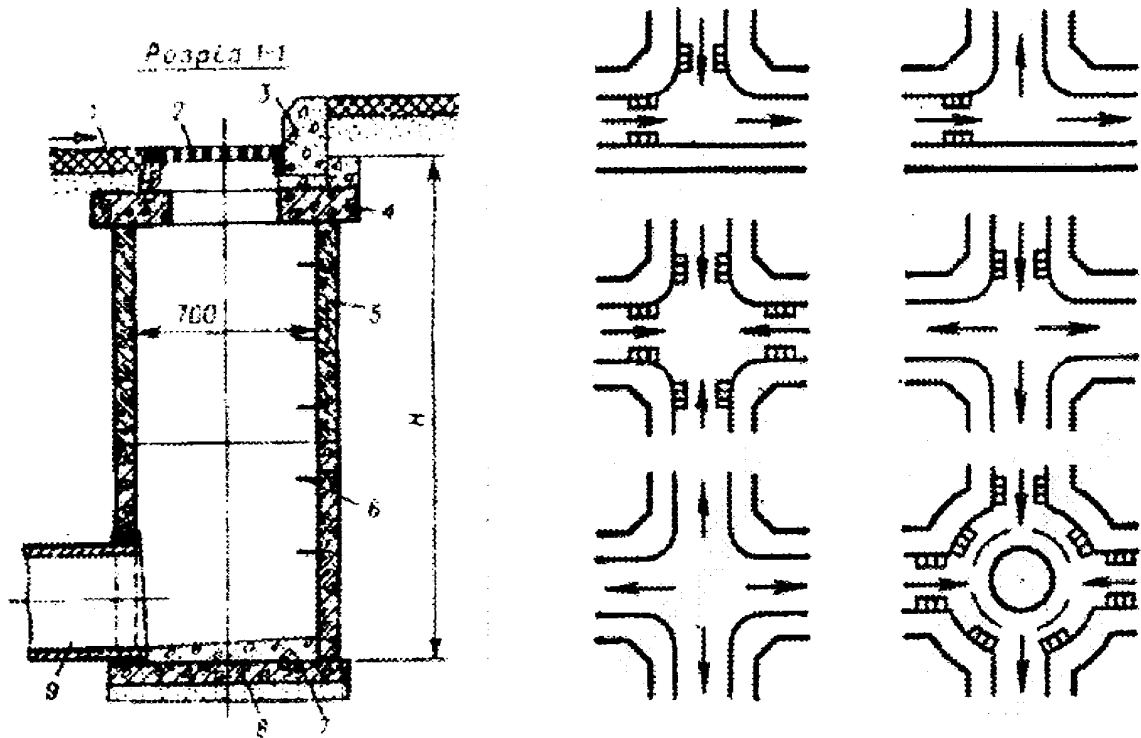


Fig. 2.18. Rainwater wells: a – construction of precast reinforced concrete; b – layout at crossroads: 1 – road surface; 2 – grid; 3 – board stone; 4 – floor slab; 5 – wall rings; 6 – mobile brackets; 7 – concrete; 8 – connecting pipeline

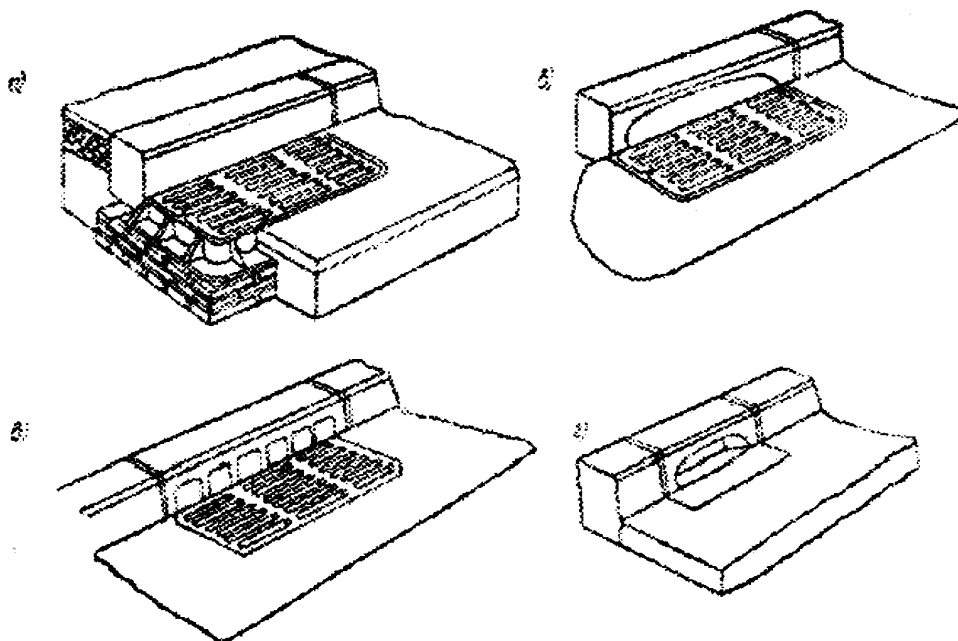


Fig. 2.19. Layout of rainwater wells on roadways: a – open with a rectangular grid in the tray; b – combined with a grid in the tray and a hole in the board stone; c – combined with a grid in the tray and a cast iron board console; d – closed with a hole in the board stone

Drainage coefficient characterizes water tightness of the water intake surface and is found as a ratio of the amount of meteoric water per 1 ha of area to the amount of rainwater drained on the same area.

Hydraulic estimation of rainwater network is carried out using the same formulas as those for domestic network.

For rainwater network ceramic, concrete and reinforced concrete pipes are used. The smallest pipe diameters for gravity networks of rainwater sewage are: for outdoor network - 250 mm, for intradistrict network - 200 mm.

Method of rainwater and melt water drain (open, closed, mixed) is selected according to technical and economic estimations. If the surface drain needs cleaning, when building new sewage systems the necessity of combined or semi-separate drainage system should be considered.

2.2.11. Peculiarities of estimating and installing a combined sewerage network

A combined sewerage system implies a single drainage system for all types of wastewater (domestic, industrial and meteoric). During heavy rains, which are quite rare, rainwater expenditure considerably exceeds domestic and industrial wastewater expenditure. The degree of mixed water pollution decreases, so a part of wastewater can be discharged into reservoirs without being treated. For this purpose, drains are provided on the main sewer or before pumping stations and waste water treatment plants. Such design solution allows to significantly reduce the size of the main sewer and waste water treatment plants, and, therefore, the cost of combined sewerage construction.

Drains are normally made side rectilinear or curvilinear (Fig. 2.20).

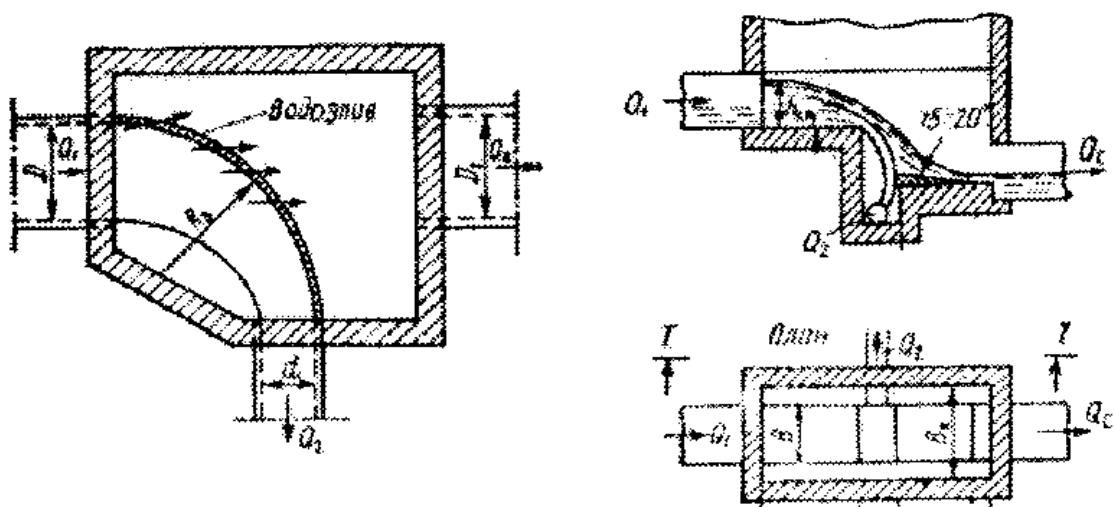


Fig. 2.20. Schemes of drains:
a – side curvilinear, b-with a bottom drain and a threshold

In the rain waste water expenditure for any area of the network that is before the drain is determined by formula (2.17):

$$q' = q_{cit} + q'_r,$$

and for areas lower than the drain - by formula (2.18):

$$q'' = q_{cit} + n_0 \cdot q_{cit} + q''_r,$$

where q_{cit} – sewage water expenditure in dry weather; q'_r - estimated expenditure of rainwater coming into the rainwater network; q'' - estimated expenditure of rainwater after drain to the estimated area; $n_0 q_{cit}$ - expenditure of the rainwater that has been drained, n_0 – coefficient of dilution (ranges within 0,5 – 5 depending on the hydraulic characteristic of the water flow and location of the drain).

The diameters of pipes of a combined network are taken with reference to the complete filling of pipes for the estimated expenditure of all types of waste water in the rain. Hydraulic estimation of a combined network capacity is checked only for industrial and domestic water. In this case the flow velocities should be not less than minimal, i.e. there should be provided self-cleaning of the network in dry weather.

2.3. Pumping of waste water

2.3.1. Pumps used for pumping waste water

In cases when gravity drainage of waste water is unavailable pumps are used. Thus, given the peculiarities of the liquid being pumped (there might be paper, rags and other impurities in it), the pumps should meet the following requirements:

- 1) they shall not be littered with wastes coming from drains;
- 2) their design must allow the cleaning of the impeller, housing, and branch pipes;

Taking into consideration all these requirements the pumps used for pumping wastewater, have a number of design features:

- a) The pumps are built with only one impeller and without guide vanes;
- b) impellers have only two or four blades;
- c) inspection hatches are installed on the pump housing and inlet branch pipe.

For pumping wastewater the pumps brand CM is manufactured. In addition, pumps designed for pumping liquids with a high content of suspended substances (dredge pumps, slurry pumps, peat pumps, screw pumps and others) are used.

2.3.2. Schemes and designs of pumping stations

According to their function sewage pumping stations can be central (pumping wastewater from the entire territory), district (pumping wastewater from individual sewage pools), linear (pumping wastewater from the sewer with the maximum

depth to the sewers which are less deep) and local (pumping wastewater from one or more buildings).

Sewage pumping stations have an engine room, receiving reservoir, household and auxiliary premises. Engine room houses primary and backup pumps as well as all support equipment for the proper operation of pumps. The receiving reservoir forms a regulatory container that provides the most effective uniform pump operation.

Regulatory volume is determined by the combined schedule of wastewater inflow and pumping and should be not less than the volume supplied by the largest pump installed for a period of 5 minutes. The receiving reservoir is equipped with grids to stop large mechanical impurities. These impurities are fractioned in special machines and then dumped into the channel before grids. Machine room and other room services are separated from the receiving reservoir water by a solid watertight and gas-tight wall.

The schemes and designs of pumping stations depend on hydrogeological conditions, the depth of inlet sewer, the type and the number of pumps, peculiarities of pumping units location, etc.

Typically, in lowlands pump stations are found deep enough, often being lower than the underground water level. In this case it is advisable that circular sewage pumping stations of shaft type be used (Fig. 2.21, b). This construction method simplifies building of the structure, which can be complicated by bad hydrogeological conditions and a considerable depth of the station location. Circular shape is beneficial in terms of the station design.

When pumping wastewater containing flammable substances and explosives, receiving reservoirs are separated from the engine room which can be placed at a smaller depth (Fig. 2.21v).

The scheme and the design of the pumping station can be considerably simplified if the station is built on dry soils at a small depth. The station can be rectangular, and the reservoir can be combined with the engine room (Fig. 2.21h).

Sewage pumping stations pumping small amounts of wastewater (local or located in rural areas) are built underground and are completely automated. A manhole is used in order to inspect the station and carry out maintenance work.

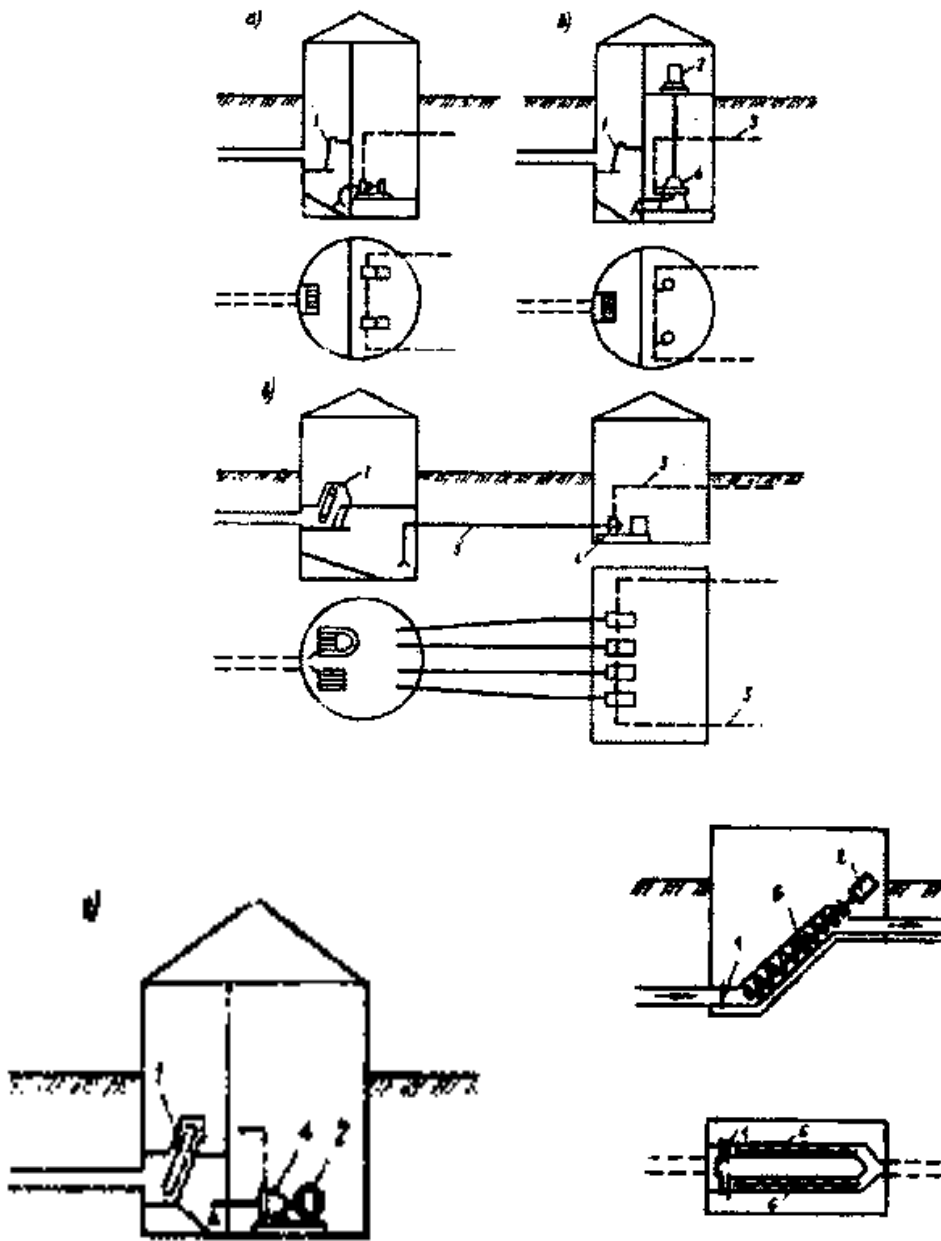


Fig. 2.21. Schemes of pumping stations:
 a, b – of a shaft type with horizontal and vertical pumps respectively, c- with separately located receiving reservoir; d-rectangular in plane; e - with screw-type pumps: 1 – grid; 2 – electric engine; 3 - penstock; 4- pump; 5-suction pipeline; 6 – screw lift

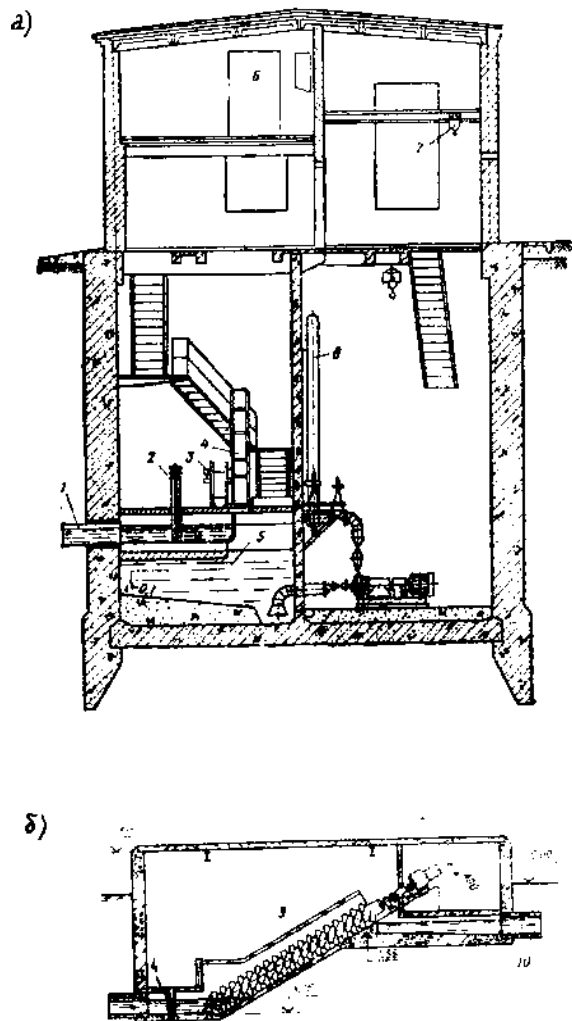


Fig. 2.22. Sewage pumping stations:

- a) of a shaft type with horizontal fecal pumps; b) with screw type pumps:
 1 – double pipeline; 2 – shield valve; 3 - hammer crusher; 4 – grids;
 5-receiving reservoir; 6 - control panel; 7 – crane- beam; 8-penstock;
 9-screw lift; 10-outlet pipeline

In case of pumping small amounts of wastewater with the height of lift not exceeding 4 m, it is recommended that pumping station with screw type pumps are used (Fig. 2.21d).

Pumps are selected based on maximum supply by pumping stations and the required pressure, which is determined by the formula:

$$H_{nomp} = \Delta Z + h_{hc} + \sum h_{\Pi} + h_{r} \quad (2.19)$$

where ΔZ is geometric height of water lifting; h_{hc} - pressure loss within the station (accepted within 1,5-0,5 m); h_{Π} - pressure loss in penstocks; h_{r} - free pressure on outflow of water (accepted within 0,5-1,0 m).

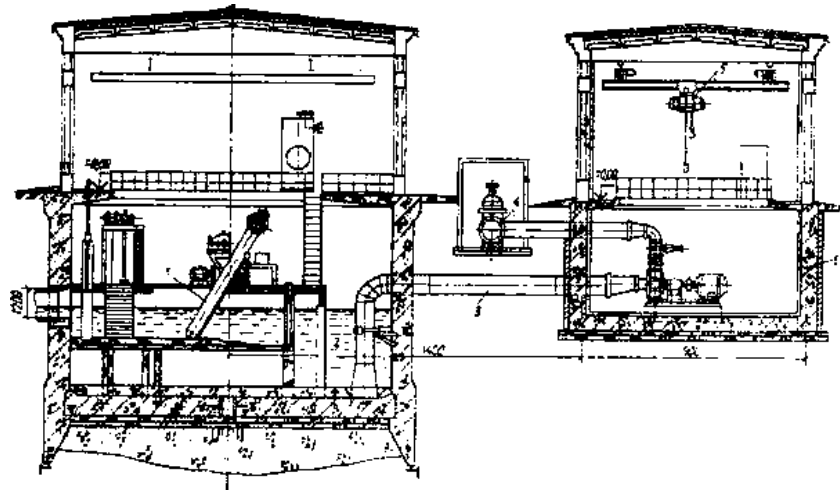


Fig. 2.23. Sewage pumping station with a separated reservoir:
 1- grids; 2- receiving reservoir; 3 - suction pipes; 4 - penstock;
 5 - crane-beam; 6-engine room

The maximum supply by pumping stations is established according to combined schedules of wastewater inflow and drainage. In most cases it is considered to be equal to the maximum inflow of wastewater.

The size of pump stations is determined based on the volume of receiving reservoir, the dimensions of equipment, the structure of auxiliary and domestic premises. The underground part of sewage pumping stations is made of concrete or reinforced concrete, and the surface part is built of bricks.

Pumping stations should be equipped with indoor plumbing, heating system, lighting system and ventilation. For practical use there have been developed standard designs of pumping stations of various capacity, with inlet pipeline being laid at different depth. Fig. 2.22, 2.23 gives examples of pumping stations.

Penstocks are, as a rule, laid in two lines. The velocity of water flow in them is about 1.5 m / sec.

2.4. Wastewater treatment

2.4.1. Composition of sewage and sewage dumping into water reservoirs

The degree of wastewater pollution is characterized by the amount of mineral, organic and bacterial contaminants which are dissolved or not dissolved.

Non-dissolved substances that have been stopped when being filtered through a paper filter are called suspended substances. The total amount of suspended substances contained in domestic wastewater makes about 65 g of dry matter per day produced by one person who uses sewage. Of the total amount of dry matter precipitation, on average, accounts for about 40 g, which is 60-75%, while light impurities (fats, petroleum products, etc.) float to the surface of water.

Organic impurities considerably complicate the process of wastewater treatment. In the presence of oxygen these impurities contained in wastewater, as the rule, mineralize under the influence of microorganisms. The amount of oxygen used to oxidize organic substances shows the degree of wastewater pollution with organic substances. This quantity is called biochemical need in oxygen, abbreviated to "BNO", which is expressed in the amount of oxygen, mg / liter. In practice BNO is determined within the periods of 5 and 20 days and mark BOD_5 and BOD_{20} respectively.

For urban wastewater BOD_{20} is within 100-400 mg / l for industrial – it widely ranges depending on technological process.

Since not all organic substances are subjected to biochemical oxidation, for the assessment of the sewage pollution with organic substances to be complete, a chemical need in oxygen (CNO) is found. The value of CNO is usually greater than that of BNO. For domestic wastewater the value of CNO is 1,2 – 1,5 times greater than that of BOD_{20} . For industrial wastewater containing hard organic substances that are difficult to oxidize, this value can be still greater.

The concentration of pollutants in wastewater, as the practice of water drain system engineering proves, is established with the rate of water drainage being taken into consideration. The greater the rate of water drainage, the pollutants concentration in domestic wastewater is less.

The pollutants concentration in wastewater measured in milligrams per liter by the number of suspended substances, BNO, the amount of ammonium nitrogen, phosphates (P_2O_5), chlorides, surfactants (SAS) is determined by the formula:

$$C = \frac{a \cdot 1000}{h_n} \quad (2.20)$$

where a is the amount of pollution per day caused by one person; q_n - daily drainage rate, liters per person.

The regulatory amount of pollution per day caused by one person for domestic wastewater is given in the regulatory documents and makes, g per day:

Suspended substances	65
BOD_{full} of non-clarified liquid	75
BOD_{full} of clarified liquid	40
Nitrogen of ammonium salts	8
Phosphates(P_2O_5)	3,3
Chlorides(Cl)	9
Surfactants (SAS)	2,5

Domestic wastewater flows to the treatment plant together with the industrial wastewater. Knowing the amount of domestic and industrial wastewater and the concentration of pollution in them, the concentration of pollutants in a mixture of wastewaters is determined:

$$C_{mid} = \frac{C_n \cdot Q_n + SC_p \cdot Q_p}{Q_n \cdot SQ_p} \quad (2.21)$$

where C_n, C_p is pollution concentration of domestic and industrial wastewaters; Q_n, Q_p - average daily expenditure of domestic and industrial wastewaters.

In determining the concentration of pollutants in industrial wastewater the test results or data given in reference literature are used. When designing wastewater treatment plants the so-called equivalent and given numbers of residents are used.

The equivalent number of residents $N_{eq.}$ is a conditional number of residents that cause the same pollution as the given expenditure of industrial wastewater. It is determined by the following formula:

$$N_{eq.} = \frac{\sum Q_p \cdot C_p}{a} \quad (2.22)$$

where a is the amount of similar pollution of wastewater made by one person per day.

The equivalent number of residents is determined by suspended substances, *BOD* and other types of pollution.

The given number of residents is equal to the sum of the equivalent and estimated number of residents.

$$N_{np.} = N + N_{eq.} \quad (2.23)$$

where N is the estimated number of people taken according to the project of locality development.

The terms of wastewater discharge into water reservoirs are regulated by the normative acts and rules, namely by the Law of Ukraine "On Protection of Environment", by "The rules of surface water protection from waste water pollution" and by "The rules of sanitary protection of coastal areas of seas."

In compliance with these rules the water quality standards for water reservoirs have been set according to two categories of water consumption. The first category includes water reservoirs used as sources of centralized or decentralized domestic water supply and also food industry water supply. The second category includes water reservoirs used for swimming, sports and recreation, as well as those located within the boundaries of localities. Besides, there have been set more stringent quality standards of wastewater discharged into reservoirs used in fish industry.

General quality indicators of industrial water discharged into open water reservoirs of domestic and cultural use are given below.

Dissolved oxygen. After wastewater gets mixed with the reservoir water, the amount of dissolved oxygen should not be less than 4 mg / l in any season in a sample taken before 12 am.

Biochemical need in oxygen (BNO). For water reservoirs of the first and second categories as well as the seas, a complete need of water in oxygen in the process of biochemical oxidation of impurities at the temperature of 20 ° C should not exceed 3 mg / l.

Suspended substances. After wastewater discharge, the amount of suspended substances in a water reservoir should not increase by more than 0.25 and 0.75 mg / L for water reservoirs of the first and second categories respectively. For reservoirs containing more than 30 mg / l of natural minerals, the accepted concentration of suspended substances in water can increase by not more than 5%. It is not allowed to dump waste water containing suspended substances whose sedimentation rate is more than 0.4 mm / s for water flow reservoirs and more than 0.2 mm / s for water storage reservoirs.

Odors, tastes. Water shall not have any smell or taste whose intensity is more than 3 points for seas and 2 points for water reservoirs of the first category, if these indicators are recognized immediately or after water chlorination. For water reservoirs of the second category these indicators are not to be recognized immediately. Water shall not have any foreign odors or taste of fish.

Color shall not be detected in a 20 cm column of purified water for reservoirs of the first category and in a 10 cm column – for reservoirs of the second category and seas.

Hydrogen index (pH) after mixing reservoir water with wastewater should be within the range of $6.5 < \text{pH} < 8.5$.

Substances floating to the surface. Waste water must not contain mineral oils or other floating substances in the amounts that can form a membrane, spots or can accumulate on water surface.

Mineral composition. For first category waters the content of inorganic substances shall not exceed 1000 mg / l, with the content of chlorides being 350 mg / l and sulfates - 500 mg / l; for second category waters mineral composition is regulated by indicator “Tastes”.

Causative agents shall not be contained in the water. Wastewater containing causative agents must be disinfected after it has undergone treatment. Methods of disinfection of biologically treated wastewater must ensure coli index of not more than 1000, with residual chlorine content being not less than 5 mg / l.

Water temperature in a reservoir as a result of dumping sewage into it shall not increase by more than 3°C in summer compared with an average monthly temperature of the warmest month of the year over the past 10 years.

Toxic substances shall not be contained in wastewater in concentrations, which are likely to have direct or indirect adverse effect on people’s health.

Water quality standards for fish industry have been set for two types of water consumption: the first type includes reservoirs used for reproduction and preservation of valuable species of fish, the second type –water reservoirs used to satisfy other needs of fish industry.

The standards of reservoir composition and water properties in the reservoirs used in fish industry can be applied to the area of waste water discharge if wastewater immediately mixes with water in the reservoir. These standards can also be applied to the area that is lower than the place of wastewater discharge (in this case the possibility of their mixing up and dilution should be taken to account). In areas of mass spawning wastewater discharge is not allowed.

The requirements to wastewater discharged into reservoirs with fish are more stringent compared with wastewater discharged into water reservoirs used for domestic and cultural needs. These requirements are as follows:

Dissolved oxygen. In the winter the amount of dissolved oxygen (after mixing of wastewater with water in reservoirs) should not be less than 6 and 4 mg / l for water reservoirs of the first and second categories respectively; in the summer it should be less than 6 mg / l in samples taken before 12 am for both categories of water reservoirs.

Complete biochemical oxygen consumption (BOD_{full}). For both categories of water reservoirs, complete BOD at the temperature of 20°C should not exceed 3 mg / l. If in winter time the amount of dissolved oxygen contained in water reservoirs of first and second categories decreases to 6 and 4 mg / l respectively, then only wastewater that does not change BOC of water can be discharged.

Toxic substances must not be contained in concentrations that can have direct or indirect adverse effect on fish or aquatic organisms consumed by fish.

Water temperature resulting from wastewater dumping must not increase by more than 3 ° C in summer and 5 ° C in winter (it should be taken into account that with the increase in temperature, the receptivity of toxic substance organisms increases).

The quality of wastewater treatment should be such that the quality of water in the reservoir after wastewater has been discharged, was not lower than stipulated by the rules of surface water protection from wastewater pollution.

The rules set general requirements to the composition and properties of water in reservoirs (after wastewater has been discharged). All these requirements must be complied with when designing wastewater discharge structures.

Sanitary protection norms allow marginally accepted concentrations (MACs) of substances which affect water quality. MACs imply the maximum concentration of substance which does not damage the processes of organic compounds mineralization or organoleptic properties of water and industrial microorganisms (fish, crabs, shellfish); which does allow any toxic effects of substances on the activities (survival, growth, reproduction, fertility, the quality of offspring) of the main groups of aquatic organisms (plants, spineless organisms, fish), which play an important role in the formation of water quality, formation and transformation of organic matter.

If wastewater, containing substances having the same limiting indicators of harmful substances (toxicological, sanitary and fishery), has been discharged into the reservoir several times, the total of the ratio of substance concentrations for one and the same reservoir with relevant MACs should not exceed 1:

$$\sum_1^m \frac{C_1}{BPC_1} \leq 1 \quad (2.24)$$

When determining the required degree of wastewater treatment, wastewater expenditure, the degree of wastewater mixing with reservoir water, wastewater composition and the quality of water reservoirs, self-cleaning properties of water, marginally acceptable concentrations of pollutants, limiting indicators of harmful

substances, health requirements, distance to the nearest water consuming object, etc.

All natural bodies of water are self-cleaning, which is a complex of biochemical, physical and chemical, and hydrodynamic (dilution) processes which lower concentrations (or remove completely removal) of pollutants dumped with wastewater into water reservoirs with, and restore the original water quality. The processes of self-cleaning include: sorption of dissolved compounds by plankton and bottomset beds, particle sedimentation and agglomeration, interaction of alkalis and acids with hydrocarbon agents, degassing of volatile substances, diluting polluted water flow with clean reservoir water, etc.

The self-cleaning property of water reservoir is limited, though. Considerable volumes of wastewater discharged, the presence of substances that have toxic effect on aquatic biocenosis and other factors hinder the processes of self-cleaning, that is why wastewater is discharged into reservoirs provided special requirements are met. For running water, the condition of wastewater discharge according to the statutory rate of harmful substances content is determined by inequality:

$$C_3 q + C_{3.B.} \cdot aQ \leq (aQ + q)C_{BPC} \quad (2.25)$$

where C_3 is concentration of pollutants in wastewater, which should be attained in the process of treatment; $C_{3.B.}$ is concentration of the same pollutant in a reservoir before wastewater discharge; C_{BPC} is MAC pollutant; a is the coefficient of mixing, indicating what amount of reservoir water mixed with wastewater in estimated alignment; Q -water expenditure in the reservoir; q -the expenditure of wastewater flowing into the reservoir.

The value of Q is determined according to data provided by weather service: q - according to technological calculations, and the value of $C_{3.B.}$ - on the basis of field measurements or based on reference data.

The coefficient of mixing a depends on many factors: design, distance to the estimated reservoir, hydraulic characteristics of flow and hydraulic parameters of reservoir.

The conditions of wastewater discharge into a still water reservoir are determined by correlation:

$$C_3 \leq C_{3.B.} + n_p (C_{BPC} - C_{3.B.}) \quad (2.26)$$

where n_p is the multiplicity of the smallest dilution.

Having divided both parts of inequality by q , we obtain:

$$C_3 + C_{3.B.} \frac{aQ}{q} \leq \left(\frac{aQ + q}{q} \right) C_{BPC} \quad (2.27)$$

The expression in brackets means the multiplicity of dilution in running waters. Then, values p and a are determined by expressions:

$$n_p = \frac{(aQ + q)}{q} \quad (2.28)$$

$$a = \frac{(n_p - q)}{Q} \quad (2.29)$$

Having substituted value a from 2.29 to 2.27, we obtain:

$$C_3 + (n_p - 1)C_{3.6} \leq C_{BPC} \quad (2.30)$$

Equation analysis (2.30) shows that in the absence of this type of pollutant in running water this expression takes the form:

$$C_{3.6} \leq n_p C_{BPC} \quad (2.31)$$

i.e. the concentration of pollutants in wastewater should be either equal to or smaller than the product of the multiplicity of dilution by MAC . In other words, the product of dilution should be such that the concentration of pollutants in running water reservoir does not exceed the maximum acceptable concentration. In terms of percentage, the required degree of waste water purification from a particular pollutant E_{nomp} , (such as suspended substances or by the value of MAC) is determined by the expression:

$$E_{nomp} = \frac{C - C_3}{C} \cdot 100 \quad (2.32)$$

It should be noted what water is prohibited to be dumped into water reservoirs: wastewater that can be eliminated by improved production technology; wastewater which can be used in closed or reverse systems of service water supply companies; wastewater that can be used for irrigation. If this is not possible for some reason, treated wastewater can be discharged into water reservoirs provided all rules and regulations are complied with.

2.4.2. Methods and schemes of sewage treatment

For wastewater treatment mechanical, chemical, physical and chemical methods can be used. For this purpose a complex of facilities is used. As wastewater flows it is cleared from, first, large-size contaminants and then smaller ones.

Mechanical treatment (percolating, settling, clearing and filtering) is used to remove suspended substances from water using grids, sand detectors, decanters, fat separators, petroleum detectors, hydro cyclones, filters and other facilities.

Rags, paper, bones, fruit and vegetable peels, various industrial wastes are stopped by grids and crushed in crushers. Having gone through the grids, water proceeds to sand detectors which detect mineral contaminants (sand, ash, slag). Most suspended pollutants which are of organic origin, are separated from wastewater in primary settlers. Substances whose volume weight is larger than that one of water, settle on the bottom. Substances that are lighter than water (fats, oils, crude petroleum, resins), resurface.

Precipitate that forms on sand detectors is dehydrated in sand areas or sand bunkers. Precipitate that forms in primary settlers is prone to decay and, therefore, it is forwarded to special facilities of sludge processing. Some facilities of

mechanical treatment (septic tanks, two-tier settlers) combine the processes of wastewater clearing and precipitate treatment.

Mechanical treatment is rarely the final stage. Most often it is prior to biological treatment.

Biological methods of treatment assume oxidation of organic matters by microorganisms. These organic matters are found in wastewater in the form of fine suspensions, colloids, and solutions. As a result of biochemical processes mineralization of organic matter takes place. Biochemical treatment method removes almost all organic contaminants remaining in wastewater after mechanical treatment.

Facilities used for biological treatment of wastewater are divided into two groups. The first group includes facilities in which biological treatment is carried out in conditions close to natural (fields of irrigation, fields of filtration and bio ponds). In the second group, water is treated in artificially created conditions (biological filters and air tanks). In the facilities of the first group, wastewater is treated fairly slowly due to supply of oxygen in soil and water of bio ponds, as well as due to the activity of microorganisms-mineralizers that oxidize organic pollutants. In facilities of the second group artificial conditions of wastewater treatment make the processes more intensive. Biomass is separated from purified water in secondary settlers.

Before discharging treated wastewater into water reservoir it should be disinfected in order to destroy pathogens remained after biological treatment. Disinfection is carried out in a number of ways: chlorination, electrolysis, germicidal irradiation, etc.

As the requirements to the degree of wastewater treatment grow and biological treatment does not always meet these requirements, wastewater undergoes some additional treatment. To ensure this different filters, contact clarifiers and bio ponds are used.

Sometimes biogenic elements – nitrogen and phosphorus - are to be removed from wastewater. These elements, when found in water, may contribute to increased vegetation of water plants.

Nitrogen is removed with physical, chemical and biological methods used. Physical and chemical method of treatment implies adding lime to wastewater, which is followed by separating ammonia.

When biological methods of nitrogen removal are used, water is aerated in the presence of carbon pollutants in special facilities, where intensive nitrification processes take place followed by the processes of denitrification. To ensure their activity, bacteria-denitrifiers use oxygen of nitrates and nitrites releasing atomic nitrogen. Phosphorus is removed from wastewater with the use of chemical methods using the following reagents: lime, salt, iron and aluminum.

Unlike treated urban wastewater, it is advisable that for some types of industrial wastes chemical or physical-chemical methods of treatment should be used, for example when removing ions of heavy metals or toxic compounds from wastewater. In the process of chemical treatment, pollutants are removed from

wastewater removed as a result of reactions between pollutants and reagents added to water. In this case, precipitating compounds can be formed, or gas evolution occurs.

Neutralization and chemical oxidation also belong to the processes of chemical treatment. Physical and chemical methods of sewage treatment include sorption, extraction, evaporation, coagulation, flotation, electrolysis, ion exchange, crystallization, and others.

Selection of sewage treatment method as well as selection of treatment facilities are quite difficult a task depending on several factors and the required degree of wastewater treatment, the possibility of utilization of valuable substances contained in wastewater and use of purified water in systems of service water supply of enterprises, terrain, hydrological conditions, population, the volume of waste water, etc.

The schemes which combine mechanical and biological treatment are widely used for urban wastewater treatment. A flowchart of such technology is shown in Fig. 2.24. Based on this scheme different options of facilities are available. One of typical schemes of urban wastewater treatment is shown in Fig. 2.25.

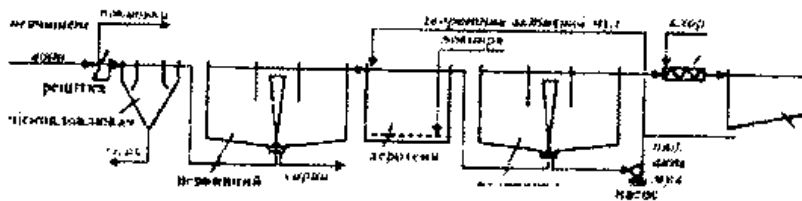


Fig.2.24. Flowchart of urban wastewater treatment

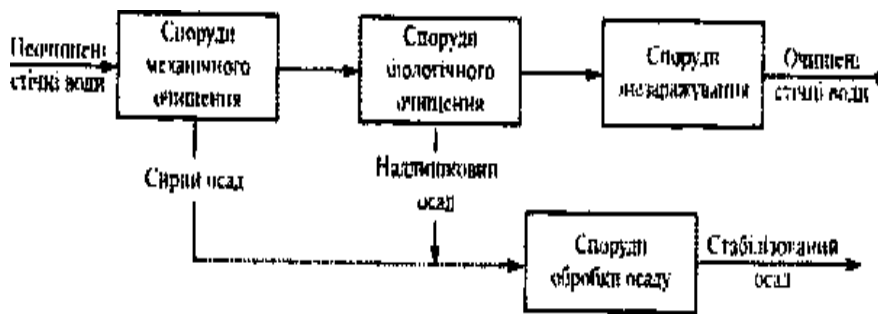


Fig.2.25. Typical technological scheme of urban wastewater treatment

2.4.3. Facilities for mechanical wastewater treatment

Grids are installed on the receiving tanks of pumping stations and on wastewater treatment plants on channels that supply wastewater. To prevent clogging or large quantities of water, grills should be systematically cleaned of wastes.

Grids are distinguished by their:

- slot width which can be gross slots of 30 to 200 mm and conventional, from 5 to 25 mm;

- design features which can be fixed and moving which are periodically or continuously lifted to be cleaned from wastes;
- methods of cleaning of wastes which imply manual and mechanical cleaning.

Grids installed in front of treatment facilities must have slots of up to 16 mm wide. Lattice bars may have round, rectangular or other cross section, but most often they are made of staff steel with the size of 60g 10 mm. When wastewater is supplied to wastewater treatment plant at some pressure, the use of grids is optional if pumping station is equipped with grids with 16 mm slots or crushers. If grids installed on pumping station have larger slots, grids are also installed on wastewater treatment plants.

For the ease of maintenance, grids are often set at an angle of 60-70 ° to the horizon (Figure 2.26). If the amount of pollutants stopped by the grid is 0.1 m³/day or more, the cleaning of grids should be mechanized. A grid with 16 mm slots, on average, stops 8 liters per year per person: bulk waste is 750 kg/m³, humidity - 80%. Pollutants stopped by the grid should be crushed in crushers and put back into the water flow in front of the grid.

Currently combined devices - grids-crushers (comminutors) – are widely used, in which pollutants are crushed without being taken from the flow. (Fig. 2.26 b).

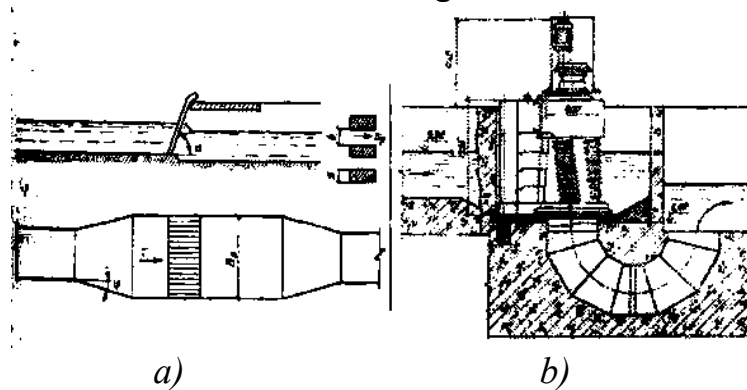


Fig. 2.26. Installation schemes: a – conventional grid; b – grids-crushers GC

When calculating grids, their size and pressure losses which are incurred when wastewater flows through them, are determined. Structural dimensions of grids are related to wastewater expenditure through the ratio:

$$q_{\omega} = \omega \cdot v = b \cdot n \cdot h \cdot v \quad (2.33)$$

where q_{ω} is wastewater expenditure, m³/sec; ω is live section area of flow, m²; v is water velocity in the slots of grid (taken as 0.8 - 1 m / s for conventional grids and 1.2 m / s – for grids-crushers), b is the size of slots, m; h is the depth of flow, m; n is the number of slots in a grid.

Conventional grids are set in premises that are heated, while grids-crushers can be set in channels without any superstructure over them. In addition to working grids, backup grids are set.

Sand detectors are intended for stopping mineral impurities contained in wastewater. Sand detectors are used because simultaneous removal of mineral and

organic impurities in settlers, there occur some problems removing sediment from settlers.

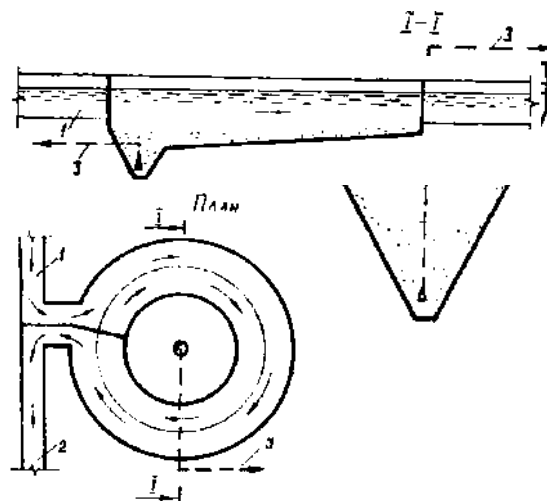


Fig. 2.27. Horizontal sand detectors:

a –with rectilinear flow of water; b - with circular flow of water:
1 – water supply, 2 – water drain, 3 –sediment discharge

Sand detectors are set to remove non-dissolved minerals from wastewater, mostly sand. The presence of sand in wastewater has an adverse effect on treatment facilities operation, because sand can accumulate in settlers, septic chambers, two-tier settlers, digesters and other structures, reducing their useful volume and preventing sediment discharge, thus disrupting the technological process of treatment plant operation. Therefore, sand detectors are a mandatory part of treatment plants with the capacity of more than $100\text{ m}^3 / \text{day}$.

The operation of sand detectors is based on the use of gravity. Sand detectors are designed so that sand and other mineral particles precipitated in them, not the light sediment of organic origin. It has been found that for sand detectors with horizontal water flow, velocity should not be more $0.3\text{ m} / \text{s}$ and not less than $0,15\text{ m} / \text{sec}$.

Horizontal sand detectors have been most commonly used, with a circular or rectilinear flow of water (Fig. 2.27). Vertical and tangential sand detectors are not that common. In some cases to improve the efficiency of sand detectors operation, water is aerated to provide complete removal of organic impurities. Helical flow of water is typical of such sand detectors.

The forward speed of water flow in aerated sand detectors is within $0,08 - 0,12\text{ m} / \text{s}$ (taking into account the rotating speed, the total velocity of water flow in this case will be about $0.3\text{ m} / \text{s}$).

Sand detectors are calculated in order to determine their size relative to the size of sand grains to be stopped and the type of facility. The area of the living section of sand detectors (or its compartment) is determined by the formula:

$$\omega = \frac{q_{\omega}}{v \cdot n} \quad (2.34)$$

where q_{ω} is the maximum expenditure of wastewater, m^3/sec ; n is the number of sand detectors (compartments), with at least two of them; v is the velocity of wastewater flow, m/sec .

The length of the working unit of sand detector is:

$$L = \frac{1000 \cdot k \cdot h \cdot v}{u_0} \quad (2.35)$$

where k is coefficient depending on sand detector type; h is the estimated depth of sand detector, m ; u_0 is hydraulic size of sand, mm/sec .

With all basic sizes for horizontal sand detector having been determined, the duration of water stay in the facility, which must be, at least, 30 seconds, at a maximum inflow of wastewater, is checked.

From experience, efficient horizontal sand detector stop 65 - 75% of all mineral impurities contained in domestic wastewater.

Sand is normally removed from sand detector using hydraulic elevators, special pumps or special mechanisms (screws, scrapers, etc.). If the amount of residue is less than $0.1 m^3/day$, sand detectors can be cleaned by hand.

Sand is dehydrated in sand areas or sand bunkers.

Settlers are a basic facility for mechanical wastewater treatment. They are used for removing coarse substances that settle or float. There can be distinguished primary settlers, which are set in front of biological treatment facilities, and secondary settlers used to separate active sludge or biological membrane. Depending on the direction of water flow, settlers can be horizontal, vertical or radial.

Horizontal settler (Fig. 2.28) is a 4 m deep rectangular tank with a ratio of width to length of at least 1:4. Wastewater are channeled to the end wall of the settler, where with the help of transverse tray 1 is uniformly distributed across the width of the settler. On the opposite side of the settler, a tray collecting clarified water 2 is set.

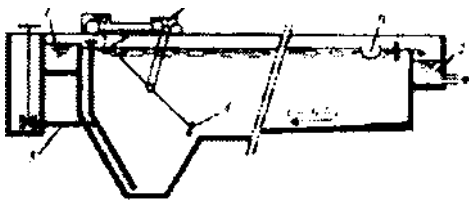


Fig. 2.28. Horizontal settler:

1 - distributing tray; 2 - drainage tray; 3 - cart;
4 - scraper; 5 - sediment discharge pipeline; 6 - fat collecting tray

Radial settlers are normally made round with the diameter from 16 to 40 m (sometimes up to 60 m) and the depth which is $1/6-1/10$ of the diameter. These settlers are called radial because water flows in a radial direction. Radial settlers can be considered as a variety of horizontal settlers, though water velocity in them is variable, reaching its maximum in the central part and its minimum in the peripheral part, while in horizontal settlers it is constant along the entire length of facility.

The design of radial settler is shown in Fig. 2.29. Polluted wastewater is supplied through the bottom pipeline 1, from which through the central distributing unit 2 it proceeds to the settler, with clarified water collected in a circular peripheral channel 3. Floating substances are removed from the surface of the liquid with the help of semi-submerged board, which is fixed at an angle to the axis of rotating farm, and then through the pipe are supplied to a floating bunker proceeding to a sludge pit.

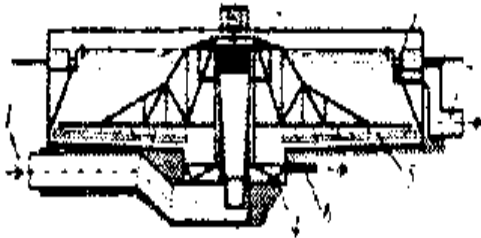


Fig. 2.29. Radial settler: 1 - polluted water supply, 2-central distributing unit 3 - collecting tray, 4 - pit, 5-scraper, b – sediment discharge, 7 - discharge of clarified water

Precipitate is shoveled into pit 4 located in the center of settler, using shutter shaped scrapers 5 fixed at the bottom of the moving farm at an angle of 45° to its axis. The farm rotating, fixed scrapers remove sediment from the bottom of the settler in the direction from the periphery to the center. The pit has the shape of inverted truncated cone. The bottom of the settler is set at a gradient of 0.02 from the periphery to the pit.

In order to remove sediment, secondary radial settler is often equipped with a sludge pump instead of scrapers.

A vertical settler is a round (sometimes square) tank with the diameter of up to 10 m, its bottom having the shape of inverted truncated cone (Fig. 2.30). Wastewater is supplied through the tray 1 to a round central tube 2 with a socket 3. Upon reaching the backing shield 4, wastewater flow changes direction from vertical down to horizontal and then, to vertical upward flow. Water flow being uniform on the working area of settler 5, clarified sewage flow over round spillway into the round collecting tray 6.

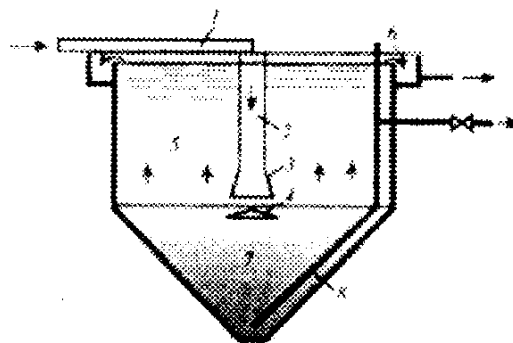


Fig. 2.30. Vertical settler: 1 - tray 2 - central tube, 3 - socket, 4-backing shield: 5 – settling zone: b - collecting tray, 7 - sediment zone, 8 - sediment pipe

Settlers also include water clarifiers, in which water is simultaneously settled and filtered through the layer of suspended sediment (Fig. 1.52), clarifiers - decomposers and two-tier settlers, in which along with water clarification the process of precipitate stabilization and compression.

In most cases, the efficiency of removing coarse substances from wastewater in settlers is 40-60% for the duration of settling of 1 -1.5 hours. To increase the efficiency of sediment removal, coagulants and flocculants, i.e. substances increasing the sedimentation rate of suspended solids, are added to waste water. This method is mainly used for industrial wastewater and very rarely for urban drainages.

The settler type is selected according to technological scheme used for sewage and sludge treatment, facility capacity, sequence of construction, geological and hydrogeological conditions. There should be at least two primary settlers and three secondary settlers. With the minimum number of settlers, their estimated volume must be increased by 20 - 30%. The presence of a number of compartments allows repairing or cleaning one of the compartments with the quality of cleaning procedure remaining practically unchanged.

Water flow velocity is 5-10 m / s for horizontal settlers and 0.7 - 1.5 m / s for vertical. Calculation of settlers, except for secondary settlers, is based on the kinetics of suspended substances precipitation, with the required efficiency of cleaning and working conditions of biological water treatment facilities being taken into consideration.

Horizontal settlers are usually used on treatment plants with a daily capacity from 15 to 100,000 m³. Unlike horizontal settlers, in radial settlers water flow velocity changes radially. Radial settlers compared to horizontal are more economical in construction and more reliable in operation. They are mainly used on plants with a daily capacity of more than 20,000 m³. On plants with a daily capacity of up to 20,000 m³ vertical settlers are recommended, and for plants with a daily capacity of up to 10,000 m³ – two-tier settlers.

Two-tier settlers can be cylindrical or rectangular, with a conical or pyramidal bottom. The top part of structure houses settling trays and the bottom – silt chamber. Settling trays function as horizontal settlers (Fig. 2.31).

Clarifier - decomposer consists of two concentric cylindrical tanks. The inner tank functions as a clarifier, while the outer – as a chamber for sediment fermentation (Fig. 2.32). Clarifiers – decomposers are designed to be installed on treatment plants with the daily capacity of up to 30,000 m³.

To reduce the amount of suspended solids in clarified water, in addition to primary settlers, pre-aerators and bio-coagulators are used. Excessive amount of active sludge or biological membrane are added to these structures, which not only increases efficiency and removes suspended solids, but also due to sorption by flakes of active sludge or biological membrane reduces the content of heavy metals and other contaminants that have an adverse effect on the process of biological treatment. In addition, the mixture of water and excessive active sludge or biological membrane is aerated for 20 min. A-A.

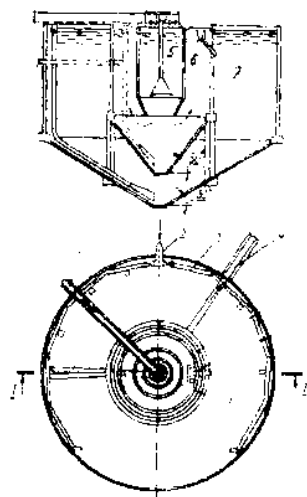


Fig. 2.31. Two-tier settler:
 1 – wastewater supply; 2 – settling trays; 3 – longitudinal slots; 4 – sludge fermentation chamber; 5 – clarified water discharge; 6 – tray for purified water discharge

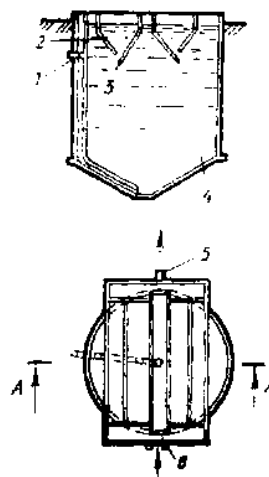


Fig. 2.32. Clarifier-decomposer:
 1 – double tray, 2 – supply to fermentation; 3 – sludge distributing pipe; 4 – chamber; 5 – chamber of sludge pipe flocculation; 6 – settling part; 7 – chamber for sediment fermentation

Preaerators are set in front of primary settlers in the form of separately built or in-built structures. Bio coagulators are installed in the form of units connected with settlers or skimmers. Preaerators are used on sewage treatment plants having air tanks, while bio coagulators – on plants with both air tanks and biological filters.

The efficiency of pollution prevention by BOD and suspended solids in primary settlers after preliminary aeration and bio coagulation increases by 20 - 25%.

2.4.4. Structures for biological treatment of wastewater

Biological methods of wastewater treatment consist in oxidation of the smallest particles of suspensions, colloids and dissolved organic substances by microorganisms, which can use as their nutrient medium many organic and some inorganic contaminants contained in wastewater. In the process of biological treatment of wastewater, a part of contaminants that are oxidized by microorganisms are used in the processes of biosynthesis (biomass creation), while the other part is transformed into harmless products of oxidation: water, CO_2 , NO_3 and others. Operation principles of modern apparatus and structures used for biological treatment of wastewater are based on methods of continuous cultivation of microorganisms.

Wide use of biological methods of wastewater treatment can be explained by their advantages: ability to remove different organic compounds including toxic ones from wastewater; simple-to-use equipment; relatively small operation expenses. Disadvantages of this method include high capital costs, strict technological regime of purification, toxic effect of organic and inorganic

compounds on microorganisms, necessity to dilute wastewater containing high concentrations of admixtures.

Structures intended for biological treatment of sewer water are divided into two groups. The first group includes structures in which water is treated in conditions close to natural: fields of irrigation and fields of filtration, structures of underground filtration and bio-treatment ponds. The second group includes structures in which water is treated in artificially created conditions in biological filters and air tanks.

Fields of irrigation are specially prepared and planned land plots that are intended for sewer water treatment with simultaneous use of these plots for agricultural needs.

Fields of filtration are land plots intended only for sewer water treatment without growing crops.

The essence of sewer water treatment is that in the process of filtering sewer water through soil its top layer stops suspended and colloid particles, which on the surface of soil particles create a film densely populated with microorganisms. The surface of the film adsorbs diluted organic substances contained in sewer water. Microorganisms use oxygen from atmosphere to oxidize contaminants and transform them to mineral contaminants. Intensive oxidation takes place in the upper (0.2 – 0.4m) layers of soil. For deeper layers oxygen supply is limited, and that's why the processes of oxidation are slower there. For the territories used for growing crops ground water should be at least 1.5 m deep from the soil surface.

The degree of domestic sewer water purification in the fields of irrigation and filtration makes, on average, 95-98% by suspended substances and $BPK_{\text{побне}}$.

Bio-treatment ponds are used for treating sewer water. Organic admixtures are oxidized by microorganisms. Anaerobic or aerobic ponds are used for water treatment. In their turn, aerobic ponds can have natural or enforced aeration. In ponds with natural aeration treatment of sewer water depends on the type and concentration of admixtures and lasts from 7 to 60 days. The volume of the ponds with enforced aeration is considerably smaller, with the required degree of water treatment achieved within 1-3 days.

Bio-treatment ponds have a number of disadvantages that limit their use: low oxidation; considerable area; seasonal operation; stagnant water zones; poor manageability of treatment process; difficult-to-clean structure.

Bio-treatment ponds are mainly used for additional treatment of sewer water that has been treated by structures of biological treatment. Additional treatment improves sanitary and hygienic indexes of purified water, decreases concentration of contaminants, increases concentration of oxygen diluted in water.

Bio-filters are used for partial or complete biological treatment of sewer water with $BPK_{\text{побне}}$ being 15mg/l. A bio-filter is a structure (Fig. 2.33) loaded with filtration material on the surface of which microorganisms develop (bio-film).

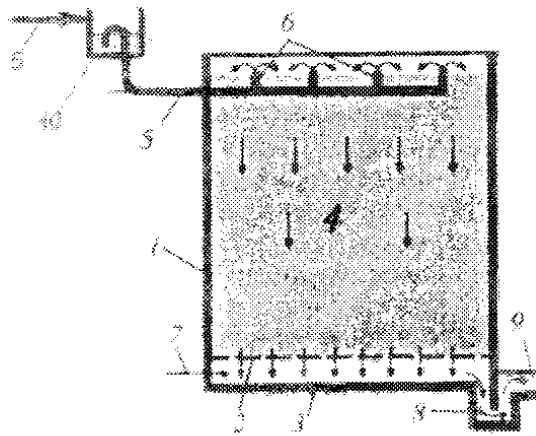


Fig.2.33. Bio-filter:

1- wall fencing; 2- mesh bottom; 3-whole bottom; 4-filtrating loading; 5-water supply; 6-distribution device; 7-air supply; 8- water seal; 9-drainage tray; 10-metering device with siphon

When sewer water is filtered through biofilter, contaminants are adsorbed by bio-film and oxidized by microorganisms in the presence of air oxygen. Microorganisms continuously grow and die off in the biofilter. Purified water with parts of bio-film, that have died off, proceeds to the secondary settler. The bacteria are the microorganisms that oxidize contaminated sewer water. Besides, micro flora and micro fauna of bio-film are represented by different molds, worms, insects, etc. Biofilters are loaded with crushed rocks, gravel, expanded clay aggregate, slag, ceramic elements, asbestos-cement elements, plastic elements, metal gauze; synthetic films. The height of loading is usually assumed to be 1.5-4m but it can be considerably bigger.

There can be distinguished biofilters with natural and enforced aeration. By their capacity bio-filters are divided into drop filters (low-capacity - up to 1000m³/day) and high - capacity (up to 50000m³/day).

Reliable operation of bio-filters can be achieved only by uniform irrigation of its surface with sewer water. Special distribution devices of mobile and fixed types (mesh pipes, special sprinklers, jet sprinklers) are used for irrigation.

Degree of sewer water treatment mainly depends on sewer water composition, height of loading, temperature of sewer water, special air amount and hydraulic loading.

In aero tanks, like in biofilters, bio-chemical oxidation of organic substances of sewer water by microorganisms takes place. Aero tanks are structures in which there's a constant flow of water mixed with active sediment. Active sediment is a mixture of aerobic microorganisms which adsorb and oxidize contaminated sewer water. The quality of active sediment depends on the type and amount of organic contaminants, presence of toxic admixtures, completeness of previous settling, duration and intensity of aeration, loading on active sediment.

Qualitative active sediment can settle quickly and effectively. Such ability is assessed in terms of sediment index, which shows the volume of active sediment

in cubic centimeters (millimeters) after being settled during 30 min. in relation to 1g of dry sediment substance. Sediment index, with active sediment for city sewer water being normal, doesn't exceed $130 \text{ mc}^3/\text{g}$. If it has a larger value, settling of sediment mixture in secondary settlers is slowed down, with a considerable loss of sediment.

Aero tank should be continuously supplied with oxygen to provide normal activity of microorganisms. Mixture of sewer water with active sediment is continuously aerated by systems of aeration (Fig.2.34). Systems supply and distribute oxygen or air in aero tank and keep active sediment suspended for it to have better contact with sewer water contaminants.

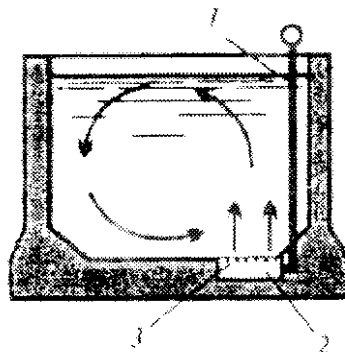


Fig. 2.34. Aero tank with pneumatic aeration:
1-air riser; 2-filter channel; 3-filter plates

The process of biological sewer water treatment in an aero tank can be divided into three stages. At the first, initial stage, as soon as fresh sewer water has mixed with active sediment, the latter adsorbs of contaminants contained in sewer water, and oxidizes easily oxidized substances. This results in sharp decrease in БПК of sewer water (by 40-80%), with diluted oxygen being completely spent on oxidation processes, bringing oxygen deficit to one. The first stage usually lasts 0.5-2 hours.

At the second stage of the process, slowly oxidized substances are oxidized and active sediment is regenerated, i.e. active sediment's properties, which considerably weakened at the end of the first stage, are renewed. The rate of oxygen consumption at the second stage is considerably lower compared with the first stage.

At the third stage of the process, nitrification of ammonium salts takes place, with the rate of oxygen consumption growing again.

Aero tanks can be classified by hydraulic mode of their operation (aero tanks of ideal extrusion, aero tanks of ideal mixing, aero tanks of transitional type), or by the amount of loading on active sediment (high-loaded, regular, and low-loaded). As a rule, high-loaded tanks do not provide complete treatment, and low-loaded, with treatment being complete, provide autoxidation of excessive active sediment.

From aero tanks, the mixture of water and active sediment proceeds to the secondary settlers for active sediment to settle (be separated). In the process of

sewer water treatment, the volume of active sediment increases due to its growing biomass. A part of active sediment is continuously pumped into aero tanks to maintain the required concentration (circulating active sediment), with the remainder proceeding to sediment compactors (excessive active sediment).

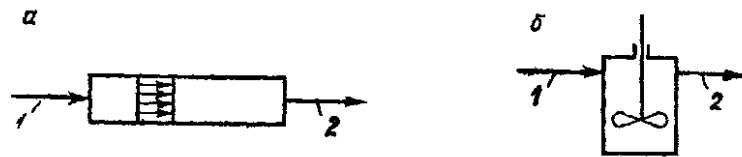


Fig.2.35. Schemes of aero tanks:
a-of ideal extrusion; b-of ideal mixing

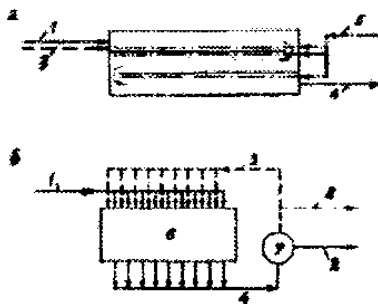


Fig.2.36. Schemes operation of aero tanks:
a-of corridor ideal extrusion; b- of mixer spraying
sewer water and active sediment: 1- sewer water
supply; 2-treated water; 3-circulating sediment;
4- sediment mixture; 5-air; 6-aerotank; 7-secondary
settler; 8-excessive sediment

Often enough, circulating active sediment contains non-oxidized contaminants, and that's why this sediment is taken to regenerators where contaminants are oxidized and the adsorptive capacity of active sediment is renewed. As a rule, regenerators occupy a part of an aero tank. Individual structures in which active sediment is mineralized are called aerobic mineralizers.

If a mixture of sewer water and active sediment is aerated longer than usual, first, the volume of active sediment reaches its maximum value, and then it drops to the initial value. This happens because a part of active sediment aerated for a long time mineralizes (autoxidizes). This process is called complete oxidization or continued aeration. Aero tanks provide high degree of sewer water treatment, with organic substances content in treated sewer water being 15mg/l according to $BPK_{\text{побне}}$. The volume of aero tank is determined by an average hourly inflow of sewer water during aeration in hours of maximal water inflow. Existing methods of aero tanks calculation take into account the process of biological treatment in them prior to nitrification stage. Urban sewer water aeration makes nearly 6-8 hours. When estimating the volume of secondary settlers and aero tanks without regenerators, circulating active sediment expenditure is not taken into account.

2.4.5. Disinfection and discharge of treated sewer water

Sewer water is disinfected in order to destroy pathogenic bacteria (causing diseases). More often, water is disinfected with gaseous chlorine or substances that contain active chlorine – chloral lime, hypochlorite, etc. The dose of chlorine used for sewer water disinfection after they have been mechanically treated makes 10mg/l, after complete biological treatment – 3mg/l. In each particular case these doses must be specified for the amount of excessive chlorine contained in disinfected water after the contact not to exceed 1.5mg/l.

Installation for sewer water disinfection with chlorine consists of chlorination plant, mixers and contact reservoirs. A chlorinator or other equipment for making chloral water is installed in chlorination plant. In order to mix chloral water with sewer water mixers of any type are used. In order to provide the required bactericidal effect, contact reservoirs are designed to ensure a 30-minute contact of water with chlorine. Reservoirs are designed as primary settlers, with sediment from them proceeding to sediment areas.

Outlets are intended for mixing treated and disinfected water with water from reservoirs. Outlet design must ensure thorough mixing of sewer water with water from reservoir, which allows better self-cleaning of water from reservoir.

Outlets are concentrated, when sewer water is discharged through one hole, and diffusing, when there are several outlets. There can also be distinguished coastal and riverbed outlets.

The choice of outlet construction and place of its location are determined by technical economic calculations.

2.4.6. Methods and structures for treatment, dehydration, disinfection and utilization of sewer water sediments

On wastewater treatment plants there's a considerable amount of sediments. They precipitate in primary settlers and also form in the process of biological treatment of sewer water in the form of biological film after having been filtered through bio-filters, or in the form of excessive active sediment after aero tanks.

Sediment removed from primary settlers is called "raw sediment". It is grey and contains 92-96% of water. Its volume weight varies from 1.004 to 1.01 t/m³. Domestic sewer water sediment contains up to 80% of organic substances. Depending on admixtures of industrial sewer water, percentage of organic substances contained in sediments of domestic sewer water can range from 65 to 85%. An organic part of sediment is represented by carbohydrates, fat-like substances and proteins which account for 80%. Sediment contains up to 3.5% of nitrogen, 1.4% of phosphorus and 0.2% of potassium, which characterizes it as a valuable organic fertilizer.

Raw sediment is dangerous in sanitary respect, as it can decay, emit gases, create favorable conditions for the development of bacteria, including pathogenic

bacteria and contains helminth eggs. That is why before being utilized, sediment should be stabilized and disinfected. For this purpose aerobic fermentation with the use of aerobic bacteria (aerobic stabilizations) and aerobic fermentation with the use of anaerobic bacteria (methane tanks, septic tanks, two-tier settlers) are used. In the process of anaerobic fermentation, there takes place a two-phase decomposition of organic substances of sediment.

The first phase is characterized by creation of a considerable amount of fat acids (formic, acetic, oily, etc.). Besides, at this phase carbonic acid, alcohol, amino acid, ammonia, carbon disulfide form. The active reaction of pH medium is less than 7, that's why the first phase is called the phase of "acid" fermentation. It is carried out by anaerobic bacteria of yeast type, oily-acid, propionic, butyl bacteria, etc. As a result of acid fermentation, sediment almost doesn't decrease in volume, gets dry very slowly, has a bad smell and can decay.

The second phase is characterized by destructions created during the first phase accompanied by emission of carbonic acid, methane, hydrogen and small amounts of carbon oxide. Active reaction pH makes 7-8, that's why this phase is called an alkali stage, or a stage of methane fermentation. Contaminants of the second phase are methane creating anaerobic bacteria. Fermented, or mature, sediment is dried in sediment areas after the second phase of fermentation. It is black because it contains sulfide of iron and humic substances; a light smell of sealing wax or asphalt is typical of mature sediment.

The content of organic substances in fermented sediment decreases from 80-75% to 50%. The final products of fat decomposition are acid and methane, i. e. these components of an organic part of sediment gasify. In the process of proteins decomposition only a part of the formed products gasify, the remainder make compounds and remain in solution.

Depending on local conditions, the station capacity and schemes of treatment, septic tanks, two-tier settlers, methane tanks and other structures are used for fermentation of organic sediments.

For sewer water and sediment treatment, with the daily sewer water expenditure of up to 25m³/day it is recommended that septic tanks be used, and for water expenditure from 25 to 10000 m³/day two-tier settlers should be used. For stations with higher capacity methane tanks or aerobic stabilizers are used.

Humidity of domestic sewer water sediment of primary settlers makes 93.8 carbohydrates, fat substances and proteins.-95.0%, secondary settlers: with the use of aero tanks – 99.2-99.7%, with the use of bio-filters – 96-96.5%.

Septic tanks are flow tanks, which are rectangular or round in the plane, and in which sewer water is clarified and precipitate is fermented (Fig. 2.37). Sewer water is in septic for 1-3 days, while precipitate fermentation takes 6-12 months.

Two-tier settlers are also used for sewer water clarification and precipitate fermentation. A two-tier settler has flow trays in its top part, and a septic chamber in its bottom part (Fig.2.31). The process of sediment fermentation in two-tier

settlers takes 2-6 months. Within this period 40-50% of organic substances decompose.

Methane tank is a tank, which is round or rectangular in the plane, and in which sediment from the settlers or excessive active sediment is fermented. The process of organic substance decomposition in a methane tank is similar to that in septic chamber of a two-tier settler, but it's more intensive due to being heated and mixed.

Methane fermentation of sewer water can be carried out in mesophilic conditions, if the temperature of the mass being fermented doesn't exceed 35°C, or in thermophilic conditions, if the temperature of the sediment being fermented is maintained within the range of 45-65°C. Each of these types of fermentation is ensured by the activity of corresponding anaerobic bacteria – mesophilic and thermophilic. For mesophilic fermentation, the optimal temperature is 33°C, for thermophilic -53°C.

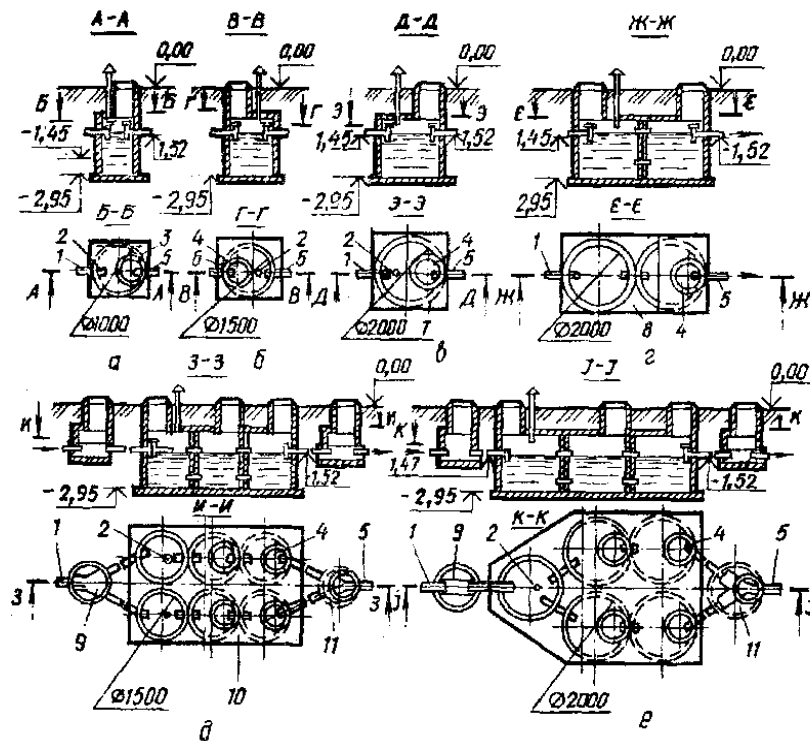


Fig.2.37. Scheme of septic tanks layout:

a,b,c – unilocular; d,e – bilocular; f – trilocular: 1- sewer water supply; 2- ventilation pipe; 3- bottom plate; 4- manhole; 5- sewer water discharge; 6- walls of septic from prefabricated reinforced concrete rings; 7,8,10,12- bottom plate; 9- distribution well; 11- metering chamber

In methane tanks, the degree of organic substance fermentation is, on average, 40%, which is sufficient. Sediment loses the smell of the rot, gains uniform porous structure, gives moisture on drying. Fermented sediment contains nitrogen, phosphorus, potassium, which are well digested by plants and that's why sediment is used as a fertilizer in agriculture.

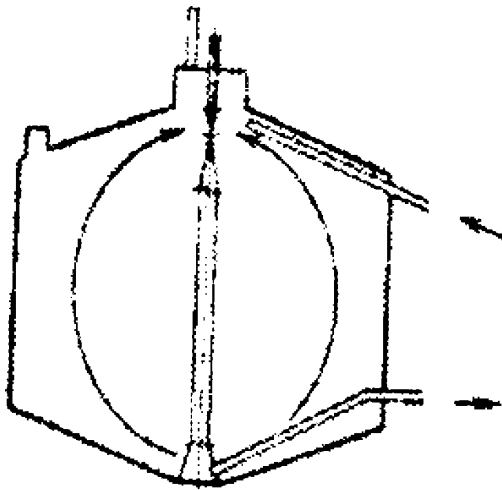


Fig.2.38. Scheme of methane tank

In the process of fermentation gas is released in methane tanks. This gas is discharged to gas-holders for storage, and then it is burnt in boiler installations.

The most rational scheme of use of methane tanks is straight-flow scheme, which implies continuous loading and unloading of sediment (Fig.2.38).

In some cases sediment can be treated with the use of aerobic stabilizers or combined technologies that contain anaerobic and aerobic fermentation.

It should be noted that further use of damp sediment is low-efficient, that's why it's dried (dehydrated). Most often, sediment areas on a natural or artificial base are used for sediment dehydration (Fig.2.39). Sediment that has decomposed in a methane tank has an average humidity of 94-97%. On sediment areas it dries and reaches the humidity of 75-80%. As a result, the volume of sediment considerably decreases and it can be transported.

The size of sediment areas is determined depending on the amount of sediment, its characteristics (fermented or raw) and climatic conditions. In winter time sediment freezes. Sediment water, that was separated from sediment, is pumped to waste water treatment structures.

For mechanical collection, loading and transportation of dried sediment roads for vehicles are built on sediment areas.

At big stations instead of being dried on sediment areas, sediment is mechanically dried in vacuum-filters, centrifuges, filter-presses or thermal driers. A vacuum filter (Fig.2.40) is a horizontal cylindrical drum covered with filtrating cloth.

The drum is divided into sectors, it is partially deepened into laundries with sediment, and is slowly rotating. A vacuum-pump rarifies the sectors that are plunged into the sediment. Sediments stick to the cloth and water percolates inside the drum after which it is discharged. Sediment is separated from the cloth with a knife. Dehydrated sediment has the humidity of 78-80%.

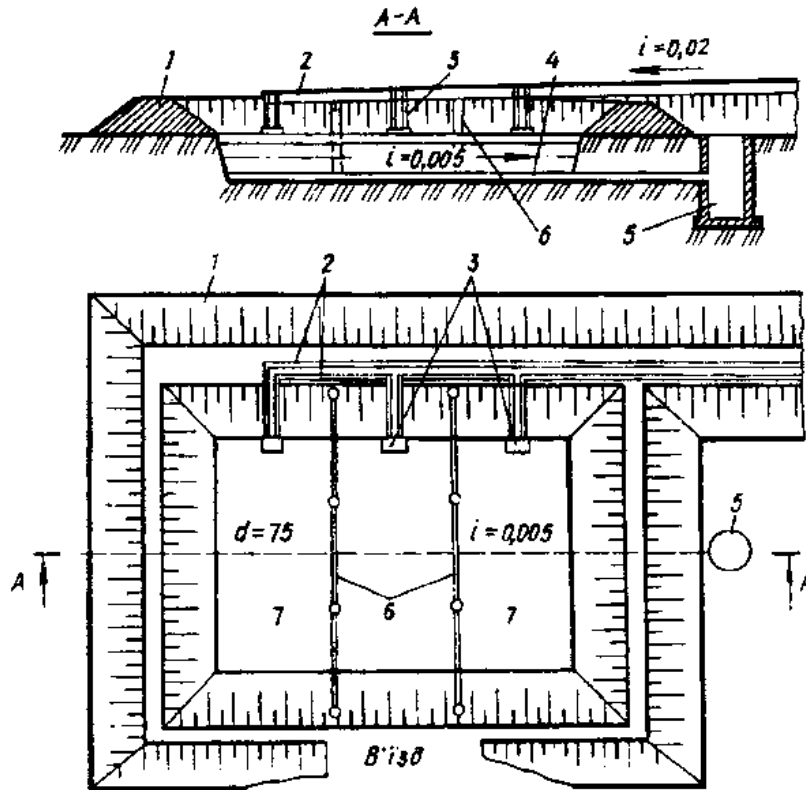


Fig.2.39.Mule sites:

1- wall fencing; 2-sediment supply tray; 3-pneumatic panels; 4-drenaige; 5- collecting well; 6-distribution partitions; 7-working cards

Sediment humidity of 50-80% can be obtained in continuously working horizontal centrifuges with screw unloading of dehydrated sediment.

Thermal drying and burning of sediment requires considerable costs that's why they are rare.

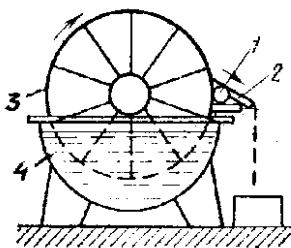


Fig.2.40. Scheme of vacuum-filter:

1- rotating roller; 2-knife; 3- drum; 4-sediment

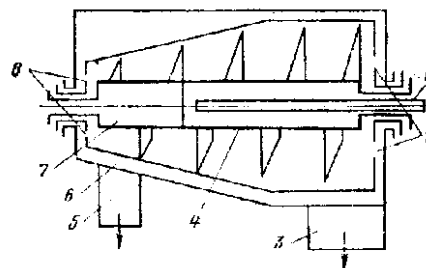


Fig.2.41. Scheme of centrifuge of HOF III type:

1-sediment supply; 2-fugate discharge; 3-fugate bunker; 4-holes for sediment supply to rotor; 5-bunker for cake unloading; 6-rotor; 7-screw; 8-holes for cake unloading

2.4.7. Structures for complete sewer water treatment

Structures of complete biological treatment ensure the degree of treatment of up to 15-20mg/l according to $BPK_{\text{побне}}$ of treated water. In a number of cases such degree of water treatment doesn't meet the requirements set by control authorities. In such case additional treatment (complete treatment) of sewer water is provided.

Biological ponds, filters, micro filters and structures of physical and chemical sewer water treatment are used for wastewater treatment.

When filters are used to complete the process of treatment of biologically treated sewer water, degree of contamination of water by suspended substances drops by 70-75%, by $BPK_{\text{побне}}$ – by 50-60%. With the use of micro filters for the same water, the degree of purification is smaller – by suspended substances - 50-60%, by $BPK_{\text{побне}}$ – 25-30%. For wastewater treatment filters with regular grain loading and floating loading are used.

With considerable areas for additional treatment available, biological ponds can be used, that ensure a drop in $BPK_{\text{побне}}$ of up to 4-6mg/l. The advantages of biological ponds (especially with natural aeration) are the simplicity of their arrangement and maintenance and minimal operation costs. High-growing plants (rush, reed mace) increase the reliability of structure operation.

Reagent methods which complete the process of treatment of biologically treated wastewater, have been widely applied. These methods are used to clarify water, reduce BPK and remove phosphorus, one of biogenic elements, that causes eutrophication of reservoirs and intensive biological clogging of pipelines and equipment. Technological schemes of reagent treatment of sewer water are, as a rule, similar to those used in water supply schemes of treating water taken from natural sources. As reagent sulfuric—acid aluminum, sodium aluminate, chloral iron, sulfates of mono- bivalent iron, silicon acid, lime, synthetic flocculants of different types.

The quality of sewer water that was additionally treated with the help of coagulants, can be improved with future sorption of residual contamination on the active coal and zeolites, and also by oxidation methods with the use of ozone, chlorine and other strong oxidants.

2.4.8. Peculiarities of treating small volumes of sewer water

When selecting the scheme and structures for treating small volumes of sewer water (individual buildings, country cottage areas, recreation facilities), in the absence of centralized sewerage typical solutions are, as a rule, used.

For complete biological treatment of small volumes of sewer water septic tanks, filtrating wells, filtration trenches, compact installations and other structures are used.

A septic tank is a horizontal flow tank receiving wastewater from sewer facilities. A septic tank operates for 4 – 6 months without being cleaned. Sediment

that decomposes in a septic tank is taken to fields and is used as a fertilizer every six months or once a year. Septic tanks have a number of disadvantages though: they are big enough since they are intended for two- or three-day amount of wastewater. Besides, gas released in the process of anaerobic decomposition of sediment go to the surface of wastewater taking with them light particles of sediment, which form dense thick crust, which complicates the use of septic tanks. Septic tanks are made of reinforced concrete or brick with manholes having double covers. Septic tanks are arranged at the distance of 5-20m from the buildings depending on daily expenditure of sewer water.

Filtrating wells (Fig.2.42) are used at the estimated inflow of sewer water of up to $1\text{m}^3/\text{day}$ for sandy and sandy-loam soils. A filtration well is a mine with a round or square cross-section in the plane of up to 2.5m deep, with the diameter of up to 2m, and the cross-section of up to $2\times 2\text{m}$. The well is made of reinforced concrete, brick and crushed stone. 1m thick filter in its lower part is made from gravel, crushed rock, coke, and other filtration materials. From the outside filtration well is strewed by the same filtration material as the filter. The thickness of strew layer is 20-25cm, which corresponds to the height of filtration part of the well. At the bottom and on the walls of the well, holes are made within the limits of filter. In reinforced concrete wells the holes have the diameter of up to 30mm and are located chequerwise on the filtration surface every 250mm. In the walls of brick and crushed stone wells vertical joints which are 2 cm wide are made. They are filled with cement mortar.

Filtration wells, intended for biological treatment of sewer water, are built behind septic tanks and are arranged at the distance of 8-10m from residential area. The estimated area of filtrating surface of the wells depends on the loading of sewer water per 1m^2 , it also depends on the soils in which filtrating wells are supposed to be built. Loading per 1m^2 of filtrating surface of the well for sandy soils is taken to be equal to 80l/day, for sandy and loamy soils – 40l/day.

Filtrating trenches (Fig.2.44) – are trenches of rectangular shape filled with filtration material which is 0.8-1.0m thick, and equipped with a network of irrigation and drainage pipes. Irrigation pipes are laid in the layer of gravel or crushed rock. At the bottom of trench pipes of drainage network are laid with the slope of 0.005 to the side of filtrate discharge. Filtrating trenches are built in the soils with low filtration or in non-filtrating soils (clay, loam).

The size of filtrating trench depends on sewer water expenditure and the loading on irrigation pipes. Loading per 1m of irrigation pipes is equal to 50-70l/day. The length of filtration trench should be up to 30m, and the width – not less than 0.5m.

Instead of filtrating trenches there can be used fields of underground filtration (Fig.2.45) – plots of land where at the depth of 0.5-1.8m and higher above the level of ground water a distribution and irrigation network from drainage ceramic, asbestos cement or plastic pipes with the diameter of 75-100mm has been laid. These fields are intended for the areas with the sandy and loamy soils.

Irrigation network of ceramic pipes is laid with the cracks of 15-20mm between the joints of pipes. At the top, joints of pipes are covered with joint bars of waterproof sheeting (roofing paper, ruberoid, etc). When laying irrigation network of asbestos-cement or plastic pipes, along the bottom of the pipe cuts are made at the distance of up to 0.2m from one another, the length of cuttings equals half the diameter of the pipe, the width – 15mm. Irrigation pipes are first laid on the layer of gravel, crushed rock or slag which is 5cm thick, and then the pipes are strewed. Strew layer is 17-20cm thick.

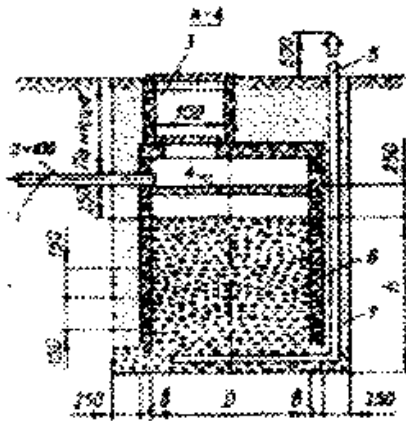


Fig.2.42. Filtrating well from round reinforced concrete rings:

1-outlet pipe of septic tank; 2-reinforced concrete rings; 3-manhole; 4-separating trough with clogged spillway; 5-vent stack; 6-filter; 7-covering; 8-ventilation channel

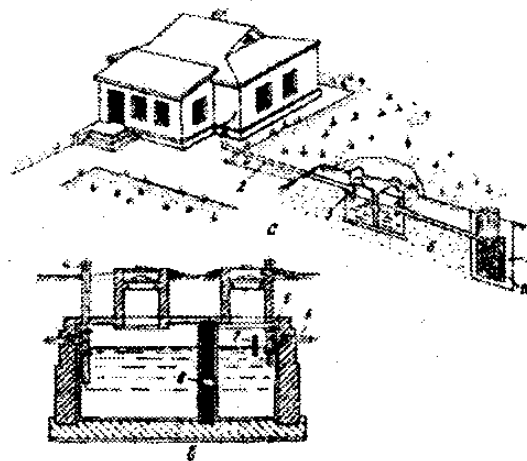
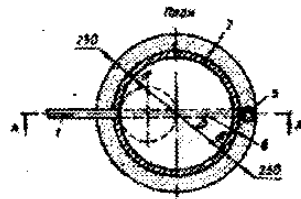


Fig.2.43. Treatment of sewer water in septic tanks and filtration wells:

a- general form; b-bilocular septic tank: 1-sewerage risers; 2-discharge from the building; 3-septic tank; 4-vent stack; 5-T-bent; 6-discharge pipeline; 7-deepened board; 8-manhole; 9-filtrating loading; 10-filtrating well

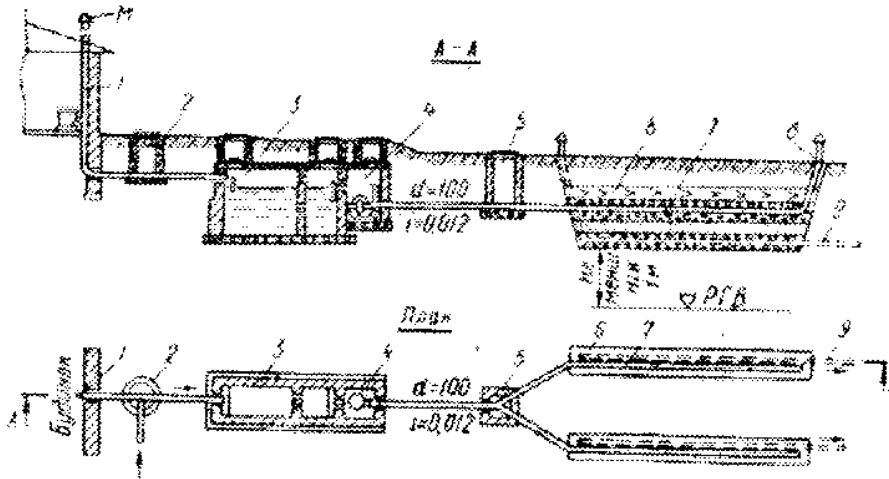


Fig.2.44. Scheme of wastewater treatment structures with filtering trenches:

1-riser; 2-well; 3-septic tank; 4-metering chamber; 5-separating well; 6-filtrating trench; 7-irrigation network; 8-vent stack; 9-drenaige network

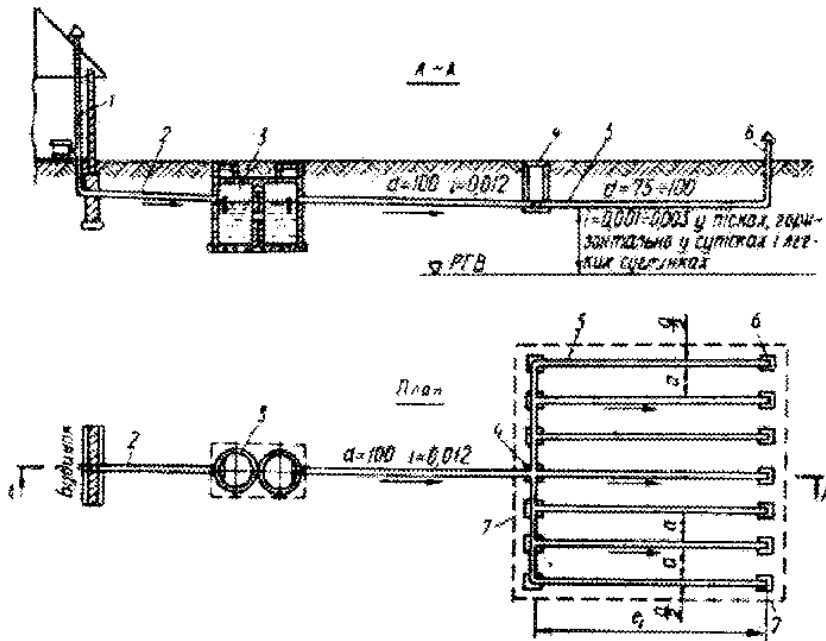


Fig.2.45. Scheme of wastewater treatment structures of local sewerage with plots of underground filtration:

1-indoor sewerage riser; 2-discharge from the building; 3-septic tank; 4-separating well; 5-irrigation pipes; 6-ventilation pipes; 7-border of underground filtration

The distance between parallel irrigation pipes for sandy soils is 1.5-2.0m, for sandy-loamy soils – 2.5m. Pipes are laid in sandy soils with a slope of 0.001-0.003, and in sandy-loamy soils – horizontally. The total length of irrigation pipes is determined by dividing the average daily expenditure of sewer water of sewer facility equipped with sewerage by the norm of their loading per 1m. The length of irrigators shouldn't exceed 20m. The pipe load depends on the soil type, average yearly temperature and the depth of the highest level of ground water. It is determined with the depth of ground water level of 2m and average yearly temperature of air from 6.1 to 11°C per 1m of absorbing well: for sand – 24l/day, for sand-loam – 12l/day. Sewer water that has been treated in septic tanks are supplied through the metering device to separating well and irrigation network.

2.4.9. Arrangement of wastewater treatment structures

Arrangement of wastewater treatment structures in the plane is determined by the composition of structures included in the wastewater treatment station, and the lie of the ground.

The area for wastewater treatment structures is selected taking into account the planning and building development of a locality. Location of wastewater treatment structures is lower downstream the river. The relief of the area should be sloping to ensure gravity flow of sewer water through the structures.

The area requires beneficial geological and hydro-geological conditions. Sanitary protection zones (gaps), perspectives of city development and wind direction are also taken into account. The width of sanitary protection zone depends on method of sewer water treatment and operation capacity of wastewater treatment station.

When designing the area for wastewater treatment structures special attention is paid to uniform distribution of sewer water among the structures, maximal possible joining of separate structures into blocks and perspective growth of operation capacity of the station.

Arrangement of structures should ensure the access to them for maintenance and repair as well as minimal length of communications: trays, channels, pipelines, etc.

The master plan of a wastewater treatment station is developed with the scale of 1:1000 or 1:500. The main and auxiliary structures and pipelines, roads, networks of plumbing and heat-supply, electric-separating devices, cable network of high and low voltage are indicated on it.

Master plan considers sanitary requirements, fire prevention measures and safety rules.

Master plan must show normative distances between separate structures.

As far as the height of its location is concerned, the area for wastewater treatment structures should be at least 0,5m higher than the maximal water horizon during flood taking into account the height of the wind wave.

The territory of the station should be arranged, lit and fenced. Rainwater must be discharged by vertical planning.

2.4.10. Operation of sewerage treatment structures

Sewerage treatment structures are used in compliance with the rules of technical operation of water supply and sewerage systems. The main task of operating sewerage treatment structures is to ensure the quality treatment of sewer water sediment, stipulated by the design of sewerage treatment structures and relevant normative documents.

Prior to operating sewerage treatment structures, when the structure is started it is checked for the operation of separate structures as well as the station on the whole. Personnel of the station are trained to operate the station. When the starting period ends, instructions on operation of individual structures with the description of their working mode are given.

Sewerage treatment structures are brought into operation after being adopted by the State commission, which gives the written permit for the operation. During the adoption it is established the correspondence of built structures to the approved project, it is checked the sizes, presence of all devices, equipment and armature and it is estimated the quality of building and loading works. After this, the structure is checked for its geometrics, with operation of all devices and structures being assessed from technological point of view.

Operation of sewerage treatment structures is characterized by the following main indexes: expenditure of sewer water by the entire structure and by individual structures; mass of wastes that were detained on the grates, their humidity, content, density, ash content; amount of sediment from sand-catchers, its density, ash content, amount of sand; volume of raw sediment from the primary settlers, its humidity and ash content, outflow of suspended substances from the settlers; the amount and the temperature of sediment and active sediment in methane tanks, as well as sediment discharged from methane tanks, its humidity and ash content; mass of active sediment (doze) in aero tanks, volume of air supplied to the structures.

To ensure regular operation of sewerage treatment structures, technological passports for all the structures are required, according to which all current and capital repairs are planned.

Depending on operation capacity and complexity of sewerage treatment structures, control department is organized, with total or partial distance control of structures and aggregates, total or partial computer control of structures and aggregates, total or partial automation of technological processes. To ensure continuous operation of all structures in case of power source failure or individual elements of automation failure, remote or automatic control of sewerage treatment structures is substituted with hand control.

3. GUIDE TO LABORATORY WORK WATER SUPPLY AND DRAIN

Module 1

Systems and schemes of water supply and drain in localities and industrial enterprises

Laboratory work 1

Calculating water consumption in localities

The purpose of work: study the material given in lectures and reference literature; acquire skills in calculating water consumption in localities.

Literature: [9, p. 7-16] ;[4, 12, 31], [30, p. 13-30].

Tasks. Calculate water consumption in localities.

Devices and materials: reference and information materials, tables, graphs, reference books, DBN, DSTU.

Working order: collecting baseline data, types of water consumers and non-uniformity of water consumption, specific expenditure, estimated water consumption.

The report must include: the front page, the purpose and objective of laboratory work; brief theoretical information; the results of water consumption calculations; list of reference literature. The report (format A-5) must include relevant formulas, graphs and tables.

Test questions

1. Characterize water consumers in localities.
2. What modes of water consumption are there?
3. What is a daily schedule and an integrated curve of water consumption?
4. What is specific expenditure?
5. How are estimated costs (daily, hourly, second and annual) found?
6. What are irregularity factors and how are they determined?
7. How is water consumption estimated in localities?

Laboratory work 2

Determining water supply systems and schemes

The purpose of work: study the material given in lectures and reference literature; acquire skills in determining water supply systems and schemes.

Literature: [9, p. 7-16] ;[3, 4, 12, 31];[30, p.31-46]

Tasks. Determination of effective systems and schemes of water supply in localities and industrial enterprises.

Devices and materials: reference and information materials, tables, graphs, reference books, DBN, DSTU.

Working order: studying and determining effective systems and schemes of water supply in localities and industrial enterprises.

The report must include: the front page, the purpose and objective of laboratory work; brief theoretical information; the results of determining effective systems and schemes of water supply in localities and industrial enterprises, list of reference literature. The report (format A-5) must include relevant formulas, graphs and tables.

Test questions

1. What water supply systems are there? How can they be classified?
2. Name water supply schemes and factors determining the selection of scheme.
3. Tell about water supply schemes with water intake from underground sources.
4. What are water supply schemes assuming taking water from surface sources?
5. Speak of the peculiarities of group water supply scheme.
6. Speak of the peculiarities of water supply at industrial enterprises.
7. Describe industrial water supply schemes.
8. What types of coolers are there?
9. Describe all types of cooling towers.

Laboratory work 3

The structure, purpose and operating principle of modern industrial pumps and controlling devices

The purpose of work: study the material given in lectures and reference literature; acquire skills in determining the purpose and operating principle of modern industrial pumps and controlling devices.

Literature: [9, p. 29-43] ;[3,4,12,31];[30, p. 139-165].

Tasks. Build the structure, determine the purpose and operating principle of modern industrial pumps and controlling devices.

Devices and materials: reference and information materials, tables, graphs, reference books, DBN, DSTU.

Working order: collecting baseline data on pumps and pumping stations, learning their characteristic features, the purpose and operating principle of modern industrial pumps and controlling devices.

The report must include: the front page, the purpose and objective of laboratory work; brief theoretical information; the results of estimating wastewater sewer system and pumping station; list of reference literature. The report (format A-5) must include relevant formulas, graphs and tables.

Test questions

1. What are the main features and types of pumping stations?
2. Describe water-lifting equipment.
3. Describe centrifugal and piston pumps, hydraulic elevators.
4. How is the operation mode of first and second lifting pumping stations determined?
5. How is the pump pressure of first and second lifting determined?
6. Describe reserve and regulatory structures.
7. Describe water towers, their types and designs.
8. How are the height and volume of tanks found?
9. What types of reservoirs are there? How is their volume found?

Laboratory work 4

Determining hydraulic characteristics of filter material

The purpose of work: study the material given in lectures and reference literature; acquire skills in determining hydraulic characteristics of the filter material for water quality improvement.

Literature: [9, p. 60-73]; [3, 4, 12, 31]; [30, p. 209-263]

Tasks. Determining hydraulic characteristics of filter material for water quality improvement.

Devices and materials: reference and information materials, tables, graphs, reference books, DBN, DSTU.

Working order: studying and determining hydraulic characteristics of filter material, determining pores of filter materials, determining absolute and nominal filtration.

The report must include: the front page, the purpose and objective of laboratory work; brief theoretical information; the results of determining hydraulic characteristics of filter materials for water quality improvement, the waste water collection system and pump station waste water; list of reference literature. The report (format A-5) must include relevant formulas, graphs and tables.

Test questions

1. Name the indicators of quality of drinking water. What are the requirements to drinking water quality?
2. Describe the basic methods and techniques of water treatment.
3. Describe the peculiar features of reagent free schemes of water clarification and decoloration.
4. Describe one-stage and two-stage reagent schemes of water clarification and decoloration.
5. What is physical and chemical basis of impurities coagulation?
6. What reagents for water clarification and decoloration are there?
7. How are filters classified? Describe the pore size of filter material. What is absolute and nominal filtration fineness?
8. Describe the process of water disinfection. What types of disinfection are there?

Laboratory work 5

The study of gravitational purification.

The study of the process of centrifugal purification of fluids.

The purpose of work: study the material given in lectures and reference literature; acquire skills in studying gravitational purification and the process of centrifugal purification of fluids.

Literature: [9, p. 29-37]; [3, 4, 12, 30, 31].

Tasks. Study gravitational purification and the process of centrifugal purification of fluids.

Devices and materials: reference and information materials, tables, graphs, reference books, DBN, DSTU.

Working order: studying gravitational purification and the process of centrifugal purification of fluids.

The report must include: the front page; the purpose and objective of laboratory work; brief theoretical information; the results of studying gravitational purification and the process of centrifugal purification of fluids; list of reference literature. The report (format A-5) must include relevant formulas, graphs and tables.

Test questions

1. Describe the peculiar features of gravitational purification of fluids.
2. Describe the peculiarities of the process of centrifugal purification of fluids.
3. Describe the basic techniques and methods of water treatment.
4. What reagents for water clarification and decoloration are there?
5. What designs of vertical settlers are there?
6. Describe designs and schemes of horizontal settlers and chambers of flake formation.
7. How are filters classified?

Laboratory work 6

Determining water pollution with fuels and lubricants.

The purpose of work: study the material given in lectures and reference literature; acquire skills in determining water pollution with fuels and lubricants.

Literature: [9, c. 236-239]; [3, 4, 12, 30, 31].

Tasks. Determining pollution with fuels and lubricants.

Devices and materials: reference and information materials, tables, graphs, reference books, DBN, DSTU.

Working order: determining water pollution with fuels and lubricants.

The report must include: the front page; the purpose and objective of laboratory work; brief theoretical information; the results of determining water pollution with fuels and lubricants; list of reference literature. The report (format A-5) must include relevant formulas, graphs and tables.

Test questions

1. Name car service enterprises.
2. What are production facilities?
3. Describe pollution with fuels and lubricants.
4. What harm does pollution with fuels and lubricants do?
5. What measures can be take to eliminate pollution with fuels and lubricants?

Laboratory work 7

Design and calculation of outdoor sewerage network

The purpose of work: study the material given in lectures and reference literature; acquire skills in designing and calculating outdoor sewerage network.

Literature: [9, c. 81-110]; [3, 4, 12, 31], [30, c. 277-290].

Tasks. Designing and calculating outdoor sewerage network.

Devices and materials: reference and information materials, tables, graphs, reference books, DBN, DSTU.

Working order: studying design and calculation of outdoor sewerage network.

The report must include: the front page; the purpose and objectives of laboratory work; brief theoretical information; the results of designing and calculating outdoor sewerage network; list of reference literature. The report (format A-5) must include relevant formulas, graphs and tables.

Test questions

1. What composition does wastewater have? What types of wastewater are there?
2. What criteria must sewage systems and schemes meet?
3. What are the main elements of a locality's sewage system?
4. How is hydraulic calculation of sewer networks carried out?
5. What is pipe filling? What pipe slope is there? What types of pipes and their connections are used for sewage system?
6. How is wastewater expenditure determined?
7. How are sewer networks traced? Describe typical tracing schemes.
8. What are the types of channel cross-sections?
9. What types of wells are installed on the sewer networks and what is their function?
10. What is the function of sewage pumping stations? How are they equipped?

Laboratory work 8

Cold and hot water supply to buildings and individual objects.

The purpose of work: study the material given in lectures and reference literature; acquire skills in studying cold and hot water supply to buildings and individual objects.

Literature: [9, c. 150-193]; [3, 4, 12, 31]; [30, c. 47-62].

Tasks. Designing hot and cold water supply to buildings and individual objects.

Devices and materials: reference and information materials, tables, charts, manuals, DBN, ISO, additional literature.

Working order: studying cold and hot water supply to buildings and individual objects.

The report must include: the purpose and objectives of laboratory work; brief theoretical information; the results of designing hot and cold water supply to buildings and individual object; list of reference literature. The report (format A-5) must include relevant formulas, graphs and tables.

Test questions

1. Describe the general scheme of indoor cold water pipeline system.
2. What water fittings are there?
3. How is indoor plumbing calculated?
4. What systems of hot water supply are there?
5. What are the types of domestic filters and under what circumstances are they used?
6. Name the materials and equipment of indoor water supply.
7. Describe inlets and gauging assemblies.
8. How is hydraulic calculation of indoor water supply network carried out? How is its axonometric scheme built?

Themes for homework

In the process of studying the subject "Water supply and drain", students do two tasks on the following topics:

1. Overview of the current domestic and foreign systems and schemes of water supply in localities and industrial enterprises.
2. Overview of the current domestic and foreign systems and schemes of drainage in localities and industrial enterprises.

One homework corresponds to 8 hours of a student's independent work. Reporting form is a typescript of the volume of 10-15 pages. Form of control - defending of the work.

Thematic vocabulary

Water supply - водопостачання
Drainage network – водовідвідна мережа
Pumping station- насосна станція
Wastewater – стічні води
Sewer network - каналізаційна мережа
Lubricants - паливно-мастильні матеріали
Pollution – забруднення
Contamination – забруднення
Filter materials - фільтрувальні матеріали
Hydraulic characteristic – гідравлічна характеристика
Clarification – прояснення
Decoloration – знебарвлення
Coagulation - коагуляція
Disinfection of water – знезаражування води
Filtration fineness – тонкість фільтрації
Pipe – труба
Drain - колектор
Centrifugal cleaning – відцентрове очищення
Plumbing – водопровід
Gauge sites – водомірні вузли
Sediments – відкладення

Septics – септики
Filtrating trenches – фільтруючі траншеї
Water intake - водозабір
Water flow - водний потік
Open network - відкриті джерела
Composing - компоновання
Node - вузол
Seamless - безшовний
Seismic areas - сейсмічні зони
Strengthen covers - зміцнювати покриття
Valve - клапан
Collapsible - складаний
Maintenance - обслуговування
Frustrated - зруйнований
Deflate - викачувати
Roadsides - узбіччя
Power supply - джерело живлення
Branched scheme - розгалужена схема
Uninterrupted supply - безперебійне постачання
Permit - дозвіл
Intended regime - призначений режим
Tying up - зв'язування
Faucet pipes - кран труби
Hinder - перешкоджати

Test questions and tasks for module control

1. What is water supply system? Give its characteristics and classification.
2. Give relevant examples of water network tracing schemes.
3. Describe the composition of wastewater.
4. Give some relevant example of water supply scheme from open sources.
5. Describe water pumping stations.
6. Methods of wastewater treatment.
7. Describe specific water consumption.
8. Draw a diagram of hydraulic calculation of network.
9. Conditions for wastewater discharge.
10. Give some relevant example of water supply scheme from closed sources.
11. Describe types of pumps.

12. Name facilities used for biological wastewater treatment?
13. Describe modes of water consumption.
14. Give basic calculations of water supply systems.
15. Name facilities used for mechanical treatment of wastewater.
16. What are the requirements to water quality?
17. What pipes are used for water supply networks?
18. Give schemes of sewage pumping stations.
19. What water sources do you know?
20. Describe the basic elements of a locality's sewage system.
21. Describe typical technological scheme of wastewater treatment.
22. Give the scheme of underground water occurrence.
23. Basic technological processes and schemes of water quality improvement.
24. What is the composition of a wastewater treatment plant?
25. Basic data for sewage network design.
26. Requirements to sewage network pipes.
27. What is curve of depression? Draw and describe it.
28. Water supply rates and modes.
29. Types of wastewater.
30. Describe the structure of sewage pumping stations.
31. Draw the scheme of hydraulic calculation of network.
32. Deepening of drain pipes.
33. What facilities are used for biological wastewater treatment?
34. Give basic data for designing sewerage network.
35. What are the requirements to water quality?
36. Describe the typical technological scheme of sewage treatment.
37. Describe water intake structures for taking water from underground sources.
38. Describe the main characteristics of pump operation.
39. Methods of wastewater treatment.
40. Describe water intake structures for taking water from surface sources.
41. Describe and give examples of sewer systems and schemes.
42. Describe wastewater composition.
43. What does hydraulic calculation of sewerage network consist in?
44. Describe water intake structures for taking water from surface sources.
45. What facilities are used for the mechanical treatment of wastewater?
46. Requirements to the design and construction of longitudinal profile of sewerage network.
47. Describe water consumption modes.
48. Rainwater sewer network.

Tests

1. Water consumers can be divided into the following groups: residential sector; watering; farms; enterprises; melioration sector.
2. In calculating water consumption varies during: a day; a year; an hour; a minute; a second.
3. A typical distribution schedule of daily water expenditure by hours depends on: the degree of building improvement; hourly irregularity coefficient; daily irregularity coefficient; the type of farm; business type.
4. Specific water expenditure is: average daily water expenditure by one consumer per year; maximum daily water expenditure by one consumer per year; hourly water expenditure by one consumer per year; water expenditure by one consumer per minute; average yearly water expenditure by one consumer.
5. The required free pressure for a free three-story building is, m: 10; 14; 16; 18; 20.
6. Water supply - is: a set of measures to ensure the water; complex structures for water; water supply; complex pipelines; steering apparatus.
7. Water supply system with water intake from underground sources may include: water wells; water clarification plant; coastal water intake well; drain; second uplift pumping station.
8. Water supply system with water from surface sources can include: water wells; water clarification plant; coastal water intake well; draining; second uplift pumping station.
9. Minimum pressure in low pressure fire protection water supply should be: 10m; 20m; the height of the tallest building; 28m higher than the highest building; 28m higher than the lowest building.
10. Water consumption for external fire extinguishing depends on: the number of residents; the number of floors in buildings; the area of 1-2- story buildings; the area of buildings having more than 3 floors; the degree of building improvement.
11. Specific water expenditure for utilities sector depends on: the degree of building improvement; the number of floors; the number of inhabitants; fire resistance of the building; division into low-rise and high-rise zones.

12. Specific water consumption for industrial enterprise depends on: the type of enterprise; product units; the fire resistance of building; production categories according to fire safety rules; building volume.
13. Capacitive pressure structures are divided into: water towers; pressure tanks; water columns; hydro pneumatic installations; hydraulic installations.
14. A water tower is a tank installed: on trunks; on roofs; on the second floor; the highest mark of the surface; in basement.
15. Water tower tank of a locality contains the following volumes: controlling; untouchable fire prevention; emergency; for its own needs; accumulating.
16. Water tower tank can be: metal; reinforced concrete; with tents; without tents; non- insulated.
17. In our country water tower tanks with the volume of, m³: 5-15; 15-800; 800-1000; 50-10000; 50-20000 are used.
18. The height of water tower (to the tank bottom) consists of: the difference in ground marks in the place of tower location and the dictating point; free pressure in the dictating point; pressure losses from the tower to the point of dictating; required free pressure in the farthest point; pressure losses from the tower to the farthest point.
19. Reservoirs of clean water are: round; square; rectangular; diamond-shaped; triangular.
20. Water supply networks are divided into: dead-end; ring; mixed; without water tower; with water tower.
21. Water supply networks are divided into: main lines; distribution lines; flexible lines; evenly distributed lines; straight lines.
22. Water supply network is calculated for: maximum economic and industrial water consumption; water supply for extinguishing fires; maximum transit to the tower; extinguishing maximum for household and industrial consumption; supply only from the tower.
23. To determine the head loss by Shevelev's tables we should know: water consumption; pipe material; diameter of pipes; geometric length; estimated length.
24. Sluiceways are divided into: gravity; pressure; combined; vacuum; mechanical.

25. A sluiceway can be: in the form of channels; in the form of gutters; made of steel pipes; ceramic pipes; concrete pipes.
26. Sluiceways can be: economic; reliable; with constant direct tilt; with constant direct reverse tilt; half-immersed.
27. The depth of laying water pipes is: 0,5 m higher than the freezing depth; 0,5 m below the freezing depth; 0,3 m below the freezing depth; 0.3 m higher than the freezing depth; independent of the freezing depth, constructive.
28. Water towers are set: in the highest points of the area; by the river; in network areas that require the greatest pressure; in areas of the network where the lowest pressures are required; in network areas serviced at the hour of maximum consumption.
29. Manholes are installed: every 0.5-1 km; in front of pits with air valves; in front of pits with outlets; alongside of the wells with outlets; at the end of sluiceway.
30. Sluiceway and plumbing network pipes are: steel; iron; ceramic; reinforced concrete; plastic.
31. Steel pipe are connected by: welding; threaded couplings; ЖИВО couplings; just sealing bells with the cuff; CAM couplings.
32. Water fittings include: valves; cranes; water column; fire hydrants; check valves.
33. Pipelines are checked for: strength; density, stability; plasticity; resistance to chemicals.
34. External waterproofing is provided for the pipes made of: steel; iron; flack; asbestos; polyethylene.
35. In the first place, sources to be used are: protected underground water; unprotected underground water; rivers; lakes.
36. The following water intake structures are used for taking underground water: water intake wells; shaft wells; buried headroom; not buried headroom; horizontal intakes.
37. Shaft wells take water from the aquifer by: bottom; lateral surface over the entire height; lateral surface within the aquifer; bottom and side surfaces within the aquifer; free water is poured into the well from the surface.

38. In the controlled area of sanitary protection zone it is banned: to locate residential buildings; bathe and wash; go fishing; have decentralized sewer; pollute the territory with sewage or pesticides.
39. Drinking water quality must comply with GOST: 2874-82; 7428-82; 5613-94; 4478-99; 43 / 44-2.5-5-96 is
40. GOST requirements to drinking water can be replaced with: construction norms and regulations; Institutional building codes; State sanitary rules and standards; State building codes; Recommendation "Drinking Water".
41. Clarification is decreasing of: turbidity; color; iron content; hardness; odor intensity.
42. Decoloration is decreasing of: turbidity; color; iron content; hardness; odor intensity.
43. Deodorization is: decreasing of odor intensity; decreasing of taste intensity; removal of iron; removal of manganese; removal of carbon dioxide.
44. Enterprises may be the following water supply systems: only domestic-drinking; only fire prevention; only industrial; stagnant; combined domestic-drinking, fire prevention, industrial.
45. The amount of water for production needs depends on: the nature of production; equipment used; the number of employees; qualification of employees; technological processes schemes.
46. Water quality for industrial needs depends on: the nature of production; used equipment; technological processes schemes; qualification of employees; production category according to fire safety rules.
47. The modes of water consumption in enterprises depends on: operation mode the company; operation mode of individual equipment; method of water use; season (summer, winter, autumn); the size of workshops.
48. The head in industrial water supply system depends on: used equipment; the height of industrial buildings and floors; available pumps; availability of tanks; availability of water towers.
49. Mitigation is removal of cations of: calcium; magnesium; potassium; sodium; manganese.

50. For mitigation the following methods are used: non-chemical; reagent; thermochemical; cationic; anionic.
51. Desalting is: removing salts from water; removing calcium cations; removing potassium cations; removing only sulfate anions; removing only chlorine anions.
52. Clarification and decoloration of surface water is carried out using: reagent; nonchemical; cation exchange; anionic exchange; cationic and anionic exchange method.
53. Nonchemical method of clarification and decoloration in the preparation of drinking water includes: water aeration; settling; slow filtering; fast filtering; electric treatment.
54. When using reagent method of water clarification and decoloration we add: coagulants; coagulant and lime; oxidant (chlorine); coagulant; sulfuric acid.
55. The primary chlorination is required for: processing hydrophobic suspension; hydrophilic suspension treatment; oxidation of iron; oxidation of manganese; oxidation of nickel.
56. According to the principle of water flow in facilities stations are divided into: non-pressure, gravity; pressure; combined; self-pouring; jet.
57. Decontamination is: bacteria elimination; destruction of viruses; oxidation of organic substances; oxidation of iron; oxidation of manganese.
58. Domestic water supply can be: cold; hot; medium; cooled steam.
59. Domestic sewage includes: exhaust pipe; riser; drainage pipes; inlet pipe; discharge.
60. Waste water is divided into: domestic; industrial; meteoric; mountain; urban.
61. Sewer systems are divided into: general flow; full separate; combined; separate incomplete; full combined.
62. The general sewage system of a locality includes: gravity street network; gravity sewers; district sewage pumping station; emergency discharges; treatment plant.
63. For gravity sewer networks pipes made of: steel; ceramics; concrete; reinforced concrete; plastic are used.

64. The minimum depth to the tray of sewer pipes with the diameter of up to 500 mm is: 1.5 m; 0.5 m less than the freezing depth; 0.3 m less than the freezing depth; 0.5 m more than the freezing depth; 0.3 m more than the freezing depth.

65. A sewage pumping station has: receiving tank; engine room; domestic premises; auxiliary facilities; headroom.

66. Sewage pollution consists of: mineral; organic; mechanical; soluble; insoluble impurities.

67. Waste water is purified in the following ways: mechanical; biochemical; chemical; radiological; speed.

68. Methods of mechanical sewage treatment are: lattice; sand-catchers; septic tanks; bio-filters; aero-tanks.

Thesaurus

Aero-tanks - tanks in which wastewater flows horizontally along separate corridors.

Coastal intakes - water intakes of shore intake well on the steep banks.

Biofilters - tanks, which are filled with grainy loading through which wastewater is filtered by downstream.

Sump - facility for settling coarse suspension and big flakes due to gravity.

Free network head - the height of water column above the ground, which is set in piezometric tube connected to any point of water network.

Water tower - a tank and a barrel designed for maintaining the required pressure in the network and storing the control and 10-minute fire prevention water reserves.

Culverts - structures designed to transport water from the water source to the consumer.

Drilling water wells - facilities which include: filter column casing, pump, hall or chamber, which is used for the extraction of ground water lying at a depth of 10-500 m from the surface.

Intakes from rivers - structures that ensure taking of water from a natural source, coarse cleaning and feeding to water networks or sewage treatment plant.

Separate water intake layout - intake well and first lifting pumping station located in separate buildings.

Combined water intake layout - intake well and first lifting pumping station located in one building.

Horizontal intakes - buildings which include: water receiving unit, manholes, collecting reservoir; used for extracting groundwater from shallow (2-3 m) and free-flow aquifers that lie at a depth of 8 m from the surface.

Bunk tank - tank on top of which are sedimentary troughs to stop admixtures contained in wastewater, with fermentation unit at the bottom.

Deodorization - reducing the intensity of smell and taste.

Softening - removal of calcium or magnesium that cause water hardness.

Decoloration - reducing color (chrominance).

Disinfection - destruction of bacteria and viruses contained in water.

Sewage or drainage system - a complex of engineering measures taken to collect, transport, treat and disinfect wastewater that was used for specific needs and, therefore, contaminated.

Desalination - reducing the amount of solids.

Unit costs - average daily water consumption by one consumer per year.

Clarification - reducing turbidity, removing colloidal and suspended particles.

Channel intakes - water intakes consisting of intake grid-well, gravity or siphon lines headroom on the sloping banks.

Water supply system - a complex of facilities which supplies all water consumers with water.

High pressure extinguishing system - systems that provide water intake from the network by hydrant and stander, and water supply through non-rubberized sleeve to the highest point of building.

Low pressure extinguishing system - systems that provide water intake from the network by hydrant and stander, and water supply by automatic pump through non-rubberized sleeve to the highest point of building.

Water supply system – the layout of water supply facilities (shown graphically).

Tracing of water network - a process which provides water networks with specific geometric shapes in-plane.

Mine wells - structures consisting of intake, trunk, headroom, designed for receiving or taking water from aquifers or free-flow layers, which are at a depth of 20 ... 30m.

Quick filters – containers filled with granular filling used to stop fine, unstable aggregate particles contained in settled water.

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Заступник директора Навчально наукового інституту Аеропортів з наукової роботи, завідувач кафедри реконструкції аеропортів та автошляхів Національного авіаційного університету, академік Транспортної Академії України, академік Інженерної Академії України, член Міжнародної асоціації спеціалістів промислової гідравліки і пневматики, доктор технічних наук, професор.

Нагороджений відзнаками Інституту екології та дизайну НАУ (2005), «Почесний дорожник» (Укравтодор) (2008), медаллю «За сумлінну працю» (2010), переможець конкурсу на здобуття «Великої срібної медалі» Академії будівництва України (2014), переможець конкурсу на кращій навчальний посібник НАУ (2015).

Народився 24 грудня 1970 р. у м. Києві (Україна). У 1993 р. з відзнакою закінчив Київський автомобільно-дорожній інститут за спеціальністю "автомобільні дороги та аеродроми". У 1991-1993 рр. навчався і проходив стажування в Німеччині (м. Нюрнберг). У 1993 р. працював дорожнім майстром Гайворонської районної дорожньо-ремонтно-будівельної дільниці.

З 1993 по 1996 рр. аспірант Українського транспортного університету. Одночасно у 1996-2004 рр, старший науковий співробітник кафедри мостів та тунелів Національного транспортного університету. У 1996 р. захистив кандидатську дисертацію на тему "Дослідження місцевого розмиву біля опор мостів при їх реконструкції методами стереофотограмметрії" за спеціальністю 05.22.11- "автомобільні шляхи та аеродроми". Доцент по кафедрі комп'ютерних технологій (2002).

З 1999 по 2003 рр, докторант Національного транспортного університету. У 2003 році обраний членом-кореспондентом Транспортної Академії України. Наукові дослідження пов'язані з вивченням засобами математичного моделювання та геоінформаційних систем процесів стоку під час стихійних лих в важкодоступних гірських районах з використанням аерокосмічної інформації та стерео фотозйомки. У 2005 р. захистив докторську дисертацію на тему "Гідрологічні розвідування мостових переходів з застосуванням методів дистанційного зондування Землі" за спеціальністю 05.22.11 "автомобільні шляхи та аеродроми".

З 2006 р. заступник директора Інституту міського господарства з наукової роботи, директор Інституту міського господарства, заступник директора Інституту аеропортів з наукової роботи Національного авіаційного університету. Завідувач кафедри реконструкції аеропортів та автошляхів.

Автор понад 300 наукових праць: 180 статей, 8 навчальних посібників, 5 монографій, 8 патентів. Учасник 45 міжнародних та регіональних наукових конгресів та конференцій.

Основні опубліковані праці:

1. Металеві конструкції. Метали і зварювання в будівництві (англ. мовою): Навчальний посібник. / Белятинський А. О., Першаков В. М., Лапенко О. І., Пилипенко О. І., Кужель Н. І., Гирич В. Ю.– К. : НАУ. – 2013. – 208 с. (Гриф МОН України. Лист № 1/11-9776 від 10.06.2013 р).

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3. Особенности функционирования автоматизированных систем управления дорожным движением в городах Украины / Белятинський А. О., Степанчук А. В., Пилипенко А. И. / Mokslas – Lietuvos Ateitis. Science – Future of Lithuania. Civil and Transport Engineering, Aviation Technologies. Vilnius (Lietuva): Technika, 2013, Vol. 3, № 5. – P. 118–125.

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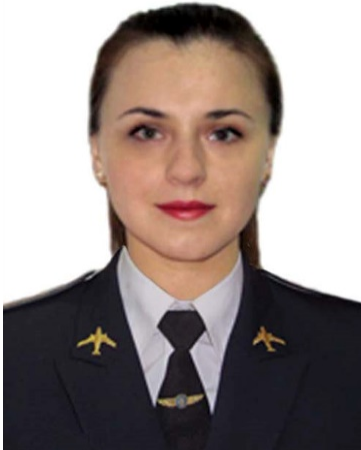
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8. Першаков В. М. Дослідження транспортних потоків в аспекті заторових станів дорожнього руху / Першаков В. М., Белятинський А. О., Степанчук О. В., Кротов Р. В. Монографія. --К.: НАУ, 2015. -176 с.

9. Першаков В. М. Вертодроми. / Першаков В. М., Белятинський А. О., Близнюк Т. В., Семірозов Н. Г. Монографія. –К. : Видавництво НАУ, 2014. – 370 с.

ЛИСНИЦЬКА
Катерина Миколаївна

Асистент кафедри реконструкції аеропортів та автошляхів, магістр з будівництва Навчально наукового інституту Аеропортів Національного авіаційного університету.



Народилася 3 вересня 1987 року у м. Чернігові (Україна).

У 2010 році з відзнакою закінчила Національний авіаційний університет за спеціальністю «Промислове та цивільне будівництво». З 2012 року – аспірант кафедри реконструкції аеропортів та автошляхів Національного авіаційного університету.

Основний напрям наукової діяльності – розрахунок та оцінка надійності будівель з урахуванням ризику прогресуючого обвалення.

Автор 15 наукових праць, учасник міжнародних та регіональних конференцій.

Основні опубліковані праці

1. Першаков В. М. Сучасні сільськогосподарські будівлі в рамних конструкціях / В. М. Першаков, К. М. Лисницька // Матеріали Всеукраїнської інтернет-конференції молодих учених і студентів «Проблеми сучасного будівництва». – 2012. – С. 171 – 172.
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